Greywater Marsh Project Proposal to Campus Center for Appropriate Technology: Analysis and Design by **Nicole Beckman**

Project Description:

In the fall semester 2003, the Campus Center for Appropriate Technology (CCAT) was informed of Humboldt State University's plan to construct the Behavioral and Social Sciences Building (BSS) on CCAT's established grounds. The organization had no other option but to dismantle all systems, and move the facility. After three years in a temporary facility, CCAT has found itself back in their permanent home and capable of reinstalling previous systems and technologies.

As difficult as this transition has been, it has enabled CCAT to analyze the needs of the organization, and establish the most appropriate solutions for the new grounds and facility. Students now have the opportunity to design, construct, and monitor the new systems and technologies; an opportunity not possible at the original site where all the technologies had already been constructed and installed. Using this transition as a prime learning experience I have taken the opportunity to analyze and design a wastewater treatment marsh that will best suit the needs and constraints of the reconstructed CCAT facility and the new site.

During the move, CCAT's facility has been connected to the municipal wastewater system, and is currently lacking alternative forms of treatment. CCAT is a demonstration house that provides insight and resources into alternative design, technology, and construction. In maintaining their mission statement, it is important for CCAT to determine a treatment method that suits its needs as a live-in, demonstration house, which will also work for the location, climate, and its position on state and university property.

Problem Statement:

CCAT is in need of a system to treat, remediate, and utilize the waste greywater that is currently being lost to the municipal wastewater system. This system must be designed and constructed, keeping in mind CCAT's mission statement, and goals as a demonstration house, as well as any constraints due to location, climate, maintenance, university support, etc.

Preferred Solution:

CCAT's ideal system would treat and remediate all of the facility's greywater onsite, and utilize this recovered resource to supplement the irrigation needs of the site.

Alternatives:

In designing the most appropriate system for CCAT's needs, research has been conducted into numerous forms and systems.

These should be listed.

The California Legal System

California's Graywater Standards are now part of the State Plumbing Code, making it legal to use greywater everywhere in California. These standards were developed and adopted in response to Assembly Bill 3518, the Graywater Systems for Single Family Residences Act of 1992[1].

The following are the lists of guidelines for any greywater system installed in California. Local municipalities and permitting agencies may require further action or more strict regulations.

System-Specific Guidelines:

- Greywater systems are only allowed for single-family homes.
- Surge tanks[2] are allowed.
- The Administrative Authority[1] must approve all parts of the plan for the system.
- Greywater system permit may require:
    - Scale drawing including all components and slope of surface
    - Details of construction
    - Log of soil absorption and ground water level
- System must not harm a geologically active area.
- System must include an operation and maintenance manual.
- System must have a permit before construction.
- System must follow the approved plans.
- Surge tanks must be on level, dry, compacted soil and anchored.

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[1] Prillwitz: California Graywater Standards

[2] Appendix I

not an alternative but a set of constraints. Other constraints are the physical setting/conditions (soil, etc.)

- Tank must be watertight.
- Surge tanks must be vented.
- Surge tanks can be underground.
- Site may be tested with percolation.

Greywater-Specific Guidelines:

- Greywater may not surface.
- No transporting of greywater. System must be located at the site that is the source of the greywater.
- Discharge cannot be within 5 ft of highest known seasonal groundwater. Evidence must exist for the known level.
- All components holding water must be marked "Danger--Unsafe Water."
- Greywater cannot include water that has been in contact with cloth diapers.
- Greywater cannot be allowed to reach any water or storm sewer in the U.S.
- Greywater cannot be used for vegetable gardens.

Arcata Educational Farm

The Arcata Educational Farm, a local Community Supported Agriculture (CSA) project, has a reconstructed subsurface marsh on their grounds. This small marsh is used to treat waste greywater from the kitchen sink, and the end use application is an apple tree. It has been calculated that the farm produces 200 gallons of greywater per week. The marsh has been sized to hold 200 gallons, giving a total retention time of one week. The system components include;

- Primary treatment[3]
  - Filtration screen
  - Settling tank[2]
  - Grease trap[2]
- Secondary treatment[2]
  - Subsurface marsh
    - Baffles[2]

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[3] Appendix I

        - Gravel
        - Bulrush[2]
- End use
    - Irrigation pipe to apple tree

The Arcata Ed Farm subsurface marsh is a simple system that treats a small volume of greywater, but this system is similar in many ways to the preferred CCAT system. The system obviously works in the climate and region, and for local permitting bodies (or lack thereof). If the design is expanded to fit the size requirements and needs of CCAT, this system appears to provide a solution to proposed problem.

Previous CCAT Greywater Marsh

It seems obvious that the previous CCAT marsh might be the best place to start research and design for the new marsh. The previous system treated all of CCAT's greywater at time of construction, and provided supplemental water for the ground's irrigation needs. The system was permitted by university officials, thrived in the region and climate, and was maintained by CCAT employees and Co-Directors. Because we know that the system worked for CCAT's needs, it might be best to consider the barriers and limitations the system posed to CCAT.

