Exploring Water Quality of Georgetown, Texas

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Environmental Issue

Water Quality

Water covers 75% of the earth’s surface. About 97.5% of this volume of water is seawater from the oceans and seas. The remaining 2.5% is freshwater. Of this percentage of freshwater, two-thirds are bound up in polar ice caps and glaciers. Approximately 0.77% is available for human consumption without expending a great deal of energy extracting and purifying water for human use (Wright, Richard T. et al., 2017, pp. 234). In 2022, The World Health Organization (WHO) reported that 73% of the global human population had access to clean drinking water (World Health Organization, 2023). The people who do not have access to clean water are often in developing countries. The lack of access to clean water is a primary contributor to the spread of preventable pathogens. Water itself is not considered a renewable resource. The water cycle does, however, continuously recycle water. Poor water quality can negatively impact ecosystems. Because of this and the limited quantity of water, it is important to maintain water quality.

On a global scale, pollutants are the primary driver of declining water quality. Pollutants come from several sources. Some point sources of pollution are sewage treatment plants, oil wells, underground coal mines, and power plants (Wright, Richard T. et al., 2017, pp. 500). Point sources are sources of pollution that can easily be tracked. Some nonpoint sources of pollution are agricultural runoff, and storm water drainage (Wright, Richard T. et al., 2017, pp. 500). Nonpoint sources are pollutants where the sources cannot easily be tracked. All these pollution sources are created by human activities.

Some pollutants, such as agricultural runoff and untreated sewage can promote the spread of several preventable pathogens. Some of these pathogens are: Typhoid Fever, Cholera, Salmonellosis, Poliomyelitis, Dysentery, and Giardiasis (Wright, Richard T. et al., 2017, pp. 500). Many of these pathogens can result in death if left untreated. At the very least, they reduce a person's quality of life.

Pollutants, such as stormwater drainage and agricultural runoff, can also introduce elevated levels of nutrients into the water, such as nitrates and phosphorus. These nutrients can promote the growth of aquatic plants and phytoplankton. The growth of these aquatic plants can consume dissolved oxygen in the water. Dissolved oxygen in the water is required to promote biodiversity of life in streams and lakes. The elevated nutrients in the water can also cause aquatic plants to be eutrophic the point where they block photosynthesis for other aquatic plants below the surface, further limiting biodiversity of benthic aquatic plants (Wright, Richard T. et al., 2017, pp. 514).

The sediment load in streams can also contribute to polluted waters. Erosion from mining sites, agricultural land, and land development can contribute to sediments entering the waterways (Wright, Richard T. et al., 2017, pp. 516). Finer sediments, such as clay can remain suspended in the water column the continue downstream until it encounters an obstruction that sufficiently slows the moving water down enough for deposition. Heavier sediments, such as sand, will often be deposited sooner, contributing to the bed load of a stream. Both sediment scenarios can contribute to declining biodiversity in streams. Finer sediments in the water column can impede light penetrating the water, limiting photosynthesis. Heavier sediments, which contribute to the bed load, minimize the areas where small aquatic life can hide and rest.

Water Quality in the Local Community

On a local level, water quality can impact our communities in several ways. The region in which I live has several known and unknown caves below our feet. These caves often are conduits for recharging our local aquifers. Particularly in urban areas, storm water drainage can introduce pollutants into the aquifers and streams. These pollutants can be petrochemicals from vehicles, fertilizer nutrients from urban lawns, debris such as tree branches and litter, and even animal fecal material from pets and wildlife. Some of these recharge zones are very porous limestone, so the water entering the aquifer is not as purified as water that percolates through sediment materials. In some locations, the water recharging an aquifer does not travel far before it exits a spring, contributing to surface water. In at least one documented instance, runoff from a developer entered a recharge zone only to exit a spring a few miles away (Huber, 2019).

An impact to downstream communities is when municipalities release untreated wastewater into the local waterways. This recently happened when my local municipality released wastewater into the San Gabriel River, because recent rains had overwhelmed the treatment's ability to treat water (Rangel, 2024). This specific incident does not impact my local community. It does, however, impact the water quality of downstream communities.

