Constructed Wetlands as an Innovative, Cost-Effective Solution for Wastewater Treatment in Small Communities

Christy Womack Vines

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Honors Program

HONORS SENIOR PROJECT APPROVAL FORM

(To be submitted by the student to the Honors Program with a copy of the Honors Project suitable for binding. All signatures must be obtained.)

Name of Candidate: Christy Womack Vines

Department: Civil and Environmental Engineering

Degree: Bachelor of Science in Engineering

Full Title of Project: Constructed Wetlands as an Innovative, Cost-Effective Solution for Wastewater Treatment in Small Communities.

Approved by:

Project Advisor (Kathleen M. Leonard, Ph.D.) Date

Department Chair (Gerald R. Karr, Ph.D.) Date

Honors Program Director for Honors Council Date
Constructed Wetlands as an innovative, Cost-Effective Solution for Wastewater Treatment in Small Communities

Christy Womack Vines

Treatment of wastewater is mandated by the Clean Water Act (CWA) as implemented by the Environmental Protection Agency (EPA) in the 1970s. The central purpose for wastewater treatment is disease prevention. Historically, many diseases, such as amoebic dysentery, cholera, polio, and typhoid fever, have been transmitted through water. Current studies are analyzing the survivability of HIV in wastewater. Chemicals from industrial processing kill fish and other wildlife and are often carcinogenic to humans.

Municipal wastewater treatment can be achieved through various types of secondary treatment methods. Some of the more common are plug flow, trickling filters, and rotating biological contractors. These types of wastewater treatment plants are expensive to construct and maintain. They also require operators to be on-site 24 hours a day. This poses major problems for communities with populations of 20,000 or less. These communities cannot afford treatment plants, and, as a result, often fail to meet EPA effluent standards. New technologies are being developed to remedy this, one of which is constructed wetlands. The hypothesis analyzed in this project is that constructed wetlands can be utilized by small communities to minimize the cost of wastewater treatment while complying with the CWA.

The efficiency and cost-effectiveness of the designed FWS constructed wetlands proves it to be a feasible choice for municipal wastewater treatment for some small communities, but not for all. For constructed wetlands to be feasible, the community must have available the necessary land resources at a reasonable price. The design engineer must recognize that each community has a unique set of circumstances. Therefore, while constructed wetlands is the ideal solution for some small communities, it cannot be established as the generic solution for all small communities.
Constructed Wetlands as an Innovative, Cost-Effective Solution for Wastewater Treatment in Small Communities

Christy Womack Vines

for
Dr. Kate Leonard
and the UAH Honors Program
November 29, 1993
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1.0 PROLOGUE

Wastewater treatment is a necessity that is often financially difficult for small communities to achieve. This project concentrates on: 1) the need for wastewater treatment; 2) the financial need of small communities to obtain effective wastewater treatment; and 3) the feasibility of constructed wetlands as a cost-effective method of wastewater treatment in small communities. This project is comparable to real-life engineering problems in that several considerations, needs, and constraints are involved.

The roots of wastewater treatment lie in the prevention of diseases [1, 193]. For example, in the early 1800s, before wastewater treatment in London, outbreaks of cholera were common. The cause of the epidemics was the contamination of groundwater (drinking water) by the raw sewage of infected persons. Many people died as a result [2,108]. In the United States, wastewater treatment and disposal was not a public concern until the late 1800s. This was because the sparseness of the country’s population allowed ample space for disposing wastes in woods, lakes, or streams. However, health problems began to arise by the early 1900s. The germ theory developed by Koch and Pasteur linked human and animal waste with disease [3, 2]. This was the first knowledge of the need for wastewater treatment. "The threat, rather than actual, out-break of epidemic of water-related diseases is the driving force for controlling water quality," says Tchobanoglous [1, 199]. Even after the connection between waste and disease had been made, decades passed with no regulations concerning the treatment and disposal of wastewater. The United States' first attempt came in 1949 with the Water Pollution Control Act. Several acts followed which did not set specific regulations and did not provide an economic means for local governments to comply with any mandates. In 1972, the Clean Water Act (CWA) was implemented by the Environmental Protection Agency (EPA). It was the first law which gave specific limits on the discharge concentrations of harmful qualities. The objective of the CWA is,
to restore and maintain the chemical, physical, and biological integrity of the Nation's waters," [3, 122-123].

According to Tchobanoglous, "Waterborne and water-related diseases are among the most serious health problems in the world today," [1, 193]. Biological contaminants are often linked to water-related diseases. These contaminants are collectively known as microorganisms. Microorganisms found in wastewater are identified by the subcategories of bacteria, fungi, algae, protozoa, worms, rotifers, crustaceans, and viruses [1, 127-138]. For example, cholera is caused by a bacteria, *vibrio cholerae*. One major symptom of cholera is extremely heavy diarrhea, which leads to dehydration. As a result, the death rate from cholera is high, especially for children and the elderly [1, 196]. Other diseases caused by bacteria are salmonellosis, typhoid fever, and shigellosis. The symptoms range from diarrhea to death [1, 196]. A well known disease caused by a protozoan is amebiasis (amoebic dysentery). Amebic dysentery causes "prolonged diarrhea with bleeding and abscesses of the liver and small intestines," [1, 196]. Worms are generally water-based, meaning that worm infections involving water occur as one stage in the lifecycle of the worm. Filariasis, a worm infection, causes blocking of the lymph node, which causes permanent tissue damage. Another worm, the guinea worm, causes arthritis of the joints [1, 196].

Viruses cause some of the most dangerous water-related diseases. "Over 100 virus types are known to occur in human feces, and an infected person may excrete as many as $10^6$ infectious particles in 1 gram of feces," [1, 195]. Viruses are host-specific, so not every virus present affects humans. Trachoma, caused by a virus, causes eye inflammation, and partial to complete blindness [1, 196]. One of the most controversial topics currently is the survivability of the Human Immunodeficiency Virus (HIV) in wastewater. One report states that, upon examination of wastewater in a laboratory situation, at room temperature HIV survived for 72 hours, but was most stable during the first 12 hours [4, 215]. This report states the experimental results obtained, but does not
make any assumptions regarding its infectability. The Center for Disease Control (CDC) states that the findings of this experiment are exaggerated. They, along with the EPA, claim that because HIV can only enter wastewater through blood, semen, saliva, and tears, the concentration of HIV in wastewater is much lower than that suggested by the experiment [5, 3]. A source from the CDC says, "Theoretically, the only way you could get HIV infection from wastewater is if you were injected with rather large amounts of it, which is hardly likely," [5, 3]. More studies are currently being conducted in this area.

