Water in the 21st Century
a global overview of current and impending water issues

Researched and Written by: Grayson M. Shor
Advised by: Dr. William Preston
Cal Poly San Luis Obispo
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Intent/goal of the project:

In the opening of the famous soliloquy written by Carl Sagan “The Pale Blue Dot” he says,

“Look again at that dot [the Earth]. That’s here. That’s home. That’s us. On it everyone you love, everyone you know, everyone you ever heard of, every human being who ever was, lived out their lives. The aggregate of our joy and suffering, thousands of confident religions, ideologies, and economic doctrines, every hunter and forager, every hero and coward, every creator and destroyer of civilization, every king and peasant, every young couple in love, every mother and father, hopeful child, inventor and explorer, every teacher of morals, every corrupt politician, every "superstar," every "supreme leader," every saint and sinner in the history of our species lived there-on a mote of dust suspended in a sunbeam.”

The goal of my senior project is to understand humanity in this context, aware of the big picture.

I plan to look at various factors effecting human impact on the environment in order to better understand where we are going. Nothing is more evident, I believe, to my understanding of the present situation than looking at how we are interacting with our planet. We are currently in resource overshoot yet the common opinion is that our industrial civilization is like an ‘unsinkable Titanic’, too big to possibly fail. As our resources dwindle our population is growing at an unsustainable rate. Yet we are not the first civilization to deplete vital resources, we must hope we are the first to overcome it.

Methods:

Through unbiased and well-researched sources I will evaluate current global patterns concerning, but not restricted to, water reserves, distribution, quality, purification techniques and technologies, as well as political, economic, and cultural factors. I have divided this report into five chapters, which should adequately encompass the above topics of interest. I plan to gather most of my information from written works (books and online content), documentaries, maps, & conceptual spatial data. Lastly, if time permits I will select a few global regions to use as case studies. I would also like to note that that this report will be written in a conversational tone so as to connect with the reader on a personal note.
Annotated Bibliography

1. "Carrying Capacity (K)." *Carrying capacity (K).* Web. 20 Apr. 2014.
   a. This article discusses the concept of carrying capacity, a topic that will be of great importance in this report. This concept will be mentioned in the context of over population and unsustainable resource utilization to exemplify the current ‘tragedy of the commons’ occurring to our water resources.

   a. The World Bank is an indispensable resource when discussing global economic trends. Although money is not an all inclusive indicator of progress or lack thereof it allows us to evaluate what people are investing in and what areas are experiencing economic hardship or affluence in accordance with resource utilization and extraction.

   a. Freedom House is a well-recognized agency that evaluates political freedom globally. We will use this information in our discussion of political factors influencing water use and management.

4. *Research from the International Water Management Institute (IWMI).*

   a. A great source of current water management techniques and practices.
This information will contribute to our discussion concerning water use in chapter two.

   a. A well-written and clear synopsis of various environmental issues, most notable concerning energy and water use. This resource will be used primarily for its clear definitions of terms, figures and images, and as a guide for how to structure certain topics we will discuss throughout this report.

   a. The Dublin Statement was written by various representatives from many countries discussing the need to conserve water. The statement argues that water is a human right, however should also be an economic good in order to reduce use and promote conservation. This topic will be covered in chapter two.

   a. A set of eight goals created by the UN. We will be focusing on goal seven which concerns water quality and use. The UN is by far the biggest player in global water use data and legislature, thus understanding their goals will allow us to better understand why and how current and future action will
be taken.

   a. A resource published every few years by scientists across the globe, the UNESCO reports will provide us with a bulk of our information, including relevant graphs, tables, and maps. The value of this resource cannot be overstated, in many ways the UNESCO report will parallel ours in earlier chapters. If you are find yourself interested in the topics covered in this report, read the five hundred plus pages in each UNESCO water report!

   a. Same annotation as above, this is a more recent article in the UNESCO water report series.

    a. Wright’s book discusses human evolution and our present quest for cheap and affordable energy. We will not use this book primarily for facts but rather for its claims concerning humanity on a broad scope. I recommended reading this book to better understand the contextual existence of humankind!
Water in the 21st Century

I. How Much Water Do We Have Access To:
   a. Global Reserves and Sources

II. Distribution
   a. What is Water Used for
   b. Climate
   c. Population
      i. Growth of Populations and its Effect on Distribution/Availability
   d. Politics & NGOs
   e. Private Companies and Commercial Sale of Water

III. Water Quality
   a. Global Water Quality Overview
   b. Causes of Pollution
   c. Pesticides and Bioaccumulation

IV. Water Purification and Conservation Technologies
   a. Selected Technologies For Water Purification
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V. Where Are We Going?
   a. Is Water the New Oil?
   b. What Does This All Mean?
**Water in the 21st Century**

We live in an auspicious time. Urbanization, industry, global trade and communication networks, peak oil, population booms, and the digital revolution have all come to full bloom in my generation. See, I was born in the year 1992; the year the Soviet Union fell and emails arose. My childhood, and that of my generation, was characterized by both curiosity and an increase in available outlets to express our inquisitiveness. Like many of my peers, I was intrigued by what was *not* here rather than what *was* in my immediate surroundings, I was interested in space, ‘the last frontier’. I was amazed at how this search for life and potential planets to colonize was only possible if one key ingredient was present, *water*.

As I became older I realized the same was true for this planet. I became amazed with the fact that all the water on Earth (at least in the past few million years) has always been here. This got me thinking; if new and immense global changes are occurring across the board, then certainly the way we interact with water, the basic ingredient for life, must be changing too.

According to the *UN World Population Prospects* (the 2012 revision) global population is expected to grow from a current 7.2 billion to a total of 9.5 billion by 2050. Fifty-three percent of that projection will be living in increasingly dense urban environments. Furthermore, “Between 2013 and 2100 the populations of 35 countries, most of them LDCs [less developed countries], could triple or more” ([http://www.un.org/en/development/desa/population/publications/pdf/trends/WPP2012_Wallchart.pdf](http://www.un.org/en/development/desa/population/publications/pdf/trends/WPP2012_Wallchart.pdf)) resulting in unimaginable sanitation and water procurement issues.
The following pages will address the question ‘where will the increasing population of the 21st century get water and how will they use it?’ To adequately investigate this broad question we will look in depth at such topics as water pollution/reserves, climate, political and commercial issues, global population trends, as well as water purification and conservation technologies.
Chapter 1: How Much Water Do We Have Access To?:

Section 1: Global Reserves

“Thousands have lived without love, not one without water.”

-W.H. Auden

Humans and water are inseparable. Throughout our species’ biological and cultural evolution where we live was dependent on adequate water supplies nearby. Arabian trade route villages around an oasis, Incan settlements near high altitude lakes, and Sumerian cities on the banks of rivers are just a few examples. One would not be overstating the truth to say that human survival and water are one in the same. In fact water has been so influential to human cultural development that, Karl August Wittfogel in his 1957 book, Oriental Despotism, introduced the idea of the “hydraulic civilization”, suggesting that governmental organization was shaped due to the need for water management for irrigation and sanitation.

Luckily for us, water is the most widely occurring substance on Earth, 71% of the planets surface area! However, much of this is non-potable salty water. Humans can drink only ‘freshwater’. So how much water do we truly have access to?

According to the UN World Water Development Report, 96.5 percent of the total volume of the world’s water is exists in the oceans and only 2.5 percent is freshwater. Nearly 70 percent of this freshwater is in ice sheets and glaciers and less than 30 percent is stored as groundwater in the worlds aquifers (UNESCO, 2003; pg, 67).
In other words, 87% of our freshwater is unavailable because it is stored in glaciers, snow, and permafrost. Of the remaining 13%, 95% is stored as groundwater. Thus the total amount of freshwater available to humans is less than 0.5% of all water on the planet (Slattery, 2012).
It is important to note that the satellites and hydrologic sensors that collect this data are subject to inaccuracies. “Many of these devices suffer from inherent errors; they lack maintenance and they are not calibrated regularly” (UNESCO, 2003; pg 68).

We now know how much drinking water there is, but who has access to this water? The fact is that potable water is not distributed evenly across the planet. Let’s compare Asia to South America.

Asia is home to 60% of the global population but only has 36% of total water reserves while South America, which contains only 6% of global population, has 26% of water reserves. That means South Americans have access to more than seven times the amount of water that Asians do!