There are several recreational activities that take place in our local waterways. Activities such as swimming, scuba diving, kayaking, boating, inner tubing, and fishing all take place in local streams and lakes. In recent years, occurrences of blue-green algae have increased, impacting the community's ability to enjoy these activities safely. These occurrences are frequent enough that cities, such as Austin, actively monitor the popular local waterways to keep the community informed whether the waterway is safe to swim in or not (Watershed Protection Department, 2023).

Human Impact

Impacted Ecological Processes

There are several portions of the hydrologic cycle that are impacted and further exacerbate the environmental impact.

Surface runoff from precipitation can exacerbate the environmental impact to water quality. In urban areas, rain washes debris and chemicals off streets and sidewalks to storm water drainage. This drainage can lead directly to the nearest stream. The introduction of these debris and chemicals can affect water quality in several ways. The debris can limit photosynthesis in the water. It can minimize resting and hiding places for aquatic organisms. It can also increase the hazards that aquatic organisms encounter. The chemicals can increase the nutrient load in the water, promoting increased growth of aquatic plants. The increased growth of aquatic plants can limit photosynthesis of other plants and consume dissolved oxygen, which can cause other aquatic organisms to perish. Both pollutants can limit biodiversity of the local waterways.

Erosion caused by natural processes and land development can contribute to sediment loads in streams. These sediment loads can limit photosynthesis and limit the resting and hiding places of aquatic organisms. Nutrients introduced to streams from agriculture and lawns can promote the growth of aquatic vegetation and phytoplankton. These aquatic plants can limit photosynthesis for other plants and can consume available dissolved oxygen. Both issues can negatively impact stream biodiversity.

Infiltration can impact the water quality of aquifers if the aquifer recharge zones do not have adequate percolation for purify water that is entering the aquifer. Contaminants entering the aquifer can require further purification for human consumption. These contaminants can also impact the biodiversity of aquatic organisms that reside in submerged cave environments.

Human Activity Impact

Stormwater Runoff in Urban and Suburban Contexts: Civil engineering strategies are implemented in urban and suburban areas to mitigate the effects of precipitation events, aiming to minimize flooding within these densely constructed environments. The presence of impermeable surfaces such as roads, sidewalks, foundations of buildings, and parking lots necessitates the implementation of sophisticated drainage systems to facilitate the removal of rainwater. These impermeable surfaces accumulate pollutants, including vehicular lubricants, antifreeze, and miscellaneous chemicals discarded on roadways. Alongside, organic, and inorganic debris, such as leaves, grass clippings, branches, sediments, and litter, are transported via the stormwater drainage system during precipitation events, eventually discharging into adjacent aquatic ecosystems such as streams, lakes, or oceans.

In the United States, the cultivation of green lawns is a prevalent practice. The maintenance of these lawns often involves the application of fertilizers and additional nutrients. The confluence of excessive fertilizer uses, and overwatering practices contributes to the runoff of nutrient-enriched waters into storm drains. Consequently, these nutrient-laden waters are discharged into proximate streams, lakes, or oceans, potentially exacerbating eutrophication and negatively impacting aquatic ecosystems.

Agricultural Runoff in Rural Contexts: Agriculture is a necessity of modern life. The advent of agriculture was what allowed people to transition from nomadic hunter-gatherers to settle in a specific location. This allowed people to harvest more food per capita than had been done in previous generations. It allowed for the creation of societies and our modern lifestyle. For all the advantages that agriculture has afforded people, it is not without its faults. The congregation of farm animals leads to increased concentrations of manure. This excess manure can make its way to local waterways during precipitation events.

Fertilizers and pesticides used to produce healthy crops can also make their way into local waterways during precipitation events. In both cases, the addition of manure and fertilizers can increase the nutrient load in the local waterways, which can negatively impact the ecosystems of the waterways.

Mining-Induced Runoff and Environmental Implications: The extraction of minerals and metals through mining activities is fundamental to the advancement of modern civilization, providing essential materials for the construction and technological sectors. From the procurement of iron ore and gold to the extraction of critical components for concrete, mortar, bricks, and modern battery technologies such as lithium, mining processes are indispensable. However, these activities are inherently destructive and characterized by extensive extraction methods that yield considerable sediment byproducts and, in certain instances, result in the leaching of hazardous chemicals and heavy metals into the environment. This resultant increase in sediment load, alongside the dissemination of toxic substances, poses a significant threat to adjacent aquatic systems. The ingress of such pollutants and sediments into streams not only contaminates these water bodies but also adversely affects the biological integrity and functioning of these ecosystems, leading to detrimental impacts on biodiversity and water quality. Chemicals and heavy metals can make their way to nearby streams, contaminating the streams and negatively impacting the ecosystem.