- Primary treatment: In the previous CCAT greywater system, the flow of greywater was inline with the particle filter, which resulted in clogs and overflow. The overflow of food particles into the sedimentation tank allowed the particles to continue on to the subsurface marsh. The addition of food particles in the treatment marsh increased unpleasant odors, and possibly caused the above-average BOD and TSS levels[4] that were experienced. The new settling tank has been constructed to keep water flowing into the system, and decrease the chance for clogging and overflow. Also, the kitchen sink had a drain that allowed larger particles to pass. During the reconstruction the sink was reused, but a new drain filter has been purchased to decrease the amount of food particles that make it to the settling tank.

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[4] Appendix I

- Two-marsh system: A student project added a subsurface marsh to the existing greywater system. The new marsh was inadvertently plumbed downstream from the other, which resulted in a number of treatment concerns. The new marsh received more greywater because of gravity flow, and retention times were increased for the new marsh. This allowed greywater to exit the system before treatment was complete. Alternately, the first marsh received less greywater than its capacity allowed for, decreasing retention time. This marsh held greywater too long, allowing it to stagnate, turn anaerobic, and thus become blackwater.

- Fecal Coliform[3] levels: During water quality tests fecal coliform levels were tested as higher at the effluent than the influent[3]. Students testing the system were perplexed for sometime, until a Co-Director watched a rat run out from the marsh cattails and bulrush. It was assumed that the fecal coliform levels were increasing due to the activities of said rat. In the construction and operation of the new marsh, consideration should be made into the potential rat habitat.

- End Use[3]: In the original marsh system, end use was not utilized to its full potential. For sometime, effluent was allowed to flow into the storm drain, which is not a legal approach. A hand pump was added to the system to transfer the irrigation water to needed areas. The future system should keep end use in mind, making any irrigation user friendly so that the laziest of gardeners won't allow this nutrient rich, recovered resource go to waste.

Although the organization has not changed much because of the move, CCAT's facility has increased in size since the dismantling of the previous marsh. The washing machine is now included in the greywater line, as well as another bathroom and future kitchenette sink. The organization is also expecting to see an increase in visitors, thus an increase in water usage, since the move to the new facility. Due to the increase in water usage, marsh volume will also have to increase. In the design of the original marsh, CCAT calculated 400 gallons of greywater produced each day. With the increase in traffic and addition of utilities, plus the incorporation of water conserving appliances

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and features in the reconstruction, it has been calculated that CCAT will generate 500 gallons of greywater every day. To allow for some additional increase in greywater production, the system will be designed to retain the greywater for seven days. If a higher level of water is entering the system, it will leave the system faster, but still well within the required timeframe, 5-7 days[5].

Preferred System

The preferred design has been created from a compilation of the designs researched and analyzed. The system will flow as follows:

1. Outlet: Due to CCAT's anticipation of this system, greywater is currently piped from the facility, separate from blackwater. There is a T-valve junction that joins the two, grey and blackwater, for municipal plumbing. Once the marsh is constructed, the greywater will be rerouted to the system, leaving the blackwater to make its solitary journey to the Arcata Marsh and Treatment Facility. The T-valve junction is housed beneath a manhole cover in the lower elevation of the property. PVC pipes will transport the greywater to the constructed system.

2. Settling Tank and Grease Trap: A modified version of AEF's system has been constructed. The system includes;

    a. 55-gallon plastic drum settling tank with one foot cut off the top. This will decrease retention time to expedite treatment of greywater.

    b. 2-inch PVC outlet pipe with 90° bend and 4-inch diameter extension. This 90° angle creates a grease-trap effect, containing fats and oil in the settling tank, and not allowing them to pass onto the marsh.

    c. Medium-diameter metal grate custom encased in the lid to the 55-gallon drum. This grate will catch solids before entering the tank. The settling tank has been constructed to ease the routine chore of cleaning the grate and tank.

3. Subsurface Marsh: According to water use calculations and retention time, the marsh must be sized to contain 3500-gallons of greywater, plus a surge capacity of a couple hundred gallons due to fluctuations in water usage.

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[5] Ludwig, Create an Oasis with Greywater

Water Usage Calculations:

→ *500 gallons per day greywater production x 7 day retention time = 3500 gallons required capacity for treatment*

The size of the entire marsh is dependent on depth, width and length. This must also fit within our land use and topography constraints.

→ *3500 gal x .134 ft cubed/gal = 469 ft cubed required capacity for treatment*

→ *469 ft cubed / 3 ft deep / 4 ft wide = 39 ft long*

According to these dimensions the subsurface marsh will be 3 ft deep, 4 ft wide, and 39 ft long, with a treatment capacity of 3500 gallons of greywater. This does not include room for surge capacity.

4. End Use: A system for end use must still be designed, but a few constraints have surfaced thus far in the design process.

   a. Clogging: Use of irrigation tape can lead to clogs in the system due to high nutrient content of the treated water, and the thin diameter of irrigation piping. A system with a larger diameter will have to be designed if immediate irrigation is our goal. The end use could be filtered through a simple sand filter to decrease the chance for obstruction. The treated water can be stored for no more than three days before final transport to crops by garden hoses. This system is not ideal because it assumes that a person will be diligently watering at least every three days. This is not likely for a student household.

   b. Gravity: Because this is a pump-free design, the treated water must be gravity-fed to its end use. There will be some design constraints regarding the available land that is downstream from the system. If the treated water is highly filtered it could be pressurized and propelled to irrigate land higher on the property. The previous CCAT marsh used a hand pump, but again, this requires constant attention, an avoidable design detail.