![Figure 1.3: Water Availability vs. Global Population](source)

Various other factors must be taken into consideration when discussing water availability and distribution, chiefly population density. When total renewable water resources in an area are compared to its population density we can more accurately evaluate the amount
of water that the population has access to (as well as assess it’s sustainability). For example, when these numbers are computed for Bolivia we find 74,743 (m³/capita year) total renewable water resources per capita compared to 36,333 in Cambodia (UNESCO, 2003; pg. 70). These numbers have very little meaning to the laymen, yet they highlight an important point when considering water in the 21st century. The way we use our water and the size of the population drawing from the reserves are very important variables when evaluating sustainable (or unsustainable) water consumption. These factors will be discussed throughout this report.

*How* we get water is just as important as evaluating the distribution of water. There are a variety of freshwater sources such as lakes and reservoirs, rivers, ice caps and glaciers, rain catchment systems (gray water), and groundwater (aquifers). Aquifers are the most important sources when considering water dependency of a population, “Globally groundwater is estimated to provide about 50 percent of current potable water supplies, 40 percent of the demand of self-supplied industry and 20 percent of water use in irrigated agriculture” furthermore, “It is believed more than 1.2 billion urban dwellers worldwide depend on well, borehole and spring sources” (UNESCO, 2003; pg. 78).

Aquifers, when compared to other sources, lose very little water from evaporation and are less susceptible to pollution yet there is a major issue.

Aquifers take hundreds and even thousands of years to replenish, in fact some never do (these are know as ‘fossil aquifers’). Since the advent of steam power aquifers have been increasingly pumped at unsustainable rates, threatening drought, drawdown, and even sinkholes. The poster child of this issue has been the giant High Plains Aquifer (also known as the Ogallala).
Stretching from Nebraska to northern Texas, the High Plains Aquifer irrigates one of the world’s leading agricultural breadbaskets, from which millions make their living growing grains to feed people in the Americas and around the world. According to Michael C. Slattery in his book, Contemporary Environmental Issues⁴, between the years from 1990 and 2005 a 12% decrease in the water storage of the aquifer was recorded, roughly a 1% decline per year. Slattery reports that, “vast areas of the aquifer have less than 30 years worth of usable water, suggesting that the era of irrigated agriculture on the Texas High Plains will probably come to an end within the next generation” (Slattery, 2012; pg. 232).
If one of the World’s largest aquifers is drying up we must wonder what is happening to the smaller aquifers. Are they too being used unsustainably?

Lakes and reservoirs (and the rivers that supply them) are also substantial sources for drinking water. Although more susceptible to pollution, these sources are much more accessible than aquifers. In the past hundred years, nearly 50,000 ‘large dams’ have been built\(^1\). These dams provide flood control, fishing and recreational grounds, and electricity in addition to water reserves during times of drought.

The important take away from the above information is that only a very small percentage of water on the planet is accessible freshwater. Due to an increasing global population the UN Global Sustainable Development Report\(^2\) has reported that, “By the middle of this century, at worst 7 billion people in sixty countries will be water-scarce [lack of sufficient available water resources to meet daily needs], at best 2 billion people in forty-eight countries”.

\(^1\)Dams built

\(^2\)UN Global Sustainable Development Report
Chapter 2: Distribution

Section 1: What is Water Used for?

I was shocked when I first learned that only 1% of water withdrawals are used for domestic purposes (part of municipal use) in the US (Slattery, 2012; pg. 238), what happens to the remaining 99%? We discussed in the previous chapter how vital freshwater is for human survival and how little we have. But how do we use this water? We learned from the above statistic that we clearly do not use much of it for drinking. In this section we will examine this question and determine what water is used for in the 21st century.

Water use can be split into four categories, industrial, agricultural, energy, and domestic consumption. Industrialized and developing nations use water in different ways. "Worldwide, agriculture accounts for 70% of all water consumption, compared to 20% for industry and 10% for domestic use. In industrialized nations, however,
industries consume more than half of the water available for human use. Belgium, for example, uses 80% of the water available for industry” (Worldometers.com)

Water is used in industry to clean, heat, cool, transport as well as a raw ingredient in products. Between 1960 and 1980 industrial water withdrawal increased significantly globally. North America’s use increased by 60%, Africa’s nearly doubled, and Asia’s tripled. That’s being said, water use for industry has been stabilizing and even decreasing throughout the World (Figure 2.2).

![Industrial Water Use by Region](image.png)

**Figure 2.2**
**Industrial Water Use by Region**
Source: UNESCO
Although industry uses a significant amount of water, agriculture uses much more by comparison. **Figure 2.3** (below) compares water use by industry to agricultural use (*in dark blue*) as well as domestic use.

Agricultural practices consume so much water because of the high indirect (not for drinking, cooking, washing, etc.) requirements of water needed to produce crops and livestock. This indirect use is referred to as the *virtual water content*, which is the sum of water used in all the steps leading to the production of the final product\(^{11}\).

For example maize production between the years of 1996-2005 consumed 10% of total World water use, about 1220 liter/kg.\(^{14}\). Furthermore meat has substantially larger virtual water content due to feed requirements as well as longer maturation periods. An organization, the Water Footprint Network, has compiled the following information:

*Figure 2.3*
Source: World Bank, 2005
“The water footprint of meat from beef cattle (15400 liter/kg as a global average) is much larger than the footprints of meat from sheep (10400 liter/kg), pig (6000 liter/kg), goat (5500 liter/kg) or chicken (4300 liter/kg). The average water footprint per calorie for beef is twenty times larger than for cereals and starchy roots. The average water footprint per gram of protein in the case of beef is six times larger than for pulses” (Waterfootprint.org).

Global water withdrawals for energy production in 2010 were estimated to be 15% of total withdrawals\(^{10}\). Water is used directly in nearly all forms of energy production.

Fracking harvests natural gas from shale rock by pumping water and chemicals at a high pressure to fracture the rock. One to eight million gallons of water is required at each fracking well.\(^{19}\) Stream hydropower, while not directly consuming water, produces a fifth of the World’s energy. In fact, “Hydropower is the cheapest way to generate electricity today. That's because once a dam has been built and the equipment installed, the energy source—flowing water—is free” (Hydropower Facts, Hydropower Information- National Geographic). Water is also used to cool thermoelectric systems such as those found in nuclear power plants. For example, thermoelectric alone consumes 49% of water withdrawals in the United States\(^{11}\). Water is also used to dilute contaminants in waste water systems associated with energy production.

Water is so vital to energy production that the World Energy Outlook (WEO) claims that, “Energy depends on water [and] is growing in importance as a criterion for assessing the physical, economic, and environmental viability of energy projects” (World Energy Outlook, IEA; pg. 2).
Lastly, water is consumed at home. Domestic use (included within municipal use) is water used in and around the house, such as in preparing food, washing clothes, flushing toilets, watering gardens/lawns, for drinking, and so on. The average American uses 155 gallons a day, while the average Chinese citizen uses 15 gallons\textsuperscript{11}.

Section 2: Climate

To further understand water in the 21\textsuperscript{st} century we must have a basic understanding of the influence climate has on water distribution.

“Scientists refer to our planet as a closed system, meaning that very little material (including water) escapes into outer space. In other words, the water that existed on Earth millions of years ago is the same water that exists today” (Slattery, 2012, pg. 226). The pathway through which water moves through the Earth’s atmosphere and its terrestrial and aquatic environments is referred to as the hydrologic cycle.
There are three key players when considering the hydrologic cycle; \textit{evaporation} (transformation from liquid to water), \textit{transpiration} (the movement of water from the soil to vascular plants and into the atmosphere), and \textit{precipitation} (rainfall). The reason it rains more in the tropics than at high latitudes is ultimately due to how the planet is warmed by the Sun (and the resulting ocean and wind currents). Thus we can think of these three factors as the mechanisms through which this heating and cooling is expressed.

Although the hydrologic cycle is very useful when conceptualizing the movement of water it is a simplification of reality. Seasonal factors also influence the distribution of water. For example, the monsoons in southern Asia (where close to a billion people depend on the rains they bring that replenish rivers used for crop irrigation) are due to seasonal changes when wind patterns shift and moisture laden air is forced up the Himalayas resulting in an orographic effect (and thus precipitation). Furthermore, other irregular occurring climatic changes such as El Nino and La Nina refer to the alteration of
global ocean temperatures and currents. This effects ocean nutrient distribution and precipitation among other things.