Erosion Impacts from Infrastructure Development: The construction of essential infrastructure, encompassing utilities such as water, sewer, stormwater drainage, gas, telecommunications, roads, and bridges, necessitates aggressive land modification techniques. Similarly, the development of residential and commercial structures, including houses, office buildings, and parking facilities, involves substantial alterations to the landscape. This process typically includes the removal of vegetation, land grading with heavy machinery, and the introduction of clay-based soils to achieve a stable, compact foundation. In regions characterized by arid conditions and high wind activity, these disturbed sediments are prone to becoming airborne, subsequently depositing in adjacent aquatic systems. Furthermore, precipitation events facilitate the mobilization of these sediments, channeling them into nearby streams. This contributes to an increase in the sediment load of the water bodies, potentially compromising water quality and affecting the ecological balance by altering habitats and the distribution of aquatic species.

The Cumulative Impact of Human Activities on Aquatic Ecosystems and Water Quality: Various human endeavors, including the application of fertilizers for lawn maintenance and agriculture, urban and infrastructural development, and mining, have profound implications for the quality of water in aquatic ecosystems. Nutrients, particularly from fertilizers, when leached into waterways, escalate the nutrient concentrations, facilitating an overabundance of aquatic plant growth. Such proliferation can obscure necessary sunlight for photosynthetic processes in subaquatic flora and deplete dissolved oxygen levels, essential for aquatic life, thus rendering the waterways inhospitable for many organisms. Furthermore, the excessive nutrient levels can catalyze the bloom of toxic algae, such as cyanobacteria (blue-green algae), which not only consumes significant amounts of dissolved oxygen but also releases toxins detrimental to the health of humans and animals, thereby diminishing the biodiversity and ecological health of the aquatic environment.

Erosion, exacerbated by construction and land development activities, introduces substantial quantities of sediments into streams and rivers. The dynamics of sediment deposition depend on the particle size; fine clay particles are transported downstream until the flow diminishes enough for them to settle, while coarser materials like sand quickly precipitate out of the water column. The accumulation of these sediments can obliterate vital habitats for aquatic life, including spawning grounds and shelters, and suspended sediments can significantly reduce light penetration, impairing the photosynthetic capacity of aquatic plants. This series of effects reduces biodiversity and the vitality of aquatic ecosystems.

Mining activities, noted for their extractive nature, further exacerbate these impacts by releasing hazardous chemicals and heavy metals into waterways. The contamination from these substances poses carcinogenic risks to aquatic life and humans alike, potentially leading to severe health issues or mortality. Together, these human-induced factors converge to degrade water quality, compromise the resilience and functionality of aquatic ecosystems, and threaten the biodiversity and ecological integrity of these vital environmental resources.

Local Community Impact

In my local community, water quality has impacted the ecological processes in several ways. The San Gabriel River flows through the city of Georgetown and is a central figure of the city's landscape. Upstream from the city, on the South Fork San Gabriel River, there is a concrete quarry whose land borders the river (See figure 1.1). During heavy precipitation, it is possible that this quarry contributes to the sediment load of the South Fork San Gabriel River. During these periods of heavy precipitation, there is a clear delineation of sediment loads at the confluence of the south and north forks of the San Gabriel River. The north fork will run clear with a green tint, while the south fork will run murky and brown. At the confluence of these rivers, the flows converge to form a clear line before blending further downstream (See figure 1.2).

Also, during exceptionally heavy precipitation events, stormwater has overwhelmed the municipal water treatment's plant ability to treat water before being discharged into the San Gabriel River. This forced the municipality to discharge untreated wastewater into the river. This water flowed downstream, away from Georgetown, but it would have affected the local ecosystem and downstream communities (Rangel, Lauren, 2024).

Increased nutrient load in the water can be seen in the river by dense vegetation and algae growth (See figure 1.3). This nutrient load comes from numerous sources. Locally the primary source is runoff from lawn fertilizers. Further upstream, the increased nutrient load can be contributed from agricultural sources.

The various sources of pollution have influenced the changes in water quality of the San Gabriel River, which I have been tracking as a volunteer for the Texas Stream Team. Since starting my monitoring efforts in September, I observed and sampled the river's water near my residence. Initially, the dissolved oxygen levels were near a threshold crucial for sustaining life (4.4 mg/L), and the conductivity was high (850 microsiemens/cm) during the same period. Fortunately, dissolved oxygen levels have improved in later samples, indicating conditions more conducive to aquatic life. Currently, I do not gather data on the nutrient content in the San Gabriel River.

Figure 1.1: Concrete quarry bordering the South Fork San Gabriel River.

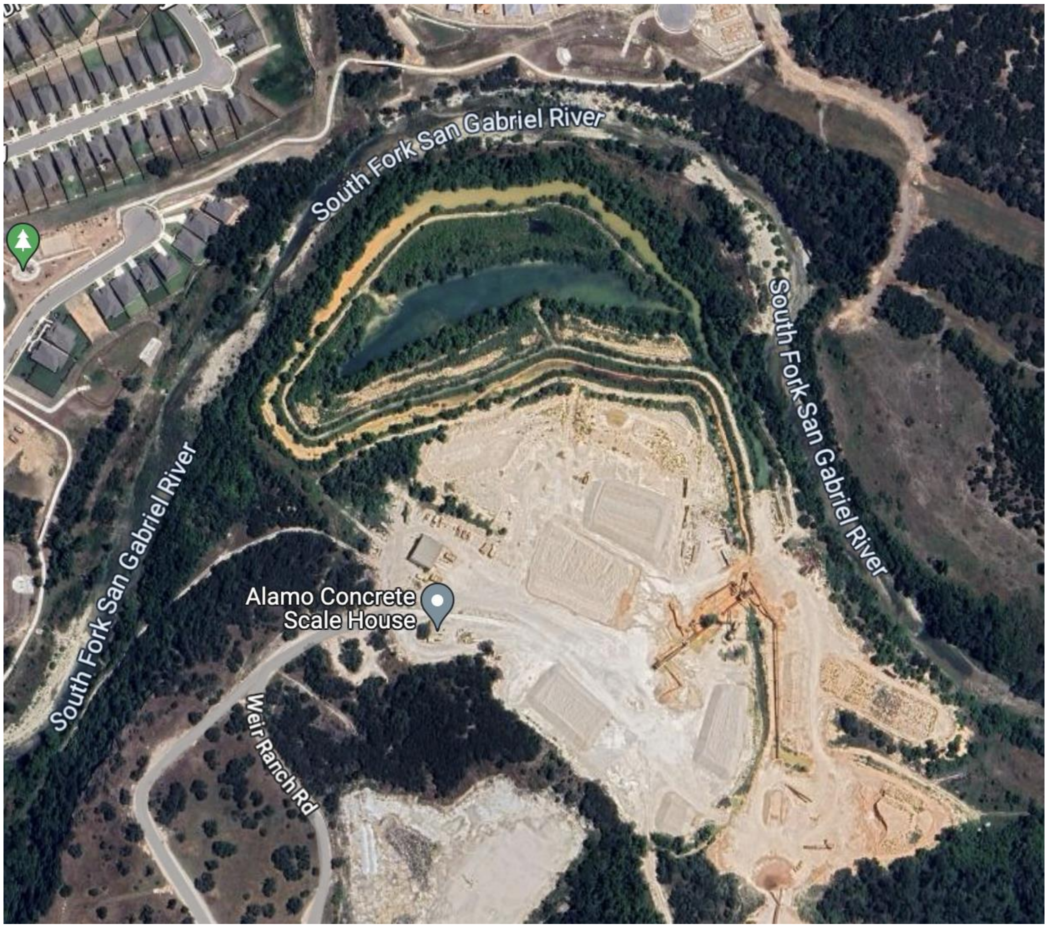
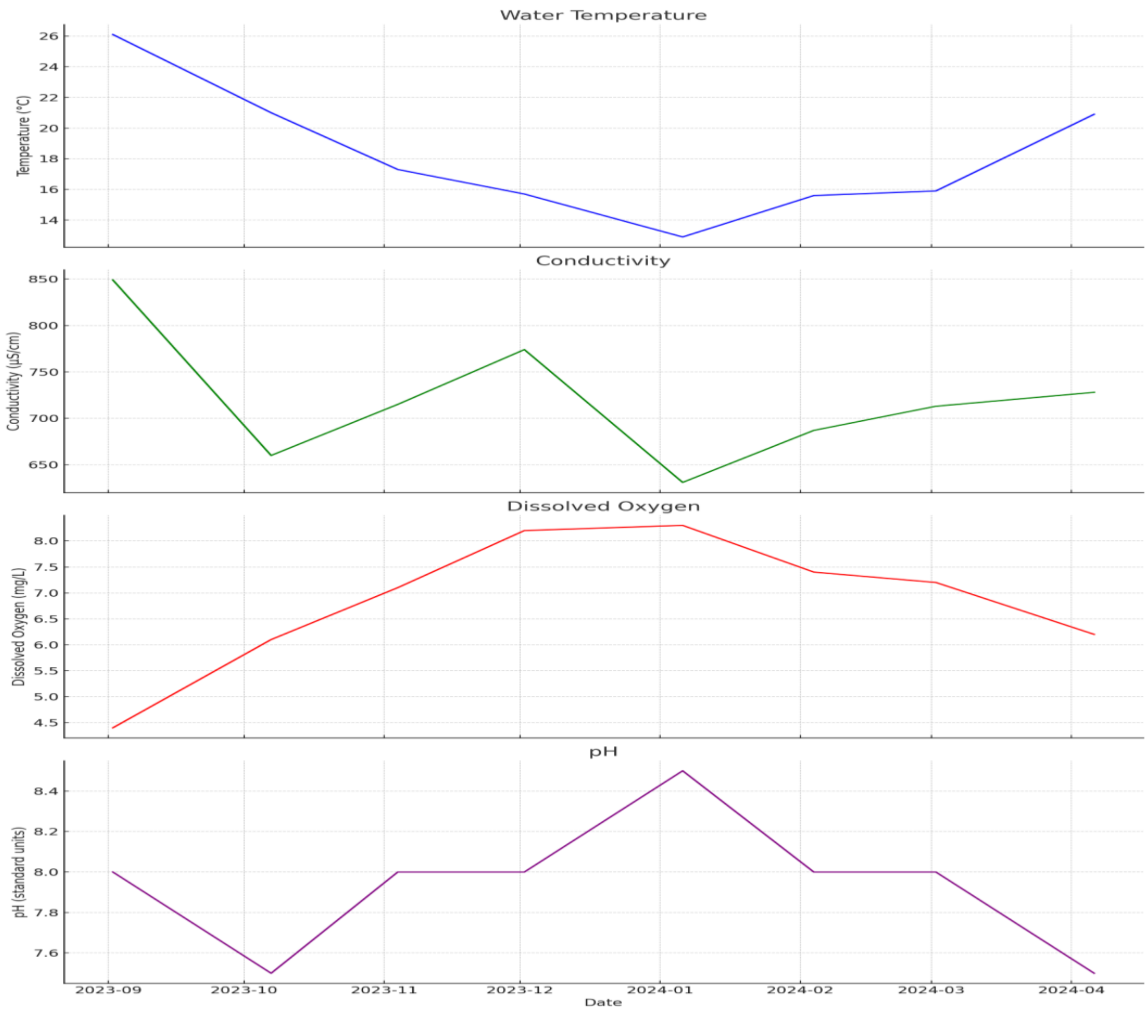


Figure 1.2: Increased sediment load at the confluence of the South Fork San Gabriel River and the North Fork San Gabriel River after heavy precipitation on April 9, 2024. The sediment load originates from the South Fork San Gabriel River, which contains a concrete quarry next to the river upstream.

Figure 1.3: Dense aquatic vegetation and algae on the San Gabriel River.

Figure 1.4: San Gabriel River water quality sampling data from September 2023 – April 2024.



Potential Solutions

Proposed Solutions

Scientists have proposed and, in some instances, actualized a spectrum of strategies aimed at ameliorating the global decline in water quality. These strategies encompass a diverse array of interventions, from the restoration of riparian zones and wetlands, which serve as natural filters and barriers to pollution, to the ambitious goal of achieving zero plastic production. Each solution targets specific aspects of the broader issue, addressing both the direct and indirect causes of water pollution to safeguard and enhance the integrity of aquatic ecosystems worldwide.

As explored in the preceding section, runoff emerges as a critical factor in water quality degradation. It serves as a main vector for introducing sediment and nutrients into aquatic systems, thereby catalyzing a multifaceted water quality deterioration. In response to this challenge, one proposed intervention involves the establishment or restoration of riparian zones at runoff origins. These zones function as a mitigative buffer, interposing vegetation between sources of pollution and aquatic systems. This vegetative buffer serves dual purposes: it aids in the prevention of erosion and facilitates the filtration of pollutants prior to their assimilation into stream ecosystems (Graziano MP, et al. 2022). Another proposed strategy is the restoration of wetlands. This approach parallels the function of riparian zones in establishing a natural barricade between sources of pollution and aquatic recipients. Consequently, wetlands serve as an efficacious natural filtration system for contaminants and pathogens. Additionally, they play a pivotal role in reducing sediment loads in streams and curtailing erosion, thereby contributing to the overall resilience and health of aquatic ecosystems (Nummi P, et al. 2020). Furthermore, wetlands significantly contribute to groundwater recharge, enhancing the natural filtration process as water percolates through the soil layers to the aquifer. This subterranean journey allows for the incremental removal of impurities, thereby improving the quality of water as it integrates into the groundwater system. This process not only augments water quality but also bolsters water availability, underlining the multifaceted benefits of wetland restoration on hydrological and ecological systems.

An additional proposed solution entails the adoption of advanced irrigation methodologies and more effective nutrient management practices within the agricultural sector. Researchers are delving into the potential of leveraging technology alongside extant online data repositories, with the objective of empowering agricultural professionals. This approach is designed to facilitate data-driven decisions, enabling the tailoring of irrigation and nutrient management strategies to the unique environmental and climatic conditions of their specific regions. Such targeted interventions are anticipated to optimize water usage and minimize nutrient runoff, thereby contributing to the reduction of water quality degradation on a global scale (Gallardo, Marisa. 2020).

Advantages and Disadvantages of the Proposed Solutions

Riparian Zones and Wetland Restoration

- **Advantages**
  - Water quality improvements: Vegetation from riparian zones can filter out pollutants before they enter the aquatic environment.
  - Biodiversity: Increased vegetation can promote biodiversity by providing food and habitat for organisms.
  - Climate change: riparian zones and wetlands can sequester carbon, thus helping to mitigate the effects of greenhouse on the environment.
  - Flood mitigation: Riparian zones and wetlands can absorb excess precipitation, thus helping to mitigate the effects of heavy rains.

- **Disadvantages**
    - Maintenance requirements: Riparian zones and wetlands can require ongoing maintenance to manage invasive species to ensure the health of the native plants.
    - Pest habitat: Riparian zones and wetlands can be a prime habitat for pests such as rodents and mosquitoes.
    - Land use conflicts: Riparian zones and wetlands require land that could otherwise be used for other purposes, such as residential and agricultural developments.
    - Economic costs: Riparian zones and wetlands can cost a significant amount of money to create the zones.

Technology based Irrigation and Nutrient Management

- **Advantages**
    - Informed decision making: Decisions can be made objectively, based on constantly updated data.
    - Quick adaptation: As environmental conditions change, and data is updated supporting the reflect the updated environmental conditions, practices and be changed to reflect the changes.
- **Disadvantages**
    - Data quality: The ability to implement objective management practices is only as good as the quality of the data that is ingested. If the data is flawed, the management practices may also be flawed.
    - Cost: Technology and maintaining large data repositories are expensive. The cost of this infrastructure could cost more than would otherwise be spent performing the management practices manually.

- Resource Intensive: The computer power required to power such large-scale systems, particularly systems that synthesize decisions based on large datasets, require a lot of energy for power and water resources for cooling. Depending on the scale, these factors could very well offset the benefits of implementing the technology.

Required Changes to Human Behavior

In terms of riparian zones and wetland restoration, the human behavior of consumption and development based on capitalist decisions would need to change. We currently have a culture of consumption based on capitalism. This is a byproduct of our evolution to agricultural societies from hunter-gatherer societies. Instead of viewing a plot of land as a product that should be developed for human use, we should be asking ourselves what the potential repercussions are of developing the land. Some land, such as those ripe for wetlands and actings as a riparian zone should be considered as an investment in promoting water quality. These decisions may not contribute to shareholder wealth, but they could help promote the quality of water resources.

