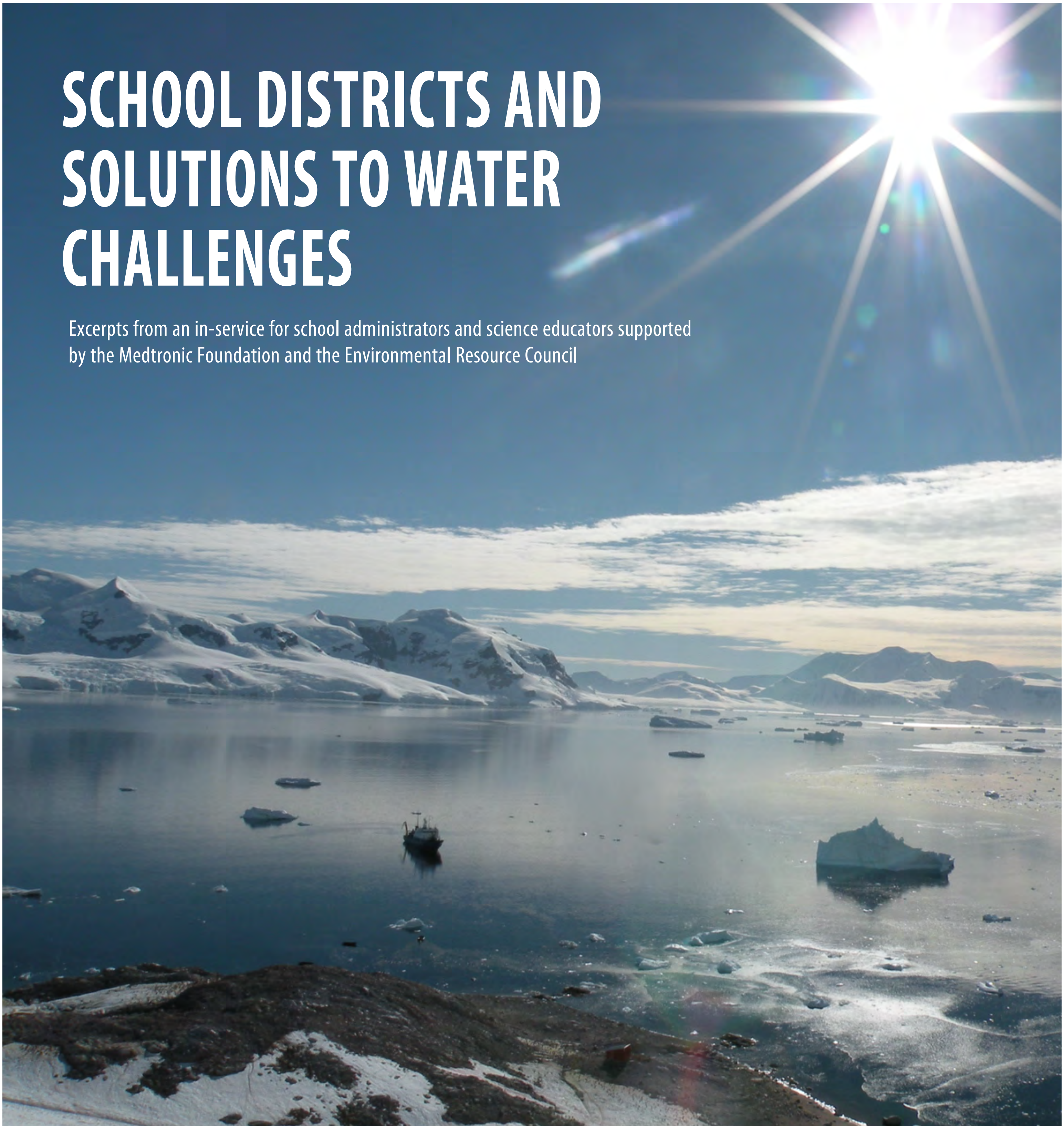
SCHOOL DISTRICTS AND SOLUTIONS TO WATER CHALLENGES

Excerpts from an in-service for school administrators and science educators supported by the Medtronic Foundation and the Environmental Resource Council







A Fridley Public School student finding solutions.

ACKNOWLEDGMENT

The Environmental Resource Council board wishes to express our gratitude to the School Board and staff of the Fridley Public School in Fridley, Minnesota which held a leading role as part of the Medtronic Foundation and Bush Foundation pilot project to support school districts addressing water ecology. We especially appreciate their commitment to integrate responsible water management with their educational process. Their community will have cleaner water but more importantly students will honestly understand how decent people and organizations properly manage water resources in the 21st century.

Fridley Public Schools
A World-Class Community of Learners

ENVIRONMENTAL RESOURCE COUNCIL

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Cover photo:

Beneath prolonged sunlight, an international academic ice cutter makes its way into a remote Antarctica harbor to better understand the continent and its relationship to the world's environment.

Antarctica is the most remote place on Earth, yet, in many ways, it is also the key to human survival and the Earth's ecology because of its relationship to water. Larger than the Continental United States, with ice sheets ranging miles in depth, Antarctica determines key ocean currents, weather patterns, and life. It is a huge but poorly understood factor in our relationship to weather and water.

Water is fundamental to our lives – for survival and quality of life – so it is critical that we understand its nature and how our behavior impacts the Earth's water. This is perhaps the greatest challenge facing 21st Century humanity.

We now know that the oceans surrounding Antarctica are teeming with life, including a thriving population of whales that were almost hunted to extinction.

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FOREWORD

With financial support from The Medtronic Foundation, the Environmental Resource Council developed and presented a seminar for school districts on water issues. The program was held at the University of Minnesota Arboretum with assistance from their staff. Attached are several selected pre-readings.

The theme of the seminar was that, through education complemented by the wise management of school property, a sense of environmental responsibility would emerge. Considering the huge environmental footprint of school property, such an approach would benefit ecosystems; more importantly, it would model, teach and inspire students to take on one of the greatest challenges of the 21st Century: How do responsible people preserve and manage water resources in a changing world?

As the world changes in terms of both climate and human population, we need to understand the challenges that surround us and work to find solutions.

"Even the Zambezi has an island."

— **Central African Proverb**

Even in a treacherous environment such as the vicious Zambezi River, we can find solutions.