Appendix I

Greywater Terminology

Administrative Authority[6]	The city or county in which the greywater system exists, typically the permitting body.
Biochemical Oxygen Demand (BOD)[7]	Rate of oxygen uptake by microorganisms present in the sample water. As oxygen is used by these organisms, either more oxygen must be replaced (typically by plants and photosynthesis), or the system will turn anaerobic (plants and microorganisms will die, and the water will pass through the system untreated). Typical BOD levels for untreated, household greywater are approximately 200-300 mg/l. Our goal for treated greywater is 20-50 mg/l BOD.
Baffles	Vertical or horizontal additions to a water treatment system, utilized to increase retention time by forcing water around barriers, instead of following a straight path.
Blackwater	Wastewater containing a high concentration of fecal matter.
Bulrush	Tall, herbaceous wetland plant, commonly referred to as cattail. Used in water treatment marshes.
Effluent	Treated water flowing out of the system.
End Use	Final use of the reclaimed greywater, typically irrigation uses. Health concerns usually limit use to fruit and nut trees and ornamentals. Greywater should not be used when watering root or leafy vegetables.
Fecal Coliform, Total[8]	The test for fecal coliform is more specifically an assay for the presence of more dangerous microbes and pathogens. Fecal coliform is used as an indicator bacterium, because its presence may imply the presence of E. Coli and other pathogens. Untreated greywater can typically reach levels of 2000 colonies/100mL. Treated greywater should be approximately 100-500 colonies/100mL.

[6] Ludwig, Create an Oasis with Greywater
[7] Wiley, Fundamentals of Environmental Engineering
[8] Wiley, Fundamentals of Environmental Engineering

Grease Trap	Separates grease, fats, and oils from influent by forcing water to flow under an obstruction before being piped to the system. Grease remains at the surface due to its hydrophobic properties.
Groundwater	The subsurface water of the earth.
Influent	Untreated greywater following into the system.
Primary Treatment	Removes easily collected materials, such as; fats, oils, grease, sand, food particles, etc.
Secondary Effluent	Wastewater flowing out of secondary treatment.
Secondary Treatment	Degrades the biological content of the wastewater. Treatment leaves less than 30 mg/L of TSS and less than 15% BOD.
Settling Tank	Site of primary treatment for small wastewater systems. Tank filters out large particles and allows for settling of smaller particles, before being piped to secondary treatment. Can also include grease trap feature.
Subsurface Marsh	An artificial marsh, used for wastewater treatment. All water treatment is conducted below grade. In a functioning system water will never surface. Treatment is primarily accomplished by microorganisms living within the root and gravel structure in the marsh.
Surge Tank	A tank in a system designed to hold maximum capacity of water so system does not back up.
Total Suspended Solids (TSS)[9]	The measurement of particulates present in a water sample. The presence of these particles represents the impurities found in the sample. Typical TSS levels before treatment of greywater is ~100 mg/l, after treatment is 5-20 mg/l.

[9] Wiley, Fundamentals of Environmental Engineering

Appendix II
References:

Allen, Laura, Cleo Woelfle-Erskine, and July O. Cole. Dam Nation: Dispatches From the Water Underground. Brooklyn, NY: Soft Skull Press, 2007.

Campbell, Stu. The Home Water Supply. Pownal, VT: Storey Books, 1983.

Del Porto, David, and Carol Steinfeld. The Composting Toilet Book. Concord, MA: The Center for Ecological Pollution Prevention, 2000.

Ludwig, Art. Create an Oasis with Greywater. Santa Maria, CA: Poor Richard's Press, 2000.

Prillwitz, Marsha, and Larry Farwell. State of California. Water Conservation Office. Department of Water Resoucres. California Graywater Standards. Sacramento: California Department of Water Resources, 1995.

Wagner, Keith G. Graywater and the Law. Humboldt State University. Eureka, CA.

Wiley, John. Fundamentals of Environmental Engineering. Washington, DC: Rodale Press, 2005.

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Problem Background and Statement