Technology is used every day in our lives to solve problems. The use of technology has made our lives easier in every way. It is only natural to want to apply technology to solve irrigation and nutrient management problems in agriculture. Technologies that help with the decision-making process based on large datasets require large data centers full of computers to operate. These computers require substantial amounts of power and water for cooling. Depending on where the data center is located and where it gets its power, it could be contributing to climate change by being powered by coal power plants. These data centers could also be consuming water from regions that already have strained water resources. When considering these technologies, particularly for promoting better environmental practices, the environmental impact of utilizing these resources should be considered.

Reducing Personal Impact

Personal Habits and Daily Activities

Maintaining a lawn: By caring for my lawn through actions like fertilizing and applying pesticides, I might be increasing the nutrient levels that eventually flow into the San Gabriel River. This risk is particularly high if I over-apply these substances just before rain, leading to runoff that carries these excess nutrients into the stormwater system.

Contribution to the treatment plant: Anytime I flush the toilet, take a shower, use the dishwasher, run a sink faucet, or wash laundry I contribute grey water to the treatment plant to process. As mentioned previously, there have been instances where the treatment plant has had to release untreated sewage into the San Gabriel water because of events that caused it to exceed its capacity.

Stormwater drainage: The driveway to my home is an impermeable surface. When it rains, water flows down the roof and onto this impermeable surface. This water then travels to the street, and into the gutter. This water is discharged to the San Gabriel River. Along the way, the water from my roof could have picked up pollutants that ended up in the San Gabriel River.

Personal Impact on Ecological Processes

I consider myself to be aware of the environmental issues that impact water quality. Based on that knowledge, I attempt to be a good steward of the water resources that I personally impact. It is evident that there is more that I can do to minimize the impact.

1) I can install rain gutters on my house. Excess rainwater that the gutters collect can be directed towards a permeable surface, such as a rain garden, or the water can be collected in a rain barrel. The rainwater collected in the rain barrel can be used to water the lawn or garden.

2) I can implement xeriscaping techniques that plant native plants – such as buffalo grass. Native plants are better suited for the local environment, have a deeper root structure, and require less water and nutrients to remain healthy. This would reduce my contribution to the nutrient load in the San Gabriel River.
3) The more water that I send down the sink or toilet, the more water that needs to be treated by the treatment plant, which ends up in the San Gabriel River. By reducing my water consumption, I can reduce the treatment plant load.

Prioritized Habits

The simplest personal habit that I can implement is changing my water consumption habits. Minimizing the water sent down the drain or that I contribute to storm water drainage will ease the burden on the local water treatment plant. Little steps, such as taking shorter showers, turning off the faucet when I am brushing my teeth, only washing laundry when I have a full load, or only washing dishes in the dishwasher when I have a full load of dishes to wash, can go a long way towards reducing my personal impact to the treatment plant. This has the added benefit of consuming less water in a region currently in a drought.

Strategies to Help Mitigate Personal Impact on Ecological Processes

There are several habits that I can change to minimize the impact of water quality in my local community.

1. Minimize the water that I contribute to storm water drainage. When watering the lawn, do not water excessively so that water runs into the street. This excess water picks up sediments, chemicals, and other debris along the way, which ultimately can end up in neighboring streams.

2. Limit the use of lawn fertilizers. Lawn fertilizers containing nitrogen or phosphorus can contribute to the excessive nutrient load in streams. These nutrient rich waters can promote excessive vegetation growth, which can minimize photosynthesis for other plants and consume the available dissolved oxygen, which is required for other organisms.
3. Dispose of chemical waste properly. Not all household chemicals can be poured down the drain when their useful lifecycle has been exhausted. Pouring these chemicals down the drain may promote an excess burden on the water treatment plant. Instead, local municipalities have facilities in which these chemicals can be taken to for disposal.
4. Volunteer. There are organizations, such as the Texas Stream Team, that rely on volunteers to monitor water quality and assess riparian zones in their local waterways.
5. Create permeable filtration zones. Use gutters to guide rainwater from your home to a rain garden or other permeable zone. This process will help filter water as it percolates into the ground.

Dataset

San Gabriel River Water Quality Dataset. https://snhu-my.sharepoint.com/:x:/g/personal/james_williams38_snhu_edu/ERI0dpFFCvNHiWBZQEZDHF0BsDCECWclaTUhWf1zdxHxXg?e=a21PaA

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