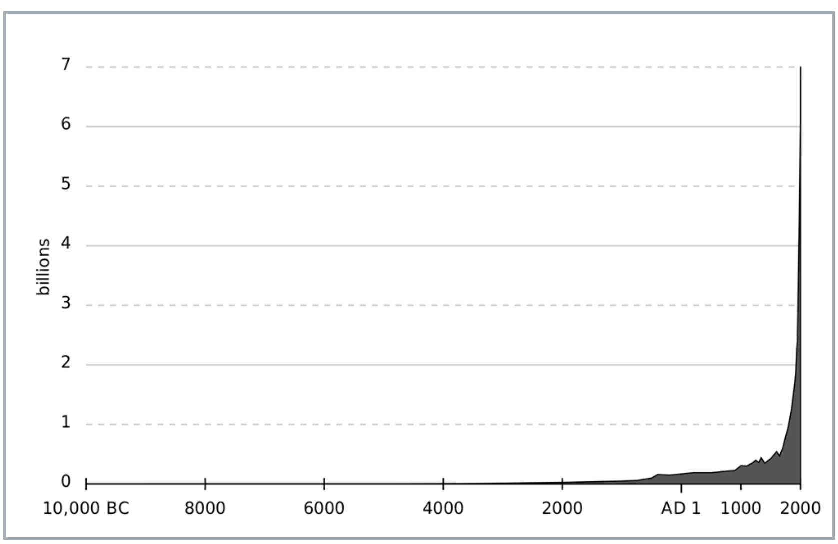
"We want science education to help create a better future built on innovation."

— **The Medtronic Foundation**

Representative theme of an organization that consistently finds solutions to the most serious human challenges.

Our World and Water

The human population is expanding geometrically, creating a huge increase in freshwater consumption. Presently, we do not have enough of the right kind of water in the right place to avoid ecological stress and human tragedy. We must understand that challenge and implement solutions.



Access to water is necessary for survival and quality of life. Understanding how water functions, especially freshwater, is critical.

In developing countries, women and children living in villages without wells walk an average of nearly four miles daily to obtain water for their families. At over eight pounds per gallon, this limits the water they need for hygiene and ingestion, but also significantly limits the lives of those who must carry water long distances, often making several trips a day. Bringing in local pumping systems or finding more efficient ways to transfer water profoundly enriches the lives of the women and children water bearers. Most often, it means that girls can go to school instead of carrying water.

The point is, we can find solutions to water problems and make them a reality. Even the treacherous and often flooding Zambezi River in East Africa can be used to our advantage. As the local Ibo elders say, even it has an island; we just need to find the right island.

We want a world with abundant, wholesome water that is reasonably available to everyone. To reach that goal, we have to start by getting a grasp on the technical realities of water.

Like nearly all non-sun planets and all asteroids, the earth contains water. In fact, the earth is mostly covered with water, but about 95% of that water is blended with mineral salts, which are toxic for human consumption (sea water). Another 2% or more of the remaining water is fresh but is "locked" in snow and ice. The vast majority of frozen freshwater is in Antarctica, one of the most inaccessible places on earth. Less than 1% is left to grow our crops, supply water for hygiene/ingestion, and for water-dependent production of energy, food, textiles, and other products. We also must share that 1% with the rest of terrestrial life.

If you took the earth and "skinned it," peeling off its outer layer from the top of Mount Everest to the deepest portion of the ocean (about 7 miles), that "skin" would be proportionally similar to two thick coats of latex paint on a basketball. If you peeled that skin off, ground it down and let it sit for a few thousand years, about two-thirds of the mass would rise to the top as water. Interestingly, if you did the same thing to yourself, i.e. ground yourself up and separated liquid from solid, you would also settle out at about the same ratio of water to dehydrated tissue. We are all a little under two-thirds liquid – your brain is 80% water by weight, which supports the rapid, complex flow of electrical impulses, allowing you to read this article. When you were a baby, you had a little higher ratio of water to tissue, but as you got older, the water ratio level decreases slightly. That ratio does not hold for most life forms. In fact, we are a bit light in the water-to-solid-matter ratio. A potato is 80% water and a cow is around 75% water.

There is a reason why the chemical, "water," connects with our sensitive side, representing a calming sense of serenity or security, and is the most consistent element in the visual arts. We come into existence surrounded

As human communities evolved, being in close proximity to fresh water was and continues to be a key factor in determining whether or not they thrive. Before the development of canals and plumbing systems, being physically close to water was arguably the leading cause of human conflict.

by water, we remain mostly water, and our health and quality of life as individuals and as a society are dependent upon our relationship to water. When that relationship fails, people get sick and societies fail; when it works, people and societies thrive.

Unfortunately, where there are concentrations of humans and, consequently, where freshwater is most needed, there is typically freshwater contamination. This contamination involves sewage, especially human and domestic animal waste, and within the last half century, water polluting chemicals – the by-products of commerce, industry and, especially, agriculture, mining and energy production. There simply is not enough freshwater for human society to continue to thrive without solutions and changes.

We are locating, tapping into and extracting more and more freshwater, but almost always, it is in locations hard to access for in-need populations. We can convert saltwater into freshwater, but the energy cost to desalinate is huge. We can pump out more water from our aquifers, but many are being depleted and contaminated with sewage, agricultural run-off, and industrial by-products.

Presently, well over 10% of the human population lacks access to water that can be safely ingested. The World Health Organization reports that over three million people die each year from water related health problems. It has long been understood that basic hygiene with soap and water on a daily basis will reduce diarrheal disease by nearly 50%, but where there is limited water access, the hygiene is understandably poor. By far, infant and childhood mortality in the world is largely the consequence of limited clean water for ingestion and access to enough water for hygiene.

"Well over 10% of the human population lacks access to water that can be safely ingested."

—World Health Organization

Although often taken for granted among developed communities, the systems and infrastructure that provide needed quantities and quality of water are basic to survival.

Each American uses close to 100 gallons of water daily. This number may be hard to accept, until we understand the connection between water, food, textiles, sewage and energy. A little less than 2,000 gallons of water are used to produce one pound of beef, an egg, 400 gallons, a t-shirt nearly 800 gallons, a pair of jeans, 2,900 gallons. All foods and most products used by our consumer society absorb freshwater. Most of the water we use relates to our use of energy, especially electricity. With the growth of Second World nations, i.e. Brazil, Russia, China, India, and South Africa, consumer use expands along with the quality of life. The acceleration may cause the human freshwater footprint to become unsustainable, unless we find solutions.

One important concept to help us confront our water challenges is that water is not really "destroyed" as it is used. It is changed, and that change often renders it toxic or unusable, at least for a period of time. Water can be contaminated with sewage or agriculture/industrial/mining byproducts, or heated and blended with chemicals or particulates in energy production. However, it can also be purified and returned to a composition that is healthy for the ecosystem and humanity. We can both contaminate and speed up restoration of fresh water.

Water Usage

1 pound of beef: 2,000 gallons

1 egg: 400 gallons

1 t-shirt: 800 gallons

1 pair of jeans: 2,900 gallons

Huge amounts of freshwater are required for nearly everything around us. It is important to understand that the water used is not really "destroyed" but is temporarily changed. Typically, it is being blended with other chemicals. In time, nature can purify this water and it can be reused, but the balance between chemical impact, or contamination, on the path to its becoming purified needs to be managed.

In the strange beauty of snow, we see water in a different way. As the delicately designed crystal hits the warm tongue, its nature changes and becomes liquid.

What is Water?

Water acts differently from almost all other compounds. The rule of thumb in chemistry is that when any compound or liquid is cooled, it will contract (get smaller). Water actually does contract as it cools down, but at a certain point, when it hits the freezing range, it explosively expands. Essentially, with the consistently vibrant motion of water molecules, they are frozen in motion, so ice takes up more space than liquid water. As ice warms, it returns to liquid and expands again. At a certain temperature and under certain conditions, water molecules shed much of what they are bound to and actually expand into ambient air as a gas or water vapor. Water molecules can be a solid (ice), or a gas (water vapor), or a liquid (water). The liquid state is fundamental to all life. Water is so critical to life that if it is not constantly replenished, the human body quickly falls apart. Within a few days without water, portions of the body – the nose, mouth, lips and eyes – will wither and, a few days after that, death will occur.

The water we ingest has to be what we call "fresh" or "clean." Most water on earth is poisonous to us; it has been blended over almost four billion years with enough minerals that it has become "salty" or brackish. Humans need salt, but only a small amount. Seawater contains over 50 times more salt than can be safely metabolized by our organs, sometimes up to 75% more. We cannot survive on saltwater – it's lethal. If there is too much salt exposure, the blood will carry salt to the kidneys, which quickly become overloaded and shut down. That is why the water we need must be evaporated out of mineralized "salt water" and reintroduced through precipitation into places where we can get at it. This involves surface water, such as rivers and lakes, and underground aquifers where freshwater is stored. These potentially clean water sources are recharged periodically through rain, hail and snow as purified water drops. What comes down to us from the sky is essentially clean. If we contaminate clean water with sewage or chemicals, or pull more water out of lakes, rivers or aquifers than is being recharged in our ecosystems, we have serious problems.

Before there were transmission electron microscopes, scientists understood that snowflakes were, in fact, a crystalized image of water molecules beautifully and consistently pulsating in rhythms captured at the moment they were transformed into solids by temperature changes. The intricate, unique snowflakes help us understand the complex chemistry of water.

As human communities confronted natural water systems, they developed patterns for successfully working with water to their advantage. Physically carrying water to where it was needed was balanced with bringing things to the water, and eventually mechanically transporting water through sophisticated engineering.

The Roman aqueducts, as well as Roman sewage systems, were necessary for complex societies to truly thrive. The movement of water through canals, aqueducts, and water-driven sewage controls helped the modern world evolve. In all cases, water was changed by human contact and as the human population expands in a world with limited freshwater, we face serious challenges.

When one studies water and human need, one soon learns that the earth has plenty of "water." There are over 300,000,000 cubic miles of water on earth. That amount almost never changes in that it is extraordinarily difficult to destroy water. You can't burn it, bury it, blow it up or drink it without it re-emerging in some form. There was a certain amount on the planet well before life began and essentially that same water exists today. There is presently around 366,000,000 gallons of useable water for every person on earth, but we still have a risky relationship to water.

From the human perspective, most water winds up in the wrong place or in the wrong form to be helpful. Clean water becomes loaded with salt, freezes or becomes "polluted" and is consequently pulled out of the freshwater bank of clean, wholesome water necessary for human life. As our population and drive for consumption expand, clean water in the right place becomes a huge human challenge. Getting the right kind of water to the right place and controlling toxic water becomes a primary human endeavor, and the ability to live within that vital rhythm is directly connected to the success or failure of human societies. Nations have and will rise and fall based on their ability to work with water.

Only a small percentage of the earth's water is in lakes, rivers or reservoirs and is non-toxic, non-ice, and accessible. Still, we have millions of gallons of potentially fresh water per person. The problem, and it is of crisis proportion, is that the needed water is often both in the wrong place and subject to geometrically expanding human populations and consequent toxic contamination. The contamination is often closest to where the human need is greatest. This is because human waste/sewage is typically the most lethal carrier of disease, and the poorer and more densely populated a region, the less able they are to control sewage or implement controls on high pollution activities, such as farming, mining and manufacturing.

The fundamental human connection to water has defined human history. Societies that have mastered access to and working with water have thrived; societies unable to do so have suffered and been limited in size or have outright collapsed.

The Roman aqueducts were absolutely fundamental to the Roman Empire; the canal systems in ancient China permitted its society to prosper for a thousand years with stability, and the strong infrastructure of canals and water hygiene inherent in post-Renaissance Great Britain allowed the British Empire to emerge. The relationship to water has been the basis for societies thriving and failing from pre-history until the present.

WASHING DISHES, WATER, AND LIFE

To better understand how water works, the next time you do dishes, try something.

When you look at dirty plates you will notice that some of the leftover debris on the plate appears to be greasy and some doesn't. If you hold the plates under cold water, the debris that is hydrophilic (having an affinity for water) and is not "greasy," will quickly blend with the water molecules and they will wash off together down the drain. This would happen with, for instance, ice cream, sugar, coffee, fruit juice or salt.

You will also notice that the greasy hydrophobic (afraid of water) debris will stay in place and the cold water will bead up on the grease and move only a small amount down the drain. It is likely that any grease forced down the drain was just broken off by the water pressure from the faucet. Grease does not like water, and water does not like grease. This would happen with substances such as margarine, bacon or peanut butter.

Now let hot water run over the grease on the plate; all of a sudden the highly agitated, wildly motivated hot water will connect with the grease and even though not really compatible, with the heat applied, they will rush down the drain together. Heated water is less discriminating in "making connections."