1. ***Problem***
   a. *Define Problem*: The Campus Center for Appropriate Technology (CCAT) has recently moved into their newly remodeled, original facility. This transition has left the organization without a majority of their previous technologies, and a need to reinstall, or redesign, some of these systems. In order to abide by CCAT's mission statement, and promote the self-sufficiency of the organization, and the University as a whole, it is hoped that CCAT will be able to treat and remediate the facility's greywater onsite. In order to treat this typical waste product, and utilize the water on site to alleviate some of the facility's irrigation needs, a system must be designed and constructed.
   b. *Current Symptoms*: Currently the facility's greywater is piped out of the house, mixed with blackwater, and is then sent to the Arcata Marsh and Treatment Facility. This potential, nutrient rich resource is being allowed to leave the site, requiring extraneous resources and energy inputs to transport and treat and forcing CCAT to use municipal water sources for irrigation needs.
   c. *Preferred Situation*: CCAT would prefer to treat all of the facility's waste greywater onsite. The end use of this process is a recovered resource that can then supplement the ground's current and future irrigation needs.
2. ***Analysis***
   a. *Diagnose Problem*: A treatment method must be designed, permitted, and then constructed. The entire scope of the project should adhere to CCAT's mission statement, and the system should espouse the organization's belief system and comprehensive planning and goals.
   b. *Symptoms by Category*:
      i. *Design*: The design of a greywater treatment system must include;
         1. *Research*: of current treatment methods, and a decision of the preferred treatment method for our site. Further research into preferred treatment method and design.
         2. *Layout*: of the components of the system, and how they configure within the specific site location.
         3. *Sizing*: of the amount of greywater to be treated by the system, and the corresponding size of the system.
         4. *Materials*: Acquiring necessary materials and tools for the project. Keep in mind the ecological and environmental impacts of materials, land, and water use.

5. *End Use*: What are our end use options (i.e.: irrigation, ponds, etc)? How much water will the system treat? Calculate the size of the chosen end use option (i.e.: land area, pond sizing, etc).

ii. *Permitting*: Open up conversation with the University and the City of Arcata. Ensure that the constructed system will abide by all laws and regulations, and fits with the University's general plan for CCAT's grounds and the larger University.

iii. *Construction*: After careful design and analysis of the system and site, and approval of all plans with responsible agencies, construction can begin. Construction will become more difficult during the rainy season, so this aspect should be either expedited, or postponed, for ease. CCAT's volunteer force and involvement with clubs and university classes will help lend the manpower necessary for construction.

c. *Notable Barriers*:

i. *Design*: Barriers to the design aspect of the project will be mostly related to the research portion, and securing reliable resources to base the design on.

ii. *Permitting:* There will be certain logistical and bureaucratic concerns that will arise, but this will only help to further the educational experience and advance our knowledge of permitting bodies, codes and laws regarding water treatment.

iii. *Construction:* A few of the foreseen barriers related to the construction of the system include:

1. *Topography*
2. *Water flow*
3. *Site selection*
4. *Weather restrictions*
5. *Physical constraints during construction*

d. *What is being done elsewhere*: There are a variety of greywater treatment facilities around the world, a plethora of which can be found locally or installed on other campuses. These will all help to solidify our design and aid in the permitting and construction aspects of the project. Some relevant systems include (references and resources will be provided at a later date);

i. *Arcata Educational Farm*: subsurface constructed marsh

ii. *Local greywater marshes*: previous student projects in the local area

iii. *Malibu City*: constructed marsh

iv. *Penn State*: living machine

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Chosen Alternative: ***Constructed, subsurface marsh.*** A constructed marsh is a human-constructed water treatment system that utilizes natural processes to clean household greywater. With the use of plants and increased surface area, Total Coliform (TC), Total Suspended Solids (TSS), and Biological Oxygen Demand (BOD) levels will all be decreased to healthy, state sanctioned levels. The end use will be irrigation of CCAT grounds.

Implementation Strategies

1. *Design*
   a. Design selection: We have decided to construct a marsh similar to the Arcata Educational Farm's (AEF) greywater marsh. Because this is a small, local system it will be easily compared to our system, environment and location. Any faults the Farm has had with their own system can then be easily modified and improved. And cecause CCAT is a demonstration home, the simplicity of the system will more readily lend itself to a broader audience. This will increase the likelihood that other households will be able to reproduce similar systems for their own needs.
   b. Design modification: Improvements upon existing designs can be made by observation of the Farm's existing system, and communication with those that constructed the system and also the Farm Directors that continuously use the system.
   c. Design finalization: Once we have worked out any kinks in the proposed design we can move forward with our final design, with the understanding that this is an organic document that may change throughout the permitting and construction processes.
      i. Current Design
         1. Outlet: All household greywater currently exists a T-valve junction, separating blackwater from greywater. This is contained beneath a manhole cover in the lower elevation of the property. PVC pipes will transport the greywater to the constructed system.
         2. Settling Tank and Grease Trap: A modified version of AEF's system has been designed and will be constructed on November 9th. The system will include;
            a. 55-gallon plastic drum settling tank with one foot cut off the top. This will decrease retention time to expedite treatment of greywater.
            b. Medium-diameter mesh net to catch solids before entering the 55-gallon drum.

c. 2-inch PVC outlet pipe with 90° bend and 4-inch diameter extension. This 90° angle will create a grease-trap effect, containing fats and oil in the settling tank, and not allowing them to pass onto the marsh. The settling tank should be constructed such that routine cleaning is easily accomplished.

3. Subsurface Marsh: According to water use calculations and retention time, the marsh must be sized to contain 3500-gallons of greywater, plus a surge capacity of a couple hundred gallons due to fluctuations in water usage.

→ *500 gallons/per day greywater production x 7 day retention time = 3500 gallons capacity for treatment*

The size of the entire marsh is dependent on depth, width and length, and the area we have available, due to land use and topography.