Chemicals also pose health threats to humans and animals. Some chemicals occur naturally in surface or groundwater sources, while others are added from pesticides, fertilizers, cleaning supplies, or industry. Magnesium occurs naturally, but has a laxative effect [1, 192]. Nitrates can lead to a condition known as methanoglobinemia ("blue babies") in which nitrates interfere with "oxygen utilization" in babies under one year of age [1, 192]. Sodium has been linked to hypertension and high blood pressure [1, 193]. Aluminum is now believed to be related to Alzheimer's disease. Many organic substances, such as fertilizers and pesticides, have been suspected as carcinogens. Some chemicals such as dibromochloropentane (DBCP) have caused human sterility after long term exposure [1, 193].

Some technical terms commonly used regarding wastewater characteristics are biochemical oxygen demand (BOD), suspended solids (SS), and nutrients. The BOD is used to measure how much oxygen is needed to stabilize, by oxidation, the organic matter present in the wastewater [3, 71]. If untreated, SS can lead to anaerobic conditions, meaning no oxygen is available in the water for use by plants and animals [3, 49]. Nutrients include nitrogen, phosphorus, and carbon, which are essential for growth of aquatic life. If available in excess for nourishment of desired plants, undesired aquatic life (e.g. algae) may proliferate. Excessive amounts of nutrients can also pollute groundwater [3, 49].
As stated above, there are many things that must be removed from wastewater in order to make it safe. The processes to achieve this removal occur at a wastewater treatment facility (WWTF). There are three main levels of treatment with increasing water quality in each level. Primary treatment includes mechanical screening and primary sedimentation. Screening removes mainly large, floating debris. Primary sedimentation involves retention of the wastewater to allow settling of SS and removal of BOD [1, 451-452]. Secondary treatment occurs next and is usually a biological process focused on removing BOD and SS from the wastewater [1, 452-453]. Tertiary, or advanced, treatment is often a chemical process focused on removing nutrients or other contaminants which remain after secondary treatment. Chlorination to destroy pathogens and decrease nitrogen is a typical tertiary treatment [1, 453].

In conventional wastewater treatment, primary sedimentation occurs in a large circular tank which mechanically removes sludge from the bottom of the tank and skims grease off of the surface of the water [3, 483]. Secondary treatment can be plug flow, trickling filters, or others. These also require the construction of holding tanks. Plug flow tanks are long and narrow while trickling filter tanks are large and circular [1, 622]. Secondary sedimentation often occurs in a tank similar to that for primary sedimentation. Advanced treatment can occur in the secondary clarifier, as in the addition of alum to remove phosphorus [6, 563]. It can also occur in a separate tank, such as breakpoint chlorination to remove nitrogen [6, 560]. The design of a WWTF includes the redundancy of tanks to allow for continued operation during maintenance on a tank and for high flow conditions. Therefore, a WWTF is a network of pipes and tanks designed for specific processes.

The construction of a WWTF is very expensive. A 1982 survey found that a WWTF to serve a population of 10,000 cost $4 million [7]. A population of 10,000 or less constitutes a small community. Most small communities cannot afford this type of facility, due to a limited tax base for capital cost. Until 1984, the EPA paid 75 percent of the
construction costs for most new WWTF under CWA. Starting in October 1984, that percentage was reduced to 55 percent [7]. The EPA plans to phase out federal grants for WWTF construction. In its place, the EPA has set up the State Revolving Fund (SRF). In the SRF program, the federal government initially allocates a certain amount of money for each state; the state must match 20 percent of that amount. The state is then responsible for providing loans at an interest rate set by the state with a maximum repayment period of 20 years [8, 5]. The idea is that, eventually, the SRF funds will grow and the states will be self sufficient for providing financial assistance for the construction of new WWTF. Communities which receive SRF loans are still responsible for 45 percent of the construction costs of the WWTF [8, 5]. Therefore, a $4 million WWTF would still cost a community of 10,000 approximate $1.8 million. A major drawback is that SRF loans cannot be applied to operation and maintenance costs, which average $0.51/1000 gallons treated [9].

Small communities have difficulty raising funds because they have a lower average annual income than urban communities, there is usually little or no commercial business to share the financial burden, and small communities often cannot get in the bond market [7]. Small communities are also often overlooked in the SRF program, because they must compete with large communities. Therefore, many communities of 10,000 or less rely on the Farmers Home Administration (FmHA) for grants and loans [10]. The FmHA has standards for selecting communities to receive funds. Priority is given to areas experiencing an identified health or sanitation problem. Also, communities must have exhausted all other sources of funding, and only public, non-profit communities are eligible [10]. Grants from FmHA may not be used for interest, initial operating expenses, refinancing, or purchasing existing facilities [10]. FmHA loans have a maximum repayment period of 40 years [11].

Because of construction and operation and maintenance expenses and the difficulty in obtaining sufficient funding, many small communities violate discharge
requirements set forth by the CWA [12, 12]. Small communities need wastewater treatment that is inexpensive, efficient, and easily maintained. One possible solution to the problem small communities face is the use of constructed wetlands for secondary treatment. Constructed wetlands have a shallow water depth and use aquatic vegetation to treat wastewater biologically [13, 776]. The aquatic vegetation, such as cattail, reed, bulrush, and water hyacinth, transfers oxygen through the roots and rhizome systems to the bottom of the treatment basins, providing a medium beneath the water surface for the attachment of microorganisms that perform most of the biological treatment [3, 994]. The treatment is an activated sludge process, where healthy microbes eat unwanted organic material, resulting in lower concentrations of BOD, SS, and nutrients [1, 664].

There are two types of constructed wetlands, free water surface (FWS) and subsurface flow (SF). In both types, the wetland bottom is graded to guarantee uniform flow and consistent water depth. The difference is that the SF wetland contains a medium, such as gravel or soil, and the water level remains below the surface of the media [13, 776]. Because of the water within the medium in the SF wetland, its water depth is usually slightly greater (12 - 30 inches) than that of the FWS wetland (12 - 18 inches) [13, 788]. There are advantages and disadvantages to each. The only obvious advantage of the FWS system is its capital cost. The average cost of construction of FWS wetland systems is $22,000/acre, compared with $87,000/acre for SF wetland systems [13, 778]. The SF system, because it has a greater water depth, requires less land than the FWS system [13, 777]. Theoretically, the SF systems should also experience fewer mosquito and odor problems, since the water surface is not exposed to the atmosphere. A common problem with SF systems is that the roots of the aquatic plants cannot penetrate the medium to reach the wetland bottom, which can lead to anaerobic conditions [13, 779]. Another problem with SF systems is that the voids in the system media have often become clogged with inorganic material, resulting in the water level rising to the medium surface [13, 780]. This defeats the purpose of having an SF
system. While the FWS system may theoretically be inferior to the SF system, a study of all constructed wetlands in the United States conducted by the U.S. EPA Risk Reduction Environmental Laboratory (RREL) concluded that the FWS wetland has actually been the most reliable and cost-effective method for wetland wastewater treatment [13, 781].