Now, if you really want to get things moving, add a little bit of dish soap to the hot water; it will create a frenzy of connections. Soap facilitates the hooking up of hydrophobic molecules and water molecules, so all the molecules will now connect and find their way down the kitchen drain. The plates will be free of debris and won't provide food for mold or microbial germs, and they will be safe to use again.

Technically, the water that has rushed down the drain will be "contaminated," in that it will be bound into both hydrophobic and hydrophilic molecules and the water won't be clean or "pure." However, the "relationships" won't last. The hydrophobic and water relationship will typically fall apart first.

Somewhere deep underground in the sewer pipes, the water will cool off, the soap will be diluted, and the inherently unstable relationship between the grease and water molecules will degrade. Essentially, the grease will now go its own way, as will the water, i.e. the grease will be pushed out of the community of water molecules and will be forced to float above the water as sort of a "scum."

There is a stronger and more permanent bond between the hydrophilic compounds and the water molecules. However, no relationship in the world of water is really permanent. Before too long, the water molecules will separate out and drift into the atmosphere as moisture, leaving behind the other chemicals. Usually, small traces of the relationship will stay with the water molecules, but the water will now be, essentially, purified. Likely, the water from the two sets of broken relationships will become part of a cloud and then, someday, become rain, snow or hail. The now naturally purified water molecules will again come down to earth and likely find their way into a plant, animal, or you.

In your body, this balance between hydrophobic and hydrophilic essentially defines the rhythm of how you live. Each of the billions of cells in your body is filled with mostly hydrophilic chemicals, constantly responding to small electrical charges and following embedded instructions that make you, you. These cells are, however, protected by a hydrophobic coating or "cell wall," the membrane that covers your cells. Through chemistry and electricity, when your blood reaches the cell, certain chemicals that the blood carries are able to penetrate the hydrophobic membrane and quickly impact the internal sea of proteins, polypeptides, and DNA that washes around inside each of your cells.

To understand the essence of water and life, and especially the concept of water pollution, this balance of hydrophobic and hydrophilic is fundamental. If this rhythm is tampered with or the wrong chemicals get blended with the water in too large quantities, the ecosystem and human health can suffer. This is the defining link between water pollution and disease.

Five Water/Human Society Imperatives

Each epic in human history has had its own evolving water challenges:

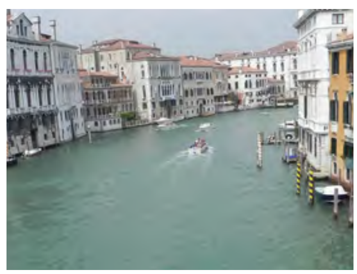
In primitive societies, and even today in water stressed communities, carrying water in jugs or containers becomes necessary unless one lives in close proximity to freshwater. Physically finding and carrying water from place to place has been a painful burden and struggle for much of humanity throughout history.

1. Ingestion and Hygiene. A human society needs some sort of access to freshwater; to the extent it is readily available, there is typically good health and social success. This water is used for direct ingestion, hygiene involving the carrying away of human waste, and to clean the human body.

As societies evolved, the efficient and mass production of food and fiber was necessary and could happen only to the degree that water could be moved in great quantities to the right place. The modern world has become profoundly efficient at pumping, moving and distributing massive quantities of freshwater to produce food and fiber.

2. Food and Fiber. Water is necessary to provide food and fiber. Even dry food like grain is, essentially, solid matter that has come into existence through access to fresh water. Controlling water sources, or searching out a location having the right amount of the right kind of water, equates to healthy plants and animals, compatible with human needs.

With remarkably little effort, huge burdens can be pushed across water. Even a child can push several tons on a raft. To the degree societies could find ways to use this capacity to transport, they had a tremendous advantage. In medieval Venice, the ability to quickly and effortlessly move products from place to place allowed it to become the first major Western manufacturing center.



3. The Ability to Transport Goods and People. Water is typically the best means for transporting goods from one place to another. Canals, bridges and, of course, ships, permit resources, armies, and technologies to be spread out with wonderful ease, to a society's advantage.

There has always been a fundamental connection between energy and water.

4. Energy. Water is fundamental to most energy development. For centuries, water has been harnessed as a power source for water wheels/mills, then for steam engines for fossil fuel energy production, and for temperature regulation regarding nuclear energy. New techniques for increasing petroleum and natural gas production require massive amounts of water to be blended with other compounds and injected into soil. By some measure, energy production is the most serious stressor of our water resources, although use for energy is often "non-consumption," meaning, the water is still around but it has been changed.

The need for water to serve a rapidly expanding population has put us in a place where water is contaminated and sometimes rendered temporarily dangerous for humans, and often becomes profoundly disruptive to the ecosystem.

5. Pollution, Ecology and Disease. This involves the blending of water with toxic compounds, which damages or renders water of little value to living things. There have been some successes in cleaning up and preventing contamination from manufacturing at a "single point" of contamination. In the United States, serious

The balance between the production of food and fiber and the contamination of our freshwater represents a profound and often divisive challenge to society.

progress began with enactment of the 1972 Clean Water Act. There has, however, been an increase in "non-point" pollution, typically tied to the need to mass produce food and fiber products and the related extensive use of fertilizers, including nitrogen, phosphorous and pesticides. This increase in non-point chemical contamination continues to pollute surface freshwater, our aquifers, and our oceans, usually through hypoxia or deprivation of oxygen. This challenge is relatively new and of great concern.

Contamination of aquifers is an example. State departments of agriculture are constantly monitoring the base level of certain pesticide burdens, which can be found in low doses in many aquifers that supply public drinking water.

The most typical pattern of freshwater pollution involves draining levels of freshwater in aquifers or clean surface water in lakes or rivers, exposing the water to pollution, and then discharging it back into downstream surface water in a contaminated state through manufacturing, mining or, most significantly, agriculture.

The most obvious risk of pollution is disease. Along with limited amounts of water, water that is infested with pathogenic microbes or has been contaminated with industrial or agricultural pollutants is the leading cause of childhood disease and death in the world.

The nature of water and its impact on people, societies, and eco-systems must be understood and the consequences of its pollution addressed now.

"Pollution, ecology and disease is arguably the single greatest challenge of the 21st Century."

The fifth imperative is arguably the single greatest challenge of the 21st Century.


Photo: Andreas/Flickr

The water burden.

"Limited and compromised water are the leading causes of illness and death among the world's children."

— World Health Organization

Water Challenged Communities

More than any other factors, the availability and quality of water determine the likelihood that low-income families will thrive.