→ *3500 gal x .134 ft cubed/gal = 469 ft cubed*

→ *469 ft cubed / 3 ft deep / 4 ft wide = 39 ft long*

According to these dimensions the subsurface marsh will be 3 ft deep, 4 ft wide, and 39 ft long, with a treatment capacity of 3500 gallons of greywater. This does not include room for surge capacity.

4. End Use: A system for end use must still be designed, but a few constraints have surfaced thus far in the design process.
   a. Clogging: Use of irrigation tape can lead to clogs in the system due to high nutrient content of the treated water, and the thin diameter of irrigation piping. A system with a larger diameter will have to be designed if immediate irrigation is our goal. The end use could be filtered through a simple sand filter to decrease the chance for obstruction. We could also store the treated water for a few days before final transport to crops by garden hoses.
   b. Gravity: Because this is a pump-free design, the treated water must be gravity-fed to its end use. There will be some design constraints regarding the available land that is downstream from the system. If the treated water is highly filtered it could be pressurized and propelled to irrigate land higher on the property.

2. *Permitting*
   a. University: We will have all plans authorized through Construction Management and Plant Operations before construction begins. Keeping all stakeholders informed will decrease the chance for future conflicts, and reduce health and safety concerns.

b. Municipal: Documenting the permitting process of our marsh by a regulatory body will serve as a demonstration to the general public for their own systems. It is important for all technologies at CCAT to be accessible to the larger population.

3. *Construction*

   a. Outlet: The majority of the outlet and junction is complete, but PVC pipe must be ran from the outlet to the settling tank location. The outlet is 3 ½ feet below grade, so a trench must be dug the entire length of the pipe, gradually gravity feeding to the settling tank. The trench cannot be dug until the university has completed the grading of the site (approximate date of grading: November 7th).

   b. Settling Tank and Grease Trap: The tank components will be adapted and compiled on November 9th. After construction we hope to dig the outlet trench and attach the tank and outlet.

   c. Subsurface Marsh: A long, deep trench (approx. 39 ft) must be dug along the perimeter of the property, with attention to the elevation of the system. The marsh is gravity-fed, so the 39-ft trench must flow downhill slowly (US building code requires plumbing outlets to drop an inch per foot from their inlet). The marsh will be lined with pool-liner, and baffles will be constructed at regular intervals. The first baffle will have a extra couple-hundred gallon surge capacity. The entire marsh will be filled with gravel and marsh plants, primarily cattail and bulrush.

   d. End Use: This system must still be designed, but there are numerous resources available in our Oasis Greywater book. The outlined systems have simple, non-clogging solutions that could be constructed by our team.

4. *Testing*

   a. One-month later: After the system has had a chance to acclimatize, water quality tests can be taken at the input and output to test the performance of the marsh. There are three contaminants that are easily tested for; these tests can be arranged by Environmental Science, Water Quality students. CCAT's previous marsh had an increased rate of Fecal Coliform at the output, it is assumed that this is because of a rat infestation. This should be considered in our design and testing.

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Monitoring and Evaluation Plan

CCAT is interested in more data logging, qualitative measurement, and publications for their records and organization. Some monitoring and evaluation will be necessary and helpful for CCAT. Our monitoring plan will include the following;

- *Soil percolation tests*
- *Water quality tests*
- *Water flow and clogging*
- *Volume of influent and effluent*

Soil percolation tests

- Typical perc test:
  - Dig a hole at the future site of the marsh
  - Presoak the hole so the soil is saturated
  - Fill the hole and time the draining of the water
- Perc tests are typically used for leach fields and an empirical formula can be used to size leach fields based on the test results. We are not creating a leach field; alternatively our marsh will be self-contained. But it is important in the event of a rupture of the pond liner, or overflow of the subsurface marsh, to know the percolation rates of your soil, in case of contamination.
- Perc tests can also be helpful for end use irrigation. Using the volume of effluent, and the percolation rate of your irrigation soil, one can calculate the area of irrigated land necessary to utilize all of the treated water. These perc tests will be performed in.
- We will be performing perc tests at the future site of the subsurface marsh, and in the irrigated land that will be used for the end use. This data will be recorded in the Greywater Marsh Folder that will be generated for CCAT.
- For general maintenance of the marsh, the substrate gravel and plants will need to be removed, and the marsh cleaned out every 3-7 years. At this point, if there has been any sinking or slumping of the subsurface marsh, or any rupture to the pond liner, there should be another perc test and replacement of the pond liner. During maintenance all greywater will be rerouted to the municipal blackwater system, the Arcata Marsh.

Water quality tests

- Certain water quality tests are used to test the treatment of greywater. You typically test the influent (sedimentation basin) and the effluent (end use), the difference between the two being your degree of treatment. We will be performing all of these tests with the help of Dr. Jeffrey Abell, a chemical oceanographer at HSU. The equipment his department uses can perform our various tests, and the

Oceanography Department is currently seeking more student projects to utilize this equipment. All tests will be funded through lab fees, or CCAT's IRA or general budget. All test results should be added to the Greywater Marsh Folder, CCAT could then choose to publish any of this data, especially for use on their webpage or Appropedia page. Water quality tests in general should be performed one month after initial construction, and then once a semester after the first tests. This provides the highest amount of students the learning opportunities associated with water treatment and subsurface marsh upkeep, while maintaining a healthy system. The water quality tests we will be performing include;

- Biochemical Oxygen Demand (BOD)
  - BOD is the rate of oxygen uptake by microorganisms present in the sample water. As oxygen is used by these organisms, either more oxygen must be replaced (typically by plants and photosynthesis), or the system will turn anaerobic (plants and microorganisms will die, and the water will pass through the system untreated).
  - Typical BOD levels for untreated, household greywater are approximately 200-300 mg/l. Our goal for treated greywater is 20-50 mg/l BOD.
  - BOD is measured by taking a sample of greywater, and diluting with de-ionized water saturated with oxygen. The Dissolved Oxygen (DO) level is measured at this point. The sample is kept in the dark at 20°C for five days, to allow oxygen to be consumed by resident microorganisms, without the ability to photosynthesize and generate more oxygen. Another DO level is taken after those five days, the difference between the two DO levels is the BOD.
  - If our BOD is not between 20-50 mg/l, there is a problem with our treatment strategy, and the system is most likely partially anaerobic. The addition of marsh plants or treatment time (enlarging the system), or a better filter system (either at the sedimentation basin or kitchen sink) could remedy a high BOD.
- Total Suspended Solids (TSS)
  - TSS is the measurement of particulates present in a water sample.
  - TSS is measured by pouring a precise volume of water through a pre-weighed filter of a specific pore size. After the filter has sufficiently dried, all water has been removed; it is weighed a second time. The difference in weight is the accumulation of solid materials, present in your water.
  - Easy filters to use and construct include sand and charcoal filters. A student could easily construct these, and the entire TSS measurement could be accomplished in an engineering or water quality class for credit. Filters can often be reused, so the constructed filter could be stored and used again when more measurements are needed.
  - TSS levels before treatment of greywater is ~100 mg/l, after treatment is 5-20 mg/l

    - A variation of substrate gravel, adequate environment for microbial growth, and a fine sediment filter will give you lower TSS levels.
  - Total Fecal Coliform
    - The test for fecal coliform is more specifically an assay for the presence of more dangerous microbes and pathogens. Fecal coliform is used as an indicator bacterium, because its presence may imply the presence of E. Coli and other pathogens.
    - Pouring sample water through a membrane filter (typically .45μm pore size). The fecal coliform bacteria remain on the filter and are transferred to a sterile Petri dish where growth occurs. The resultant colonies are calculated as a microbial density.
    - Untreated greywater can typically see levels of 2000 colonies/100mL. Treated greywater should be approximately 100-500 colonies/100mL. The university has the ability to test fecal coliform levels but if this seems infeasible at the time samples can also be sent out to labs that provide water quality testing services.

Water flow and clogging

- The flow of water through the system and end use must be monitored to prevent anaerobic activity and/or clogging.
  - Monitoring the flow of water through the system can be done visually, making sure there is no backup into the sedimentation basin, and no overflow in the subsurface marsh. Seeing greywater anywhere in the system is not preferred, there should be little retention within the sedimentation basin, and all other treatment water should be subsurface. Visual inspections of the system should be done on a weekly basis; this requires only a quick look at the system, which can be done in conjunction with other maintenance.
  - If there is any overflow or backup within the system, there may be clogging in the end use. If irrigation is used, a wide diameter piping is preferred to discourage clogging, sand filters can also be used after treatment. CCAT may choose to not use irrigation altogether, but simply a hose system which will prevent clogging issues.

Volume of influent and effluent

- After construction the volume of the influent and effluent should be intermittently monitored to ensure that water usage rates have not fluctuated over time.
  - CCAT is constantly maintaining their systems and site, and the future addition of water-conserving features or appliances may change the influent levels. The volume can be measured at the sedimentation basin over a 24-hour period. If the influent volume decreases dramatically, the holding capacity of the subsurface marsh may be too great. This increases the chance for the greywater to turn into blackwater due to stagnation. If the influent level increases dramatically the subsurface marsh may become too small. The holding capacity won't be long enough, and the greywater may exit the system before it has completed

treatment. Water quality tests should be performed to ensure that treatment is producing adequate results.

- The effluent volume can be measured at the end use. This volume is the amount of treated water available for irrigation. It is important to ensure that you have an adequate amount of irrigated land for this end use. Only certain plants and crops can be irrigated with this treated water, and will need to be located below the outlet for gravity flow.

CCAT may choose to use the data and research generated by the construction and maintenance of the greywater marsh to promote and encourage greywater treatment to the larger community. All important data and research will be stored in one central location, the Greywater Marsh Folder. Any extraneous materials will not be included in this folder, due to my experience at CCAT and the overwhelming amount of research and documents stored in CCAT's immense resources. The Folder will be more approachable and accessible if extraneous materials are kept from piling up.

There are employee positions and educational opportunities associated with providing this research to the larger community. CCAT's webpage or Appropedia page are optimal dissemination methods for the continued research of greywater treatment and subsurface marsh construction. CCAT's web administrator or the Engineering 115 students that create CCAT webpages are ideal students that have the ability and resources publish this data and research.

Greywater Marsh Project Proposal for the Campus Center for Appropriate Technology

Analysis and Design by Niki Beckman

Introduce myself & project
— Co-D
— seeking experience in marsh construction

Greywater Basics

- *Definition*: Greywater is any type of wastewater that does not contain high concentrations of fecal coliform
- Fecal coliform is an indicator bacterium usually found in the presence of E. Coli and other dangerous bacteria
- Water typically found to have measureable levels of fecal coliform
  - Toilet water
  - Water used to wash cloth diapers
  - Water with high concentration of food particles
- This water is considered blackwater

Some greywater background & basics
it is not inherently dang. itself
this is not appropriate for marsh-style treatment

Greywater Basics

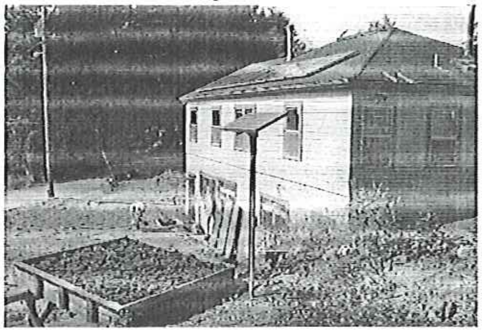
- Some common sources of greywater
  - Bathtub and Shower
  - Bathroom Sinks
  - Kitchen Sink?
  - Dishwasher?
  - Washing Machine?
- Considerations
  - Use of sink garbage disposal
  - Washing of cloth diapers
  - Use of detergents, soaps, etc.

Why do some sources have ques. marks
Some considerations determine the likelihood of your water to turn anaerobic before treatment.
low levels of salts, phosphates & borons will be the best for plant & microorganism health.

Greywater Basics
- Why Use
- End Use
- Don't ...

- In the case that a pathogen makes it thru the system it is important to keep treated greywater from the materials you ingest.
→ roots will not transfer pathogens to fruit.

Campus Center for Appropriate Technology (CCAT)



This design & proposal was made for the Campus ...

Campus Center for Appropriate Technology (CCAT)

- Construction of BSS Bldg relocated CCAT facility to new grounds
- CCAT is a demonstration home for alternative design, technologies, and construction.
- All technologies were dismantled for future installation
- Opportunity for students to learn from the design, installation, and monitoring of new systems and technologies

Due to BSS & relocation...

demo house so: there is an educ. need to reinstall the previous systems

we can learn from the prev. systems to create the appropriate sol'ns for the organization today.

Current Situation

- CCAT is connected to municipal sewer system
- All wastewater is pumped to Arcata Marsh and Treatment Facility
- Facility is plumbed with two exit pipes: greywater vs. blackwater

After the relocation, CCAT has found itself... connected to sewer

I will talk abt this later in the presentation

Problem Statement

- CCAT is in need of a system to treat, remediate, and utilize waste greywater
- System must keep in mind CCAT's goals and mission statement
- Analyze other constraints due to location, university support, climate, maintenance, etc.
- CCAT's ideal system would treat and remediate all of the facility's greywater onsite, and utilize this recovered resource to supplement the irrigation needs of the site.

Now that we know the background we are able to state our problem.

→ as a demo house & educ. facility

~~Analyze other systems for~~

→ Now that we have considered the problem we can determine our ideal situation...

In my research & analysis of this ideal system, I studied numerous alts. & highlighted a few that aided my decision...

Alternatives Considered: California's Legal System

- Greywater system guidelines have been standardized and can now be installed legally everywhere in California
  - Some local municipalities may require further guidelines, or restrict construction altogether
- Applicable Policies
  - State Plumbing Code
  - Assembly Bill 3518
  - Graywater Systems for Single Family Residences Act of 1992

→ these are the policies & codes that have aided in making a legal CA system

→ they were drafted for water conservation reasons.

Alternatives Considered: Arcata Educational Farm

- Local Community Supported Agriculture (CSA) project has constructed a small subsurface marsh
- Treats waste greywater from the kitchen sink
- End use application is an apple tree

This is an easily constructed, & maintained local system. B/c of this it may work for our student organizatn as well.

Seems like a good starting point – the old marsh.

→ learn from issues w/ prev. system

Alternatives Considered:
Original CCAT Greywater Marsh

- CCAT's previous marsh treated and utilized all of the facility's greywater, but the system was not perfect
- The relocation has become an opportunity to learn from previous systems and establish appropriate solutions
- Problems with the previous system
  - Clogs in primary filter
  - Two-marsh system
  - End use

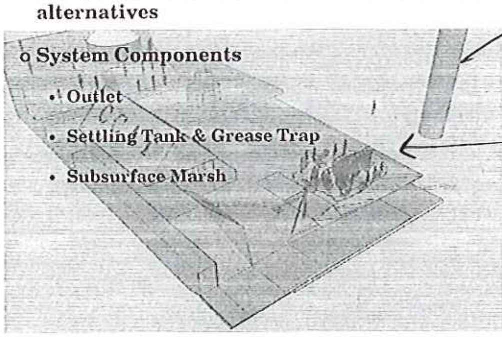
have already constructed filter that allows water to flow around clog.

end use ~~wasn't easily maintained,~~ ~~automatic~~ end use preferred – no holding of greywater – 3 day max.

expansion created hydraulics problem gravity is a concern.