As stated before, constructed wetlands can cause mosquito proliferation, because mosquitoes thrive in shallow, still water with vegetation [1, 646]. One way to help control the mosquito population is to stock the wetland with wildlife that naturally preys on mosquitoes, such as mosquito fish, dragonflies, damsel flies, nymphs, and water beetles [1, 646]. Other options include chemical control agents, biological control agents, and more frequent plant harvesting [3, 1011]. The most important factor in controlling mosquitoes, however, is to insure the maintenance of aerobic conditions in the wetland [1, 646]. If anaerobic conditions are allowed to evolve, the natural predators cannot survive and stagnated, swamp-like qualities will arise.

Wastewater treatment is essential for the control of transmission of water related communicable diseases. It is a series of complex processes which, by conventional methods, can be astronomically expensive for small communities. It is believed that constructed wetlands could be very beneficially as secondary municipal wastewater treatment in small communities. The following constructed wetland design for Vineville, a community of 5000 people, will examine this hypothesis. All influent qualities and effluent requirements were given and are listed in the Appendix.
2.0 DESIGN REPORT

2.1. Population Forecasting

The initial population of Vineville, a small town in North Alabama, is 5000. The population forecast was performed by assuming an exponential growth of 2%. The equation for the population forecasting is as follows [2, 67]:

\[ N(t) = N(0) \times (1 + r)^t \]

where

- \( N(t) \) = Population in \( t \) years,
- \( N(0) \) = Population at current time,
- \( r \) = Growth rate,
- \( t \) = Number of years (design life)

As shown in the calculations in the Appendix, using this equation projects that the population in 20 years will be:

\[ N(20) = 7430 \text{ people} \]

2.2. Flow

The given daily flow for Vineville is 600 L/capita/day. The peak flow is 150% of the average flow. The design flow will be the average flow plus 1/24 of the peak flow. As shown in the calculations in the Appendix, this results in a design flow of:

\[ Q_{\text{design}} = 4728 \text{ m}^3/d \]

NOTE: Calculations for population and flow are on page A-2.
2.3. Mechanical Screens

From the given solids analysis, it is assumed that 5% of the suspended solids (SS) are larger than 0.05mm and are removed by mechanical screens. The mechanical screen used is the Aqua Guard Screen Model AG-S Self Cleaning Filter Screen [14]. It removes particles from 1mm to 200mm diameter by performing coarse and fine screening simultaneously. Figure 1 illustrates the mechanical filtering screen and Table 1 gives the effluent qualities of the wastewater.

![Aqua Guard Mechanical Filtering Screen](image)

Table 1: Effluent Qualities From Screening

<table>
<thead>
<tr>
<th>PARAMETER</th>
<th>INFLUENT. mc/L</th>
<th>% REMOVED</th>
<th>EFFLUENT mc/L</th>
</tr>
</thead>
<tbody>
<tr>
<td>SS</td>
<td>220</td>
<td>5</td>
<td>209</td>
</tr>
</tbody>
</table>

NOTE: Calculations for screens on page A-3.
2.4. Primary Sedimentation

Initially, it was planned to use an aerated lagoon for primary sedimentation. However, the EPA suggests the use of conventional sedimentation tanks, because lagoons are land consumptive [15, 25]. Because the constructed wetland requires a large quantity of land, it is wise to use as little as possible for primary treatment.

The primary sedimentation tanks were sized according to the design flow and the surface overflow rate (SOR) [1, 497]. The design flow previously calculated was used; the hydraulic detention time was assumed to be 3 hours and the average SOR of 40 m/d was taken. Table 2 gives the dimensions of the primary clarifier.

<table>
<thead>
<tr>
<th># OF TANKS</th>
<th>DIAMETER, m</th>
<th>DEPTH, m</th>
<th>DETENTION TIME, hr</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>13</td>
<td>4.5</td>
<td>3</td>
</tr>
</tbody>
</table>

It is more economical to construct one tank now and to construct an identical tank in 10 years when the present one will require more regular maintenance. It is assumed necessary to put a Weir skimmer on top of the sedimentation tank to remove grease in the water. The primary sedimentation tank is illustrated in Figure 2.

![Figure 2: Primary Sedimentation Tank](image)

After the tank was dimensioned, effluent qualities of primary sedimentation had to be determined. Because constructed wetlands are not effective in removing phosphorus, alum was added to the primary clarifier [15, 22]. To achieve 80% phosphorus removal, alum was in an Al:P weight ratio of 1.6:1 [6, 565]. This resulted in the addition of 8 mg/L of alum. The addition of alum also increases the percent removal of SS and BOD$_5$ in primary sedimentation [16, 59]. Table 3 shows the effluent qualities from primary sedimentation.
Table 3: Effluent Qualities From Primary Sedimentation

<table>
<thead>
<tr>
<th>PARAMETER</th>
<th>INFLUENT, mg/L</th>
<th>% REMOVED</th>
<th>EFFLUENT, mg/L</th>
</tr>
</thead>
<tbody>
<tr>
<td>SS</td>
<td>209</td>
<td>88</td>
<td>87</td>
</tr>
<tr>
<td>BOD₅</td>
<td>215</td>
<td>50</td>
<td>107.5</td>
</tr>
<tr>
<td>TKN</td>
<td>20</td>
<td>10</td>
<td>18</td>
</tr>
<tr>
<td>PO₄⁻</td>
<td>5</td>
<td>80</td>
<td>1</td>
</tr>
</tbody>
</table>

The outflow of sludge was easily determined by using the percentage of suspended solids removed and their average density. The outflow of sludge is 4.8 m³/d, resulting in the outflow of water being:

\[ Q_{\text{out}} = 4723.2 \text{ m}^3/\text{d} \]

The addition of alum in primary sedimentation results in the presence of aluminum in the sludge. Therefore, the sludge cannot be used for agricultural purposes. The sludge is transported to an incinerator.

NOTE: All calculations for primary sedimentation are on pages A-4 through A-7.
2.5. Constructed Wetlands

Alabama has few constructed wetlands operating as municipal wastewater treatment facilities (WWTF). Those that do exist show that Alabama tends to favor subsurface flow (SF) constructed wetland systems [18, 220]. A national study of existing wetlands has shown that, overall, free water surface flow (FWS) wetlands are more efficient than SF wetlands [13, 781]. Therefore, this design is a FWS wetland system.