The World Health Organization estimates that, to remain healthy, the average adult male must ingest .8 gallons (3.028 liters) of fresh water per day, and an adult woman, .6 gallons (2.271 liters). Although variable by age, weight, and climate, a reasonable estimate is that a child should ingest .5 gallons (1.89 liters). If additional water is available for hygiene purposes, even if its purity is not assured, health is further improved, especially among children. Limited and compromised water are the leading causes of illness and death among the world's children.

The amount of water needed for general hygiene and basic sanitation, which does not necessarily need to be potable (safe for drinking), is variable. The amount of water needed for washing clothing and personal hygiene is, perhaps, three times the amount needed for ingestion.

The quantity and quality of water a typical water-challenged family can acquire directly most often correlates to income. Wealth equates to having more ready access to water and to better health, and is usually simply a factor of distance to a water source. The UN defines "low income" populations as families earning $995-$3,945 per year and having an average of three children. The United Nations has estimated that "low income" populations are typically 1.5+ miles from a water source.

So, low-income families require around 10 gallons of water per day, or essentially 85 pounds of water. As incomes rise, families are typically smaller, so in lower middle-income families (earning over $3,945 per year), the amount of needed water would generally be around 8 or 9 gallons, with 2 or 2.5 gallons safe to drink.

Cleanliness and hygiene are understood by all societies to be critical to health, but the struggle to achieve them is overwhelming to some societies because of limited quantity and quality of water.

Although improved sanitation and other health care advances have substantially improved over the last 50 years in many developing countries, with subsequent reduction in infant mortality, we still have unacceptably tragic levels of childhood disease and death attributed to compromised water. Childhood mortality within low-income populations is 120 per 1,000 live births; among lower middle-income groups, it is 60 per 1,000 live births. This compares to childhood mortality rates of 7 per 1,000 among high-income populations.

The water burden limits the lives of many young people, especially young girls.

The leading cause of serious illness and death among water-challenged children involves bacteria-induced gastrointestinal infections, resulting in diarrhea and consequent death through dehydration and related complications. Among low income, water-challenged populations, childhood mortality involves 3.3 million deaths, worldwide, annually. Where adequate water and soap for hygiene have been provided, and hand-washing promoted, diarrheal disease has been reduced by 45% among low-income populations.

Low-income populations are primarily located throughout Africa, in portions of Central American and in Haiti, and lower-income populations in sections of Eastern Europe, portions of the Caribbean, the Middle East, India, Indochina, and in more remote areas of China.

As societies emerge from underdeveloped to developed status, there are typically problems involving water and sewage infrastructure. This picture shows Dubai, which, with petro-dollars, has constructed remarkable state-of-the-art Western buildings and amenities. Yet, in the same city, there is essentially no functioning sewer system; literally thousands of tanker trucks must carry in water and carry out sewage. The risks as well as the ongoing costs associated with both are significant. An understanding of water and its role in the human community must become integrated with any responsible development.

Problems also exist in the more populated "emerging" nations, often referred to as the BRICS nations (Brazil, Russia, India, China and South Africa). The "BRICS" term has also come to include other rapidly developing nations, e.g. the Philippines, Ecuador, Vietnam, etc. These are regions or nations where responsible public health and civil engineering/infrastructure have not caught up to rates of more obvious commercial development.

In India, government census data sought to quantify water availability and identified that 45% of its citizens do not have "routine access" to safe drinking water. Those people are termed, "away" people, since they must carry water from a water distribution site at least several kilometers "away." This means that 540 million Indians – more than the entire populations of the United States, Mexico, and Canada – must physically move heavy burdens of water to survive. Understandably, this population has an array of health problems relating to poor hygiene, especially gastrointestinal disease.

Because of water access challenges in India, 40 children under five years of age die per hour, principally from contaminated water and consequent diarrhea. Put another way, there are 365,000 contaminated-water deaths of children under five occurring each year in India, more than 10% of the population of the United States. While India has the most targeted data, allowing projections based on the link between water availability and childhood mortality, it is reasonable to assume that other developing countries have similar public health situations. These emerging populations have increasing disposable incomes, but also have serious water challenges.

Beyond health issues, the significant time and effort required for obtaining and transporting water degrade quality of life, especially that of women and children. Typically, it is the women and children, especially young girls, who are responsible for making the trek to a water site, filling the

The funeral of a five-year old girl from Central Africa named Vani. She, like hundreds of thousands of other children from water-stressed and resource-stressed communities, died of dysentery. Dysentery is caused by gastrointestinal infections, typically from limited water for hygiene and compromised drinking water.

containers, and then transporting the water supply back to the family. They usually have to make this journey twice a day, since an adult can carry only about 40 or so pounds (18 kilograms) of water, or 5 gallons (19 liters), and a child, less. The better part of a day must be committed to physical transport of water. In developing nations, this "water burden sacrifice" has been identified as a leading factor in limiting a girl's educational opportunity. The physical and psychological drain on the quality of life among women and young children is hard for 21st Century water-privileged communities to comprehend.

Almost by definition, poor civics is inherent within water-deprived communities. Access to limited water resources is often denied to the most vulnerable and least empowered families in these poorly governed communities. Similarly, the rapid but poorly managed development in emerging nations is problematic. Sewage drainage systems are often unprofessionally constructed, using low-grade and poorly joined PVC plastic piping laid in shallow ditches. These are typically placed in close proximity to piping used for fresh water delivery. In other words, ditches bringing in PVC piped potable water also carry out PVC piped sewage. Professional soil testing, which is an institutionalized part of civil engineering projects in developed nations, is not typically part of water and sewage projects in developing nations. If there is an abrasion or insult to the physical subsurface area shared by both systems, especially if the pipes were laid in incompatible soils with low-grade piping, the drinking water rapidly becomes directly contaminated with sewage. When the system fails, potable water must again be either physically transported from a great distance or treated.

Finding or creating wholesome, potable water, and moving that heavy burden of water via human labor over a distance, is a constant struggle for an eighth of the world's population. This constitutes a water challenge demanding a human solution.

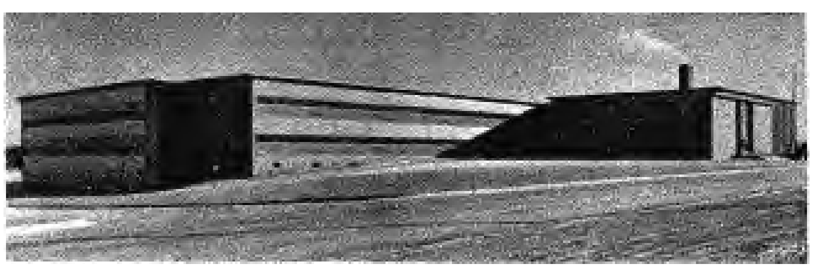
After World War II, in spite of the clear dangers inherent in ingestion of lead by children, most school water fountains contained lead fixtures that leached into students' drinking water. A lack of understanding for water-related issues was a tragic part of the post-war American school buildings.

"Next to farms and possibly roads, the school facility is typically the most contaminating, non-point pollution source in any community."

School Water Management

Post-War School Buildings

After WWII, to better cope with the baby boom, American school buildings were typically one or two-story construction with huge roofing systems and a general insensitivity to environment. Many classrooms had no windows, and few had windows that the teacher could independently open. Beyond that, post-war building products were filled with toxins, including formaldehyde and asbestos, and nearly all the early drinking fountains had lead fixtures, causing low-dose lead to leach into the water. A well-read medical textbook from the 1840s had warned about dangers of lead fixtures and consequent contaminated drinking water for children. Yet, lead-contaminated water found its way into America's children, although at low dose through post-war school drinking fountains.



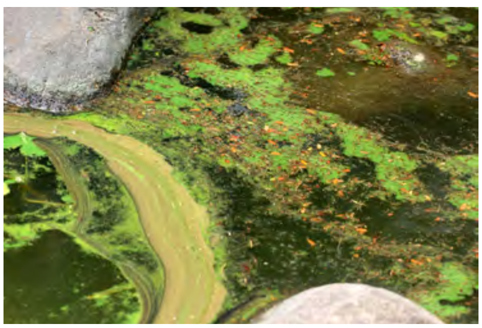
In addition to lead-contaminated drinking water, the post-war school buildings created excessive, contaminated run-off from fertilizers and pesticides on school grounds, parking lots, and massive roofing systems. This picture shows a suburban school built shortly after World War II.

What was going on outside the building regarding water was also environmentally problematic. In fact, the local school district often pollutes more surface water than any other developed property in most communities. Instead of using citywide athletic facilities, local YMCA's or public libraries, these post-war buildings sought to be largely self-contained communities, typically constructed on the outskirts of towns, near rivers or lakes that would permit easy drainage. These super-sized plots also included large, chemically-treated green spaces (athletic fields) and monster parking lots.

The school buildings themselves had huge, flat, black roofs, which often leaked, with the water seepage allowing mold to grow, seriously degrading indoor air quality. The water run-off from the facility was consistently contaminated with road salt and other chemicals and blended with run-off from athletic fields and parking lots, containing heavy burdens of fertilizer and pesticides. The thousands of new post-war school buildings drained huge quantities of contaminated water into local surface waters and aquifers.

Whether converting an old school into a new, larger facility, or breaking ground in a new suburban development, the landscape architecture of post-World War II was typically a water ecology disaster.

In the 1950s, '60s and '70s, when most of these school buildings were constructed, water controls typically involved attempts by municipalities, or occasionally counties and/or watershed districts, to make certain that run-off from these buildings did not flood neighboring areas. The goal was to get storm water and snow melt drained as fast as possible into natural surface water. Water contamination was not a consideration.



A signal of the presence of toxic water, typically the result of uncontrolled agricultural pollution, involves surface water saturated by pesticides and fertilizers that create algae or "pond scum." Often toxic in their own right, these growths also absorb oxygen at levels that harm other species and contribute to the pollution of large bodies of freshwater.

Storm water, too, made a significant contribution to contamination, flowing and polluting first local surface waters, then proceeding to degrade rivers, lakes and aquifers and, eventually, oceans. The "dead zone" in the Gulf of Mexico is caused primarily by heavy doses of fertilizer, specifically nitrogen, phosphorus, and herbicides flowing downstream, eventually impacting hundreds of square miles of ocean. As this water moves downstream, it creates semi-toxic algae blooms, with consequent hypoxia (oxygen deprivation) in adjacent waters.

Although not as damaging as post-WWII agricultural or industrial practices, water run-off from these new school buildings was seriously contributing to contamination of our fresh water. Next to farms and possibly roads, the school facility is typically the most contaminating, non-point pollution source in any community.

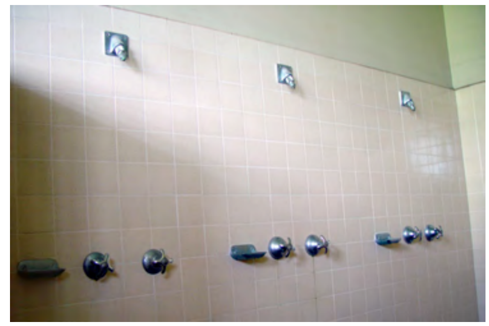
In recent years, school districts have begun to correct the inherent environmental flaws of post-war school buildings. Drinking fountains no longer leach lead, there is quick response to mold from failing roofing systems and, slowly, school facilities are moving to control polluted water run-off.

General Hygiene

The first category of water for consideration is "black water," or water contaminated with human waste, human washing areas, including hand-washing stations and showers, and water from food processing in kitchen facilities. Essentially, this is water associated with causing disease. Given the large number of individuals in a confined school area, the control of biologically-contaminated water or black water is primary.

New technologies for responding to black water may involve low-flow urinals and two-stage toilets. There have been experiments with waterless urinals and controls for showers using reduced water in favor of increased water pressure. Significantly, the use of controlled storm water (gray water) as sewage water, as opposed to using potable water for toilets, has worked in some larger buildings. This conversion of light gray water, usually from roofing systems, can also be used for plant irrigation and some cleaning activities.

Where these options have been installed and maintained correctly they appear to be paying for themselves over time, but they are still new and considered cutting-edge. Some school LEED certified buildings (Leadership in Energy and Environmental Design) have identified three to five year returns on investment for the two-stage toilets and low-flow urinals. Obviously, the reduced flow of gray water reduces surface water contamination to ecological advantage.



It has become clear that poor hygiene in school locker rooms is the principal cause of the spread of MRSA.