![Figure 2.6: Average Global Ocean Temperatures](source: NASA)

All the above climatic factors are natural occurrences, yet in both the 20th and 21st century we are experiencing the first human induced global climate change. The United Nations has stated that climate change will result in many adverse affects such as:

“Changes in evapotranspiration…the magnitude and timing of runoff, the intensity of floods and droughts have had significant impacts on regional water resources, affecting both surface water and groundwater supply for domestic and industrial uses, irrigation, hydropower generation, navigation, in stream ecosystems and water based recreation” (Water for People, Water for Life, 2003; pg. 76).

Sadly those who live in areas that periodically experience mild to extreme drought/flooding are most at risk to have these instances increase. The effects of
human induced climate change will be considered in further detail towards the end of this report.

Section 3: Population

During the fierce years of WWII global population peaked around 2.5 billion. As Nazi Germany was dismantled and the atomic bomb was dropped on imperial Japan an even larger bomb began to explode across the planet and is still doing so today, the ‘population bomb’. In 2012 global population reached 7.2 billion, with an unprecedented average annual gain of 81 million people. The UN Population Division has since then projected global population to reach 9.6 billion in 2050 and 10.9 billion in 2100\textsuperscript{17}.

![World map: Projected population growth, 2010–2100](image)

Most of this population growth has (and will) occur in less developed countries (LDCs), due to high fertility rates. Yet there is good news, global fertility rates are
lowering towards zero growth (about 2.1 children per couple). In fact, the UN Population Division estimates LDCs fertility rate dropping from an average of 4.53 to 2.87 by 2050. Never the less, “The World’s population has tripled in 72 years, and doubled in 38 up to the year 1999” (Slattery, 2012; pg. 22).

Figure 2.8
Source: Slattery, 2012

Figure 2.9: Distribution of World Population
Source: Slattery, 2012
The above information is critical when discussing what may be the most important concept covered in this synopsis to understand water in the 21st century, carrying capacity. Carrying capacity (K#) is defined as:

“the theoretical equilibrium population size at which a particular population in a particular environment will stabilize when its supply of resources remains constant. It can also be thought of as the maximum sustainable population size; the maximum size that can be supported indefinitely into the future without degrading the environment for future generations” (Oregon State University, Carrying Capacity, pg. 2).

Reverend Thomas Malthus (1766-1834) put forth an idea in, An Essay on the Principle of Population, that populations grow at an exponential rate while food production grows at an arithmetic (linear) rate. When the population exceeds the local biological carrying capacity (total available resources) a few things can occur.

1. The population will experience dieback (population collapse to below K#).
2. A period of overshoot (population exceeds carrying capacity) and then dieback will occur.
3. Quality of life will decrease to the point that everyone will have to subsist with fewer resources than before (only possible, if there is enough resources available to satisfy the basic biological needs of that population).

Malthus presents a problem, how do we maintain/increase the quality of life of ever increasing numbers of humans without destroying the environment? Malthus’s concept has unsettled scholars and laymen alike since it was first published. It seems to
go against the western belief that science can solve any problem. But in fact, technology overall has kept pace with population growth, maintaining and even increasing (for some) quality of life. During the Green Revolution (specifically between the years of 1985-2005) crop production increased by $28\%^{11}$.

So we must wonder, when can we truly say carrying capacity has been reached? At two points, when we begin to degrade our environment at a rate faster than it can be regenerated or when our supply of resources remains constant. Globally I feel confident that we have met the first constraint noted by deforestation, pollution, and erosion, at rates unimaginable just 100 years ago, especially in areas throughout Africa. But have we met the second constraint? Ronald Wright in his books, *A Short History of Progress*, thinks we have:

“Ecological markers suggest that in the early 1960s, humans were using about 70 per cent of nature’s yearly output; by the early 1980s, we’d reached 100 per cent; and in 1999, we were at 125 per cent. Such numbers may be imprecise, but their trend is clear- they mark the road to bankruptcy” (Wright, 2004; pg. 129).

If we consider all the information we have learned thus far in this report a paramount question should come to our minds. Do we have enough water for the projected populations? Will 10.9 billion people be able to survive off the 0.5% of potable water we have access to? There truly is no simple yes or no answer to this question. At current rates of consumption, I foresee our species out-pacing carrying capacity. However if we reduce the amount of water we use per person as well as develop
additional water purification technologies (some of which will be covered later in chapter 5) it is very well possible we could avoid surpassing carrying capacity at least in water.

The World Health Organization (WHO) suggests that five gallons is the minimum water requirement to meet a person’s daily needs. But at the start of the 21st century 20% of the world’s population did not meet this standard. Slattery sums up the issue:

“By 2025, two out of three people in the world will experience significant water shortages. By then, water use is expected to have increased 40% and 17% more water will be required for food production to meet the needs of growing populations” (Slattery, 2012; pg. 240).

Population may be the biggest threat to water supply in the 21st century. We must keep in mind that no matter what ones political, religious, or national ideals are we die without water.

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Figure 2.10
Source: UNESCO
Sometimes our minds and leaders can be ignorant to this fact. In the next session we will discuss the part politics and NGOs play in water distribution and quality.

Section 4: Politics and NGOs

“A leader is best when people barely know he exists, when his work is done, his aim fulfilled, they will say: we did it ourselves.” -Lao Tzu

Is water a human right or an economic good? The debate surrounding this question has deep political, economic, and social implications. If water is a human right, we have equal ownership of the resource. Yet, if water is an economic good it can be bought, traded, and owned exclusively. The debate around this question is vast and complex; it would take many chapters to adequately discuss the relevant philosophical ideals of property and human rights as well as the sociopolitical and economic context. One thing is clear, however, leadership of particular interest when discussing water rights and economics.

In this section we will discuss the role of international agencies, governments, and NGOs in the acquisition of water by their constituents. If you are interested about the broader context and debate over water rights watch Blue Gold: Water Wars, a documentary on this issue.

In the year 2000 the United Nations established eight international development goals called the ‘Millennium Development Goals’ (MDG). Goal number seven, ‘ensure environmental sustainability’, includes an objective to, “Halve, by 2015, the proportion of the population without sustainable access to safe drinking water and basic sanitation”
This goal was met five years ahead of schedule, providing more than two billion people with access to ‘improved drinking water sources’ between 1990 and 2010\textsuperscript{13}.

This achievement highlights the possibility to overcome seemingly impossible tasks if governments cooperate. Cooperation concerning water has undoubtedly prevented various conflicts. A study by Oregon State University (OSU) in the United States has investigated water interactions:

“[OSU] has attempted to compile data covering every reported interaction over water going back 50 years. What is striking in these data is that there have been only 37 cases of reported violence between states over water (30 of them in the Middle East). Over the same period more than 200 water treaties were negotiated between countries. In all, 1,228 cooperative events were recorded, compared with 507 conflict events, more than two-thirds of which involved only low-level verbal hostility” (Vital Graphics, grida.com).

It is clear that many national governments are maintaining an active dialogue over water. Legislation drafted by local and state governments have also improved citizen’s access to clean drinking water. For example, in Punjab, Pakistan the Punjab Rural Water Supply and Sanitation Project drafted by the federal government had brought safe drinking water to 800,000 people as well as freed women and children from the labor and time consuming chore of fetching water from point sources. A study in 2009 found that the average household income increase by twenty four percent. Forty five percent of the time that would have been devoted to water procurement was now devoted to income-generating activities, and more children were reported to be attending school\textsuperscript{18}.
Legislation in the United States has also been successful. Acts such as the *Clean Water Act* (effective in 1972) put forth regulations and controls of water pollution (particularly ‘point-sources’ such as a sewage pipe dumping into rivers). Another bill, the *Safe Drinking Water Act* (SDWA), is a federal law that requires the Environmental Protection Agency (EPA) to set standards for drinking water quality and administer state implementation. This bill also outlines groundwater protection policies. Although it is clear that legislation can clearly solve water quality and quantity issues laws are only as strong as the governments that enforce them.