A major factor in designing wetlands is the temperature, or climate, of the area. The National Weather Service in Huntsville stated that the average daily summer temperature is 25°C (77°F), and the average daily winter temperature is 5°C (41°F) [17]. The average of these temperatures, 15°C, is used as the design temperature. During the extremely hot days, the wetland detention time will be shorter, and during the extremely cold days, the detention time will be longer [19, 182].

For the physical dimensions of the FWS wetland, a depth of 0.30m was chosen, because it both falls into the acceptable depth range for FWS wetlands and readily supports vegetation [15, 24]. The dimensions were calculated using the recommended length to width ratio of 10:1 [19, 184]. The total resulting surface area of the wetland was 4.265 ha (approximately 10 acres). The total surface area was calculated and divided into 10 channels, each with a 1% slope to insure proper drainage [19, 184]. Table 4 gives the physical dimensions of the FWS constructed wetland. Note that the detention time ranges from 1 day to 7 days; this is temperature dependent.

<table>
<thead>
<tr>
<th># OF CHANNELS</th>
<th>LENGTH, m</th>
<th>WIDTH, m</th>
<th>DETENTION TIME, day</th>
<th>SLOPE</th>
<th>Q THRU EACH CHANNEL</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>653</td>
<td>65.5</td>
<td>3 average range (1-7)</td>
<td>1%</td>
<td>472.32 m/d</td>
</tr>
</tbody>
</table>

Table 4: Dimensions Of FWS Constructed Wetlands

Once the wetland dimensions were calculated, the effluent characteristics had to be determined. No specific percentage of SS removal in constructed wetlands was provided. However, case studies have shown that wetlands with approximately 60 mg/L influent SS concentration have an effluent SS concentration of less than or equal to 8 mg/L [15, 18]. Therefore, it is safe to assume an effluent SS concentration of 8 mg/L. For nitrogen, the percent removal ranges from 60%-86% [15, 22]. Because this constructed wetland operates in a mild climate, the value of nitrogen removal is chosen to be 85% [15, 22]. Phosphorus removal is negligible in constructed wetlands [15, 22]. Table 5 gives the effluent qualities for the constructed wetland.

12
Table 5: Effluent Qualities From FWS Constructed Wetlands

<table>
<thead>
<tr>
<th>PARAMETER</th>
<th>INFLUENT, mg/L</th>
<th>% REMOVED</th>
<th>EFFLUENT, mg/L</th>
</tr>
</thead>
<tbody>
<tr>
<td>SS</td>
<td>67</td>
<td>assumed 88</td>
<td>8</td>
</tr>
<tr>
<td>BOD$_5$</td>
<td>107.5</td>
<td>72</td>
<td>30</td>
</tr>
<tr>
<td>TKN</td>
<td>18</td>
<td>85</td>
<td>2.7</td>
</tr>
<tr>
<td>PO$_4^-$</td>
<td>1</td>
<td>0</td>
<td>1</td>
</tr>
</tbody>
</table>

NOTE: All calculations for constructed wetland are on pages A-8 through A-12.
2.6. Vegetation

There are many types of vegetation that are effective in constructed wetlands, from emergent plants to floating plants [18, 74]. Cattail, reed, and bulrush survive year-round and are efficient in FWS wetlands [15, 25]. However, cattail and bulrush are subject to predation by muskrats, resulting in less effective vegetation [13, 777]. Reed (*Phragmites communis*) grows and spreads faster than cattail [13, 777]. Its roots penetrate deeper, allowing for a larger oxygen transfer to the wastewater [15, 25]. Therefore, reed is more effective in FWS constructed wetlands than cattail or bulrush. The three types of aquatic vegetation cannot effectively be used in combination, because cattail usually "chokes out" the bulrush and reed [15, 24-25]. Therefore, only reed is used in this wetland.

Harvesting of vegetation is over-rated and is often done needlessly. The only time vegetation should be harvested is when it becomes too dense. Build up of grassy clumps disturbs the flow of wastewater through the channel and can cause anaerobic conditions in those areas [15, 28]. Harvesting may also be considered if extreme mosquito problems arise [3, 1011].
2.7. Mosquito Control

"The objective of mosquito control is to maintain the mosquito population below threshold levels for disease transmission or nuisance," [18, 299]. The still water and dense vegetation of constructed wetlands provide an ideal environment for mosquito growth. However, wetlands also provide natural means of controlling mosquitoes [1, 646]. Constructed wetlands attract dragonflies, damsel flies, nymphs, and water beetles, all of which eat mosquitoes or their larvae [1, 646]. Wetlands can also be stocked with mosquito fish (*Gambussia afinis*) to control mosquitoes, but BOD loading must be low [1, 646]. Wetlands also attract various types of salamanders, frogs, toads, snakes, and birds [18, 110-112]. These animals eat mosquitoes and/or each other. It is a natural means of balance in the ecosystem.

There are other possible solutions to mosquito control. It is very important to maintain aerobic conditions in the wetland, because anaerobic conditions only further encourage mosquito proliferation. Primary treatment reduces the BOD and SS loading on the wetland, helping to insure aerobic conditions [3, 1011]. Other possibilities include more frequent harvesting or the application of chemical or biological control agents [3, 1011]. However, while most chemical and biological control agents are relatively inexpensive, their use is not encouraged. Control agents add more contamination to the wastewater and mosquitoes could build up a resistance to the agents [18, 299].

There are more mosquito problems with FWS wetlands than with SF wetlands. This is because the water surface is exposed in FWS systems. Because this wetland has effective primary treatment, mosquitoes are not anticipated to be a large problem. Therefore, this FWS constructed wetland will rely on natural means, such as dragonflies, water beetles, and frogs to control the mosquito population.
2.8. Costs

The test of the effectiveness of constructed wetlands for municipal wastewater treatment in small communities is the comparison of the cost of the wetland with that of a conventional WWTF. The following analysis compares the FWS constructed wetland to a conventional plug flow WWTF. The assumption was made that any land needed was already owned by the city. Sewage collection systems were not included in the cost estimates; they are assumed to be equal for both systems.

The FWS constructed wetland WWTF consists of mechanical screening, primary clarifier, and constructed wetland. A total construction cost breakdown is given in the Appendix. Unit prices for purchasing/planting vegetation, clearing/grubbing the site, embankment, and excavation are expected to decrease 10%-20% as contractors gain experience in wetland construction [18, 595]. Operation and maintenance (O&M) costs can be assumed comparable to those of water hyacinth systems [20, 44].