Regarding reduced water strategies for showers, we have concerns regarding methicillin-resistant staphylococcus aureus (MRSA). It has become clear that poor hygiene in school locker rooms is the principal cause of the spread of MRSA, a debilitating infection that periodically spreads among both male and female young adults, especially athletes. Reducing water flow relative to showering may, in fact, be counter-productive to personal hygiene with unacceptable consequences.* The replacement of showerheads needs to carefully take into consideration potential impact on hygiene and topical infections. Adequate water pressure, abundant heated water, quality soap, and hygiene promotion in school activities is important.

Asthma is directly connected to ambient air hygiene, both at home and in schools.

The most significant increase in disease among students in the last decade relates to asthma. Asthma is directly connected to ambient air hygiene, both at home and in schools. Moisture in ventilation systems and behind walls from roof system failure is the necessary component for infestation of mold, and consequent asthma. Asthmatic reactions result from presence of dust mites and dander, and establishment of molds and fungus in buildings. Although a genetic predisposition is typically part of the asthmatic condition, the school environment is a principal factor. A "commissioning" or third-party inspection of ventilation systems, including testing for moisture and seeking out and eliminating sources of moisture, is important to safeguarding the health of building occupants, especially in high human density buildings like schools.

Stagnant water, typically found in water pans near heating and ventilation systems can (rarely) relate to Legionella or other potentially toxic microbial growths and, under the right conditions, can integrate itself into the building atmosphere and cause health problems. Use of over-the-counter aqua-disinfectants for standing water in heating and ventilation systems is important.

**There has been some unpublished research indicating that the quality of the shower heads, the body soap used, and especially the segregation of towels (making certain that towels are not shared among students), reduces spread of the MRSA infection. Coloring or providing other unique identifiers on towels and awareness that mixing them up or sharing them is risky would likely help reduce the spread of MRSA.*

Finally, promoting hand washing, particularly for elementary and middle school students, is valuable. The use of disinfectants*, soap, and warm water, and most importantly, getting across the concept of hand/mouth contact for spreading disease, are all important safeguards.

Drinking Water

For those schools using wells, it is well-established that there are sometimes base levels of pesticides/fertilizers in well water, but the greatest concern is pathogenic bacteria. Usually, the amount and dosage of any contaminant is small enough so that it does not represent a risk, but the monitoring of free-standing wells by local or state health departments is important, and periodic testing of well water at the source of ingestion makes sense. Municipal water systems are typically well monitored by state and local public health departments. If there is a problem with water quality, it almost always will be within the building.

Making clean water readily available to the community, especially for drinking, is a universal and appreciated signal of kindness.

Use of bottled water has become a salient issue in some districts. The underlying public distrust in "government" potable water has clearly contributed to the use of bottled water. On the other hand, the cost of shipping and storing bottled water is considered by many to be environmentally wasteful. Some have indicated concerns for the leaching of chemicals into beverages contained in plastic bottles. This issue has no clear technical resolution. In our view, no reasonable health risk has been documented regarding the use of bottled water, but the practice creates waste and the cost seems unjustified.

The most logical consideration for the direct ingestion of safe water is a filtration approach at the site of water ingestion. The same filtering process used with bottled water (which has a 1,700% cost mark-up) can be implemented at reasonable cost by most districts with the establishment and promotion of filtering water stations, i.e. upgrading the traditional drinking fountain. Typically, municipal water can be relied upon to be potable and safe. Contamination within a building's plumbing system is a more likely concern, and periodic (every five years) testing for chemicals and microbes at the source of ingestion may make sense, even if the district is using municipal water sources.

Controlling Water Run-Off

Storm water run-off controls are a significant issue for school districts and the community. There are a number of established engineering controls involving porous surfaces within parking lots, rain gardens, or other civil engineering mechanisms designed to avoid contaminated surface water from infiltrating and damaging ecosystems.

**There is controversy regarding the use of routine anti-bacterial products, based mostly on ecological impact. We come down on the side of selective use of a lower dose isopropyl alcohol-based or other antibacterial disinfectant use in schools. When there is an outbreak of upper respiratory infection (the flu) or other contagious disease, or an outbreak is anticipated, commercial antibacterial topical compounds should be distributed for one or two weeks, but they should not be institutionalized for continual use in schools.*

An elementary school plans for establishing a ravine and riparian restoration area. They are creating a wetland to protect an adjacent river.

It is important to note that rain gardens and other landscape options are fairly new and best practices have not been firmly established. There have been significant expenditures by school districts for failed rain garden systems and, in some cases, consequent litigation. The design, implementation and maintenance of rain gardens and other civil engineered storm water controls are rarely codified in statute or regulation and plans should be reviewed through a third-party commissioning process.

The design, implementation and maintenance of rain gardens should be carefully thought out and plans always made in conjunction with local water planning authorities. It is important to note that the implementation of rain gardens may reduce a school district's cost for impervious surface fees, even as less use of potable water will reduce the water bill. A carefully thought out water policy has financial advantage for the school district, but the key is, carefully thought out.

When looking at the way a school district can best approach water controls, one of the calculations that may be helpful is to identify the amount of roof surface run-off water and find ways to use it to advantage. The alternative is to run it through the typical storm water system, where it becomes part of the problem of freshwater contamination and generates impervious-surface fees for the school.

While run-off from parking lots and athletic fields or maintained green areas may also be considered "gray water run-off," roof run-off is many times cleaner and typically has no major toxic burdens. It is logically termed, "light gray water." Roof water can be treated through filtration and/or with ultraviolet radiation, and then safely introduced for both toilets and internal cleaning, but not used for drinking or food preparation. It is naturally "soft" and is unlikely to scale or calcify plumbing. In many ways, it is superior to municipally treated water for plumbing and cleaning, and also obviously cheaper.

Although highly variable depending on geography, the working number of between eight and nine thousand gallons of water per thousand square feet of roof can be used for planning. This water can be captured, stored, and used. Depending upon the present or future potable water cost in your community and the estimated cost of plumbing, underground or above ground storage, and the energy costs for independent pumping and ultraviolet treatment of the water, there could be a favorable cost balance over time. By reducing run-off, you would be saving money by not using and paying for potable water for non-potable purposes, ecologically reducing the draw on our limited potable water supplies, working with "soft" water for cleaning, and reducing impervious-surface fees the school district pays to local government. Again, the whole approach must be carefully thought out. Putting this all together is a new approach and there is ambiguity with anything new.

This shows a water-stressed community's effort to provide purified water for children by exposing plastic beverage bottles containing hand filtered water to direct sunlight, and sunlight reflected at different ultraviolet frequencies into the bottles. While this method must be undertaken cautiously, it often provides cleaner, more wholesome water for water-stressed communities.

The ultraviolet treatment process is compact and straightforward, although there are often energy costs. The roof (light gray) water is passively pushed through a pipe that emits ultraviolet radiation and most of the bacteria are destroyed. The water should not be considered potable, but it is safe, even preferred, for other uses.

The use of non-potable water for washing or even for human waste control, i.e. black water, may be a cause for concern in the community. Also, people sometimes confuse ultraviolet radiation with potentially hazardous ionizing radiation. Public perception and thoughtful cost estimates are important considerations in configuring internal use of roofing system run-off.

In some situations, roof run-off for non-potable use involves the run-off being stored underground, treated with filters and/or ultraviolet radiation, and then pumped into higher building areas. It can then be used for flushing toilets, watering plants, cleaning building surfaces, etc. There are both design/implementation and energy costs, which must be considered.

Such procedures for decontamination and use of snow melt or rainwater do not apply to storm water that has gone through parking lots or green spaces, as this would introduce fertilizer, pesticides, a heavy burden of suspended particles, and an unknown matrix of microbes (dark gray water).

Mechanisms for temperature exchange relative to storm water have also been experimentally implemented and appear to have promise in terms of being financially viable in energy savings. Essentially, storm water is maintained in a contained area deep enough so it will not freeze, and chemicals are pumped through the sitting water. The process involves "squeezing heat" out of dark gray pond water or capturing cold underwater temperatures for summer building cooling. The process involves pressurization and heat exchange and is considered somewhat cutting-edge.

The approach school facilities take in dealing with water, which will be responsive to quality ecology and cost effectiveness, will likely evolve over the next few years as potable water and non-potable water disposal become more costly and new technologies become less expensive.

Minnesota's First Wetland

In 1972, the Federal Clean Water Act was passed and the State of Minnesota's response, in part to clarify the Federal Act, would be implemented as the Minnesota Environmental Rights Act.

Minnesota's first "wetland," and use of the Minnesota Environmental Rights Act to protect water, involved a farmer, Bill Bryson (near Albert Lea in South Central Minnesota), who wanted to preserve a wetland he owned from being bisected under eminent domain for a road project undertaken by Freeborn County.

After a long and emotional conflict involving both the local water authority and Attorney Charles Dayton, who at the time was working with an environmental group associated with the early environmentalist and author, Ralph Nader, the matter wound up in the Minnesota Supreme Court.

The complex court action involved teams of attorneys, engineers, and the judge traveling to actually see the wetland, which was the center of this emotional legal controversy. Once out of the courtroom and standing on a hill overlooking the wetland, the group was struck by the beauty of the property and enchanted by the opportunistic landing of a number of ducks and general presence of wildlife. They were clearly impacted by both the beauty of the wetland and the obvious role it had in the ecology of the area.

The Minnesota Supreme Court eventually found that the land should be protected under the Act, overruling lower courts. The Justices wrote the following as part of their determination:

> *"To some of our citizens, a swamp or marshland is physically unattractive, an inconvenience to cross by foot and an obstacle to road construction or improvement… It is (also) quiet and peaceful – the most ancient of cathedrals – pre-dating the oldest of manmade structures. More than that, it acts as nature's sponge, holding heavy moisture to prevent flooding during heavy rain falls and slowly releasing the moisture and maintaining the water tables during dry cycles.*
>
> *In short, marshes and swamps are something to preserve and protect."*
>
> **— Minnesota Supreme Court**

Minnesota had its first legally protected "wetland."

The action was not supported by local water authorities or much of the community, which wound up paying a bit more for an alternate roadway. On the right is a sample of one of many letters that Mr. Bryson and his wife received.

The alternate road was built and both the wetland and the Bryson farm survived, and a protocol was established for the preservation of wetlands while allowing responsible development.

While it was hard for people to initially understand the value of wetland, today, wetlands are known to be valuable to humans and the ecosystem.

Mr. William Bryson:

What do you mean by spending the taxpayers money on a dam old slough. Now this is a threat. Drop this whole matter or there will be a quick fire at your place soon. You won't even know it until it is out of control. We mean business. This sure stinks… (some expletives).

(Signed)

Taxpayers

Fridley Public School students finding solutions.

"Children are our best hope to finding solutions to our water challenges."

Property Solutions as Education

In 2006, Hamline University, Minnesota's oldest post-secondary higher education institution, piloted a water ecology program involving students, educators, and others working with local water control authorities and civil engineers. The objective was to control the school's stormwater, but also provided a remarkable water ecology education experience. What occurred was moving to everyone involved.

Hancock Elementary School was constructed pre-World War II in the old style of educational buildings. It had high windows, high ceilings, thick walls, and a small multi-story footprint. It was replaced with the new, environmentally insensitive, post-war school construction style building. It had a large, impervious surface parking lot, a huge flat roof, and an increased ecological footprint. Without complementary civil engineering alterations, the playground area flooded consistently. The students were often denied the use of their playground and the extensive surface water generated was contaminated with fertilizer, pesticides, and debris from the huge new property footprint.

Hamline University Center for Global Environmental Education (CGEE) financed an effort, under the direction of Peggy Knapp, Assistant Professor at the Hamline School of Education, now with the Freshwater Society, to bring together concerned students, educators, school facility managers, local water planners, and a number of other local groups to work as a team to "fix" the storm water problems and to learn from the fix.

A Geotechnical Engineer working with 4th grade students to plan storm water controls at St. Paul's Hancock Elementary School. The students wanted a dry playground and to stop contaminating surface water.

The 4th grade students came to understand not only the relevant civil engineering criteria, but also the long-term eco-impact of responsible controls for storm water. Those involved in professional water planning also learned from faculty, students, and educators regarding what would enhance the school property and the school experience as they designed the controls. It was an inspirational experience for everyone involved. It engaged many students who initially had limited interest in science studies. It showed how their lives were enriched with better water controls, and the civic engineering professionals were inspired by being part of the educational process.

We believe that the project demonstrated that wisely responding to school property water concerns can become a powerful part of a school's life, motivating students toward finding responsible environmental solutions.

The dynamic of water is huge, both to our ecology and to the health and safety of all people. The school should teach and model responsible water ecology for the community, and especially as a real-world example to our children, who are our best hope to finding solutions to our water challenges.

Thinking through solutions to our greatest challenge.

As science permits us to better understand our environment, it's beauty does not diminish. Rather, a sense of guardianship for something of value becomes part of us.

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