Preferred System

- Designed from a combination of researched alternatives



- System Components
  - Outlet
  - Settling Tank & Grease Trap
  - Subsurface Marsh

this is a preliminary drawing a CCAT volunteer created for the system.

Now that we have a preferred sol'n we can look @ the system components.

System Components:
Outlet

- CCAT anticipated the installation of a greywater marsh and installed a T-valve junction to keep greywater separate from blackwater throughout household plumbing

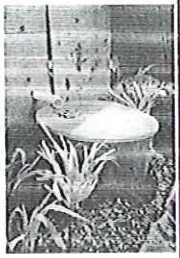
During construction we installed a unique plumbing feature to keep grey- & black- separate.

Toilets are the only source of blackwater

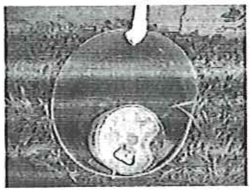
– Explain T-valve junction

I have constructed a settling ... & ... based on AEF designs.

System Components:
Settling Tank & Grease Trap



- Sediment and food particles trapped by filtering screen, water flows into tank



- Grease floats to surface, water forced to flow under pipe or bucket, free of oils and fats

Explain how sett ... & ... work → minus 1 ft.

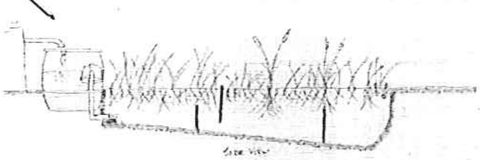
used 55-gal drum, metal grate, 90° elbow, PVC piping, etc.

This water then flows into subsurface marsh ↓

this is a good representation of a grease trap

System Components:
Subsurface Marsh

- Artifical marsh, all treatment is conducted below grade
- Treatment is primarily conducted by organisms living within gravel and root structure



its not the plants that clean the ~~water so much as the~~ beneficial microorganisms.

You have to size your marsh precisely to hold all the graywater you produce for 5-7 days of treatment.
Any less – the water won't be fully remediated

Any more – the water may turn anaerobic – blackwater

System Components:
Subsurface Marsh – Sizing Calculations

- Water Usage Calculations
  - Multiply gallons produced per day by retention time equals capacity
  - Multiple gallons by .134 ft³ per gallon equals volume of capacity
  - Divide volume by depth and width equals length
- Measured Capacities
  - Arcata Educational Farm has estimated 29 gallons produced per day
  - Previous CCAT facility estimated 400 gallons produced per day
  - Current CCAT facility estimates 500 gallons produced per day (due to expansion of facility and usage)

There are calculations for sizing your greywater marsh

System Components:
Subsurface Marsh – Sizing Calculations

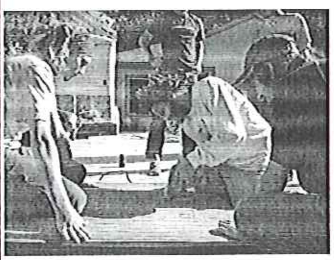
- Water Usage Calculations
  - 500 gallons per day greywater produced x 7 day retention time = 3500 gallons marsh capacity
  - 3500 gal x .134 ft^3/gal = 469 ft^3 marsh volume
  - 469 ft^3/3ft deep/4ft wide = 39 ft long
- CCAT's proposed subsurface marsh
  - 3 feet deep — optimal depth for root penetration
  - 4 feet wide — works best for our topography
  - 39 feet long → will be wrapped around the western boundary along roadside – barrier btwn org. garden & road debris.

That is the generalized plan for the future marsh

— Here is some of the progress we have made on the construction of the system

Construction:
Present System

- Settling Tank & Grease Trap



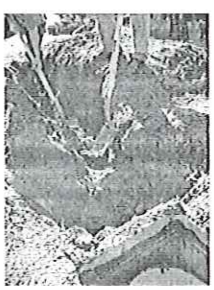
— 55-gal drum w/ 90° PVC greasetrap

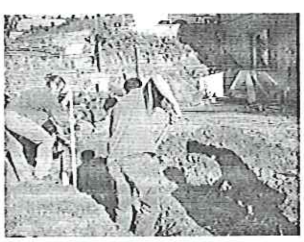
→ installing metal grate filter into tank lid.

This tank will be installed 3ft below grade b/c of CCAT plumbing.

Construction:
Present System

- Beginnings of Trench for piping to Subsurface Marsh

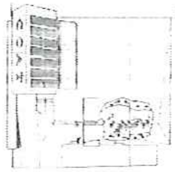




Dug the hole for settling tank & began digging trench for piping.

Then the marsh will have to be dug out & constructed.

CONCLUSION:



- Preliminary design has been completed. All documents produced in this course will be provided to CCAT
- Construction will continue in January, all greywater should be rerouted for treatment in February
- Monitoring and water quality tests will be completed one month after construction
  - BOD, TSS, Fecal Coliform tests

BOD : Biochemical Oxygen Demand