The conventional plug flow WWTF that would provide treatment comparable to that of the constructed wetland would require mechanical screening, primary sedimentation, plug flow, secondary sedimentation, and breakpoint chlorination. Construction costs for this type of WWTF range from $1.50 - $2.00/gallon treated, depending upon the extent of treatment and sophistication of the plant [21]. The breakpoint chlorination, needed to remove excess nitrogen, is tertiary treatment. Therefore, a construction cost of $1.75/gallon is used. O&M costs are assumed to be the same as those in Huntsville, Alabama [9]. Table 6 tabulates the comparative costs of construction and O&M for the two treatment systems.

Table 6: Comparative Costs Of FWS Constructed Wetlands and Conventional Plug Flow

<table>
<thead>
<tr>
<th>COST</th>
<th>FWS CONSTRUCTED WETLAND</th>
<th>CONVENTIONAL PLUG FLOW</th>
</tr>
</thead>
<tbody>
<tr>
<td>CONSTRUCTION</td>
<td>$716,113</td>
<td>$2.19 million</td>
</tr>
<tr>
<td>O&amp;M</td>
<td>$0.40/1000 gallons</td>
<td>$0.51/1000 gallons</td>
</tr>
</tbody>
</table>

NOTE: All calculations for costs are on pages A-13 through A-14.
2.9 Flow Chart

INFLOW

AQUA GUARD MECHANICAL FILTERING SCREEN

PRIMARY SEDIMENTATION

SLUDGE TO INCINERATOR

FWS CONSTRUCTED WETLAND (10 CHANNELS)

OUTFLOW
2.10. Recommendation

The efficiency and cost-effectiveness of the designed FWS constructed wetland proves it to be a feasible choice for municipal wastewater treatment for Vineville. Through this design project, this engineer has learned that constructed wetlands may not be the perfect solution for every small community. Many small communities will not have the resources assumed to be available in this design. For example, in this project sufficient land was assumed to be available and already owned by the city. This is not the case for most small communities; the purchase of land will significantly increase the construction costs of the wetland. It was also assumed that wetland drainage and vegetation growth would occur as theorized. In real-life, unforeseen obstacles often arise in such technologically innovative facilities. As an example, the vegetation may not multiply at the theorized rate, causing a decrease in the calculated efficiency.

From this project, this engineer now realizes that while constructed wetlands is promising technology for small communities, it is not the ideal solution for all. The situation of each community is unique and must be treated as such. If this project was to be done again, this engineer would design the constructed wetlands for a specific, existing community rather than a fictitious one. That way, no convenient assumptions could be made about available resources. The cost comparison between the constructed wetlands and the conventional WWTF might be closer in such a real-life scenario.
REFERENCES


5 Gover, Nancy. "HIV in wastewater not a recognized threat, other pathogens can be." *Small Flows* July 1993: 3.


9 Keith Boyd. Western Area Wastewater Treatment Plant. Huntsville, Alabama.


14 Brochure on Aqua Guard Screen Model AG-S Self-Cleaning Filter Screen. Parkson Corporation. Ft. Lauderdale, FL.


17 National Weather Service, Huntsville, AL


APPENDIX
Design Calculations
GIVEN INFORMATION FOR DESIGN

Current Population = 5000
WWTF Life = 20 years
Flow rate = 6000 L/capita/day
Peak flow rate = 150\% of average daily rate

Influent Characteristics

\begin{align*}
\text{BOD}_5 &= 215 \text{ mg/L} \\
\text{SS} &= 220 \text{ mg/L} \\
\text{PO}_4^{3-} &= 5 \text{ mg/L} \\
\text{N} &= 20 \text{ mg/L} \\
\text{pH} &= 6.7
\end{align*}

Effluent Requirements

\begin{align*}
\text{BOD}_5 &= 30 \text{ mg/L} \\
\text{SS} &= 45 \text{ mg/L} \\
\text{TKN} &= 3 \text{ mg/L} \\
\text{PO}_4^{3-} &= 1 \text{ mg/L} \\
\text{pH} &= 6.0 - 9.0
\end{align*}

For SS, particle density \( \rho_p = 1400 \text{ kg/m}^3 \)
Assume exponential growth at 2% over a design life of 20 years.

\[ N_0 = 5000 \]
\[ N_e = N_0 (1 + r)^t \]
\[ N_{20} = 5000 (1 + 0.02)^{20} \]
\[ N_{20} = 7430 \text{ people} \]

**Flow Rates**

\[ Q_{ave} = \left( \frac{0.1 \text{ cm}^3}{\text{capita day}} \right) (7430 \text{ persons}) \]
\[ Q_{ave} = 4450 \text{ m}^3/\text{day} \]

\[ Q_{peak} = 1.5 \times Q_{ave} = 1.5 (4450 \text{ m}^3/\text{day}) \]
\[ Q_{peak} = 6675 \text{ m}^3/\text{day} \]

\[ Q_{design} = Q_{ave} + (1/24) Q_{peak} \]
\[ = 4450 + (1/24) (6675) \]
\[ Q_{design} = 4723 \text{ m}^3/\text{day} \]
DESIGN OF GAL RACKS

\[ A = \frac{Q_{\text{design}}}{V_a} \]

where

\[ V_a = \text{approach velocity} = 0.5 \text{ m/s} \]
\[ A = \text{clear spacing between bars} \]

\[ A = \frac{4728 \text{ m}^3/\text{day}}{(0.5 \text{ m/s})(86400 \text{ s/hr})} = 0.109 \text{ m}^2 \]

The above relation limits the head loss through the rack. Continuous cleaning also limits head loss.

Specifications provided by Parkinson Corporation recommend use of the Aqua-Guard Screen Model AG-S Self-Cleaning Filter Screen [14]. It has course screening to remove solids with diameters larger than 14 mm. Its fine screening removes particles as small as 1 mm in diameter. This screen eliminates the need for a grit chamber [14].

Assume that 5% of the given concentration of suspended solids are large enough to be removed by screens.

\[ \text{SS Influent} = 220 \text{ mg/L} \]
\[ \text{SS Removed} = (220 \text{ mg/L})(0.05) = 11 \text{ mg/L} \]
\[ \text{SS Effluent} = 209 \text{ mg/L} \]
**Primary Sedimentation**

$Q_{SR} = 40 \text{ m}^3/\text{d} \quad [1, 1.97]$  

**Surface Area**

$$A_s = \frac{Q_{SR}}{\text{Design SOR}} = \frac{4723 \text{ m}^3/\text{d}}{40 \text{ m}^3/\text{d}}$$

$$A_s = 118.2 \text{ m}^2 \approx 119 \text{ m}^2$$

**Tank Diameter**

$$d = \left( \frac{4A_s}{\pi} \right)^{1/2} = \left[ 4 \left( \frac{119}{\pi} \right) \right]^{1/2}$$

$$d = 12.3 \text{ m} \approx 13 \text{ m}$$

Build one clarifier with $d = 13 \text{ m}$ now and add a second one in 10 years.