Without a doubt, a successful country is built upon an educated populace that is free and involved in leadership and governmental decisions. So what does freedom have to do with water? Free people have a say in what water is used for and who should get what. If a nation’s water is controlled by a few, the resource may not be equally distributed. The United Nations Development Programme (UNDP) states the risk of aquatic political inequality:

![Department of Water Supply & Sanitation (Punjab) treatment facility](http://www.pbdwss.gov.in)
“Water is power, and those who control the flow of water in time and space exercise this power in various ways. It is often claimed that clean water tends to gravitate towards the rich and wastewater towards the poor….The way in which societies govern their water resources has profound impacts on settlements, livelihoods, and environmental sustainability” (Water, A Shared Responsibility, 2006; pg. 47 chapter 2).

Because of its influence on water use and distribution, let’s look at the status of global political rights. Freedom House is a US based NGO which conducts research and advocates for political and social rights. This organization has visually summarized the status of governments across the world (see figure 2.12 Green = free, yellow = partly free, purple = not free).
By comparing the map of political freedom to the map **figure 2.11** of water ‘scarcity’ (more than 75% of river flows are allocated to agriculture, industries or domestic purposes) we notice that most of the areas that are only ‘partially free’ and ‘not free’ correspond to areas that have or are approaching *physical water scarcity*. Correlation does not imply causation; we cannot conclude that poor governance is the main cause of scarcity. But we can hypothesize that as these populations grow (many of these countries are LDC with high birth rates) the demand for dwindling water resources will not equal supply. Without a path to express opinions and influence government allocation and use of water in a peaceful manner political conflict may ensue.

![Figure 2.13](image)

*Figure 2.13*
*Source: International Water Management Institute (IWMI)*

We are already witnessing supporting evidence of our above hypothesis. Thomas Friedman, a journalist for the *New York Times* claimed that the conflict in Syria was due
in part to a long term drought. Luckily, Freedom House has found that the amount of ‘free’ countries have been increasing over the past few decades (see figure 2.14 below).

![Free Country Growth](source: Freedomhouse.org)

It is my belief that we can safely claim that without political freedom the water issues of the 21st century will be more difficult (if possible at all) to overcome. Although political freedom is increasing it may not be progressing fast enough. Information and an open dialogue concerning water quality and quantity needs to be freely accessible to the citizens of all countries as it allows the possibility of responsible, sustainable, and fair usage. Still today, 2.5 billion people in LDCs lack access to improved sanitation facilities. Government can either be the key to solving our water issues in the 21st century or its hindrance. So what about private interest? Is there a benefit to classifying water as an economic good? Will a price tag result in people using less water in a more sustainable way in accordance with supply? Many governments around the world believe this.

Privatization is the act of transferring an enterprise from the public sector to the private sector. Water privatization is not a new idea, France has had privatized water since the days of Napoleon. According to the Ministry of the Environment, 75% of water...
services in France are supplied by the private sector, primarily by two companies, Suez and Veolia. England, as well, privatized much of its water under Margret Thatcher (Prime Minister, 1979-1990) who supported and ultimately succeeded in privatizing the public regional water authorities (RWA) throughout England and Wales. “Annually between 1995 and 1999, governments around the world privatized an average of thirty-six water supply or wastewater treatment systems [annually]” (Water, A Shared Responsibility, 2006; pg. 48 Chapter 2). But why?

Section 5: Private Companies and Commercial Sale of Water

In the previous section an important question was asked, is water a human right or an economic good? In 1992 five hundred experts and representatives from around the world gathered in Dublin to answer this question. The conference published its consensus and recommendations for dealing with the water crisis as The Dublin Statement on Water and Sustainable Development. The participants recommended that local and international action follow four principals:

1) “Effective management of water resources demands a holistic approach, linking social and economic development with protection of natural ecosystems.

2) Water development and management should be based on a participatory approach, involving users, planners and policy-makers at all levels.

3) Women play a central part in the provision, management and safeguarding of water.

4) Water has an economic value in all its competing uses and should be recognized as an
economic good” (The Dublin Statement on Water and Sustainable Development, UN; pg. 1-2)

Principle number four is the most relevance to our initial question. The published statement does support water as a human right however, the authors believe that not establishing a price tag on water is the reason it has been used unsustainably. “Managing water as an economic good is an important way of achieving efficient and equitable use, and of encouraging conservation and protection of water resources” (The Dublin Statement on Water and Sustainable Development, UN; pg. 1).

Yes, public water systems obviously can be wasteful because there is limited economic incentive to limit wasteful consumption. Additionally, elected and appointed officials are subject to corruption, can impose policies for personal benefit, or accept bribes from third parties that are detrimental to the public good. However, are private companies not also subject to waste and dishonesty? Think of it this way, a public system may suffer from inefficiencies but the service or product is owned and somewhat directly regulated by the people using it. On the other hand, private water companies have little incentive to invest in public water systems' improvements or maintenance activities that will produce benefits beyond the end of the privatization contract's term. Additionally, private water companies have little incentive to encourage conservation because as usage goes down so does revenue.

Another issue with classifying water as an economic good is the resulting restriction on access for those who cannot afford it. Commodities are sold to the highest bidder, rich countries can afford to pay for metered water, but many LDCs struggle to
even pay for the basic infrastructure. Citizens are too poor to pay for metered water and thus many die from dehydration, drink from polluted sources, steal water, or are subsidized by the government. UNESCO cites an important point made by the World Bank on this issue, “…pro-poor policies relying on cross-subsidization have created an inefficient and unsustainable water services sector with serious impacts on the environment in many countries” (Water, A Shared Responsibility, 2006; pg, 401).

Let’s step back from theory and look at water through the eyes of a potential investor. The poster child of water privatization in recent years has been the bottled water industry. It is estimated to be a $100 billion market world-wide⁴, and growing. **Figure 12.15** is the stock prices over the past year of two of the world’s largest private water companies, Suez and Veolia.

![Figure 12.15](source:Bloomberg.com)

Why are bottled water sales increasing? Simply, because people believe it is safer than their local tap water. Surely, only people in countries with poor water sanitation are the
only ones that believe this, right? UNESCO’s World Water Development Report (2012) found otherwise:

“When asked why they are willing to pay so much for bottled water when they have access to tap water, consumers often list concerns about the safety of tap water as a major reason for preferring bottled water (NRDC, 1999). While most companies market this product on the basis that it is safer than tap water, various studies indicate that it is not safer than tap water, various studies indicate that bottled water regulations are in fact inadequate to ensure purity or safety.

The World Health Organization (WHO, 2000) warns that bottled water can actually have a greater bacterial count than municipal water. In many countries, the manufacturers themselves are responsible for the product sampling and safety testing. In the United States, for example, the standards by which bottled water is graded (regulated by the Food and Drug Administration) are actually lower than those for tap water” (Water, A Shared Responsibility 2006; pg. 402).

It is clear that consumers are willing to spend substantially more on water they believe is sanitary, and marketing tactics have taken advantage of this. Duke University found that the average cost of bottled water and vended water in the U.S. was $0.90 per gallon. This may not seem like a lot to you, but it does when you compare it to the average cost of tap water in California: $0.80 per 500 gallons³!

The bottom line is that water is a commodity unlike any other. It is an inelastic good because people are willing to pay whatever the cost that is necessary for survival. Demand is higher than supply and as population growth and current industrial practices
progress the cost of water is bound to increase. An article titled, *The Race to Buy Up the World’s Water*, by Newsweek sums up the market potential:

“Everyone agrees that we are in the midst of a global freshwater crisis. Around the world, rivers, lakes, and aquifers are dwindling faster than Mother Nature can possibly replenish them; industrial and household chemicals are rapidly polluting what’s left. Meanwhile, global population is ticking skyward. Goldman Sachs estimates that global water consumption is doubling every 20 years, and the United Nations expects demand to outstrip supply by more than 30 percent come 2040. According to a 2009 report by the World Bank, private investment in the water industry is set to double in the next five years; the water-supply market alone will increase by 20 percent” (*Newsweek: The Race To Buy Up the World’s Water, August 2010*).

Clearly water is a great investment yet are the economic gains for few fair when they make it harder for the majority to acquire water? On the other hand, perhaps selling water as a private and economic good will lead to decreased waste and increased investment in infrastructure due to a price of purchase that correlates more closely with true value. It is hard to say what is the better choice, however we can be certain that the way water globally is distributed in the 21st century will differ greatly from all that occurred before.

We have learned about how much water we have in chapter one and now the distribution of that water in chapter two however an important question has not been answered, what are we (humans) doing to our available reserves? The *Newsweek* article excerpt above states that we are, “rapidly polluting what is left”. Lets investigate this claim in chapter three, *water quality*. 
Chapter 3: Water Quality

Section 1: Global Water Quality Overview

What is safe drinking water? The World Health Organization (WHO) defines safe drinking water in two ways, accessibility and potability (how safe the water is to drink). For water to be considered accessible it must be within one kilometer from its place of use and have the capacity to readily supply at least twenty liters (5.3 gallons) of water per member of a household per day\(^5\). However potability is a bit more difficult to define. Since 1958 WHO has periodically published international standards and guidelines for drinking water quality. These reports include evaluations of chemicals, microbes, pharmaceuticals, and similar contaminants that may be found in water and establish limits on safe human ingestion, beyond which may result in acute or chronic illness.

So now that we have an idea of what safe drinking water is what happens to people that have limited or no access to clean water? Based on JMP (WHO and UNICEF Joint Monitoring Programme) analyses, “It is estimated that between 1990 and 2008 an estimated 1.77 billion people gained access to improved sources of drinking water; yet, by the end of 2008. 884 million people still lacked access to improved water sources” (WHO/UNICEF JMP: Drinking Water; Equity, Safety, Sustainability, 2011). Of those 884 million people WHO found that:

- “1.6 million people die every year from diarrheal diseases (including cholera) attributable to lack of access to safe drinking water and basic sanitation and 90% of these are children under 5, mostly in developing countries;
- 160 million people are infected with schistosomiasis [a water-born parasite that
causes the infected to pee blood and possibly loose vision causing tens of thousands of deaths yearly; 500 million people are at risk of trachoma from which 146 million are threatened by blindness and 6 million are visually impaired;

- Intestinal helminthes (ascariasis, trichuriasis and hookworm infection) are plaguing the developing world due to inadequate drinking water, sanitation and hygiene with 133 million suffering from high intensity intestinal helminthes infections; there are around 1.5 million cases of clinical hepatitis A every year” (WHO/UNICEF JMP: Drinking Water; Equity, Safety, Sustainability, 2011)

The text above includes heart wrenching statistics but, this information is necessary to understand the context and seriousness of the relationship between water quality and human health.

It is obvious that polluted water can carry pathogens and harmful contaminants yet many believe that this is only a problem effecting LDCs (less developed countries), this is far from the truth. For example, in the United States (the richest country on the planet), “80% of our nation’s streams averaged five or more contaminants at detectable levels” (Slattery, 2012; pg. 248) including chemicals harmful to human health.

Safe drinking water is necessary for all human beings and will increasingly become harder to provide for a growing global population, a population that will require more food (and thus more use of fertilizers) and more manufactured goods (increasing chemical accumulation and runoff). We can identify this as a positive-feedback loop. Meaning, all things constant (i.e. current consumption patterns stay the same), as
population increases demand for drinking water will increase while decreasing supply as it is polluted and utilized by the above factors.

Section 2: Causes of Pollution

As noted in chapter two, section one (what is water used for?) agriculture is by far the largest consumer of water, therefore we will be focusing primarily on agriculture-induced water pollution (quality and pollution are the most extensively studied aspects of water based publications, a simple search of the web will give the interested reader a plethora of additional information and resources about other causes of pollution).

There are two types of pollution sources, point-source and non-point source (NPS). Point-source refers to pollution that can be linked to a single outlet while a non-point source cannot. For example (figure 3.1), a sewage pipe dumping into a lake is a point-source while runoff from many agricultural fields into a drainage basin is a NPS. NPS are difficult to monitor and regulate and therefore are the largest and most serious water quality issues.

Figure 3.1
Source: lujiamin.words.com
The largest NPS of water pollution is from agricultural runoff, primarily from fertilizers such as chemical synthetics and natural manures. Nitrate (NO$_3^-$), a form of Nitrogen, is a nutrient necessary for plant growth and is one of the most common chemical fertilizers that is applied to fields to increase fertility and yield.

Nitrates are of particular concern when discussing agricultural water pollutants because of its weak bond to other nutrients found in soil. This weak bond allows NO$_3^-$ to leach easily in runoff and thus be deposited in water bodies where it can accumulate. Other heavily used fertilizers, like phosphorus, ‘stick’ to the molecules in the substrate (soil) thus are less likely to be leached in runoff.

If nitrates accumulate in water bodies it can produce large algae blooms causing acute hypoxia resulting in the death of aquatic life (aka, “dead-zones”), this process is called eutrophication. The runoff from agricultural fields bordering the Mississippi river, which carries fifteen times more nitrate than any other U.S. river, has created the largest seasonal dead zone in the world in the Gulf of Mexico. These algae blooms not only deplete oxygen in the water and reduce the penetration of light to underwater photosynthetic plants, but some also produce toxins that make the water unpalatable.

The use of fertilizers seems to be on the rise. Figure 3.2 shows levels of soil degradation, primarily due to over use of fertilizers and human activities and figure 3.3 exemplifies the positive global trends of fertilizer use.
A boost in fertilizer use first came about during the *Green Revolution* (occurring between the 1940’s and late 1960s) in accordance with new research, development, and technologies having to do with increasing crop yields. Yet another devastating water pollutant common today are pesticides.

**Section 3: Pesticides and Bioaccumulation**
The most comprehensive study of its kind, a decade long analysis by the USGS National Water Quality Assessment (NAWQA) found that, “pesticides are frequently present in streams [most vulnerable] and ground water [least vulnerable], are seldom at concentrations likely to affect humans, but occur in many streams at concentrations that may have effects on aquatic life or fish-eating wildlife” (USGS: Pesticides in the Nation's Streams and Ground Water, 1992–2001—A Summary). More specifically, “less than ten percent of stream sites and about one percent of wells had concentrations greater than a human-health benchmark (the point above which adverse health effects are likely)”.

However, “concentrations of pesticides were greater than water-quality benchmarks for aquatic life and (or) fish-eating wildlife in more than half (56%) of the streams with substantial agricultural and urban areas in their watersheds”. Interestingly, over the course of the study many of the insecticide and pesticide levels dropped substantially (i.e. diazinon, chlorpyrifos, and malathion were found above benchmark levels in 95% of streams from 1993-1997 and dropped to 64% from 1998-2000) due to legislative and regulated banning of certain chemicals (see figure 3.5 for a visual summary of the study).

![Figure 3.5](source: USGS)
If we take the above information at face value we would conclude that there are low levels of pesticides in our drinking water and thus pesticides have only a limited effect on our health. But let’s examine the whole picture. The effects of pesticides on aquatic life, which was noted to be very significant by the NAWQA study, can affect us just as much (or more!) if we consume this aquatic life. I am referring to bioaccumulation.

“Bioaccumulation is the uptake of organic compounds by biota from either water or food. Many toxic organic chemicals attain concentrations in biota several orders of magnitude greater than their aqueous concentrations, and therefore, bioaccumulation poses a serious threat to both the biota of surface waters and the humans that feed on these surface-water species” (USGS.gov).

In other words, animals (and some plants) higher on the food chain are more susceptible to accumulating toxins in their body due to the increasing number of calories the creature must consume to sustain itself. Only about 10% of the energy consumed by prey is accessible to the predator, due to the use of about 90% of the initial input energy for metabolic activities by the prey. Thus, creatures higher on the food chain must eat more than their prey to get the sufficient nutrients (see figure 3.6).

When we consider trophic levels and bioaccumulation we realize something, as primary producers/consumers become contaminated with chemicals the creatures that are higher on the food chain (and thus need to eat increasingly more calories) accumulate the toxins their prey hold in their tissues (see figure 3.7).
Figure 3.6
Source: https://vle.whs.bucks.sch.uk/course/view.php?id=1365

Figure 3.7
Source: http://connectingthe.coast.uwex.edu/Investigate/cpPersistentPesticides.html

The numbers are representative values of the concentration in the tissues of DDT and its derivatives (in parts per million, ppm).
Human beings are at the top of the food chain and eat many of the other tertiary consumers that have bioaccumulated toxins in their body from their prey. In a very simplified form, eventually we eat (and drink) whatever we put into our environment. In this way, water quality is very important to observe and maintain as it is strongly connected to human health.

Many of the studies noted in this section emphasize the United States, a country with some of the strongest environmental protection laws on the planet. But even here water pollution remains a threat. In countries with limited environmental protection law (primarily Less Developed Countries, LDCs) the funds necessary to ensure water quality are limited or non-existent. In addition, larger populations (and thus more mouths to feed) make the yield-increasing benefits of fertilizers and pesticides attractive. Thus environmental law and preventative measures against water pollution are key however they may complicate even larger issues.

In the 21st century the use of chemicals may decrease in developed countries but actually increase in the more populous less developed countries. I believe we will see only a moderate increase in preventative measures yet a substantial growth in water purification technologies and methods. In the next chapter we will discuss water purification methods and technologies to better understand how dirty drinking water be made potable.
Chapter 4: Water Purification and Conservation Technologies

Section 1: Selected Technologies For Water Purification

“Because each purification technology removes a specific type of contaminant, none can be relied upon to remove all contaminants to the levels required for critical applications. A well-designed water purification system uses a combination of purification technologies to achieve final water quality” (http://www.freedrinkingwater.com/water-education/quality-water-filtration-method-page3.htm).

We discussed in the previous chapter what clean and safe drinking water is yet how is contaminated water filtered and refined to meet these specifications? We cannot tell from sight alone if water is of appropriate drinking quality but instead need complex and sometimes expensive chemical, microbiological, and bacteriological water analyses tests. Not many of these tests were in practice when the first public water treatment system (a sand filter) opened in 1829 in Chelsea, London\(^2\). Yet, from humble beginnings we have at our disposal today a variety of water quality tests and filtration techniques ranging from multimillion-dollar water treatment plants to affordable filtration straws (lifestraw) that can fit in your pocket. Lets cut to the chase, how is water purified in today’s modern society?

![Water Treatment Plant Diagram](http://cofcof.ca/surface-water-treatment-plant-flow-diagram/)
The first step is to pump and contain the contaminated water from a river, lake, aquifer, etc. This water is then pumped through a screen to filter out any large objects (i.e. sticks, rocks, trash, human waste). Interestingly, this step may sometimes be skipped when treating ground water as many of the large materials are filtered out as the water seeps through soil and rock.

Once filtered the water’s pH is tested and adjusted by adding in various organic or inorganic chemicals (pure water has a pH of seven, which is neither acidic nor alkaline). This water is then pumped to a mixing chamber where chemicals (either inorganic metal salt coagulants or organic polymers) are added to the water to assist the removal of harmful particles dissolved in the water, such as bacteria, viruses, algae, clay, silt and the like. These chemicals coagulate with dissolved particles in the mixing chamber to form “froc” (via flocculation), which are aggregated masses of the aforementioned dissolved contaminants (this makes their removal easier).

The water and heavy froc are then moved slowly over a ten to fifteen foot deep basin or chamber where heavier particles sink to the bottom forming sludge. This process is called sedimentation. The sludge is (usually) continuously removed from the basin and stored for cleansing.

It is important to note that this sludge is a concentrated mix of water contaminants, its disposal can have serious environmental impact if not properly handled of (which is usually an expensive endeavor). “Most of this waste is disposed in landfills and lagoons, or is applied to agricultural fields” (Drinking Water Waste Treatment, EPA).
Now the water enters the final stage, filtration. There are a variety of commonly used filtration methods. The most common are *rapid sand filters* (see figure 4.1) that are comprised of a top layer of charcoal and a larger bottom layer of sand. Gravity is used to filter the water down through the layers where particles are caught in the pores of the substrate. Another type is the *slow sand filter* (figure 4.2).

These filters use consecutive layers of sand from fine grain on top to large grains on the bottom. They depend upon a thin biological layer that forms on the fine grain sand to aid the filtration process. Besides being slower than rapid sand filters, slow sand filters cannot be backwashed (meaning the harmful particles caught in the pores of the sand cannot be removed without removing parts of the filter).
Yet another technique, *Membrane filters* (figure 4.2) have limited use.

**Figure 4.3**

Water is pumped through a screen that has very small pores, which can filter out most particles (including protozoa such as giardia and cryptosporidium) but cannot filter out dissolved substances such as heavy metals. These filters are primarily used in industry to filter water-exiting factories via point-sources (discussed in chapter 3).

It is important to note that many water treatment plants across the globe add liquid chlorine to water (a practice introduced in the 19th century) as it enters the first stage of treatment or exits the last stage to ensure the eradication of bacteria and other pathogens.

Other additional methods may be used at this point depending on the initial source of the water. These include the use of ozone, additional chemicals, water fluoridation (for dental health), and other similar techniques. I’d like to elaborate on two such techniques, reverse osmosis (RO) and ultraviolet (UV) radiation.

**Reverse Osmosis (RO)** is one of the most commonly used water treatment techniques. RO is unique because it removes a very high percentage of contaminants. The
following paragraph clearly and accurately describes how the natural process of osmosis is different than RO,

“Natural osmosis occurs when solutions with two different concentrations are separated by a semi-permeable membrane. Osmotic pressure drives water through the membrane; the water dilutes the more concentrated solution; and the end result is equilibrium. In water purification systems [reverse osmosis], hydraulic pressure is applied to the concentrated solution to counteract the osmotic pressure. Pure water is driven from the concentrated solution and collected downstream of the membrane” (Different Water Filtration Methods Explained, Freewastewater.com)

Ultraviolet (UV) Radiation also uses natural processes. UV radiation is harmful to any living beings’ DNA if exposed for long periods, with no protection an organism’s cells can become cancerous or be destroyed all together. UV systems apply this to contaminated water by exposing it to high-energy light (see figure 4.5) killing the microorganisms in the process. It is important to note that although UV systems are simple, they do not removed dissolved metals/particles, but only kill pathogens.
Now that we have a comprehensive understanding of traditional/common modern water purification methods I’d like to discuss new and emerging technologies. We will focus primarily on desalination however we will also discuss a few other technologies briefly.

Desalination is the removal of salt from saline (salt) or brackish water in order to make it suitable for human consumption. Desalination was used by over 300 million people in 2011 and is predicted to nearly double by 2020. Most of this growth will occur in the Middle East where desalinated water accounts for 9% of total supply. An estimated $120 million industry in 2010, which is expected to grow 17.7% from 2010-2020 (Saudi Arabia acquires 70% of its water from desalination!), see figure 4.6.
Although desalination seems to be *the* solution to our water issues there are many factors working against it. Chiefly, desalination remains energy intensive (therefore expensive) and its continued use (and implementation) will depend on fluctuations of available energy and newly developed technologies. This was not always the case, before the 1970s, desalination was not commercially viable due to expensive technological costs (don’t get me wrong, the technology is still expensive today, just not as much) but new innovations have significantly reduced costs. Let me explain.

There are four methods of desalination, multi-stage-flash (MSF), multi-effect distillation (MED), mechanical-vapor collection (MVC), and reverse osmosis (RO). RO was the game changer. RO made it significantly cheaper to desalinate sea and brackish water, so much so that most of the plants built today use RO (see figure 4.7).

“Until recently, purifying seawater cost roughly five to 10 times as much as drawing freshwater from more traditional sources [source: USGS]. RO filters have come a long way, however, and desalination today costs only half of what it did 10 to 15 years ago” (The Cost of Desalination, HowStuffWorks.com).

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**Figure 4.7**
New technologies have continually lowered operation costs. Innovations such as the use of isobaric chambers (which reduce the atmospheric pressure around the water and thus reducing the amount of energy it takes to heat the water) have nearly cut in half the production cost, so much so that a plant in Israel was able to produce some of the cheapest desalinated water yet at $0.527 per cubed meter\textsuperscript{10}.

And yet there are still major areas for improvement, primarily the RO membranes. Current membranes are made from aromatic polyamides, which are subject to biofouling, or the accumulation of a thin layer of organic material, which clogs the membrane. Many new types of membranes are in development, including a few promising designs at Massachusetts Institute of Technology in the United States.

It is clear technological breakthroughs have been advancing desalination and reducing production costs yet transportation, energy, and environmental costs have become the major barriers to large-scale desalination\textsuperscript{13}. Pumping or driving water from low coastal zones to inland or upland locations takes both time and money and is usually accomplished so with combustion based machinery (petroleum/oil powered). A topic for another day is peak oil and the increasing cost of crude oil as supply decreases and demand increases (look to chapter two to understand how our increasing global population is playing a role in this issue), additionally most of the reserves of global oil are in unstable regions (see figure 4.8).
We cannot rely on the price of oil to stay constant and thus should not base such valuable infrastructure (such as water treatment plants) of which peoples lives depend upon around its use. Alternative technologies such as geothermal, wind, nuclear, and solar power are already in use at plants around the world.

All of the above aside desalination does seem promising for the over 3.2 billion people globally that live within 120 miles of a coast. In China for example (a population of over 1.2 billion) 60% of the total population live in coastal provinces and it could be the next major country to start construction of desalination plants\textsuperscript{12}. So is desalination cost effective? Well, it depends on the energy source in use, continued technological breakthroughs, and where one lives. Lets now take a look at a few up-and-coming water purification technologies. We begin with nanofiltration (NF).

NF is a form of membrane filtration involving nanometer (nm) sized cylindrical pores that are slightly larger than those used in RO. NF has been in use since the 1980’s
primarily as a water softener, yet recent studies at the University of Nottingham have found NF to be a promising method of bioremediation. Their research has shown that bacteria can be used in the filtration process to digest the contaminants that accumulate on the membrane without stopping the filtration process. Professor Nidal Hilal, the lead researcher said, “By using bioremediation and nanofiltration technology combined, the water cleaning process is integrated — using far less energy than current processes” (Sciencedaily.com). However, currently this process is not used on a commercial scale. Rather, NF is used more commonly as a preliminary filter in RO systems (see figure 4.9). A research article titled ‘Nanofiltration in Drinking Water Supply’ claims nanofiltration is nothing more than a very thin filter,

“…one may assert that the term “nanofiltration” does not reflect any special process with the determination of the transfer mechanism and characteristic only of it. It can be characterized as the reverse osmosis (RO) process at low process on charged membranes. However, the term ”nanofiltration” perhaps is due to the commercial name of composite RO membranes with a thin and ultrathin selective layer” (Sciencedaily.com).

**Figure 4.9**

Whether RO and NF are distinctly different or not they both share a common problem, they remove most if not all minerals from their purified water. Interestingly, the WHO has conducted a study which has found this lack of minerals to have only limited adverse
health effects (we get most of our minerals (i.e. zinc, magnesium) from food), yet the study did conclude that these necessary minerals, if absorbed through drinking water, are retained at a higher level than through non water sources\(^6\).

A common issue with water purification is distribution of the final product (as noted in chapter two). Entrepreneurial endeavors have sought to solve this problem by creating small, personal purification systems that are both cheap and easy to use. Two such examples are LifeStraw and the Drinkable Book.

According to LifeStraw’s website, “LifeStraws have been distributed to nearly every major international humanitarian disaster since 2005 [the year it hit the market]”

**Figure 4.10** (Lifestraw.com) The company (Vestergaard) has stated the straw's target consumer to be people in developing nations in which, “One person in six does not have access to drinking water, and 6,000 people a day die from water-borne diseases” (http://news.bbc.co.uk/2/hi/africa/4967452.stm). Vestergaard discounts the filter for this market to $3.50 a straw and it costs about $20 for developed nations (Amazon.com).

As seen in **figure 4.10**, the filter is relatively small (9 inches in length) and has no moving parts or battery packs. LifeStraw packs the below specifications:

- Filters at least 1,000 liters of water (264 gallons)
- Weighs only 54 grams (2 oz.)
- Removes up to 99.99999 percent of waterborne bacteria
- Removes up to 99.9 percent of waterborne protozoan cysts
- Reduces turbidity by filtering particles of approx 0.2 microns
- BPA Free and contains no chemicals
  (Buylifestraw.com)
However, the straw does have its limitations. The LifeStraw may filter organic life as you suck but it does not separate out dissolved chemicals like those found in pesticides and fertilizers. As discussed in chapter three (Water Quality) these are very abundant in most developing nations whom have limited environmental regulations that limit the release of chemicals into water bodies, the very sources people may drink from with their LifeStraw. Nonetheless, the straw does protect people from water borne protozoa such as *giardia* and *cryptosporidium*, which cause many of the diarrheal deaths associated with unclean water consumption.

Another interesting personal filtration system is *The Drinkable Book* (see figure 4.11). Each page of the book has two removable filters that can clean up to one-hundred liters of water, over three liters of water a day if spread out over a month (at this rate a book can last a single person up to four years!14 Wired.com describes the book as so:

“The Drinkable Book isn’t a water filter, exactly. While most water filters trap harmful content, the Drinkable Book works a little differently. As dirty water passes through the paper, bacteria absorbs the silver ions [embedded in the page] which causes it to die. Think of it like poison for the poison found in your water. Liquid drips through the thick paper like coffee seeps through the filter in a pour-over cup and into a box.” (Wired.com)

Yet The Drinkable Book suffers from the same limitation the LifeStraw does, they do not remove dissolved metals but only kill organic life found in the water. Killing the organic life is most important when considering human life in the short term, however chemicals may lead to chronic life-long degenerative diseases. The best way to deal with dissolved chemicals is to not have them enter drinking sources in high concentrations in the first place, a hard task to accomplish in the industrial 21st century.
Section 2: Conservation Measures and Techniques

There are two methods by which all water conservation can be categorized, behavioral and engineering practices. Behavioral practices refer to how we use our water while engineering practices are mechanical fixtures such as water pressure, plumbing, material types used, and the like. Let’s talk briefly about a few technologies and behavioral changes, which can (and in most cases already do) conserve water.

Let’s talk about behavioral changes, some of these may seem self-explanatory but the idea and preserved value of conservation and being ‘green’ are a relatively recent cultural trend which associates cause-and-effect on a scale that much of the industrializing regions of the World are just catching on. The US Environmental Protection Agency (EPA) has an expansive list of water conserving techniques at http://water.epa.gov/polwaste/nps/chap3.cfm of which I wish to highlight just a few,

Figure 4.11
Source: http://www.wired.com/2014/05/smart-solution-a-book-whose-pages-filter-dirty-water/#slide-id-852321
primarily low flow toilet installation and native landscaping. The EPA website cites an interesting study concerning low flow toilets:

“"The effectiveness of low-flush toilets has been demonstrated in a study in the City of San Pablo, California. In a 30-year-old apartment building, conventional toilets that used about 4.5 gallons per flush were replaced with low-flush toilets that use approximately 1.6 gallons per flush. The change resulted in a decrease in water consumption from approximately 225 gallons per day per average household of 3 persons to 148 gallons per day per household a savings of 34 percent!" (How to Conserve Water and Use it Effectively, EPA.gov)

It is clear low flow toilets reduce water use and wastewater production, however there is a catch. The installation of these toilets cost $250 per unit and only saved $46 per year (roughly five years to recoup the investment). So, the urban residents must ask themselves, ‘is this worth it?’ Well if they read this full report they clearly would believe it is (refer to chapter one)!

Another behavioral factor is what we decide to do with our lawns. A lush grass lawn in the middle of Texas may look pretty but at what cost? High water and fertilizer use are inevitable. The use of native plants require much less watering as well as have various other ecological benefits. Additionally behavioral changes such as watering lawns/crops in the morning or evening reduce the amount of water lost from evaporation as well as systematic leak detection and repair.

Lets now talk about the more interesting (I think) side of water conservation, technological methods. I am most excited about grey water, drip irrigation, and hydroponics. Grey water is the collection of relatively clean waste water from showers, sinks, dishwashers, rainwater, and the like to be reused to flush toilets, water lawns, and so on (see figure 4.12).
Drip irrigation (see figure 4.13) is a conservation-based method primarily used in large-scale agriculture. Plastic piping is used to apply low-pressure water directly to a plant's base in order to reduce water runoff.

Lastly, hydroponics (see figure 4.14) is a unique plant cultivation method that uses no substrate (soil) but rather a closed system. Hydroponic systems have many
advantages since it is a closed-system, such as no nutrient pollutants are directly released into the environment, pests/diseases are easily spotted, and harvesting is easy.

We have discussed in this chapter water purification and conservation technologies and identified useful terms and categories to evaluate these fields. Knowing how your water is cleaned, brought to you, and how to use it efficiently are just as important as knowing where your water is from. When you turn your tap on is the water from a far away lake or is it from your local watershed. I encourage you to be proactive in educating yourself on how the above information applies to the water you drink and use each day and to change inefficient use-habits. Water is synonymous with life, when we waste water we waste life.
Chapter 5: Where Are We Going?

Section 1: Is Water the New Oil?:

In my eyes there are two types of war, those caused by conflicting beliefs, which include feelings of supremacy and inferiority, and those over resources. Since I’ve been born I have witnessed a technologic revolution that has sped a globalizing force that homogenizes cultures and people. One such example of this is the extinction of regional languages in favor of lingua francas such as English, French, Chinese, and Spanish. The Sapir-Whorf hypothesis supports my belief that language extinction creates a homogenous culture, the theory claims that, “…differences in the way languages encode cultural and cognitive categories affect the way people think, so that speakers of different languages will tend to think and behave differently depending on the language they use“ (https://www.princeton.edu/~achaney/tmve/wiki100k/docs/Sapir%E2%80%93Whorf_hypothesis.html). I’d like to focus on the later cause of conflict, that over resources.

There is no denying that our growing global industrial civilization is addicted to cheap and affordable energy, none more so than fossil fuels. In fact, we can say with great confidence that there are as many of us on the planet today because of oil (see figure 5.1).

Figure 5.1
Source: http://energybulletin.net/node/33164

![World oil production vs world population](http://energybulletin.net/node/33164)
Oil also influences how we interact and the political decisions we make. WWII was started in part (at in the Pacific Theater) due to conflict over oil. Furthermore, the Nazis lost the war in part to a dwindling supply of petroleum. Kuwait was invaded by Iraq at the command of Saddam Hussein in an attempt to acquire more oil, America invaded Iraq and fought in Afghanistan under the guise of a ‘war on terrorism’ (an auspicious enemy that has always will always be present) to secure oil supplies. Ukraine is pressured to follow Russian political demands because it relies on its imported oil and gas. It is clear that fossil fuels influence political and cultural actions, so how does this relate to water? “In fact, if there’s one thing water has in common with oil, it’s that people will go to war over it” (http://www.newsweek.com/race-buy-worlds-water-73893).

Although oil may be important for the continued growth of industry it is not a necessary ingredient for life. A human can only go a few days without water until dehydration and a halt of ATP-synthesis cause death. We thus cannot shy away from the fact that people will fight and die for water when there is a limited supply…and the reality is that we are entering a century that (I theorize) will be characterized by water scarcity. Don’t think that you won’t be affected, even the peaceful western United States is expected to have various water crises and conflict in the coming years (see figure 5.2).

**Figure 5.2**
Source: http://landsat.gsfc.nasa.gov/?p=299
Supply aside, over 240 million people are expected to be without water sources that are protected from contaminants by 2050⁶. GRID-Arendal, a UN Environment Programme (UNEP) affiliate sums up the topic perfectly.

“Water is an essential commodity upon which all life on Earth depends. For most nations, economic development is inextricably linked to the availability and quality of freshwater supplies. Although everyone uses water on a daily basis, we often take this vital commodity for granted – particularly in regions with a natural abundance of water. We forget that, in many regions, the availability of water is a matter of life and death” (http://www.grida.no/publications/vg/water2/page/3208.aspx).

Where are these areas of ‘natural abundance’? As we covered in chapter two, scattered across the globe however, if I were to choose the ‘middle-east of water’ it would be southeastern South America. Already multinational water corporations such as Thames, Vivendi, Suez are purchasing and privatizing water sources throughout the continent with the support of *conditionality* requirements (essentially do x, y, and z to get monetary loans from us) agreed upon between the World Bank and these nations. Already, armed conflict has occurred in Bolivia in response to these corporation’s ‘pay or go thirsty’ policies (to formulate your own opinion when considering if water is an economic good or human right refer to chapter two, section five). In the 21st century we may witness a majority of global political and economic focus switch from energy sources (a phenomena that started in the 1850s) to water sources. Those regions that have abundant water supplies could become the Saudi Arabias of the 21st century.
Section 2: What Does This All Mean?

We have covered a lot of information, opinions, and questions since we began. We have asked five big questions in this report, how much water do we have access to, where is it distributed, which of this is potable and clean, how can we make more of it, and now we ask our final question, what is the significance of all this information?

Humanity is at a crossroads; our attachment to growth (economic and political) is competing against sustainable practices. Yet on the bright side, the gaps between global communities are becoming smaller and information is becoming more accessible to every human being. All the previous information is not simply only about Water in the 21st Century but instead includes the essentials for us to realize that we, globally speaking, will have to alter our cultural practices and beliefs in the coming century if we wish to allow every human being access to the vital resources necessary for life and happiness.

For example, our eating habits may have to change. Much of the meat produced is eaten disproportionally by wealthier nations, which requires abundant amounts of water and feed to raise. Instead we could use these resources to grow more plant products to feed the growing populations (see chapter two, section three) in all countries.

We may also see the ways we use and generate energy change due to decreasing supplies of cheap fossil fuel and increasing environmental impacts. Growing evidence is supporting concerns about global-warming or climate-change. For example, the Intergovernmental Panel on Climate Change (IPCC) has published in 2014 that climate change has affected the frequency and magnitude of droughts and floods at a global scale. This could be further influenced by the two most populated countries, China and
India, whom are experiencing modern changes in lifestyle that result in higher water and energy consumption, resulting in increased waste generation, resource utilization, and harmful emissions.

Furthermore, many areas get their water from glacier melt, such as the Andes and Himalayan regions. These areas may be experiencing abundant water currently due to increased runoff as their local environment heats but the glaciers contain a limited amount of water and once they melt completely those areas will experience catastrophic drought. Sadly,

“Global warming threatens food and water supplies, security and economic growth, and will worsen many existing problems, including hunger, drought, flooding, wildfires, poverty and war, says the [2014 IPCC climate] report written by hundreds of scientists from 70 countries. Nobody on this planet is going to be untouched by the impacts of climate change” (http://www.latimes.com/nation/la-na-0401-climate-change-20140401-story.html#ixzz2xc7CxB)

Yet, humans are ‘plastic’; our ability to use our big brains and adapt is the defining characteristic of our species. Humanity has come so far; we evolved to be bipedal when adapting to drying conditions in Africa millions of years ago, sent a man to the moon, discovered the genetic framework of which all life depends upon, and everything in between. Yet as one would quickly learn after reading the Athenian tragedy by Sophocles, *Oedipus the King*, our species greatest strength is also our greatest weakness.

In my eyes I see humanity tends to confuse knowledge with wisdom. We seem to be gathering information at ever increasing rates but digesting it at the same rate we did hundreds of years ago. Is it wise of us to continually destroy our only planet? I think not. But through the eyes of pure knowledge one many claim, ‘we will discover some way to
fix all of this’. Well I have news for you, there is NO substitute for water just as much as there is no replacing an extinct species.

So, *where are we* going? I hope towards wisdom! I implore you, as a citizen of the 21st century, to strive for it. Yes, this is no easy feat, it takes self-discipline and self-reflection. To conquer ourselves and not our planet and the other species we share it with should be our ultimate goal. If we truly see the interrelatedness between all things, at that point, and no other, we will truly have wisdom.

"*When we try to pick out anything by itself, we find it hitched to everything else in the Universe.*"

* -John Muir
Chapter One Works Cited: How Much Water Do We Have Access To?


Chapter Two Works Cited: Distribution


Chapter Three Works Cited: Water Quality


   <http://connectingthecoast.uwex.edu/Investigate/cpPersistentPesticides.html>.


Works Cited Chapter Four: Water Purification and Conservation Technologies


   http://www.ph.ucla.edu/epi/snow/1859map/chelsea_waterworks_a2.html.


   <http://www.epa.gov/rpdweb00/tenorm/drinking-water.html>.