Assume detention time, $\theta, = 3 \text{ hr}$

$$V = (4723 \text{ m}^3/\text{d})(3 \text{ hr})(1 \text{ day/24 \text{ hr}})$$

$$V = 591 \text{ m}^3$$

**Depth, $h = \frac{V}{A} = \frac{V}{\pi r^2} = \frac{591 \text{ m}^3}{\pi (6.5 \text{ m})^2}$$

$$h = 4.5 \text{ m}$$

There will be one tank with $d = 13 \text{ m}, h = 4.5 \text{ m}, \theta = 3 \text{ hr}$ built now. An identical tank will be added in 10 years.

A weir skimmer is included on top of tank to remove grease.
Note: Constructed wetlands are not effective in removing phosphorus [15,52]. To eliminate the necessity of secondary sedimentation, alum is added to the primary sedimentation tank to remove the necessary amount of phosphorus [16,59]. The alum also increases the reduction rate of BODs and SS in primary sedimentation [16,59]. Sludge produced in this process will contain aluminium and cannot be used for agricultural purposes. Therefore, the sludge will be transported to an incinerator.

**SS Removal**
Because alum is added, 63% of SS are removed [16,59].

- **SS Influent** = 209 mg/L
- **SS Removed** = (209)(0.63) = 132 mg/L
- **SS Effluent** = 67 mg/L

**BODs Removal**
Because alum is added, 50% of BODs is removed [16,59].

- **BODs Influent** = 215 mg/L
- **BODs Removal** = (215)(0.50) = 107.5 mg/L
- **BODs Effluent** = 107.5 mg/L

**Nitrogen Removal** [4,55,62]

- **TKN Influent** = 20 mg/L
- **TKN Removal** = (20)(0.10) = 2 mg/L
- **TKN Effluent** = 18 mg/L
PRIMARY SEDIMENTATION (cont)

Phosphorus Removal
Phosphorus Removal = 80% [14, 59]
Phosphorus Influent = 5 mg/L
Phosphorus Removed = 5(0.80) = 4 mg/L
Phosphorus Effluent = 1 mg/L

Amount of Alum added for 80% removal [6, 565]

<table>
<thead>
<tr>
<th>% Removal</th>
<th>Al: P weight ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>75</td>
<td>1.2:1</td>
</tr>
<tr>
<td>30</td>
<td>x:1</td>
</tr>
<tr>
<td>25</td>
<td>2.0:1</td>
</tr>
</tbody>
</table>

\[
\frac{85-75}{20-1.2} = \frac{85-80}{20-x}
\]

\[
10x = 10
\]
\[x = 1.0
\]

Al: P = 1.0:1
Influent phosphorus = 5 mg/L
Alum added = (5 mg/L)(1.0)

\[
\text{Sludge Outflow, } q_{in} = 4723 \text{ m}^3/\text{d}
\]

\[
(0.63)(269 \text{ m}^3/\text{L})(4728 \text{ m}^3/\text{d})(1 \text{ kg}/10^4 \text{ mg})(1000 \text{ L/m}^3)
\]

\[
= 6719.94 \text{ kg/d}
\]

\[
\frac{6719.94 \text{ kg/d}}{1400 \text{ kg/m}^3} = 0.48 \text{ m}^3/\text{d} \rightarrow SS
\]

Assume moisture content of 90%
\[
\frac{0.48}{0.10} = 4.8 \text{ m}^3/\text{d} \text{ outflow of sludge}
\]
PRIMARY SEDIMENTATION (concluded)

Q_{sludge} = 4.8 \text{ m}^3/\text{d}

Outflow of water

Q_{out} = Q_{in} - Q_{sludge}
\quad = 4728 - 4.8
\quad = 4723.2 \text{ m}^3/\text{d}
CONSTRUCTED WETLANDS

TEMPERATURES

From National Weather Service, Huntsville [17]

Average Summer High = 89°F (31.6°C)
Low = 68°F (20°C)
Average = 77°F (25°C)

Average Winter High = 52°F (11.1°C)
Low = 32°F (0°C)
Average = 41°F (5°C)

For WWTF design, use average annual temperature ± 15°C

Note, however, that detention time in the constructed wetlands will increase in the winter and decrease in the summer.
CONSTRUCTED WETLANDS (CW)

Note: AL has few constructed wetlands operating as municipal wastewater treatment facilities. Those that do exist show that AL tends to favor SF wetlands [18, 220]. A national study of constructed wetlands has shown that, overall, FWS wetlands are more efficient than SF systems [13, 781]. Therefore, this is an FWS wetland.

Detention Time [19, 182]

\[ t = \frac{\ln C_0 - \ln C_e}{K_T} - 0.6539 \]

\[ K_T = K_0 (1.1)^{(T-20)} \]

\[ K_s = 0.0057 (1.1)^{-5} = 3.54 \times 10^{-3} \]

\[ t = \frac{\ln 107.5 - \ln 30}{\ln (3.54 \times 10^{-3})} - 0.6539 \]

\[ = 1.27629 - 0.6539 \]

\[ t = 0.62301 \]

\[ t = 2.7 \text{ days} \times 3 \text{ days} \]

\[ t = 3 \text{ days} \rightarrow \text{Note: At } T = 25^\circ \text{C, } t = 1 \text{ day} \]

\[ \text{At } T = 5^\circ \text{C, } t = 7 \text{ days} \]

Surface Area [19, 182-183]

\[ A = \frac{Q [\ln C_0 - \ln C_e - 0.6539]}{\psi K_T} \]

Assume water depth = 0.30 m, which is good for growth of cattails, reeds, and bulrushes [15, 24]

\[ A = \frac{4.723.2 \text{ m}^3/\text{d} [\ln 107.5 - \ln 30 - 0.6539]}{\psi (3.54 \times 10^{-3})(0.30 \text{ m})} \]

\[ A = \frac{2944.41}{0.06903} \]

\[ A = 4265.4 \text{ m}^2 = 4.245 \text{ ha} \]

\[ A - 9 \]
CONSTRUCTED WETLANDS (c.wd)

Wetlands Channel Dimensions [19, 184]

Use L: W ratio of 10:1

\[ A = LW = \frac{L^2}{10} \]

\[ \frac{L^2}{10} = 426.54 \text{ m}^2 \]

\[ L^2 = 4265.4 \text{ m}^2 \]

\[ L = 65.3 \text{ m} \times 65.3 \text{ m} \]

\[ W = \frac{L}{10} = \frac{653}{10} = 65.3 \text{ m} \times 65.5 \text{ m} \]

\[ L = 653 \text{ m} \]

\[ W = 65.5 \text{ m} \]

Divide area into 10 parallel channels, each 65.3 m long and 65.5 m wide. Assume 1% slope for proper drainage

Flow through each channel

\[ Q = \frac{1}{10} (4723.2 \text{ m}^3/\text{d}) \]

\[ Q = 472.32 \text{ m}^3/\text{d} \text{ through each channel} \]

BOD5 Removal

Wetland is designed for effluent BOD5 = 30 mg/L

BOD5 Influent = 107.5 mg/L

BOD5 Effluent = 30.0 mg/L
CONSTRUCTED WETLAND (Cont.)

SS Removal
SS Influent = 67 mg/L

No specific percentage of SS removal is provided for constructed wetlands. However, case studies have shown that wetlands with this approximate SS influent concentration have an effluent SS concentration of ≤ 3 mg/L [15, 18]. Therefore, it is safe to assume an SS effluent concentration of 3 mg/L.

SS Effluent = 8 mg/L

Nitrogen Removal
TKN Removal = 35% [15, 22]

The upper value of removal was chosen because of the warm climate in which the wetlands exist.

TKN Influent = 18 mg/L

TKN Removed = (18 mg/L)(0.85)
   = 15.3 mg/L

TKN Effluent = 2.7 mg/L

Phosphorus Removal
Phosphorus removal is negligible in constructed wetlands [15, 22]

Phosphorus Influent = 1 mg/L
Phosphorus Removal = 0
Phosphorus Effluent = 1 mg/L
Vegetation

Cattail, reed, and bulrush survive year-round and are efficient in FWSS wetlands [15, 25]. However, cattail and bulrush are often subject to predation by muskrats and nutria [13, 77]. Reed grows faster than cattail and its roots penetrate deeper than cattail [13, 77]. Because of this, the oxygen transfer is higher and the reed is more efficient [15, 25]. Cattail, bulrush, and reed cannot be used effectively in combination, because the cattail usually "chores out" the bulrush and reed [15, 24-25]. Therefore, only reed is used in this constructed wetlands.
**COSTS**

Costs for FWS Constructed Wetlands WWTF

Construction cost of primary clarifier = $920,000 [21]

Construction Cost of Wetlands [18, 595]

- Vegetation
- Clearing and grubbing site
- Embankment
- Excavation

For wetlands with $A = 42454 m^2$ and $V = 12794.2 m^3$

\[
\text{Cost} = (\$7.50/m^2)(42454 m^2) + (\$2.50/m^2)(42454 m^2) + (\$3.50/m^3)(12794.2 m^3) + (\$3.50/m^3)(12794.2 m^3)
\]

Cost of Construction = $511,113$

Total Construction Cost = $711,113$

Operation and maintenance costs are comparable to those of water hyacinth systems [20, 44].

O&M costs = $0.40/1000 gallons treated

Costs for Conventional Plug-flow WWTF

Costs for constructing a conventional plug-flow WWTF ranges from $1.50 - $2.00/gallon, depending upon the extent of treatment and sophistication of the plant [21].

The conventional plant that would provide treatment comparable to that of the wetlands WWTF would require breakpoint chlorination, tertiary treatment, to eliminate excess nitrogen. Therefore, assume a cost of $1.75/gallon.

Flow = 1.25 MG

Construction cost = $(\$1.75/G)(1.25 MG)$

Construction cost = $2,19 million

A - 13
COSTS (concluded)

O₄ M costs are assumed to be the same as those in Huntsville, AL. The provided value of O₄ M costs = $510/1MG [9]

O₄ M costs = ($510/1MG)(1x10³)

O₄ M costs = $0.51/1000 gallons
ACKNOWLEDGEMENTS

Special thanks are extended to Dr. Kathleen Leonard of UAH and Mr. Roy Brittian of Ladd Environmental Consultants for their assistance in this endeavor.
As my undergraduate study is close to completion, I am pleased to present the full report of my project to you and all instructors and students, as the fulfillment of the senior project requirement in the Honors Program.

The full title of my project, "The ObjectTeacher: Adapting Object-Oriented Design to Instructional Design," reflects the topic and the interdisciplinary aspects of my research. The original intention was to enhance my knowledge of the Object-Oriented Technology concepts and techniques, by playing the role of a programmed teacher. As my research gradually revealed in front of me another broad area, computer-assisted instruction, I was attracted and decided to shift my emphasis of research and development to the art of the design of instructional software. As an experiment, the approach I used in this project demonstrated my attempt to apply Object-Oriented software engineering techniques to the design of courseware. Due to the time and resource constraints, I was not able to give a full implementation of the software, which leaves us with an incomplete validation of this design experiment.

During the two terms of research and development of this project, Dr. Harry Delugach met with me every week to review my progress and discuss the problems and ideas. I would like to thank him for his advice and encouragement. I would also like to thank you and the Honors Program for giving me this opportunity to conduct the kind of research that brought the disciplines of computer science and educational science together. With the completion of this project and other requirements of the Honors Program, I am now even more prepared and confident to go on for a more specialized higher education in computer science.
Attachment 2

THE HONORS PROJECT PROPOSAL

Constructed Wetlands as an Innovative, Cost-Effective Solution for Wastewater Treatment in Small Communities

PROPOSED TITLE: ________________________________

STUDENT: Christy Womack Vines

STUDENT #: 075969 PHONE: 536-9021 (H) 922-1512 (W)

ADDRESS: 2109-E Epworth Drive, Huntsville, AL 35811

THIS PROJECT FULFILLS REQUIREMENTS FOR THE UAH HONORS PROGRAM & DEPARTMENTAL & COURSE CREDIT IN Civil Engineering (CE 459)

PROPOSAL APPROVED BY:

PROJECT ADVISOR: ____________________________ DATE: 2/1/93

DEPARTMENT CHAIR: __________________________ DATE: 2/1/93

DATE PROPOSAL RECEIVED IN HONORS OFFICE 2/1/93

DATE PROPOSAL APPROVED BY HONORS COUNCIL __________________________

SIGNATURE OF HONORS DIRECTOR __________________________
THE HONORS PROJECT PROPOSAL

PRELIMINARY ABSTRACT: Describe your overall topic in terms of 1) the general issue with which you are concerned, 2) the specific question or questions you have formulated as your particular emphasis, including any hypothesis you may have formulated, and 3) the general ways in which you will go about addressing your question. YOUR ABSTRACT SHOULD BE CONFINED TO THIS SPACE.

Treatment of wastewater is mandated by the Clean Water Act (CWA) as implemented by the Environmental Protection Agency (EPA) in the 1970s. The central purpose for wastewater treatment is disease prevention. Historically, many diseases, such as amoebic dysentery, cholera, polio, and typhoid fever, have been transmitted through water. Current studies are analyzing the survivability of HIV in wastewater. Chemicals from industrial processing kill fish and other wildlife and are often carcinogenic to humans.

Municipal wastewater treatment can be achieved through various types of secondary treatment methods. Some of the more common are plug flow, trickling filters, and rotating biological contractors. These types of wastewater treatment plants are expensive to construct and maintain. They also require operators to be on-site 24 hours a day. This poses major problems for communities with populations of 20,000 or less. These communities cannot afford treatment plants, and, as a result, often fail to meet EPA effluent standards. New technologies are being developed to remedy this, one of which is constructed wetlands. The hypothesis to be analyzed in this project is that constructed wetlands can be utilized by small communities to minimize the cost of wastewater treatment while complying with the CWA.

The approach to analyzing this hypothesis is three-fold. An extensive research of pertinent literature has been conducted to gain knowledge of the advantages and disadvantages of constructed wetlands. Secondly, plans are being made to visit an operating constructed wetland in Northeast Alabama. Lastly, a constructed wetland will be designed for a small community as specified by Dr. Kate Leonard. Upon completion, a recommendation of the use of constructed wetlands for the community will be made.
THE REMAINDER OF THE PROPOSAL CONSISTS OF THREE SECTIONS AND A PRELIMINARY BIBLIOGRAPHY. ADDRESS EACH SECTION IN TURN, USING THESE SECTION HEADINGS IN YOUR DISCUSSION TO CLEARLY INDICATE EACH PART OF THE PROPOSAL. CONFINE YOUR DISCUSSION IN EACH SECTION TO NO MORE THAN ONE SINGLE-SPACED TYPED PAGE. USE THE ATTACHED FORM FOR THE BIBLIOGRAPHY.

PLEASE WORK WITH YOUR PROJECT ADVISER TO ADAPT THE TERMINOLOGY POSED IN EACH SECTION TO YOUR PARTICULAR DISCIPLINE.

I. BACKGROUND/LITERATURE REVIEW. Summarize the "body of knowledge" or range of perspectives that inform your particular research topic. Be specific in terms of the contributions of individual researchers, theorists, methodologists, critics, etc., to your line of inquiry.

II. RESEARCH QUESTION. How does your work relate to the background you've discussed above? What is the particular question or theme that you will address and how do you expect it to contribute to the inquiry in this field? Do you have a working hypothesis or perspective?

III: METHODOLOGY/APPROACH. How will you go about addressing your question? Be specific in terms of research design, statistical procedures, analysis of primary texts, use of archival sources or data bases, etc., as appropriate to your discipline.
1. BACKGROUND

The primary purpose of wastewater treatment is the prevention of disease and illness. Wastewater is a means of transportation for many biological and chemical contaminants. Microorganisms enter wastewater largely through human and animal waste. These organisms can enter other humans or animals to cause various diseases, such as polio, cholera, and dysentery. Concern has currently been raised about the transmission of HIV through wastewater. Chemicals from industry are also dangerous to humans. Magnesium, nitrate, phosphorus, and sodium are a few chemicals found readily in wastewater. These chemicals, in excess, can lead to hypertension, diarrhea, and oxygen deficiencies in infants. To help eliminate the unnecessary dangers to public health, the Environmental Protection Agency (EPA) implemented the Clean Water Act (CWA) in 1972. It established minimum standards for wastewater treatment effluents.

To meet EPA requirements, secondary, and sometimes tertiary, treatment must be utilized. There are many types of processes used for secondary treatment. Some of the most common are plug flow, trickling filters, and rotating biological contractors (RBCs). These methods are very effective, but the hardware is very expensive to construct and maintain. The complexity of the system also requires 24-hour on-site operators.

While wastewater treatment is relatively inexpensive for large cities, it is often a tremendous financial burden on communities with populations of 20,000 or less. As a result, these communities often fail to meet the EPA standards for effluent wastewater. New technologies are being developed to assist small communities; one of these is constructed wetlands. Constructed wetlands rely on natural treatment, utilizing various aquaculture which thrive on nutrients that are unwanted in wastewater. Constructed wetlands take longer to treat wastewater, but there are also positive side-effects. Constructed wetlands are natural wildlife preserves and can be used for public parks and nature trails.
II. RESEARCH QUESTION

The hypothesis set forth for this project is that constructed wetlands can be used in small communities to minimize wastewater treatment costs while complying with the CWA. Several questions evolve around this hypothesis. What type of preliminary treatment and aeration should be used? What types of aquacultures — duckweed, water hyacinth, cattail, or bulrush — should be used to achieve maximum efficiency? How long will the wastewater have to be held in the treatment marsh and enhancement marshes? Will one large wetland be most efficient and economical, or should several smaller wetlands be constructed? What are possible public uses for the constructed wetlands? Is there sufficient land available? Is the climate adequate?

All of these are important questions with important answers. Use of constructed wetlands is limited at this time. Constraints, such as land, odor, and mosquitoes, make this option unattractive or unfeasible for some areas. Results from this project will give insight into the feasibility of widespread use of constructed wetlands as a natural wastewater treatment alternative for small communities in the southeastern United States, especially North Alabama.
III. METHODOLOGY/APPROACH

Evaluation of the proposed hypothesis is three-fold. It includes researching and using available literature, visiting an existing constructed wetland, and designing a constructed wetland for a small community.

The literature research includes textbooks, design manuals, EPA brochures, and various technical journals. Research covers topics such as public health, the needs of small communities, general wastewater management, and specific information on constructed wetlands. Some titles include: "Detection and occurrence of waterborne bacterial and viral pathogens," Microbiology for Environmental Engineers, and the EPA Design Manual for Constructed Wetlands and Aquatic Plant Systems for Municipal Wastewater Treatment.

Research has revealed that two constructed wetlands are currently being used for wastewater treatment in North Alabama; one is in Stevenson and the other is on Sand Mountain. Effort is being made to contact the design engineers and to visit one of the plants. This will give a visual understanding of the concepts being researched.

The focus of this project is the design of a constructed wetland for a small community. Dr. Kate Leonard will provide the data for influent qualities of the wastewater. The questions presented in section II will be analyzed to optimize efficiency and minimize costs for wastewater treatment. Upon completion of the design, a recommendation will be made to support or refute the proposed hypothesis.
BIBLIOGRAPHY

List below the major sources you will be using in each of the appropriate categories.

PRIMARY SOURCES: (including texts, documents, data sets, as relevant)


SECONDARY SOURCES:

Journals and other periodicals:

Civil Engineering. Journal of the American Society of Civil Engineers (ASCE).


Monographs, other reports/studies, government documents, etc.:


Key Books:
