IPRO 325
Developing Affordable Water, Energy and Shelter Solutions for the World's Rural Poor

Final Report

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0.1 Introduction

The objective of IPRO 325 is to improve the quality of life for the world's rural poor by designing, building and testing solutions that cost $5 or less and that can be implemented and maintained by local people utilizing locally available materials.

In the first semester, of Fall 2006, the team identified the three most severe problems in which the following semesters should choose to focus. These problems fell into the general categories of water, energy and shelter.

Last spring, the team divided into two main subgroups to focus on creating water and energy solutions. In addition to engineering potential solutions, both the fall and spring teams aimed at improving awareness on campus of the nearly 3 billion people that live on less than $2 per day.

This semester, the team divided into three subgroups, one for each of the three major problem categories: water, energy and shelter. Due to the various projects amongst the subgroups and the complexity of each, the subgroups have completed individual deliverables, including the Final Report . However, in the spirit of the team, we have presented it as a collective whole.

Water Filtration Subteam

0.2 Background

Water-borne diseases are a worldwide pandemic. Every year more than five million human beings die from illnesses acquired from unsafe drinking water. Most of these people are living on the American equivalent of less than one dollar per day.

By eliminating the threat of water-borne disease, we will greatly improve not only the life expectancy of poor rural populations of the world, but the quality of life, as well. Most of the millions who die each year are children. In addition, adults are greatly weakened by the loss of water and nutrients that are associated with diarrheal diseases. With barely enough food to provide sufficient calories to get them through their day, these nutrients are precious. With increased health, they will be able to be more productive and lead a happier life style. The sociological impact goes far beyond the prevention of loss of life.

Preliminary literature research found two examples of low-cost techniques that have been implemented in third world conditions: the SODIS solar water disinfection technique and slow sand filtration. Both of these methods have serious limitations. The latter requires the filtered water to be stored for significant periods in open areas, which often leads to recontamination. The SODIS technique uses solar UV radiation to neutralize any microbes present in the water. Unfortunately, it is inefficient in areas with water of perceptible turbidity because any sediment suspended in the water blocks the transmission of the crucial UV rays. The only existing low cost method of reducing this turbidity is sedimentation - allowing the suspended particles to settle in a reservoir for 24 hours. This method is slow and does not reduce turbidity appreciably.

The SODIS system has been implemented with success in many parts of the world where conditions are ideal. These communities are now thriving in comparison to how they once were. A new method for reducing turbidity can be developed but must use only materials that can be obtained locally in extremely poor communities throughout the world and reduce turbidity faster and more effectively than the current method. This method may allow SODIS to implement their program on a significantly wider scale.

0.3 PURPOSE

Our objective was to develop an extremely low-cost turbidity reduction method, which will take the place of sedimentation as the SODIS recommended method for reducing turbidity from the local water supply. This method of alleviating the problem of water-borne disease was decided upon because the research involved had a very narrow focus and the SODIS program, which would provide a simple way to deliver our solution to the communities in need. We did not expect to accomplish this entire task within the semester. Instead, our objective was to produce, through recursive design and testing phases, a prototype of a system that meets the applicable requirements. The requirements were that the system could be assembled locally in our target location of Western Nicaragua for a price of less than five dollars. The system must reduce turbidity faster and more effectively than the existing sedimentation method and the system must be environmentally sustainable.

The reason the subteam focused its efforts upon Western Nicaragua were two-fold. First, this location is one of the areas where the SODIS method is inadequate due to less than ideal sun exposure and frequently turbid water, the two most typical problems faced by SODIS. Secondly, two members of the subteam have made plans to travel to Western Nicaragua in early January. Thus, it will be easy to obtain firsthand records of the feasibility of our solution.

By far, the largest constraint on the subteam's ability to accomplish our objectives was time. With more time, the subteam would have been able to employ a much more comprehensive testing and design strategy. Since there was not adequate time, in many cases the testing was restricted to purely qualitative methods, often with significant margins of error. Because of this, further rounds of testing will be necessary in order to unequivocally justify the conclusion that the prototype system is superior to existing methods.

A past IPRO team was responsible for discovering the SODIS program and suggesting that something be done to improve upon it. A future IPRO team will be responsible for convincing the SODIS group that the prototype built this semester is superior to the sedimentation method. They will do this by subjecting the system to systematic and comprehensive testing to prove its effectiveness with regards to durability, turbidity reduction, flow rate, ease of use, and cost. Once they have collected sufficient data to scientifically show that the system produced by this semester's IPRO subteam is superior to the sedimentation method based on those criteria, they will contact the SODIS group to suggest that they consider altering their recommendations for removing turbidity to include our solution.

0.4 Research Methodology

Now that we have identified the purpose of our project we will discuss the process and methodology we used to accomplish our objective. As mentioned in the previous sections, our research would focus on designing the least expensive, most efficient method for the reduction of water turbidity using only materials available to the rural poor of developing nations. In order to set to work on this large task, our team broke its responsibilities down to the following five objectives assigning a team member to lead each phase:

1. Obtain necessary resources. (Brian Schiller)
2. Set efficiency standards for filtration/sedimentation through extensive research. (Ryan Witthans)
3. Design and build a working prototype. (Ashley Ono)
4. Test prototype. (David Curtin)
5. Develop field manual for implementation of the overall water treatment system. (Jessica Henson)

i. Obtain Necessary Resources

The first of these responsibilities, obtaining necessary resources, was accomplished by following a two-phase plan led by Brian Schiller. David began by first approaching John Zasadzinski, the Biology, Chemistry, and Physical Sciences (BCPS) chairman, and requesting funds for the project on the grounds that the work the three BCPS students (Brian Schiller, Ryan Witthans, and David Curtin) were doing also fell under the category of undergraduate research. With potential funding from the BCPS department, Brian Schiller and Ryan Witthans prepared a formal presentation and budget request and delivered it to Tom Jacobius, the head of the IPRO department. Dr. Jacobius agreed to the basic funding needs of the team amounting to $417. With this funding now secure our group was able to continue on and begin the testing that would allow us to set the efficiency standards for our filtration work.

ii. Set Efficiency Objectives

In order to create a standard for efficiency our team would need to first develop the criteria by which the data was to be assessed. Because the elimination of bacteria by the SODIS process is dependent on the amount of ultraviolet light that can penetrate the solution, it made sense that we would use the percentage of UV light that passed through our solutions as the dependent variable of our testing. Ryan Witthans determined that we would need to determine precisely what wavelength of UV light we wished to measure. In order to do this, our team took a solution of turbid water and measured the transmittance (amount of light that passed through the solution/ amount of light exposed to solution) across the entire UV range (400 to 220nm). From this test we discovered that UV wavelength that was most hindered by the turbid water was at 283nm. The team agreed to set this as our dependent variable to be measured in all future tests.

Now that we had our test variables determined we needed to establish a baseline against which to measure the success of our product. Our team realized early on that this baseline would be determined by the methods currently used by SODIS. The SODIS method of water filtration was found in their published field manual and was easy to test. SODIS recommends letting turbid water settle in a large vessel followed by pouring the liquid through a shirt or rag or whatever type of fabric is available. In order to test the effectiveness of this method, our group employed the following experimental procedure devised by Ryan Witthans:

1. Prepare batch solution of turbid water by adding dirt to water and stirring/shaking vigorously until solution is saturated with dirt.
2. Remove a small ~20mL sample of turbid water for testing in the ultraviolet/visible light (UV/vis) spectrometer.
3. Allow solution to settle for 24 hour.
4. Pour out the top layer of the solution (presumably some of the dirt particles will have settled down to the bottom of the bucket and the clearer top portion of the solution can be separated). Pour this portion through a clean piece of fabric (preferably a T-shirt or some other article of clothing not intended for filtration purposes) and into a clean vessel
6. Remove a small ~20mL sample of SODIS-filtered water for testing in the ultraviolet/visible light spectrometer.
7. Standardize the UV/vis spectrometer by placing vacant quartz vessels in both the test and reference slots.

NOTE: A UV/vis spectrometer works by splitting a light beam in two and measuring the difference in transmittance between the sample vessel and a reference vessel which is usually filled with deionized water. Steps 7 and 8 are standard methods of calibrating the machine to ensure the data is accurate.

8. Fill both quartz vessels with deionized water and calibrate the spectrometer such that the difference between the vessels is set to zero
9. Clean and dry the quartz vessel in the sample slot and fill it with the sample of SODIS-filtered water
10. Use the UV/vis spectrometer to measure the transmittance of UV light at 283 nm.

This data would serve as the baseline against which all of our future experiments were to be measured. Ryan Witthans then appointed David Curtin to draft a formal standards statement for our project which is provided below.

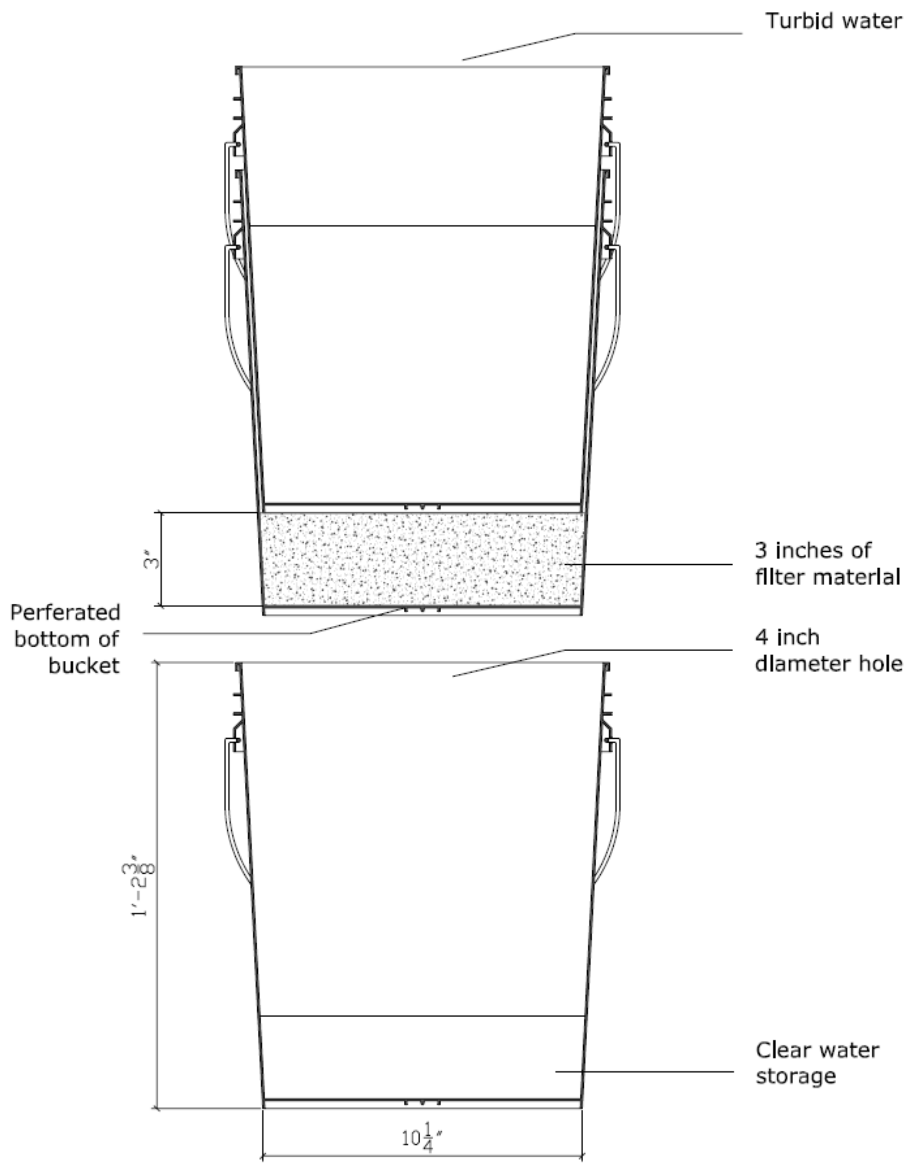
> "In order for the solar disinfection process to be efficient enough to be practical within the latitudinal boundary of 35º, the turbidity of the water used must not exceed 30NTU (nephelometric turbidity units).
>
> The SODIS manual recommends that any source water exceeding this turbidity limit be treated to reduce its turbidity. However, the manual is not explicit in its recommendation as to the manner in which the water shall be treated. It is implicitly suggested that the locally available materials will dictate the method of treatment. One basic method has been used prominently by SODIS teams: sedimentation by storage combined with crude filtration by fabric. This system has indeed proven capable of reducing the turbidity of source water to the acceptable level. However, there is certainly room for improvement. That is the possibility upon which our IPRO team is focused. Therefore, the benchmark for our project will be this method.
>
> The areas upon which we may impove this method will include: rate of treatment, overall reduction of turbidity, overall reduction of microbial counts, ease of use, availability of materials, and cost. Thus, in assessing the effectiveness of alternate pre-treatment solutions we shall evaluate based on these six criteria. The former three criteria will be assessed objectively and quantitatively through laboratory trials. The ease of use shall be assessed subjectively by a panel of volunteers who, given instructions, will be asked to implement the filtration system in a controlled setting. Cost and availability of materials shall be assessed through a comprehensive research process. After a solution has been evaluated with regard to each criterion, our subteam shall subjectively determine its relative value in comparison with the benchmark system. Any pre-treatment methods which surpass the benchmark shall then be subjected to further field testing."

iii. Design and Build a working prototype

While Ryan Witthans, with the help of David Curtin and Brian Schiller, was developing the efficiency standards for the laboratory testing, Ashley Ono was utilizing her architecture background and computer-aided design (CAD) skills to prepare the design of the team's prototype. This prototype would be built strictly from materials that were already available to the rural villagers of developing nations. To do this Ashley employed the help of Jessica Henson, the team's other architecture major who also had the benefit of prior experience with an aid organization that traveled to Nicaragua. This gave the design group the advantage of intimate knowledge of the types of materials that would be available.

Using this knowledge, the design team drafted a list of the materials that could be used for the prototype. One of the more amusing details of this project was that even though our team made incredible efforts to use materials that would be inexpensive and available to the rural villagers of developing countries, those types of materials (sand, gravel, straw, volcanic rock…etc.) are not readily available to us living in a city. Ashley gave Ryan Witthans, David Curtin, and Brian Schiller the task of acquiring these materials, while she and Jessica Henson worked on drafting the design.

The initial design, featured on the next page, utilizes a three-bucket system that was drafted by Ashley Ono.



Buckets were chosen because they are widely available in the garbage dumps scattered throughout developing countries and can be easily transported by a person to its desired location. The bottom bucket is connected to the system via a lid w/ a 4inch diameter hole. The purpose of this lid was to separate the bottom bucket (in which the clear water would be kept) from the rest of the system. Since the clear water in the bottom bucket would later be transported for the SODIS application of bacterial disinfection, it was important for the design to incorporate a barrier that would allow the easy removal of the bottom bucket. Above the lid sits the middle bucket, which was perforated with a knife to allow water to drain into the bottom bucket. A piece of fabric similar to that used in the SODIS method is placed in the bottom of the middle bucket and is covered with three inches of the selected filter material developed by David Curtin, Ryan Witthans, and Brian Schiller (See section iv for more information). Placed immediately above that is the top bucket which was also perforated with a knide so as to create perforations that would allow for a controlled rate of flow of turbid water from the top bucket to the middle bucket. This controlled rate of flow was important so that the turbid water would not overwhelm or flow around the filter. The first prototype was then constructed by Brian Schiller and Ryan Witthans. Some of the pictures of its use are provided below:

iv. Testing

The purpose of the testing phase was to determine which factors would allow for the creation of the most effective and efficient filter. Before the testing began, a list of potential filter media was created by David Curtin, Ryan Witthans, and Jessica Henson. Again the single focus of the list was to find materials that would be available to rural villagers in developing nations. David Curtin and Ryan Witthans were able to contribute to this list from their extensive research into filter-type materials used throughout the world in developing countries and Jessica Henson was able to utilize her experience in Nicaragua to share with the team her intimate knowledge of the materials that were available there. Once the prototype was constructed, David Curtin along with Ryan Witthans and Brian Schiller took it to the 33rd street beach to perform the first round of testing. This round of testing would evaluate the plausibility of different filter mediums. A summary of the methods used in the trip prepared by Ryan Witthans is provided below.

Ryan Witthans
IPRO-325
November 8, 2007

Materials & Methods – Testing Round 1

Materials

2.5 gallon filtration apparatus
Coarse, unwashed sand
Crushed volcanic rock
Coarse charcoal
Fine charcoal
Lake Michigan water
Stopwatch
Ruler

Methods

This round of testing was performed at 31st Street Beach in Chicago, IL, on October 13, 2007.

Approximately 2L of turbid water was prepared by mixing fine sand particles with water obtained from Lake Michigan. For all filtrations, this mixture was shaken and a defined volume was mixed with lake water to create 3L of a feed mixture. Samples of both the Lake Michigan water and the feed mixture were taken.

Four filter media were tested during these trials. They composed of combinations of: coarse, unwashec sand, obtained from 31st Street Beach; crushed volcanic rock, obtained from Home Depot, pulverized into particles measuring smaller than one-eighth inch diameter, and washed; and charcoal, both coarse and fine, produced by team member David Curtin (as described in a separate document). The specific filter media used were: sand, crushed volcanic rock, 1:2 coarse charcoal/sand, and 1:2 fine charcoal/sand.

Individually, each of the four filter media were loaded into the cleaned filtration apparatus to a column height of 3 inches, an arbitrary height chosen for ease of testing. The 3L feed mixture was loaded into the top of the apparatus as a stopwatch was started. The amount of time for the feed to empty from the top bucket (the amount of time required for all water to enter the filter column) was recorded. Once most of the water was collected in the bottom bucket, a small sample was taken and the output water was filtered again through the apparatus. Samples were taken after the third and fifth repeated filtrations before the apparatus was cleaned and reloaded with another filter media.

The optical absorbence of the feed sample was measured on a UV/Vis spectrophotometer, and a prominent peak was found at 283 nm. The optical absorbances of all collected samples were taken at this wavelength and recorded. Results can be found in a separate document (iGroups→results-1.pdf).

From the data collected at the beach, the team discovered that the sand mixed with charcoal method significantly outperformed volcanic rock and sand as a filter medium to reduce the turbidity of water. With this data uncovered, David Curtin designed the next battery of tests to determine the most efficient blend of charcoal and sand as well as investigate the possibility of replacing the charcoal powder (which would require specific instructions to produce) with fire ash. Research performed the previous semester as well Jessica Henson's experience indicates that fire ash is already widely available due to the use of fire wood as a primary cooking fuel. The research methodology as well as some preliminary results can be found in the report provided below:

Dave Curtin, Ryan Witthans, Brian Schiller, Jessica Henson
IPRO-325
October 30, 2007

Testing - 2nd Round

On October 30, 2007, a large sample of turbid water was prepared by mixing soil, obtained from the area south of IIT's Herman Union Building, with tap water, from Wishnick Hall room 218. This yielded 6 gallons of turbind waer for testing. Several filtration media were tested by filtered through this water. The 2.5 gallon filter apparatus was loaded with each filter media to a depth of 3 inches and 2.35 L of turbid water was filtered during each test. The filter media used were

1:4 charcoal:sand, with a cloth liner
1:8 charcoal:sand, with a cloth liner
1:16 ash:sand, with a cloth liner
1:8 ash:sand, with a cloth liner
1:16 ash:sand, with a cloth liner

On October 31, 2007, the 1:8 charcoal:sand filtration media test was run again because prior results disagreed with expectations. It was surmised that the input water used during that test contained an amount of "sludge" that interfered with filtration. This layer of sludge was allowed to settle out of the input mixture immediately before further tests. Other filtrations may be similarly repeated.

The absorbancies of all collected samples were determined using a spectrophotometer at 283 nm. Because the suspended particles settled out of the mixture quickly, measurements were taken of both still and recently shaken samples in some instances.

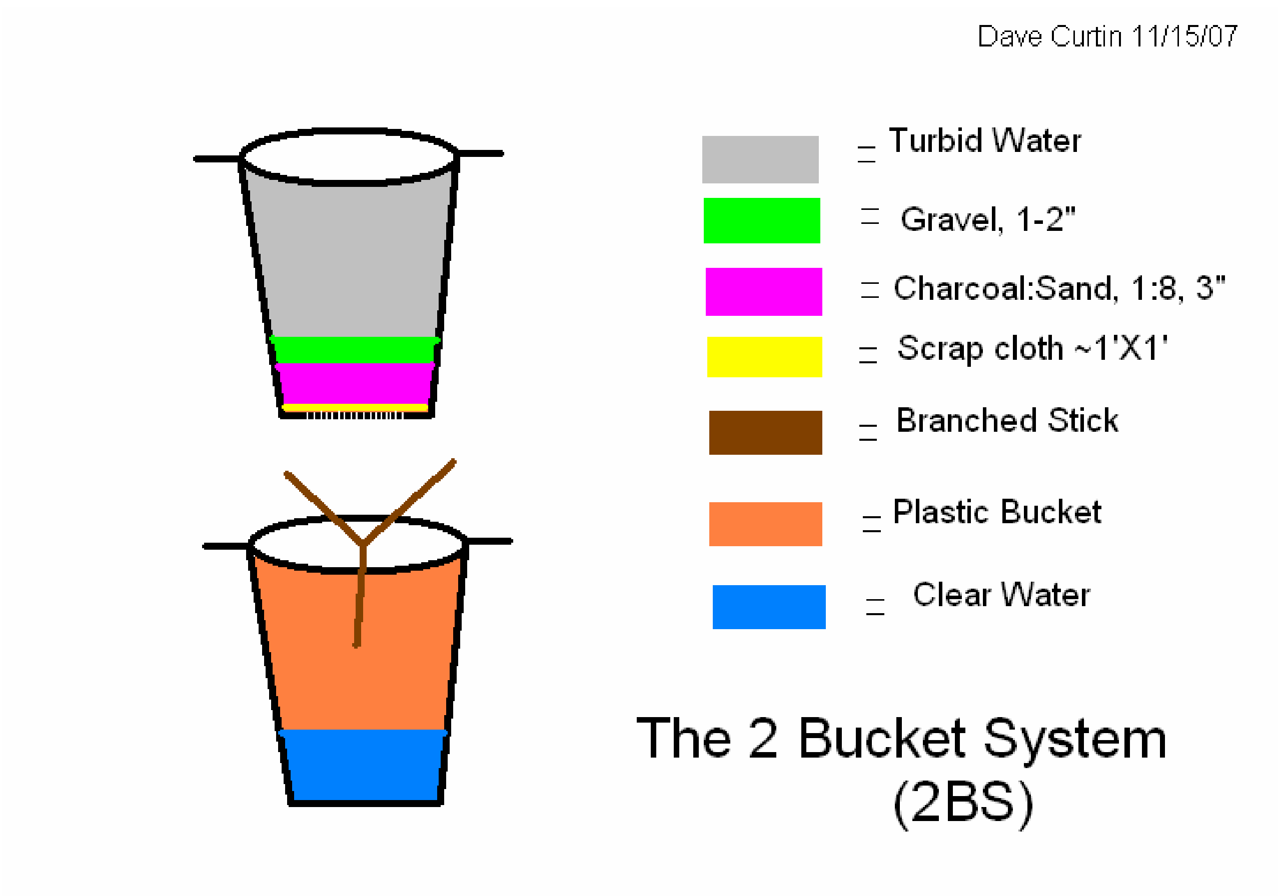
Optical Absorbance Measurements (283 nm)

	Still		Shaken		
	10/31/07	10/30/07	10/30/07	10/31/07	Time
Deionized water	0.000	0.000	0.000	0.000	
Input water	2.150	2.150	2.150	2.150	
1:4 C:S	0.088		0.091		4:25
1:8 C:S	0.258	0.205	0.273	0.209	5:30
1:16 C:S			0.526		4:20
1:8 A:S	0.143		0.143		>10:00
1:16 A:S	0.205		0.205		2:08

Following the second phase of testing, David Curtin decided to investigate the possibility that some of the filter material was seeping into the bottom bucket and actually contributing to the measured turbidity. To test this David Curtin created an experimental design using finer grain sand (which communication with aid workers in Nicaragua revealed was available) for the filter material.

iv.5. Design Revisited

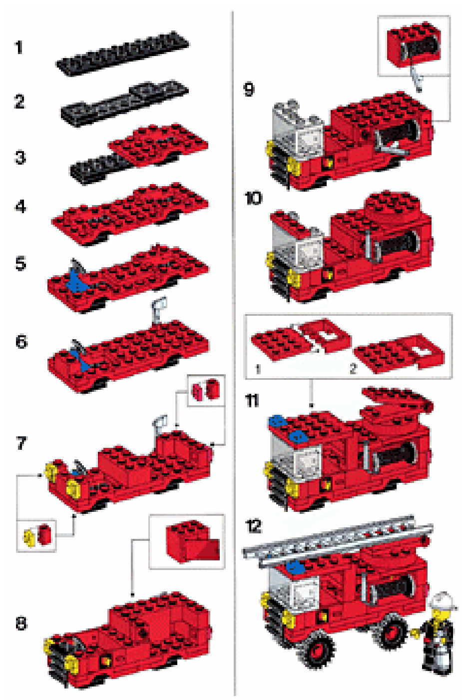
As is often the case in any project, performing the testing objectives gave the team additional insights into how to make a more efficient filtration design. Realizing that the most difficult to find of the materials would be buckets (especially one with a functioning lid) David Curtin suggested adjusting the filtration unit from a three-bucket system to a two-bucket system. David also decided that using a Y-shaped stick would prove easier and more cost effective than trying to obtain a lid that properly fit the bucker system. It is also believed that the pressure change caused by the transfer of water from the filter bucket to the collection bucket without a corresponding air flow caused a suction effect that contributed to some filter material adding to the turbidity of the clarified water in the collection bucket. Below is a diagram of the new two-bucket system:



v. Field Manual/Implementation

The final objective of our team was to develop a field manual that could be used to teach anyone anywhere in the world how to build and use our product. This phase was headed up by Jessica Henson who, due to her experiences in Nicaragua, had more direct exposure to the conditions we as a team will be trying to improve than anyone. As part of her project she tasked Brian Schiller and Ashley Ono to begin investigating possible methods of creating a field manual that could be used to overcome the barriers formed by differences of language and illiteracy.

The initial idea, proposed by Brian Schiller, was to use a "Lego-type" instruction manual where a diagram of all the materials was shown on the first page and the subsequent pages displayed diagrams of the product in its various phases of construction. An example diagram from the Wurlington-Bros company is provided below:



Ashley Ono then came up with the suggestion of using pictures instead of diagrams, believing that it would be easier for people to see the actual work that was being done to construct and operate the filtration system. Brian Schiller suggested that the final field manual should contain actors of a similar cultural look as the rural villagers we are aiming to help, but that for IPRO day such a task would require too much time and resources. Instead the team should be the subject of the pictures themselves. The objective leader, Jessica Henson, then came up with the idea of using Photoshop to cartoonize the pictures taken and making the characters look more familiar to the rural villagers we are trying to help.

The biggest contribution to the implementation objective will take place at the end of the semester when Jessica Henson and Ryan Witthans will be traveling to Nicaragua and David Curtin will be traveling to Peru to see first hand the realities of rural village life in developing nations and the restrictions and obstacles that must be overcome in order to develop a self-sustaining water filtration system.

0.5 Assignments

(see attached gantt chart for semester schedule)

Team Members

Name	Major	Skills	Interests
Curtin, Dave	Chemistry	Microsoft Office, Biology Lab, Chemistry Lab, Spanish Language	Improving quality of life through science and engineering. Eliminating the pandemic of diarrheal disease through simple water treatment.
Henson, Jessica	Architecture	Microsoft Office, AutoCAD, 3D Max, Photoshop, Illustrator, SAP2000, MathCad, Spanish Language	Improving the quality of life for all human beings, Water Systems (natural and man-made), and helping in developing countries without infringing on their culture.
Ono, Ashley	Architecture	Microsoft Office, AutoCAD, 3D Max, Photoshop, Illustrator,	Improving the quality of life for those who live in developing countries to the best of my capabilities.
Schiller, Brian	Chemistry	Microsoft Office, Spectrometry, Lab Techniques	Helping improve the quality of life in developing countries through.
Witthans, Ryan	Chemistry	Microsoft Office, Spectrometry, Lab Techniques	Improving the heath and welfare of humans, especially in developing countries.

Team Responsibilities:

1. Obtain necessary resources.
2. Set efficiency standards for filtration/sedimentation through extensive research
3. Design and Build a Working Prototype
4. Test Prototype
5. Design Field Manual for Implementation of the Overall Water Treatment System

Individual Member Responsibilities:

Name	Role	Task Group	Tasks
Curtin, Dave	Chemist	Design Testing Field Team	Research Microbes, Set efficiency standard for prototype, Design and Testing of Prototype, Secure Funding for Project Final Presenter
Henson, Jessica	Team Leader Engineering Binder	Location Educational Materials Field Team IPRO Day Deliverables	Manage administrative tasks, In-depth location research, Act as Liaison to other subgroup leaders, research similar projects, Abstract, Posters, Final Presenter

Ono, Ashley	Subgroup Secretary Building Leader	Design Location Educational Materials IPRO Day Deliverables	Lead prototype construction, Take Minutes, Aid in Location Research, Manage Schedule In MS Project, research similar projects, Design drawings of prototypes, posters
Schiller, Brian	Chemist	Design Testing Educational Materials	Code of Ethics, Secure Funding for Project Research Existing Methods and SODIS, Design and Testing, Education Materials Final Presenter
Witthans, Ryan	Chemist Schedule Keeper	Design Testing Field Team	Research Turbidity, Manage Schedule in MS Project, Secure Funding for Project Midterm Presenter, Final Presenter

0.6 Obstacles

In the developed world take clean water for granted, but how do you take dirty water and make it clean using only the materials available to rural villagers in developing nations? Just as with any project this team faced obstacles right out of the starting gate. In fact the project is an obstacle in and of itself. To create a feasible answer to this problem, our group was forced to first take a look at the obstacles that previous attempts at water purification had failed to overcome in the developed world. Through a series of research reports our team discovered the single greatest obstacle that solutions failed to overcome was **self-sustainability**.

There have been hundreds of attempts that spend millions of dollars to address the problem of water purity in developing countries. The problem with all of the ones that failed is that they are not self-sustainable. Colloidal silver, chlorine tablets, high-pressure forward osmosis; these are all ideas that have been proposed as solutions to water contamination in the *third world*. These are not sustainable solutions. Think about the things you own: your car, your cell phone, your computer, your remote control. Most of these things have failed to work at least once. So what do you do? You take your car to the mechanic or cell phone to the store or some other expert, except in the third world, there is not a way of getting in contact with *an expert*. The people in these villages don't have clean water let alone a telephone or e-mail. We need to create a way for these people to sustain their own production of clean water while overcoming the severe obstacle of not having any of the things that we have. Since our culture is completely different, we have no valid conception about their way of life.

Now that we have those big issues out in the open we can begin to discuss the smaller, specific obstacles our team faced throughout the semester. We will begin by looking at the obstacle of trying to identify/create a solution for a culture other than our own. To overcome this obstacle we had the benefit of having a team member, Jessica Henson, who had previous experience working with an aid organization on a trip to rural Nicaragua. The insight and knowledge that Jessica brought back from that trip proved invaluable to the group, but it still wasn't enough. In order to overcome the cultural obstacle we had to make ourselves aware of several factors including: local and national laws, potential agreements or contracts made between our group and the local villagers, any codes of conduct we may be subjected to as researchers *or* as aid workers in another country, the manner and efficiency in which we seek to accomplish our work, the way the community or communities we are working with view outsiders, how and why we establish personal relationships with any or all of the people we are seeking to help, and, finally, understanding their spiritual and moral values. Because these concepts are abstract and apply not only to the water sub-team, but to the entire IPRO 325 team, these obstacles were overcome by the IPRO 325 team as a whole. For the complete summary of all identified pressures and risks please view our **Code of Ethics**. These issues will be discussed is this report as they were confronted by our team.

Our team was very fortunate in that the water team from the previous semester had already discovered a practical and sustainable method of water purification for use in developing countries. The SODIS system which uses ultra-violet light from the sun to kill harmful bacteria in water has been a proven success in several test sites across the third world. The SODIS system requires only sunlight, PET (PETE) plastic bottles (which are widely available across the developing world), and time. As mentioned, the SODIS method has proven successful where implemented, but it has one very significant drawback—it requires clear water in order to function. The problem with that is that there aren't very many places in developing countries where clear water is available. Therefore, the SODIS system is a step in the right direction, but it still leaves millions of people without any means of purifying their water. That's is where this project will focus. Thanks to the SODIS method, we could modify our main objective (obstacle) from creating a system that made water safe to drink, to creating a system that removed water turbidity to a level appropriate for the SODIS method.

The first practical obstacle our team faced in this endeavor was in meeting the stretch objective of designing a solution that could be built for less than **$5**. In order to overcome this obstacle our team, with the help of Jessica's intimate knowledge, tried to create a list of the materials that would be freely or cheaply available to rural villagers living in developing countries. Beyond that we had to face the additional ethical consideration of realizing that some materials, although available may be used for only spiritual or ceremonious circumstances and forbidding their use. Limiting ourselves only to materials on the list we created, we set about to create our $5 product. See the **Research Methodology Design** section for more details about the materials used in the product.

As the design fell into place, our team became aware of another obstacle it had previously ignored. The team was composed of five members: two architecture majors and three chemistry majors, and included two people who lived off campus and four people with additional jobs. Coordinating our efforts would be a major obstacle to overcome. The team set to work by dividing into two teams: one science based (for the chemistry majors) and the other design and implementation based (for the architecture majors). Tasks were divided equally among the five team members and each relied on a constant stream of e-mail updates and progress reports in class to stay on top of the direction of the overall project. Jessica Henson, the team's leader, also made it clear that each team member was to ask for help when needed and the team as a whole did an excellent job of communicating and accomplishing all of its assigned tasks.

Once the groups were formed and the task assignments handed out our team really began to accomplish a significant amount of work. It turned out the three-bucket design and had a working prototype inside of a couple of weeks. The next obstacle came from the testing subteam. The subteam was faced with the difficulty of creating a standard turbidity solution against which any reduction in turbidity could be measured. Because the testing subteam was planning on performing a multitude of tests, it would require a lot of this standard solution, but only so many tests can be performed on any given day and the standard solution volume required would be in the tens of liters. The testing subteam first sought to address this obstacle by creating a concentrated turbidity solution which could then be diluted with a known amount of water and have that dilution serve as the standard solution. Unfortunately, after dilution the standard sample was not turbid enough to function as the benchmark for turbidity reduction and the first several tests had to be ignored. But the testing subteam would overcome this setback and rely on another scientific principle for creating their standard turbidity solution. Water, just like any liquid, has a point where it becomes saturated with solute (in this case dirt). Because the point of saturation will be reached at exactly the same concentration of dirt every time, the testing subteam could use this as their benchmark by which to measure turbidity reduction. The subteam further insured their data by also measuring the transmittance of the standard solution before treatment for each test. This way turbidity reduction as a percentage of initial water quality could also be determined.

This leads us to the next obstacle our team faced. One of the key advantages to our work rests in our ability to utilize the SODIS data and methods. Unfortunately, the SODIS data and methods were all developed using a measurement of water turbidity. Water turbidity is measured by shining a light on the water solution and measuring the amount of light scattered at 90 degrees. The amount of light scattered is directly proportional to the number of particles floating in solution. Unfortunately for our team, IIT does not have a device with which to measure turbidity. The team's initial approach to this obstacle was to try to find another source for the turbidometer (device that measures turbidity). However, these are very difficult to find. We inquired at other departments at IIT as well as with other schools. We received no positive response from either the University of Chicago or Northwestern University, and though we managed to speak with both JoBeth D'Agnostino and David Crumrine, the heads of the environmental sciences and chemistry departments at Loyola, we were unable to locate a turbidometer. Our next effort was to obtain the funding to purchase one. Ryan Witthans was able to find a vendor online who gave discounted prices to institutions of higher learning, but neither the IPRO office nor the BCPS department was willing to invest the $900 required.

Although frustrating, these challenges merely strengthened our resolve. If we couldn't find a material solution to the problem we thought we would reinvestigate the science. And that is where we found our answer. The SODIS method is dependent on the turbidity of water not because of the turbidity itself, but because the suspended particles in the solution (indicated by turbidity measurements) prevent the ultraviolet light from penetrating deeply enough into the solution. The factor that indicates how effective the sunlight will be at killing the bacteria in the water is not indicated by turbidity, but instead by the transmittance of light through the solution. Because IIT has a spectrophotometer, capable of measuring the transmittance of ultraviolet light through a water solution, we now had an appropriate way to measure our test data.

The test subteam wasn't the only group running into obstacles. The team members working on the implementation and design had a few of their own. The problem that first became obvious to the team was that there was a tremendous language barrier that had to be addressed. If the rural villagers we were trying to help couldn't speak English, we had to develop a new method of communicating with them. The problem was much larger than that. Not only could these people not speak English, but in some cases they are illiterate. The question became how to teach villagers how to build and repair the prototype. The initial idea was to use a "Lego-type" instruction manual where a diagram of all the materials was shown on the first page and the subsequent pages displayed diagrams of the product in its various phases of construction. The team then came up with the suggestion of using pictures instead of diagrams, believing that it would be easier for people to see the actual work that was being done to construct and operate the filtration system. We then decided that the final field manual should contain actors of a similar cultural look as the rural villagers we are aiming to help, but that for IPRO day such a task would require too much time and resources and the team should be the subject of the pictures themselves. But Jessica Henson then came up with the idea of using Photoshop to cartoonize the pictures taken and making the characters look more familiar to the rural villagers we are trying to help, believing that this would make understanding and acceptance easier.

This was by no means the end-all solution to the implementation problem. A big deal was made in the beginning of this section about the challenges that would have to be overcome in order to make our solution work. This is true because if our solution isn't understood, isn't accepted, isn't embraced then it will never sustain itself and it will never outperform the dozens of failed solutions that came before it. Our team is so dedicated to developing a sustainable implementation scheme, that three of our team members: Jessica Henson, David Curtin, and Ryan Witthans will be traveling to rural villages in Peru and Nicaragua this winter to learn first-hand the challenges implementation presents and discover for themselves the best way to overcome this greatest obstacle of all.

0.7 Results

To determine the efficacy of our filters, samples were taken of each volume of water fed into the filter and each output volume that permeated through. Samples were measured for optical absorbance at 283 nm, a wavelength chosen as a convenient representative for measuring water contaminants in the ultraviolet range. Sample absorbencies were measured on a Varian Cary 100 UV/Vis Spectrophotometer capable of making measurements in the ultraviolet and visible spectrum. Measured absorbencies were mathematically converted to percent transmittance values with the equation;

$$\%T = 10^{2-A}$$

where A is the optical absorbance. A useful variable in comparing results was introduced, the transmittance improvement calculated as;

$$\%T_{imp} = \%T_{out} - \%T_{in}$$

where the percent transmittance of the filter input is subtracted from the percent transmittance of the filter output. This variable proved especially useful in comparing different filter types that had been tested with varying input water absorbance.

The first round of testing was completed on October 13, 2007, at 31st Street Beach in Chicago, Illinois. The testing methodology can be found in the Research Methodology section of this report, and the data gained can be seen below.

Testing - 1st Round

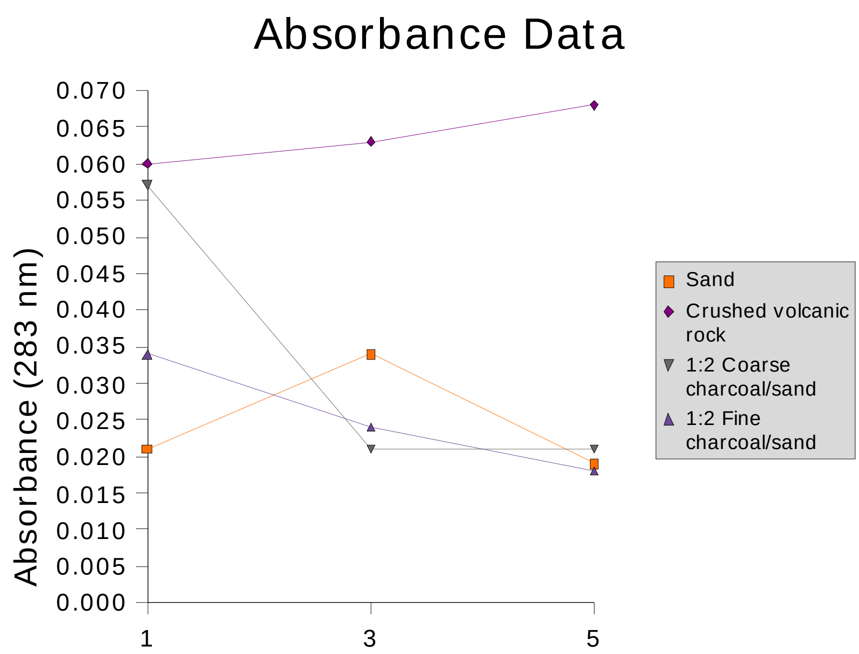
Optical Absorbance Measurements (283 nm)

Absorbance of Lake Michigan water = 0.017

Absorbance of input water (water + sand) = 0.042

Filter material	Number of passes through filter			Time of first 3L filtration
	1	3	5	
Sand	0.021	0.034	0.019	55 sec
Crushed volcanic rock	0.060	0.063	0.068	50 sec
1:2 Coarse charcoal/sand	0.057	0.021	0.021	71 sec
1:2 Fine charcoal/sand	0.034	0.024	0.018	ND

Here, all data is expressed in terms of absorbance, and not transmittance. Higher absorbance readings mean that the sample is absorbing more light, and is therefore more turbid. The best filter media are those that show the lowest possible absorbance levels. This data has been organized in graph form as shown below.



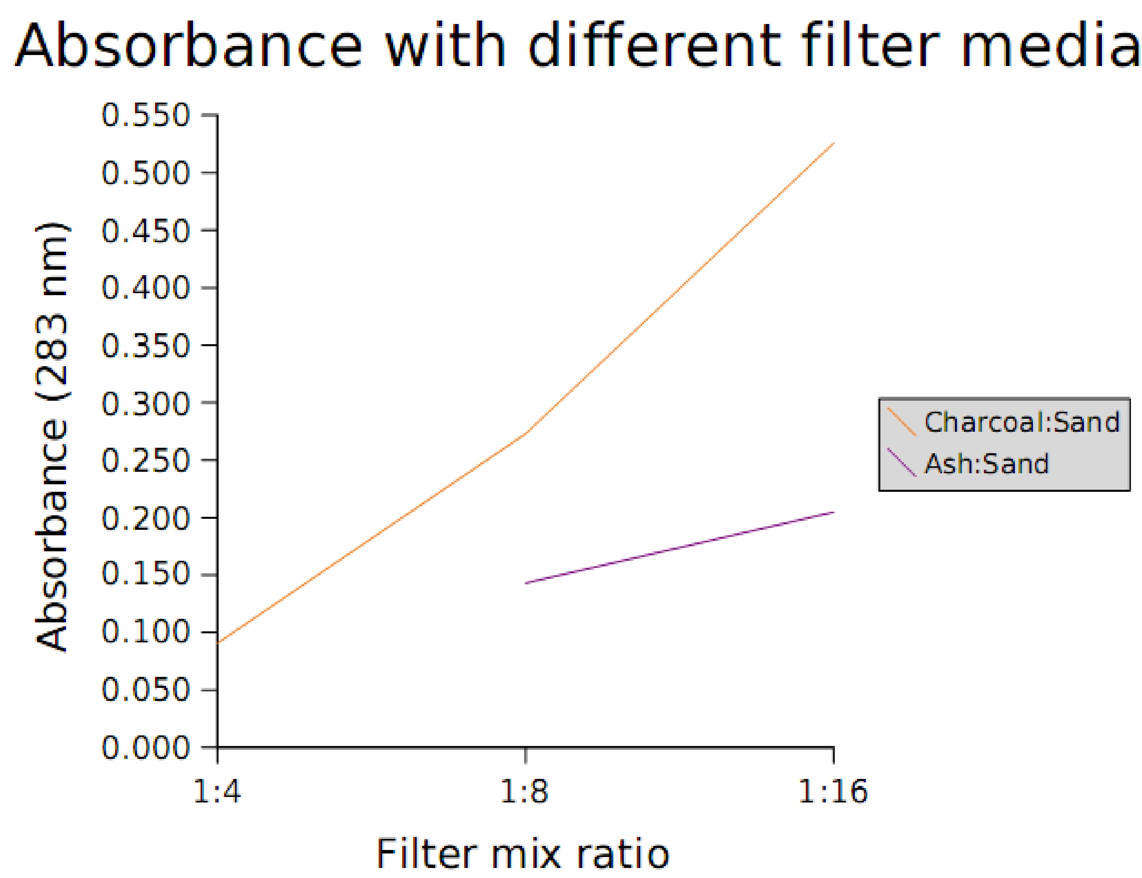
It can be quickly realized that crushed volcanic rock performed the worst of the four filter media. The sand filter performed best on the first filtration of the turbid input water, but was matched by the mixtures of sand and charcoal after five filtrations. From this data, it was determined that sand and charcoal would be excellent candidate filter materials for subsequent tests, as they performed reasonably well. Furthermore, we concluded that crushed volcanic rock was a poor filter material, surmised to be a result of contamination of the filtered water by large amounts of volcanic rock dust.

The second round of tests was completed on October 30, 2007, following the methodology in the Research Methodology section of this report. The optical absorbance of each sample can be seen below. Grayed cells in the following spreadsheet signify that no data was recorded.

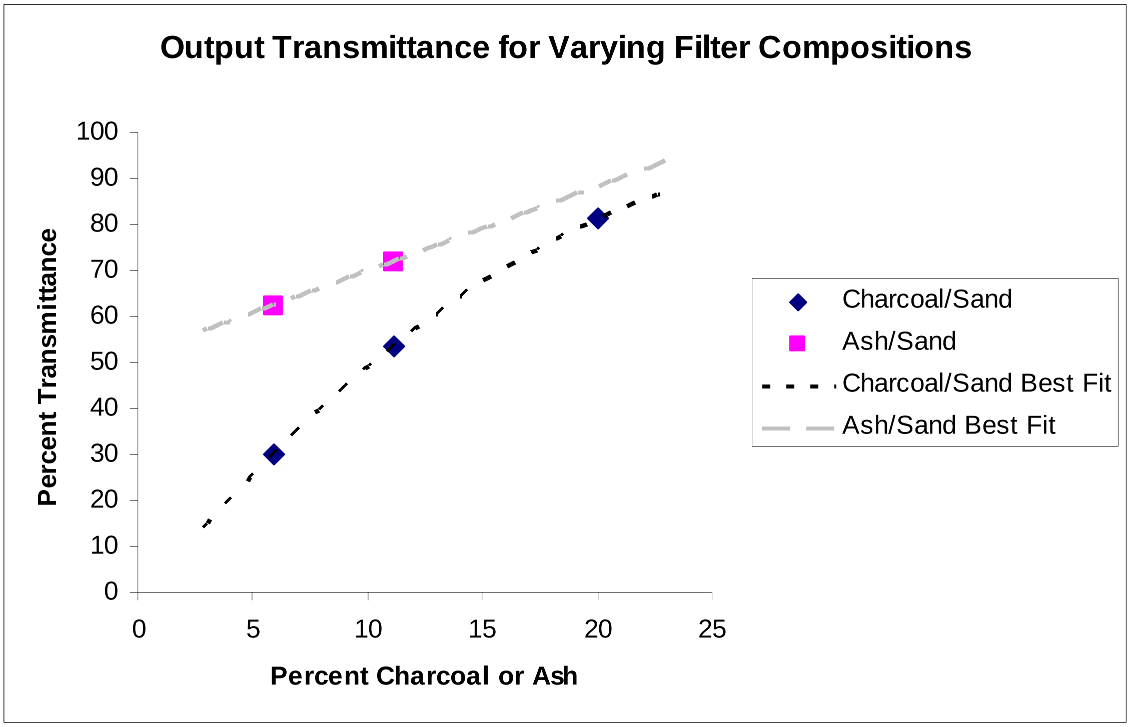
Optical Absorbance Measurements (283 nm)

	Still		Shaken		
	10/31/07	10/30/07	10/30/07	10/31/07	Time
Deionized water	0.000	0.000	0.000	0.000	
Input water	2.150	2.150	2.150	2.150	
1:4 C:S	0.088		0.091		4:25
1:8 C:S	0.258	0.205	0.273	0.209	5:30
1:16 C:S			0.526		4:20
1:8 A:S			0.143		>10:00
1:16 A:S			0.205		2:08

This data was collected in absorbance form. It was decided that the shaken samples were uniformly mixed and would therefore best represent filter performance, while the particles in the still samples could have settled out depending on the length of time that the sample had been at rest. The data taken from shaken samples on October 30, 2007, was complete and therefore was used to create the following chart plotting absorbance versus filter mix ratio.



The collected absorbance values were converted to percent transmittance values following the previously explained equations, and the filter mix ratio was converted into a percentage of additive to the sand, either ash or charcoal. A 1:4 volume ratio of ash:sand, for example, would contain 20% ash by volume and 80% sand. When these values are plotted, the following graph emerges.

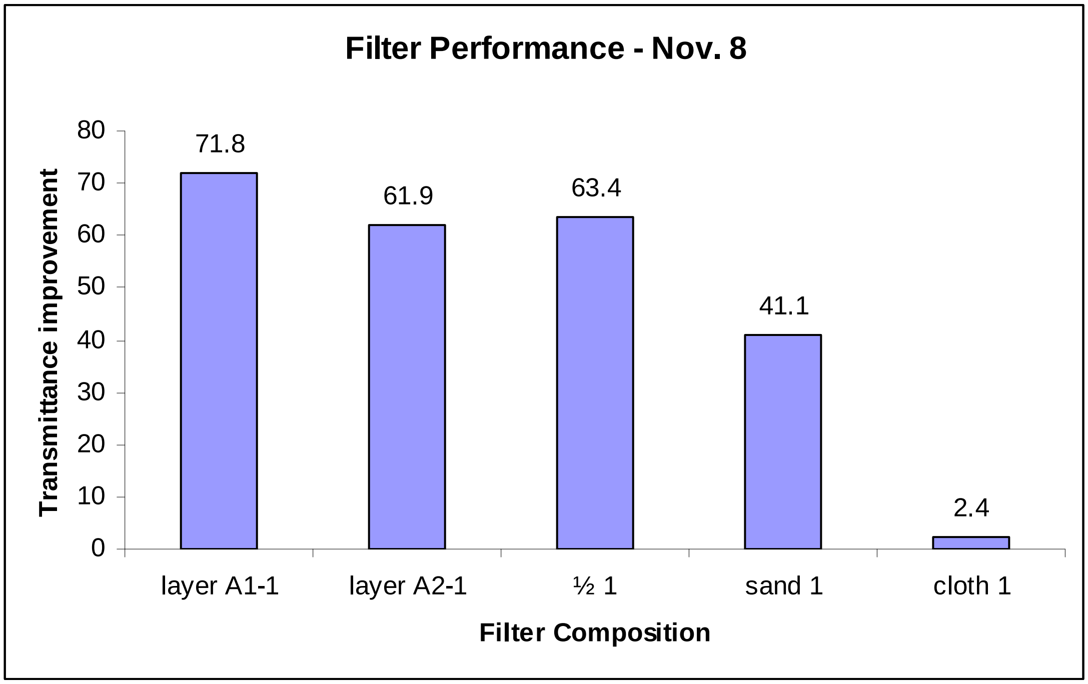


It can be seen that the charcoal/sand filter appears to asymptotically approach a maximum percent transmittance. This implies that if the percentage of charcoal were to be increased to 100%, the filter output would measure below 100% transmittance. Because only two points of data were collected for the ash/sand filter, an asymptotic curve could not be accurately created. However, it is expected that the ash/sand filter curve would exhibit similar characteristics.

Another round of testing was performed on November 8. 2007. During this round of testing, a new filter design was considered. Layered filters, in which the filter was made of different layers of varying media, were created to end the problem of charcoal dust passing through the filter to cloud the output water. Two different layer systems were tested along with a filter composed of one-half charcoal and one-half sand (½ 1) and filters composed of only sand and only cloth. The results were collected in absorbance and translated to transmittance improvement in the rightmost column shown below.

	A	T	%T	time (s)	%T{imp}
source	1.747	0.018	1.8		
layer A1-1	0.133	0.736	73.6	620	71.83
layer A2-1	0.196	0.637	63.7	856	61.89
source	2.150	0.007	0.7		
½ 1	0.19	0.641	64.1		63.41
sand 1	0.38	0.418	41.8		41.08
cloth 1	1.51	0.031	3.1		2.38

When the transmittance improvement values are plotted against filter composition on a standard bar chart, it is easier to see the relative efficacy of each filter. It can be seen that both of the layered filters and the half-and-half sand and charcoal filter perform similarly, beating the sand filter. The cloth filter barely increased the transmittance at all.



We found that the SODIS-recommended method of clarifying water involved cloth filtration after sedimentation, so we decided to further investigate the efficacy of this method. As described in the Research Methodology section, a turbid sample of water was prepared and allowed to sit and settle for 16 hours before being strained through a cloth, resulting in an increase of the transmittance from 0.05% to 16.41% as shown in the chart below.

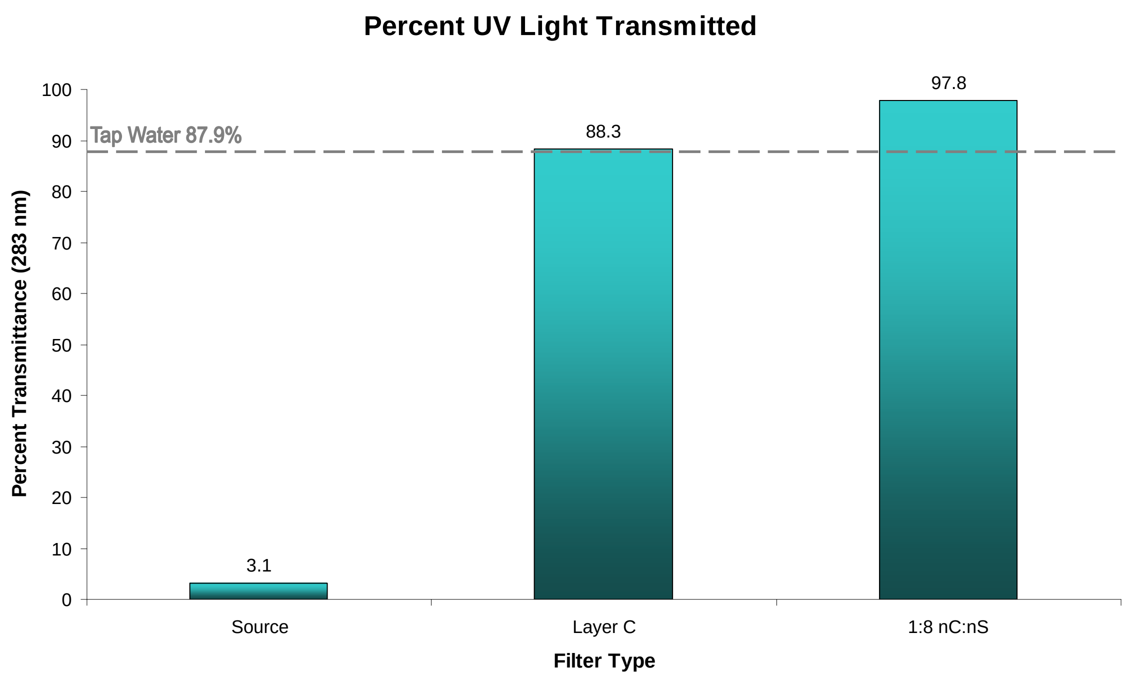
	A	%T	%T{imp}	Notes
Input	3.280	0.05		
Output 1	0.785	16.41	16.35	/w cloth after 16h
Output 2	0.810	15.49	15.44	after 24h

When another sample was taken after 24 hours without being strained through a cloth, the transmittance was 15.44%. The transmittance improvement values of 16.35 and 15.44 are low compared to the values achieved by our filtration apparatus.

Another round of tests utilizing finer sand obtained from Home Depot was begun on November 12, 2007 and continued through the thirteenth. It was quickly found that the purchased sand had considerable amounts of dirt that tended to degrade water quality through filtration. After this sand was washed, the following data was collected. Layer C consists of a top layer of 1:4 charcoal:sand over 4 parts of sand, which was mixed to yield the 1:8 charcoal:sand filter as described in the Research Methodology section.

	A{in}	A{out}	%T{in}	%T{out}	T improvement
New sand (unwashed)	1.51E+00	2.79E+00	3.09	0.16	-2.93
New sand (washed)	1.51E+00	1.54E-01	3.09	70.15	67.06
Layer C	2.86E+00	5.40E-02	0.14	88.31	88.17
1:8 Charcoal: New sand	2.86E+00	9.80E-03	0.14	97.77	97.63

The unwashed sand merely made the water more turbid, and the washed new sand did not significantly outperform previous test results. However, both the Layer C filter and the 1:8 charcoal:sand filter performed exceptionally well. We tested the transmittance of tap water obtained from Wishnick Hall and found it to be 87.9%, while the filtered water reached 88.3% and 97.8% transmittance, respectively. These results are shown below in a chart that graphically presents the gathered data.



Since it was observed that the 1:8 mixture of charcoal to sand performed best out of all tested filter media, we chose to proceed with this filter through durability tests with the small amount of time left in the semester for testing. This involved repeatedly passing turbid volumes of water through the same filter and measuring the filter effectiveness for each volume. Roughly 20 gallons of turbid water were filtered in four 5 gallon segments, each taking approximately 8 hours. The collected data is shown below.

Volume	Date	Time	A in	A out	%T in	%T out	%To-%Ti
1	11/15/07	04:15:00 PM	2.87E+00	3.31E-02	0.13	92.66	**92.53**
2	11/16/07	12:30:00 AM	3.47E+00	1.14E-02	0.03	97.41	**97.38**
3	11/16/07	11:30:00 AM	3.34E+00	1.51E-02	0.05	96.58	**96.54**
4	11/19/07	12:30:00 AM	2.95E+00	2.74E-02	0.11	93.89	**93.77**

It can be seen that over the four volumes of turbid input water, the filter effectiveness did not decrease substantially. It is surprising to see that the second filtration proved more effective than the first, most likely due to the sediment from the first filtration lodging in the pores of the filter media and slowing the second filtration volume, allowing more sedimentation. The final filtration took more than 24 hours, suggesting that filter replacement will be based upon flow rate and not upon filter effluent turbidity increasing.

Through this primary research, the IPRO team gained an intuitive understanding of filter types and their physical properties. We found that smaller filter media particles, such as finer sand or crushed charcoal, produced higher quality output water while sacrificing some of the filtration speed found with filters composed of larger particles. Furthermore, we found that filter materials interact when mixed. For example, sand has mixed capabilities to prevent charcoal, ash, or other additives from entering the output water, as does cloth and gravel to a certain extent. Since we found that charcoal plays an important role in drastically decreasing turbidity and increasing transmittance of the output samples, the capability of sand to retain charcoal in the filter and not leech it into the output water is essential to proper filter performance.

This filter may find use in clarifying murky stream or lake water to allow the SODIS solar water disinfection method to find more widespread use, potentially providing great health benefits to those that are currently forced to consume tainted water that cannot currently be treated by the SODIS method. Though we are happy with the progress made this semester, future team members could improve upon this research by gathering more comprehensive data and also by researching implementation methods and strategies to maximize adoption and benefits to users without impinging upon their culture and traditions. Further recommendations are detailed in the Recommendations section of this report.

0.8 Recommendations

There are a handful of recommendations that can be made to the next semester's IPRO team. Even though this semester's research was extremely successful in identifying an effective water filter that could be made inexpensively from locally available materials, more research is needed on different filter compositions and their effect on filtration characteristics. This research must be combined with specific knowledge of the available water quality at potential implementation sites. Also, close cooperation with the SODIS organization is needed, and much more research on implementation methods and locations is required.

Testing of different filter column heights with different sand/charcoal compositions, both for single use and prolonged use, would be extremely beneficial. As found in the Results section of this paper, the filter we developed this semester initially requires approximately 8 hours per 20 liters, but soon requires more than 24 hours as the filter becomes clogged with sediment from the turbid input water. Our filter also produces extremely clear water, but the SODIS method may not require water of that clarity, and some water quality may be sacrificed for speed of filtration or durability over repeated filtrations. This might be accomplished by reducing the filter column height, reducing the amount of charcoal mixed in with the sand to form the filter media, or by the addition of another material such as gravel, straw, or other plant material to the filter column. Though our method currently seeks to improve local water clarity to allow application of the SODIS solar water disinfection process, it would also be beneficial to determine the capability of similar filtration to remove pathogenic bacteria, possibly negating the need for a disinfection step following filtration.

Once this data is collected, it may be analyzed to create an equation relating filter performance, in terms of output water quality and output rate, to filter composition and input water quality. This way, an optimum filter composition can be quickly and easily chosen based upon a short look at the local water. Knowledge of the local water quality may be obtained directly, through the physical gathering and testing of samples by the IPRO team, or secondarily, by close communication with health- or environmental-related groups working in locations that might benefit from the filtration-assisted SODIS method. Furthermore, close cooperation with SODIS will allow us to obtain better knowledge of the requirements of SODIS. Primarily, we know that the SODIS method requires water of a certain clarity (28 nephelometric turbidity units [NTU]), but we are currently unaware of a specific relation of these NTU units to commonly used absorbance and transmittance values.

Finally, and perhaps most importantly, the future IPRO team must work to determine the best method and strategy to implement this water filtration method where it will provide the most benefits. Many organizations seek to provide aid to those living in poor rural areas, but each organization practices a different strategy and follows a different code of ethics. For example, the SODIS organization seeks to gain the trust of the village leaders before implementing their solution, but does not wish to change the culture of those they are helping. On the other hand, missionary groups often provide aid but sometimes seek to catalyze the shedding of old traditions and the adoption of a new culture. The current code of ethics states that we do not wish to change the culture of those that we wish to benefit. Following a thoughtful code of ethics, the future IPRO team must develop an implementation strategy. Possible deliverables include a strategic plan, a manual for those implementing the method, a culturally-sensitive pictorial manual for third-world rural inhabitants that benefit from the filter, and standardized surveys to determine the water consumption habits of those we wish to target. Contacting several experienced humanitarian aid organizations will undoubtedly be of great benefit to the future IPRO team. The future focus of the water purification segment of this IPRO should be based squarely on implementation, a goal that must be shared by all IPROs that wish to affect a positive impact on the developing world.

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Energy Subgroup

0.2 Background

The most significant source of indoor air pollution in poor countries is smoke from the burning of low cost biomass fuels in inefficient stoves or open fires. According to the World Health Organization, indoor air pollution is one of the most severe global environmental risks, and is estimated to cause 1.6 million premature deaths each year. There is now strong evidence to support a link between indoor air pollution and health, particularly respiratory diseases; increasing evidence suggests links with cataracts, TB, asthma, and possibly low birth weight and heart diseases. Indoor air pollution is strongly linked to poverty as it is the rural poor who rely on lower-grade fuels and do not have access to clean technologies for cooking and lighting. These inefficient practices also have other consequences, including contributing to deforestation and causing people to spend a significant portion of their time gathering fuel. Estimating the costs of these consequences is very difficult, but improving cooking efficiencies will certainly offer the opportunity for a higher standard of living.

In response to these global health and environmental problems, improved stove technologies have been developed. We are attempting to develop affordable solutions that can be implemented by the local populace. High-efficiency cook stoves that burn less charcoal and other biomass provide tremendous socioeconomic, environmental, and health benefits to stove users and their communities. Our improved stoves will be incredibly fuel-efficient, helping families save on energy costs. The use of these stoves will also slow the rate of deforestation by reducing the consumption of charcoal and wood.

There are currently locations in India, China, and South America that are using improved stove technologies both solar and conventional. High-efficiency cook stoves and solar ovens provide tremendous socioeconomic, environmental, and health benefits to stove users and their communities. High-efficiency stoves reduce the amount of wood, charcoal, or kerosene needed to cook. Solar ovens use a combination of strategies to cook food. These include converting light to heat, concentrating sunlight, and/or trapping heat. If the poor had access to these technologies, they could use free fuel (solar energy) when available, and use a high-efficiency stove otherwise. The resultant reduction in the consumption of wood and charcoal would help slow deforestation, reduce the amount of time spent gathering fuel, and extend the life-span of those involved. These new technologies have been found to be more fuel-efficient and release fewer harmful pollutants. However, much work is still needed to determine their effectiveness under the tough environments often found in developing countries.

The sub-group has identified two different types of cookers; solar oven cooker and conventional rocket stove. Solar cookers use the sun's energy focused as heat while conventional cookers use biomass fuels, such as wood, charcoal, and kerosene. An extensive archive of solar projects can be found at www.solarcooking.org. One of the most successful of these ventures has been the implementation of the CooKit solar oven by a volunteer group associated with the Solar Cookers International. Projects such as these have achieved positive results around the world. However, there is still more that can be done.

The main constraints encountered during this project were encountered during the design phase, and are listed in section 6.0 Obstacles.

Implementation of our developed prototypes will begin January 2008 when students from our project team will be traveling to Nicaragua to begin field testing.

0.3 Purpose

Our objective was to develop a low-cost, energy-efficient cooking stove that would help eliminate air toxins associated with open-fire cooking, the leading method of preparing food for the world's rural poor. While there is a vast amount of research currently dedicated to the advancement of solar cooking and a renewed interest in conventional stove cooking, an affordable solution is yet to exist which is the primary reason for our team's decision to further pursue this project. By using the previous semester's research and prototype designs as a starting point, we hoped to expand the team's knowledge of not only solar cookers, but all cooking methods available to the poor in order to allow for more implementation opportunities.

The initial goals the team set for the semester were to further research and document cooking methods, design and develop both a conventional stove and a solar oven, test and improve the prototypes in three cycles, find sponsor organization, and make recommendations for implementation steps for future semesters. As the semester progressed and the reality of the scope of the problem became realized, our subgroup was forced to reassess our original goals. Thus, the subgroup identified the semester goals to be further research, design and test prototype and create in-depth documentation for future semesters to conduct improvements.

Constraints to the projects, set by the initial IPRO 325 team in fall 2006 and continued throughout this semester, include creating solutions that remain within a $5 spending limit and can be sustained by the local populace. These constraints, we believe, are critical to the success of the projects because too often "solutions" are either too expensive for the local populace to purchase without the aid outside donors or are too complex to be fixed and maintained without outside specialists, therefore, leaving many villages with unfulfilled promises of an improved livelihood.

0.4 Research Methodology

The problem faced is that much of the world's population lives in rural and underdeveloped areas lacking adequate living conditions—largely clean water, efficient cooking methods, and sufficient shelter. People of these areas are in need of affordable solutions to allow them to obtain and sustain healthy lives.

To combat this problem the Energy Subgroup focused on improving the efficiency of stoves and the methods to implement them in Nicaragua as well as the Deserts of China. The subgroup researched current stoves designs, both those used by people in rural areas, as well as, stoves that are commercially available in order to develop a method of creating a stove that is as, if not more, efficient and utilizes local building materials. Several models were built and tested against the commercially available models to judge success. We were then able to make an informed decision into how we, at IIT, can implement the prototype designs in the field. Our process throughout the semester is as follows:

1. Identified specific locations for future implementation to focus our stove designs and design materials.
    1. Nicaragua
    2. Southwest China

2. Discussed and planned project course as a whole group to better understand the problem to be solved.

3. Familiarized with the previous research done during the preceding semester on solar ovens and broaden the scope to stoves that uses conventional fuel.
    1. All researched information was collected, documented and archived in the Engineering Notebook, as well as in designated folders on iGroups to provide easy access for current and future IPRO. Research was done based on the following criteria:
        i. Advantages and disadvantages of solar and conventional cooking
        ii. Existing designs for solar and conventional cooking
        iii. Past and present projects involving solar and conventional cooking
        iv. Geographical and social factors related to solar and conventional cooking

4. Gathered and presented individual research in order to select solutions on which to develop and introduce into the said region, based on the following criteria:
    1. Highest level of cooking efficiency
    2. Lowest level of CO2 pollution
    3. Affordability
    4. Ability to be prototyped by student group
    5. Ease of local production
    6. Ease of local material usage
    7. Ability to be implemented by student group

5. Obtained commercial stoves as benchmarks to:
    1. Test
    2. Reverse engineering

6. Designed and built stove prototypes based on done research to maximize efficiency. Three stoves are built:
    1. Clay core stove with wood as fuel
    2. Metal core stove with wood as fuel
    3. Parabolic umbrella solar cooker

7. Tested the three prototypes in determining if efficiency can surpass commercial stoves.
    1. Qualitative and quantitative testing results were compared.
    2. All testing data was collected, documented and archived in the Engineering Notebook, as well as in designated folders on iGroups to provide easy access for current and future IPRO.

8. Completed final deliverables with summarized details in research, design and testing done during this project.
    1. Final report
    2. Final presentation
    3. Final prototype designs

9. Determine the "next steps" for future IPRO group

0.5 Assignments

Team Members

Name	Major	Skills	Interests
Aubry, Curtis	Architectural	HVAC Analysis, AutoCAD,	Alternative materials for construction and sustainable

		Photoshop, MS Office	energy
Dogbe, Ernest	Electrical	MS Office, MATLAB, Pspice, C++.	Affordable renewable energy for use in developing countries.
McClain, Jaime	Architecture	Microsoft Office, AutoCAD, 3D Max, Photoshop, Illustrator	Creating affordable solutions for use in developing courtiers. Micro-enterprising and micro-loans.
Przybysz, Nicholas	Mechanical	Microsoft Office, AutoCAD, Pro Engineer, Matlab, some programming.	Creating the most efficient energy for the least amount of fuel
Seagren, Ian	Electrical	MATLAB, RET screen, MS Office, Pspice, Java, Assembly	Power electronics, sustainable energy & development, communications & economy
Shi, Heling	Mechanical	SolidWorks, Microsoft Office, Photoshop, iWork, iLife, basic	Mechanical and thermal design of energy infrastructures and/or appliances

Team Responsibilities:

1. Identify cooking problems in rural impoverished areas of the world
2. Conduct extensive research into existing solutions, programs, and outreach
3. Identify target area and local populace
4. Develop and test a prototype that addresses need for efficient and sustainable cooking methods
5. Make recommendations for future semesters
6. Send group of students to field test in Nicaragua and bring back information to team

Individual Member Responsibilities:

Name	Role	Task Group	Tasks
Aubry, Curtis	iGroup Organizer Engineering Notebook	Conventional Oven	Testing Procedures, Midterm Presenter Prototype building, Design of Metal Rocket Stove Testing cycles 1-3, Abstract, Final Report recommendations, IPRO Day presenter
Dogbe, Ernest	Ethics Organizer	Solar Oven Code of Ethics Location	Research box solar cookers and testing standards Testing, Materials Collecting, Box Solar Oven design Code of Ethics
			Carried out experiments on commercial solar oven and on solar prototype
McClain, Jaime	Team Leader Subgroup Leader	Conventional Oven Location Interest Group	Contact w/ P.Land, Alternative Rocket Design Oven Research, Midterm Presenter Materials collection, Prototype testing cycles 2-3, Overseer of all IPRO Day deliverables, Final Report Purpose and Assignments, IPRO Day presenter
Przybysz, Nicholas	Team Member	Conventional Oven Project Management	Testing Facilities; contact w/ Mast Location Specific Research, Terracotta Prototype building and design, Testing Cycles 1-3, Testing results, Final Report coordinator, IPRO Day presenter, Engineering Notebook entries
Seagren, Ian	Subgroup Co-Leader	Solar Oven	Sub-group co-leader, solar cooker development Studied engineering notebook done by Spring 07 IPRO Researched parabolic solar cookers and testing standards
			Participated in the design and

			construction of parabolic umbrella solar cooker
Shi, Heling	Engineering Notebook Organizer, Meeting Minute taker	Solar Oven Location Interest Group	Location research, prototype building Parabolic Design and build, contact w/ CSA Notebook meetings with Advisor Team meeting minute taker Participated in the design and construction of parabolic umbrella solar cooker

0.6 Obstacles

We faced quite a number of obstacles throughout the project; this problem would not be a pressing issue if obstacles did not exist. Among these obstacles were a $5 USD total cost constraint, difficulty acquiring testing equipment, finding a suitable method of simulating sunlight, and addressing the high cost of implementation.

In addressing the $5 USD constraint, we used materials that were cheap and easily available. We seek to use materials that could easily be obtained in locations worldwide, such as clay. Other easily obtainable materials are garbage. In further semesters, more location specific research should be done to ensure the materials and construction methods will be effective in the implementation locations.

In addressing the difficulty of acquiring testing equipment, we were able to acquire testing equipment from the university. We also used our own money to buy light bulbs, cardboard, aluminum sheets and other tools. More research has to be conducted into reflective surfaces. A highly reflective surface would improve our results tremendously. Additionally, work should be done early in the project planning phase to identify the necessary equipment for testing. Testing equipment should be acquired early to avoid scheduling conflicts and other inconveniences. Testing locations were also difficult to secure. We were not able to obtain a location to test the stoves indoors to simulate conditions in rural villages, so testing had to be done outside. The MMAE department also had limited testing equipment. The team constantly needed thermocouples to test temperatures, but only two were available for use.

When the commercial rocket stove was ordered, it took longer than anticipated for the product to arrive. This delayed reverse engineering as well as actual testing. With the delay in testing the testing procedure for the stoves was not fine tuned and it took several sessions of experimentation to figure out the ideal testing parameters.

Sponsors have been found to assist in covering the high implementation cost. An anonymous donor has offered to match funds raised by IIT students. The challenge with this is a team of 3 students will be going to Nicaragua and 1 student to Peru in January of 2008, which does not offer much time for fund raising. To alleviate this stress, the group of students participating in implementation is focusing on soliciting funds from university departments and private donors.

Throughout the semester different obstacles emerged and were addressed appropriately. The first major obstacle in our group was a difference in work ethics values. Many group members believed that being on time and showing up was very important and also keeping up with ones responsibilities when assigned tasks. Our team rapidly addressed this issue during regular meeting and established importance to several aspects of work ethics.

Time was always an issue within the groups. As more and more research takes place, the different groups begin to realize that they do not have the time to undertake all of the ideas they originally planned. To fix the problem the group had to meet and discuss the areas of the project that were most vital and needed the time allocated. Groups focused on tackling the initial problem and leaving the problem in a state that could be taken over and improved upon in the following semesters. Scheduling times to meet and test was also an issue within the Energy subgroup. Many students had classes and other commitments that had to be worked around to make time for testing.

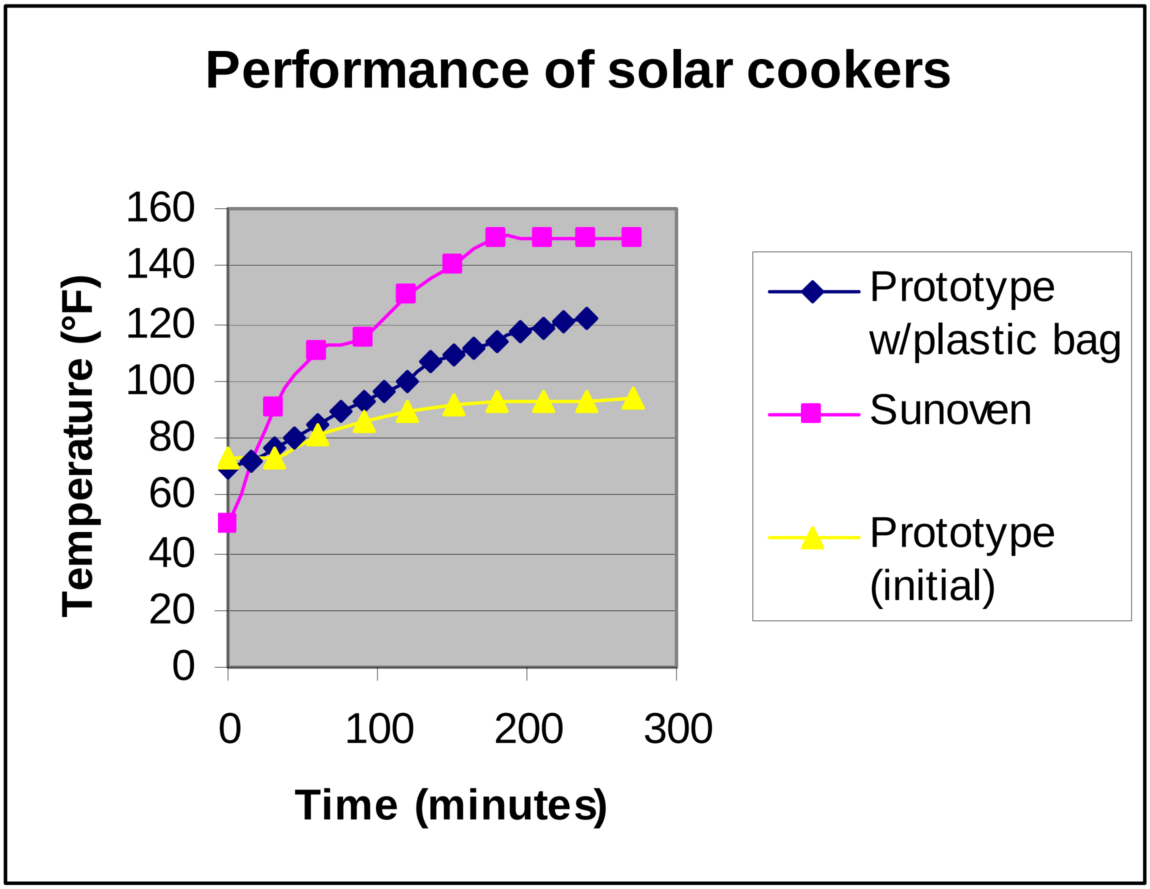
0.7 Results

Solar

Our testing procedure was based on the standard set by the American Society of Agricultural Engineers. This standard provides a uniform and consistent measure of solar cooker performance. For our benchmark of performance, we used the Sunoven. This is a commercially available box style solar oven that was obtained by the IPRO team from last semester for a discounted rate of $160. In their tests, the Sunoven achieved a maximum temperature of 320 degrees Fahrenheit, which is about 90 degrees above the necessary temperature needed for cooking.

Our first goal was to test the Sunoven outdoors, to see if we could achieve results similar to last semester's team. During our first test, the Sunoven only reached a maximum temperature of 250°F. We waited a few days and then ran another test. This time the maximum temperature obtained was only 200°F. It became clear that we were not going to be able to test outside, as it was October, and the outdoor temperatures would only continue to drop. We had to make an adjustment, and we decided to try and test indoors.

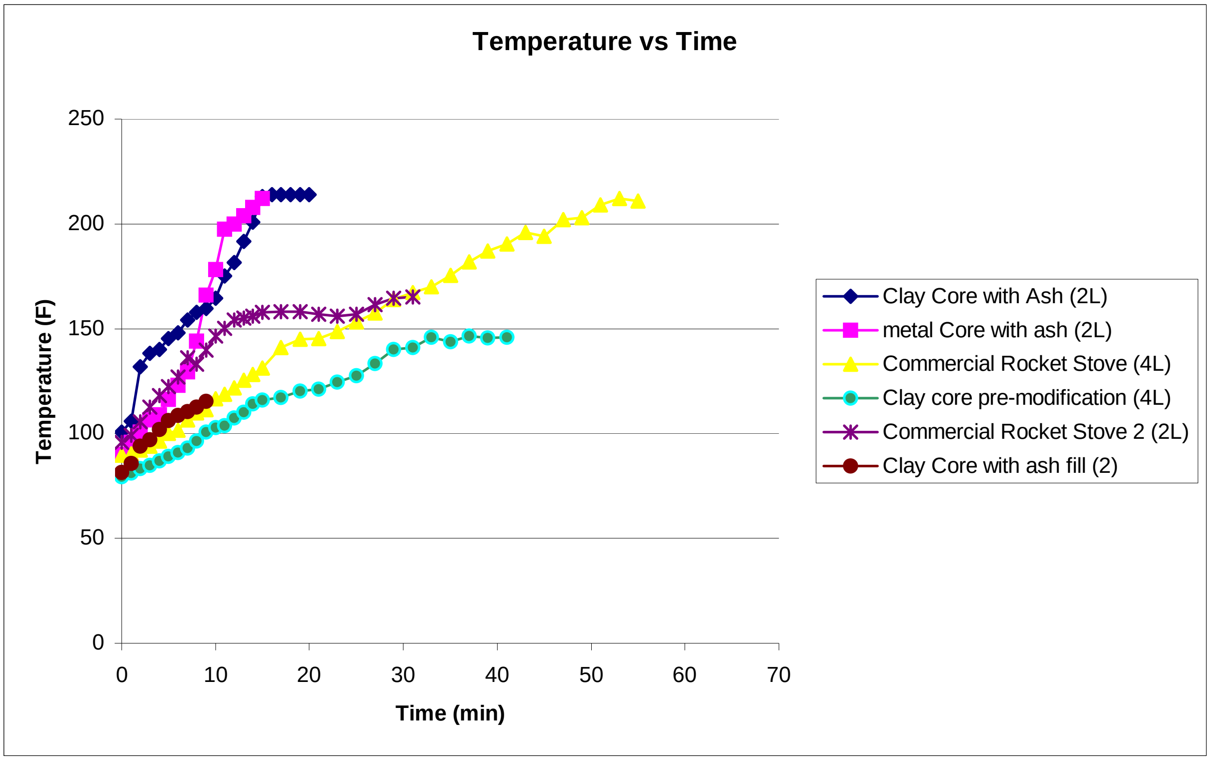
When testing outdoors, variables such as wind speed, time of day, and cloud cover must be taken into account. When we moved the tests indoors, we were able to eliminate these uncontrollable weather variables. This allowed us to only be concerned with the following variables: time, amount of water in pot (6 cups), ambient temperature (72°F), and water temperature. During the initial indoor tests, we focused on testing the benchmark. For our first indoor test, we used a sunlamp to simulate sunlight. This did not work at all, as the temperature of the Sunoven did not even rise above the ambient over the course of four hours. Upon investigation, we learned that these lamps replicate the visible light spectrum, but do not produce much heat. We brainstormed to try to think of a way to replicate outdoor conditions, and came up with the idea of using reptile tank lighting. For our first attempt, we used a 250W bulb. The result was a disappointing maximum temperature of 110°F. We then added a second 250W bulb, and achieved a maximum temperature of 150°F. It was clear that adding more bulbs was not going to greatly improve the situation. At this point, we decided that we needed to start testing the prototype. We used the same 2-250W bulb setup, and we were hoping to get a maximum temperature close to 150°F, since that's what the Sunoven achieved in the same environment. Our first test on the prototype only yielded a maximum temperature of 93.5°F. This was disappointing, since this was only 20°F above the ambient. To try to improve the situation, we enclosed the pot in a plastic cooking bag. The results were much better, reaching a maximum temperature of 121°F.



The results of the final test were encouraging, as the maximum temperature of our prototype was over 80% that of the Sunoven. If we could obtain a similar relationship outdoors, it is possible that our prototype could reach a temperature of about 250°F. This would be hot enough to cook food. Outdoor tests need to be run on our prototype though before such a claim could be confidently made. The results of our tests are promising, and our design would cost significantly less than the Sunoven. If a discarded umbrella and cardboard are used, then the cost is only about $4-5 per unit. It is our hope that further work will improve the design.

Stoves

Research conducted determined that the most effective stove we could create out of local materials would be a rocket stove. This stove utilizes the fuel in a more efficient manner and decreases the amount of air pollution in the process. Two different designs were developed out of materials that could be found locally as scrap or for free from the earth. One design uses clay bricks to create a chamber for the fire to flow, while the other uses cans that could be found leftover from food. Both of these designs were tested against a commercially purchased rocket stove as well as the simple three stone open fire. The graph below illustrates the results of our testing.



The table below gives detailed information on each test and the amount of wood used.

Stove	Water volume (L)	Volume Wood[m^3]	Mass wood (kg)	Energy (MJ)	Max Temp (F)	Max Temp (C)
Metal core with ash fill	2	0.0008	0.4389	8.1191	225.0000	107.2000
Clay core with ash fill	2	0.0006	0.3292	6.0893	214.0000	101.1100
Commercial Rocket Test 2	2	0.0004	0.2194	4.0595	165.0000	73.8000
Clay core with ash fill test 2	2	0.0005	0.2743	5.0744	115.5000	46.3800
Commercial Rocket Test 1	4	0.0006	0.3024	5.5952	212.0000	100.0000
Clay Rocket original	4	0.0008	0.4179	7.7000	146.6000	63.6000

As seen from the graph, both of the rocket stove prototypes preformed very efficiently, as the brought 2L of water to boil in approximately 15 minutes. The commercial rocket stove is smaller than the IIT designs, so has a harder time bringing the water to a boil within the same time period, but does use less fuel. There is an choice that must be made, should less fuel be used to achieve a boil, or a quick boil with more fuel.

When attempting to test the open fire, weather conditions were unfavorable and a suitable fire was not able to be kept. As seen from the table and the graph, the second tests with the commercial stove and the clay stove were also done under the same weather conditions. A combination of damp wood and strong winds did not allow the stoves to reach boiling and each stove went out several times during the test. Had the wood been dryer, it is believed that more favorable results could have been reached as in earlier tests.

Stove	CO2 level [ppm]
Metal core with ash fill	600
Clay core with ash fill	500
Commercial Rocket Test 2	800
Clay core with ash fill test 2	1000
Commercial Rocket Test 1	Maxed reader
Clay Rocket original	inconclusive

The table above give the CO_2 readings in parts per million for each test. For the first two tests the operators were still learning how to use the readers and where the best placement was to take the readings. On the subsequent tests, the CO_2 was taken from about a foot away and level with the escaping gasses of the stove. These numbers are acceptable values for cooking. However, these are for outdoor readings, so the results could be drastically different if taken indoors. No facilities were available to test this hypothesis however. Overall these tests illustrate illustrates that our designs work efficiently and provide a feasible solutions to our problem.

0.8 Recommendations

Based off on the research and development of the solar prototype, the energy sub-group recommends that subsequent teams continue to explore and enhance the current design. The efficiency of the Sunbrella can be improved significantly given the time and resources. More research has to be conducted into reflective surfaces. A highly reflective surface would improve our results tremendously The current prototype could be served as a framework design for the future IPRO. However, different types of reflective surfaces could be tried out to lower the cost of production and increase the efficiency of the cooker. Additionally, due to a number of unfavorable testing factors, i.e., weather and outdoor temperature constraints, the prototype was tested indoor with a high-wattage lamp simulating the sunlight. The same indoor testing configuration was used for the commercial benchmark, which was also unable to reach the target temperature. Further testing in outdoor environments is needed to further validate the efficiency of the prototype.

The rocket stoves could become more efficient if for the metal core stove a pot skirt is used. This addition would allow hot air to flow up the side of the pot as well which would better utilize the heat that is emitted and therefore more efficiently bring the water to a boil.
The testing procedure for the rocket stoves could be greatly improved to gain more accurate results. The boiling test works fine to show that the stove works, but health wise the tests are not certain. We used a syringe to draw air which was then fed through a testing tube to gain the parts per million of CO_2 particles. All testing was done outdoors. This is not always going to be the case for families in rural areas. They may be cooking indoors, so a better method of testing the stoves is needed to gain more accurate results in this situation. A hood could be used to accurately record and collect all of the particulates that are emitted during the testing to gain a more accurate result of the effectiveness of the IIT stoves.

Future goals for both the solar and the conventional stoves consist of developing easy to understand instructions or manuals. These manuals should be detailed enough to give the viewer a clear understanding of what needs to be done, yet must be extremely simple as it will need to be implemented in various regions. For this to work, it should contain no text and only pictures.

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0.10 Acknowledgments

We would also like to thank the instructors Prof. Ferguson, Prof. Braband, and Prof. Schug for helping to open our eyes to the inequity in the distribution of wealth across the world, and uniting us in a cause to create lasting change, great or small.

Shelter Subgroup

0.2 Background

According to the World Health Organization (WHO), 792 million people around the world suffer from malnourishment. Five million children die every year because of malnutrition. Malnutrition is a general term which indicates a lack of some or all nutritional elements necessary for human health. It is dividend into two basic types: protein-energy malnutrition (which can result in starvation) and micronutrient malnutrition (not having enough of the trace vitamin and minerals needed for proper functioning). The WHO estimates that one out of three people in developing countries suffer from micronutrient malnutrition. It is caused by an imbalanced diet, usually lacking in fruits and vegetables. Crops such as tomatoes, mangoes, pears, bananas, and papayas, which provide necessary nutrients not found in the more common cereal crops, often rot before they can be eaten.

It is estimated that twenty percent of after-harvest losses in fruit and vegetables occur during storage. Losses during storage are directly related to temperature and relative humidity. The prevailing high temperature in tropical countries not only hastens all the physiological activities such as respiration, transpiration, and ripening of fresh produce, but also affects the chemical composition eventually leading to spoilage. The favorable environment for storage of fruits and vegetables is low temperature and high humidity due to their high moisture contents. The problem can easily be solved using modern refrigeration technology. However, rural cultures and communities in developing countries do not have electricity delivered to their villages and cannot afford to generate their own electricity due to high initial costs. In Nicaragua over fifty-two percent of the population has no access to electricity. However, evaporative cooling is an easy and inexpensive system that can be used to lower temperatures for food storage.

Refrigeration systems already exist that work on the base idea of evaporative cooling. The biggest constraint of using evaporative cooling as a means for "refrigeration" is the location and climate. The preferred climate is dry, with little humidity, hot, and low elevation. If the surrounding climate is too humid or too cold, the water will not evaporate.

In Nigeria, the Zeer Pot is being implemented. It is simply a pot inside another pot with sand in the gap between them. Water is poured into the sand and as it evaporates, it cools whatever is inside it. Studies show that evaporative cooling systems can keep certain foods up to fourteen days longer than just leaving them in the sun. Other designs that are currently being used in poor countries are the Bamboo Cooler, the Almirah Cooler, Charcoal Cooler, and the Naya Cellar Storage. All projects are similar in the fact that they use evaporative cooling to the keep the contents inside fresh for longer periods of time. In some areas it is possible to use the same system on a larger scale, which is the aim of our project. We have made a larger, fixed refrigerator using a layer of adobe bricks and a clay pot, with wet sand in the gap. The idea is primarily based off the work done by the Indian Agricultural Research Institute that has developed the Static Cooling Chamber that can be made in any part of India from local materials.

Although these refrigeration systems are already used in different areas around the world, they have not been implemented in all the places where they could help the local population. For our project, we are focusing on Nicaragua and southwest China, both areas with a hot, dry climate for at least part of the year. The crops in these areas are mostly cereals which do not need refrigeration but do not provide enough nutrition. Other crops, which could be used to supplement the cereals, are planted in small quantities because of their short shelf life. With added refrigeration, these crops could become an important part in eliminating malnutrition in these areas.

0.3 Purpose

The purpose of the cooling subgroup is to create an evaporative cooling refrigeration system that can help the rural poor store fruits and vegetables, and thereby help combat micronutrient malnutrition.

The original objective of the IPRO 325 cooling subgroup was to develop and implement a more effective and efficient way for the world's poor to store food. Our primary objective was to create a working prototype of an evaporative cooling refrigeration system that can successfully store food for a longer period of time using all local materials from the region which we are targeting. Our secondary objective was to design a manual explaining the benefits of our system as well as how to use and assemble it.

Throughout this semester, we accomplished our primary objective. We have created a working prototype of an evaporative cooling refrigeration system and have begun extensive testing on it. The system is built entirely out materials that are easily available in both China and Nicaragua and, for the populations in those areas, available at almost no cost.

The tests were designed to test the humidity and temperature difference inside our refrigerator and the outside air. Due to time constraints we did not have a chance to test using actual fruit, but hope the task will be continued next semester.

During the semester we realized that for many of the tasks (especially those involving the construction of clay pots) we had grossly underestimated the amount of time and resources these tasks would take us. As a result, we had much less time for testing than originally planned. Also, the making of an instruction manual (our second objective) has been pushed back to next semester. A plan for suggested future tests and improvements is also provide for future semesters.

0.4 Research Methodology

Theory explanation: What is evaporative cooling?

Evaporative cooling refers to the reduction in air temperature that occurs when water evaporates. Latent heat is the energy required to change matter from one state to another. In this application, it refers to the amount of heat need for water to change from a liquid into a gas. This heat comes from the liquid itself and the surrounding gas and surfaces. When a liquid evaporates, it can cool an object or a liquid in contact with it.

A simple example of evaporative cooling would be when the body sweats in order to cool down its own temperature. Whenever dry air passes over water, some of the water will be absorbed into the air. This is why evaporative cooling naturally occurs near waterfalls, at rivers, lakes and oceans. The hotter and drier the air is, the more water can be absorbed. This happens because the temperature and the vapor pressure of the water and the air attempt to equalize. Liquid water molecules become gas in the dry air, a process that uses energy to change the physical state. Heat moves from the higher temperature of the air to the lower temperature of the water. As a result, the air is cooler. Eventually the air becomes saturated, unable to hold more water, and evaporation ceases.

0.5 Assignments

Design

The adobe prototype was designed largely as a result of material requirements. Adobe was an excellent choice because of it's near universal availability and thermal properties. The downside of using adobe was the massive size requirements. There were three major factors which determined the size of the brick and, in turn, determined the size of the prototype.

First, a relatively thin wall provides ample insulation. It was our hypothesis that keeping the heat out would produce a cumulative cooling effect preferable to constantly fighting the heat. Second, even when waterproofed, adobe is susceptible to long-term water damage. A wall must be thick enough to resist standing water with as little maintenance as possible. Finally, individual adobe bricks must be large enough to keep their structural integrity through the curing process. Based on our research, a brick need to be four inches by eight inches by sixteen inches (10cm x 20cm x 40cm).

Once the brick was sized, the design of the unit became a matter of module rather than speculation. When properly bonded, the prototype could have an interior dimension of eight inches by eight inches, twenty-four inches by twenty-four inches, forty inches by forty inches, and so on in sixteen inch increments. An interior of twenty-four inches and exterior of forty inches was the most practical option. Professor Peter Land worked with us to overcome several key adobe-related logistical problems.

The size requirements would make it very difficult for a team of our size to build a two-layered, fixed brick system. Besides the physical limitations, we wanted to try to work with a new system, combining ideas from different existing precedents. Therefore, we decided to try a design containing a large terra cotta pot inside the adobe chamber. This was also advantageous as it facilitated a flexible testing schedule.

Testing

We have completed various tests which have proved that the system we are trying to create actually works. Our second major focus was to test and find ways to make this system more efficient. We were testing for three different things with the adobe construction: the ratio of volume of pot being cooled vs. surface area of sand exposed to sun, the ratio of surface area of the pot in contact with the sand vs. the surface area of sand exposed to sun, and the shape of pots.

Before we could run any of our tests, however, we had to create a controlled environment for testing in order to obtain a similar temperature and humidity as our target regions. To do this, we created a containment center in which we controlled the temperature and humidity. All the tests we conducted were conducted for an eight hour duration.

Analysis

To analyze our results, we compared the data to our benchmark, which was the zeer pot system. The two categories of analysis that we concentrated on were the shape of pots and the ratio of volume of pot being cooled vs. surface area of sand exposed to sun.

To do this analysis, we compared the seventeen inch by seventeen inch square pot to the nine inch by nine inch square pot. Similarly, we compared the nine inch diameter pot to the fourteen inch diameter pot. In both cases we found fairly similar results. We found that the cooling done in the small size pots was more than the cooling done in the larger pots. Therefore, we figured out that less volume being cooled and more sand being exposed leads to more cooling taking place.

Also, we compared the nine inch by nine inch square pot to the nine inch diameter pot and found that the cooling done in the nine inch diameter was less than the cooling done in the nine inch by nine inch square pot. Therefore, we figured out that the square pots were more effective for cooling than the cylindrical pots.

Individual Task Assignment

Name	Role	Tasks
Eliza Bober	Location Subgroup and Minute Taker	Worked with the location subgroup to help identify possible locations for implementation purposes, and took minutes for class meetings
Shreyas Dole	Testing and analysis specialist	Designed and setup the format of experiments for testing
Amber Heinz	Team Co-Leader	Also our Terracotta Liaison and worked with Steve Stanard on the pottery part of our project
Phil Korol	Construction Manager	Designed our testing enclosure and adobe forms
Bryan Murillo	Notebook keeper	In charge of Engineering Notebook
John Sullivan	Team Co-Leader	Also our Adobe Liaison and worked with Prof. Land in making sure we go the right while making adobe bricks

0.6 Obstacles

Our main obstacle was that we as a group were far less acquainted with adobe and terra cotta (clay) than the people we are trying to help. While this is not an obstacle for the people of our site, it became a huge obstacle in the development of our prototype. The adobe making process went very smoothly and successfully, but the clay pot inserts became very difficult, taking much more time and money to create than we had estimated. The extra time needed to make clay pots delayed our testing procedure a bit, but we were still able to do the most important tests in time.

We also ran into some issues during our testing process. The equipment we used to simulate our site's climate created very humid conditions that caused damage to our surge protector. Because of this, some of our earlier tests had to be discarded. Nonetheless, we were able to continue with testing after the problem was fixed.

0.7 Results

Our subgroup for IPRO 325 was able to successfully design, construct, and test a working prototype for an evaporative cooling refrigeration system. We were able to design a structure that was made out of materials that would be local to the poor that we are trying to help, and we feel that it would be able to be built and sustained by them with proper instruction.

After successfully simulating an environment similar to the areas we are focusing on, we ran several tests using varying sizes and shapes of pots within our adobe structure, as well as tests with a pot in pot system. Our tests yielded an average temperature drop between ten and fourteen degrees Fahrenheit inside the adobe structure, and our best result was up to a seventeen degree drop using a nine inch by nine inch pot. While existing zeer pot systems claim up to a twenty degree temperature decrease, our pot in pot test yielded an average result of seven degrees Fahrenheit. Therefore, since our adobe and terra cotta mix system was able to yield a better result than our zeer pot system, we feel that with further development, our system can perhaps be even more successful than our precedents.

Within only one semester we were able to prove the potential of developing this or similar evaporative cooling refrigeration systems. With more time and effort, a very successful system will result that can be implemented by future groups to truly help the world's rural poor.

0.8 Recommendations

While we were successfully able to prove that our system was able to decrease the temperature, further testing and development would be necessary to produce the most effective cooling device for the rural poor. First, additional testing on the sizes and shapes of terra cotta pots would prove which type was most effective as well as durable within our adobe structure. As noted in our obstacles, we found that the larger pots tended to crack more easily, so if testing proved that larger pots were more successful in cooling, then further steps should be taken into making these pots more durable.

After testing different scales and geometries, we would suggest testing different materials. By adding a layer of a different material, or substituting something all together, better results may occur. Since different materials have differing capabilities for conducting and insulating, finding an ideal material would be necessary. Alternative materials might also be experimented with for the lid of the pots to determine the best conditions for ventilation, conductance, insulation, transparency, etc.

Besides doing timed tests to determine the temperature and humidity levels, additional tests should be run using actual food from the target region. By leaving some fruit inside the prototype and some outside, it will be evident how much longer the food can be stored using our system. In this scenario, it will be ideal to change the environment according to the time of day so as to have the most accurate portrayal of real conditions.

Once an optimal system is developed, it should be tested in the region that it is meant to be implemented in to verify its capabilities. If it is able to be built and is successful in allowing for longer storage of food, a pamphlet or other method of explaining our system should be developed. It should be able to explain how the system works, how to construct and maintain it, and the benefits of using it in a way that is able to be understood by anyone regardless of language or education level.

After all this is done, implementation should be attempted in a region that has established connections to assure safety. If the system is successfully adopted by the community, it should be able to be implemented into surrounding areas in the future. Although it may need to be adjusted to adapt to other regions, further research and development may make it usable in many locations throughout the world.

0.9 References

The Zeer Pot.

http://www.scienceinafrica.co.za/2004september/refrigeration.htm

Adobe

http://www.zetatalk.com/shelter/tshlt04c.htm
http://www.epsea.org/esp/pdf2/adobe.pdf
http://www.elmerfudd.us/dp/adobe/brick/htm (accessed September 15, 2007).

Zero Energy Cooling Chamber

www.iari.res.in/

0.10 Acknowledgements

IIT Faculty

Peter Land of the College of Architecture guided us through the process of making an adobe. His help allowed us to successfully construct the adobe structure for our prototype using materials and methods that the people we are trying to help would be able to use.

Steve Stanard of the Psychology Department guided us through the process of creating terra cotta pots and allowed us to use his personal pottery studio to build, store, and fire out pots. With his help, we were able to make the pots under very similar conditions that the world's poor would be making them using a low heat kiln and local clay materials.

Outside Assistance

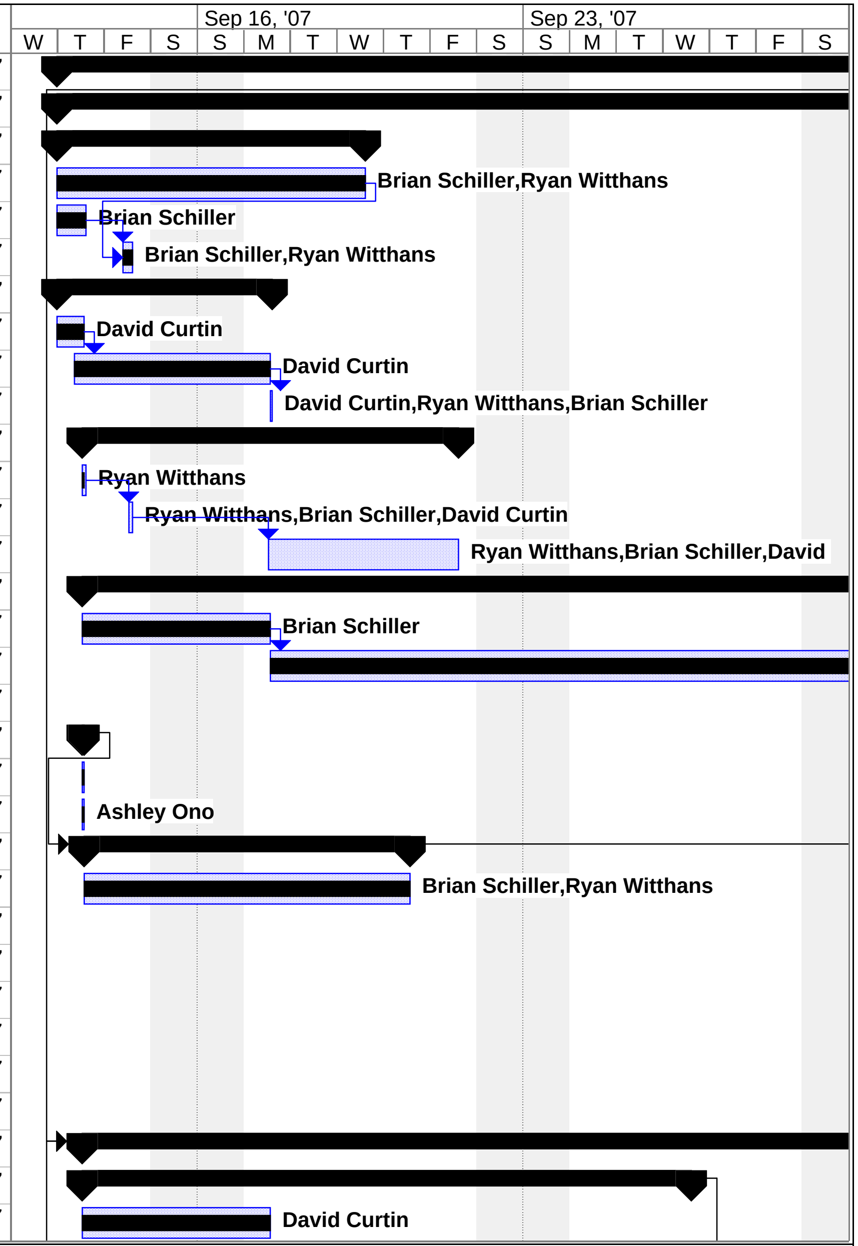
The Murillo family provided us with space and resources to build our adobe bricks in their backyard. They were very instrumental in helping us create, monitor, and relocate all our bricks as well as providing other equipment and accommodations for our group throughout the entire process.

Donations

<u>Calumet Pallet Co Inc.</u>
Donated: A wood pallet for us to build our prototype on
2640 S Calumet Ave
Hammond, IN , 46320-1105
Phone: 219-932-4550
FAX: 219-937-4550
Website: www.calumetpallet.com

<u>ABI, Inc. (American Bentonite International)</u>
Donated: All the bentonite that we needed for making our adobe structure
Phone: 1-800-992-2880; Website: http://americanbentonite.com/

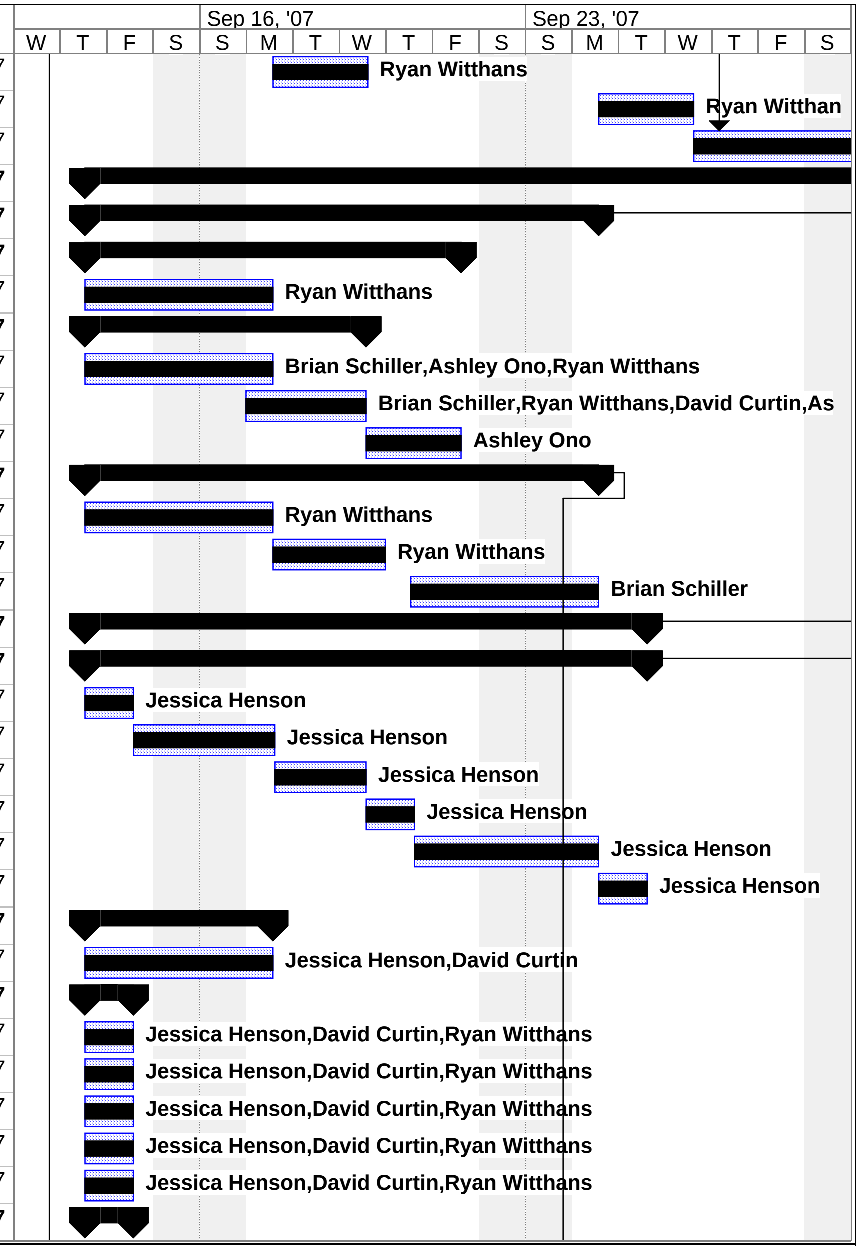
ID	i	Task Name	Duration	Start	Finish
1		**Aquire resources**	**7.13 days**	**Thu 9/13/07**	**Tue 10/23/07**
2		**Raise funding**	**4.63 days**	**Thu 9/13/07**	**Tue 10/9/07**
3	✓	**IPRO funding**	**1.25 days**	**Thu 9/13/07**	**Wed 9/19/07**
4	✓	Prepare presentation	10 hrs	Thu 9/13/07	Wed 9/19/07
5	✓	Arrange meeting with Dr. Jacc	2 hrs	Thu 9/13/07	Thu 9/13/07
6	✓	Meet with Dr. Jacobius	2 hrs	Fri 9/14/07	Fri 9/14/07
7		**BCPS money**	**0.75 days**	**Thu 9/13/07**	**Mon 9/17/07**
8	✓	Meet with Dr. Zasadzinski	1 hr	Thu 9/13/07	Thu 9/13/07
9	✓	Prepare project summary	5 hrs	Thu 9/13/07	Mon 9/17/07
10		Follow-up meeting with Dr. Za	1 hr	Mon 9/17/07	Mon 9/17/07
11		**Alumni BCPS newsletter funding**	**1.75 days**	**Thu 9/13/07**	**Fri 9/21/07**
12		Arrange meeting with editor	2 hrs	Thu 9/13/07	Thu 9/13/07
13		Meet with editor	2 hrs	Fri 9/14/07	Fri 9/14/07
14		Answer follow-up questions frc	10 hrs	Mon 9/17/07	Fri 9/21/07
15	✓	**McNight fellowship**	**4.63 days**	**Thu 9/13/07**	**Tue 10/9/07**
16	✓	Research grant proposal requ	5 hrs	Thu 9/13/07	Mon 9/17/07
17	✓	Prepare grant proposal	30 hrs	Mon 9/17/07	Mon 10/8/07
18	✓	Contact grant review board	2 hrs	Mon 10/8/07	Tue 10/9/07
19	✓	**Arrange space**	**0.13 days**	**Thu 9/13/07**	**Thu 9/13/07**
20	✓	Request lab space	1 hr	Thu 9/13/07	Thu 9/13/07
21	✓	Request shop space	1 hr	Thu 9/13/07	Thu 9/13/07
22	✓	**Aquire equipment**	**1.25 days**	**Thu 9/13/07**	**Thu 9/20/07**
23	✓	Attempt to find turbidometer	10 hrs	Thu 9/13/07	Thu 9/20/07
25	✓	**Aquire materials**	**2.5 days**	**Tue 10/9/07**	**Tue 10/23/07**
26	✓	**Containers**	**1.25 days**	**Tue 10/9/07**	**Tue 10/16/07**
27	✓	Bottles	10 hrs	Tue 10/9/07	Tue 10/16/07
28	✓	2.5- and 5-gallon buckets	3 hrs	Tue 10/9/07	Wed 10/10/07
29	✓	Steel drum(s)	5 hrs	Tue 10/9/07	Thu 10/11/07
30	✓	Filter media	20 hrs	Tue 10/9/07	Tue 10/23/07
31	✓	**Set SSF effectiveness standards**	**3.13 days**	**Thu 9/13/07**	**Mon 10/1/07**
32	✓	**Literature research**	**2.5 days**	**Thu 9/13/07**	**Wed 9/26/07**
33	✓	Research microbes	5 hrs	Thu 9/13/07	Mon 9/17/07



Project: water-timeline-2-DNU
Date: Thu 11/29/07

Task	Milestone	External Tasks
Split	Summary	External Milestone
Progress	Project Summary	Deadline

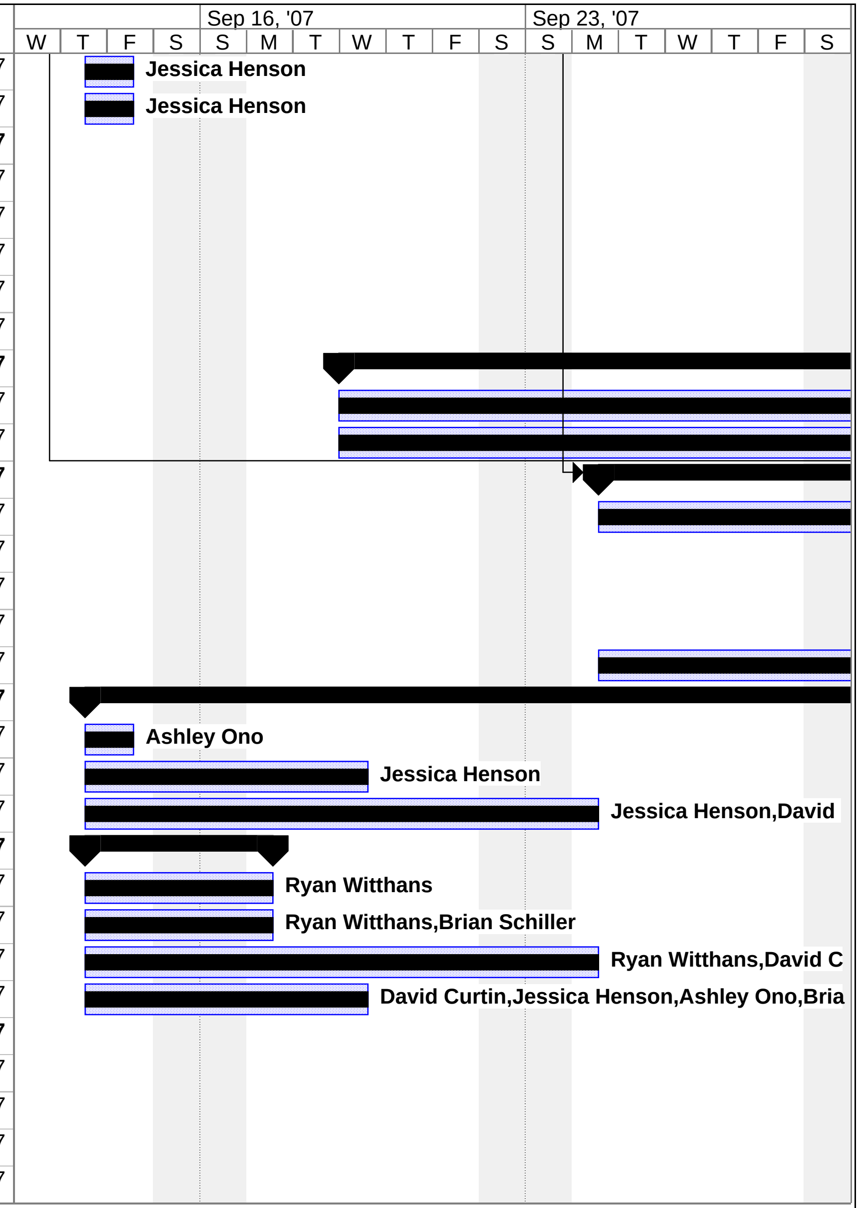
ID		Task Name	Duration	Start	Finish
34	✓	Research turbidity units/measurem	5 hrs	Mon 9/17/07	Wed 9/19/07
35	✓	Research SODIS requirements	5 hrs	Mon 9/24/07	Wed 9/26/07
36	✓	Write formal standards	5 hrs	Wed 9/26/07	Mon 10/1/07
37	✓	**Research and development**	**13.5 days**	**Thu 9/13/07**	**Tue 11/27/07**
38	✓	**Literature research**	**1.88 days**	**Thu 9/13/07**	**Mon 9/24/07**
39	✓	**Previous designs**	**1.75 days**	**Thu 9/13/07**	**Fri 9/21/07**
40	✓	SODIS system	5 hrs	Thu 9/13/07	Mon 9/17/07
41	✓	**Filtration systems**	**1.13 days**	**Thu 9/13/07**	**Wed 9/19/07**
42	✓	Designs	5 hrs	Thu 9/13/07	Mon 9/17/07
43	✓	Materials	5 hrs	Mon 9/17/07	Wed 9/19/07
44	✓	KlarAqua	5 hrs	Wed 9/19/07	Fri 9/21/07
45	✓	**Introduction strategy**	**1.88 days**	**Thu 9/13/07**	**Mon 9/24/07**
46	✓	KlarAqua	5 hrs	Thu 9/13/07	Mon 9/17/07
47	✓	SODIS system	5 hrs	Mon 9/17/07	Wed 9/19/07
48	✓	Contact International Develop	5 hrs	Thu 9/20/07	Mon 9/24/07
49	✓	**Determine specific location qualities**	**2.25 days**	**Thu 9/13/07**	**Tue 9/25/07**
50	✓	**Materials**	**2.25 days**	**Thu 9/13/07**	**Tue 9/25/07**
51	✓	Containers (bottles, drums)	3 hrs	Thu 9/13/07	Fri 9/14/07
52	✓	Vegetation	3 hrs	Fri 9/14/07	Mon 9/17/07
53	✓	Volcanic rocks	3 hrs	Mon 9/17/07	Wed 9/19/07
54	✓	Soil type	3 hrs	Wed 9/19/07	Thu 9/20/07
55	✓	Textiles	3 hrs	Thu 9/20/07	Mon 9/24/07
56	✓	Other salvagable materials	3 hrs	Mon 9/24/07	Tue 9/25/07
57	✓	**Water quality**	**0.63 days**	**Thu 9/13/07**	**Mon 9/17/07**
58	✓	Turbidity	5 hrs	Thu 9/13/07	Mon 9/17/07
59	✓	**Pathogens**	**0.38 days**	**Thu 9/13/07**	**Fri 9/14/07**
60	✓	Bacteria	3 hrs	Thu 9/13/07	Fri 9/14/07
61	✓	Viruses	3 hrs	Thu 9/13/07	Fri 9/14/07
62	✓	Parasites	3 hrs	Thu 9/13/07	Fri 9/14/07
63	✓	Cysts	3 hrs	Thu 9/13/07	Fri 9/14/07
64	✓	Polution	3 hrs	Thu 9/13/07	Fri 9/14/07
65	✓	**Weather patterns**	**0.38 days**	**Thu 9/13/07**	**Fri 9/14/07**



Project: water-timeline-2-DNU
Date: Thu 11/29/07

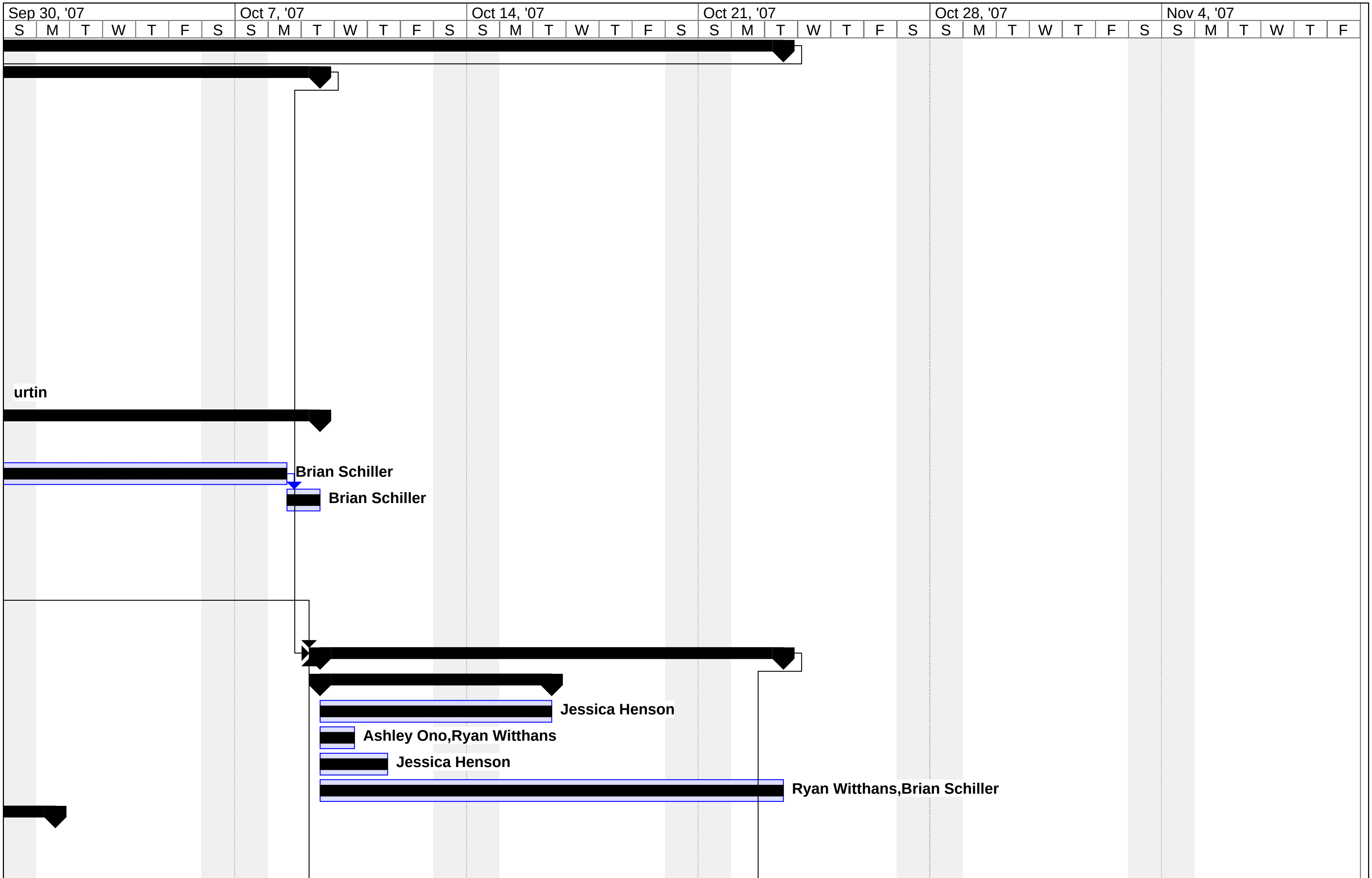
Task		Milestone	◆	External Tasks	
Split		Summary		External Milestone	◆
Progress		Project Summary		Deadline	⇩

ID		Task Name	Duration	Start	Finish
66	✓	Research historical weather cc	3 hrs	Thu 9/13/07	Fri 9/14/07
67	✓	Calculate overhead/bottle requ	3 hrs	Thu 9/13/07	Fri 9/14/07
68	✓	**Create prototype**	**5 days**	**Tue 10/23/07**	**Tue 11/20/07**
69	✓	Brainstorm preliminary designs	20 hrs	Tue 10/23/07	Tue 11/6/07
70	✓	Sketch designs	10 hrs	Tue 11/6/07	Tue 11/13/07
71	✓	Create CAD drawings	10 hrs	Tue 11/13/07	Tue 11/20/07
72	✓	Select single design (interchangeal	2 hrs	Tue 11/13/07	Wed 11/14/07
73	✓	Construct prototype	40 hrs	Tue 10/23/07	Tue 11/20/07
74	✓	**Run tests**	**12.5 days**	**Wed 9/19/07**	**Tue 11/27/07**
75	✓	Turbidity tests	100 hrs	Wed 9/19/07	Tue 11/27/07
76	✓	Evaluate prototype/filter media	30 hrs	Wed 9/19/07	Tue 10/9/07
77	✓	**Create implementation scheme**	**6.88 days**	**Mon 9/24/07**	**Wed 10/31/07**
78	✓	Author field manual	20 hrs	Mon 9/24/07	Mon 10/8/07
79	✓	Test manual	20 hrs	Mon 10/8/07	Mon 10/22/07
80	✓	Evalutate manual	5 hrs	Mon 10/22/07	Wed 10/24/07
81	✓	Revise manual	10 hrs	Thu 10/25/07	Wed 10/31/07
82	✓	Arrange trips to Central and South Ame	30 hrs	Mon 9/24/07	Mon 10/15/07
83	✓	**Produce IPRO deliverables**	**13.75 days**	**Thu 9/13/07**	**Wed 11/28/07**
84	✓	Meeting Minutes	3 hrs	Thu 9/13/07	Fri 9/14/07
85	✓	Weekly Reports	10 hrs	Thu 9/13/07	Wed 9/19/07
86	✓	Engineering Notebook	15 hrs	Thu 9/13/07	Mon 9/24/07
87	✓	**Project Plan**	**0.63 days**	**Thu 9/13/07**	**Mon 9/17/07**
88	✓	Timeline	5 hrs	Thu 9/13/07	Mon 9/17/07
89	✓	Methodologies	5 hrs	Thu 9/13/07	Mon 9/17/07
90	✓	Midterm report	15 hrs	Thu 9/13/07	Mon 9/24/07
91	✓	Peer reviews	10 hrs	Thu 9/13/07	Wed 9/19/07
92	✓	**IPRO Day**	**3.75 days**	**Thu 11/8/07**	**Wed 11/28/07**
93	✓	Make posters	10 hrs	Thu 11/8/07	Wed 11/14/07
94	✓	Write abstract	1 hr	Thu 11/8/07	Thu 11/8/07
95	✓	Create presentation	30 hrs	Thu 11/8/07	Wed 11/28/07
96	✓	Final Report	30 hrs	Thu 11/8/07	Wed 11/28/07



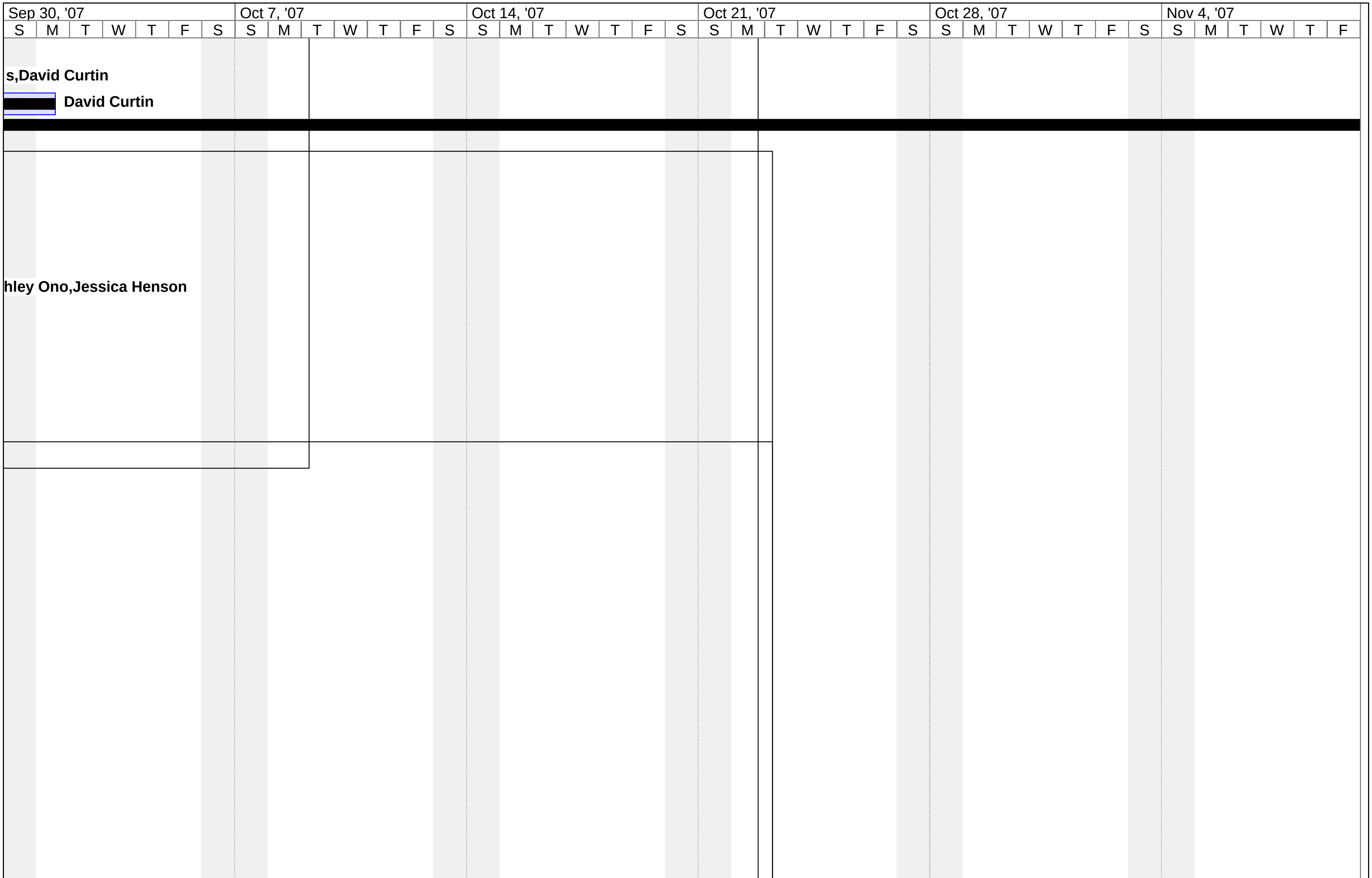
Project: water-timeline-2-DNU
Date: Thu 11/29/07

Task		Milestone	◆	External Tasks	
Split		Summary		External Milestone	◆
Progress		Project Summary		Deadline	⇩



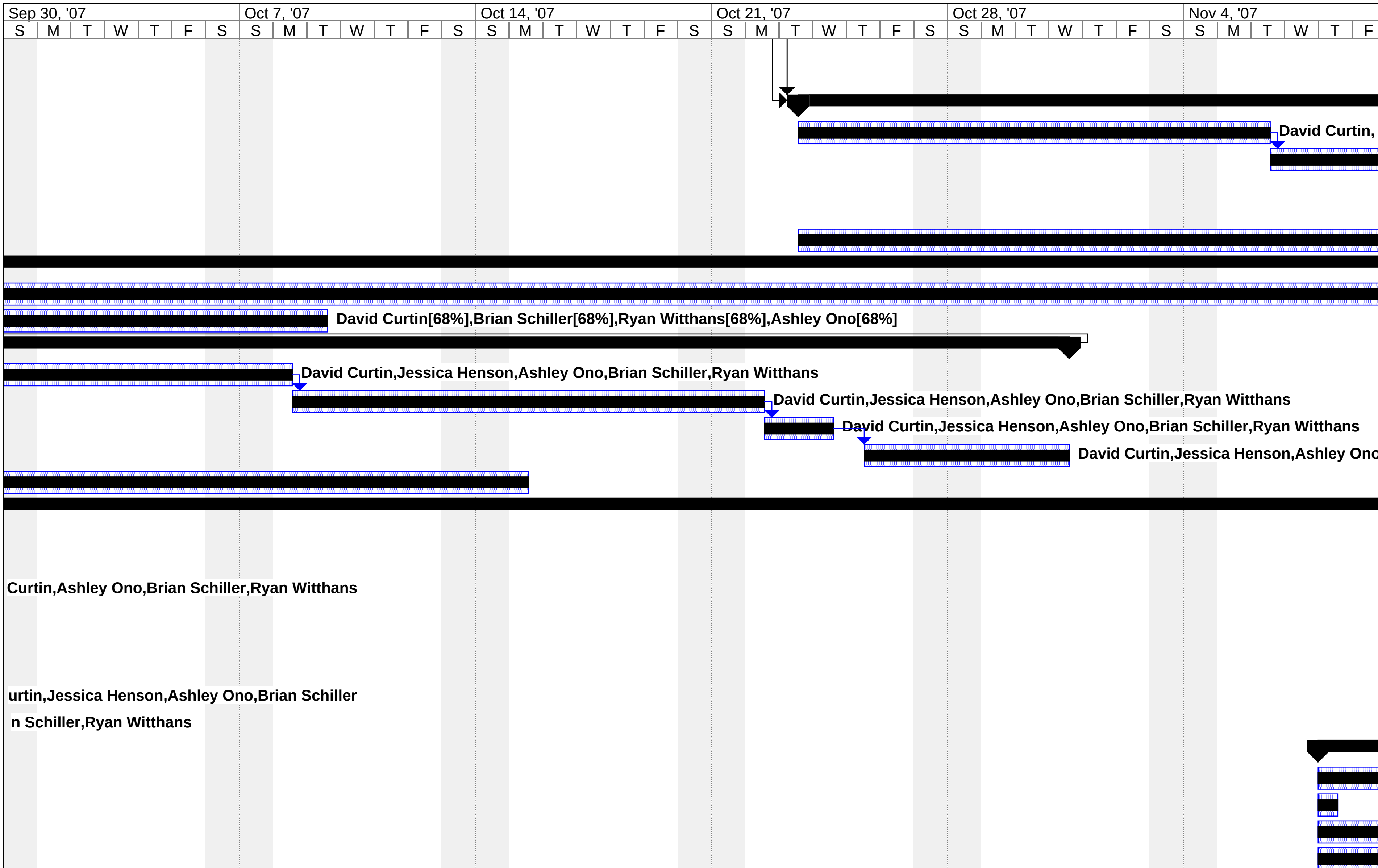
Project: water-timeline-2-DNU
Date: Thu 11/29/07

Task		Milestone		External Tasks	
Split		Summary		External Milestone	
Progress		Project Summary		Deadline	



Project: water-timeline-2-DNU
Date: Thu 11/29/07

Task		Milestone		External Tasks	
Split		Summary		External Milestone	
Progress		Project Summary		Deadline	



Project: water-timeline-2-DNU
Date: Thu 11/29/07

Task		Milestone		External Tasks	
Split		Summary		External Milestone	
Progress		Project Summary		Deadline	

	Nov 11, '07							Nov 18, '07							Nov 25, '07							Dec 2, '07							Dec 9, '07							Dec 16, '07				
S	S	M	T	W	T	F	S	S	M	T	W	T	F	S	S	M	T	W	T	F	S	S	M	T	W	T	F	S	S	M	T	W	T	F	S	S	M	T	W	T

Project: water-timeline-2-DNU
Date: Thu 11/29/07

Task

Split

Progress

Milestone

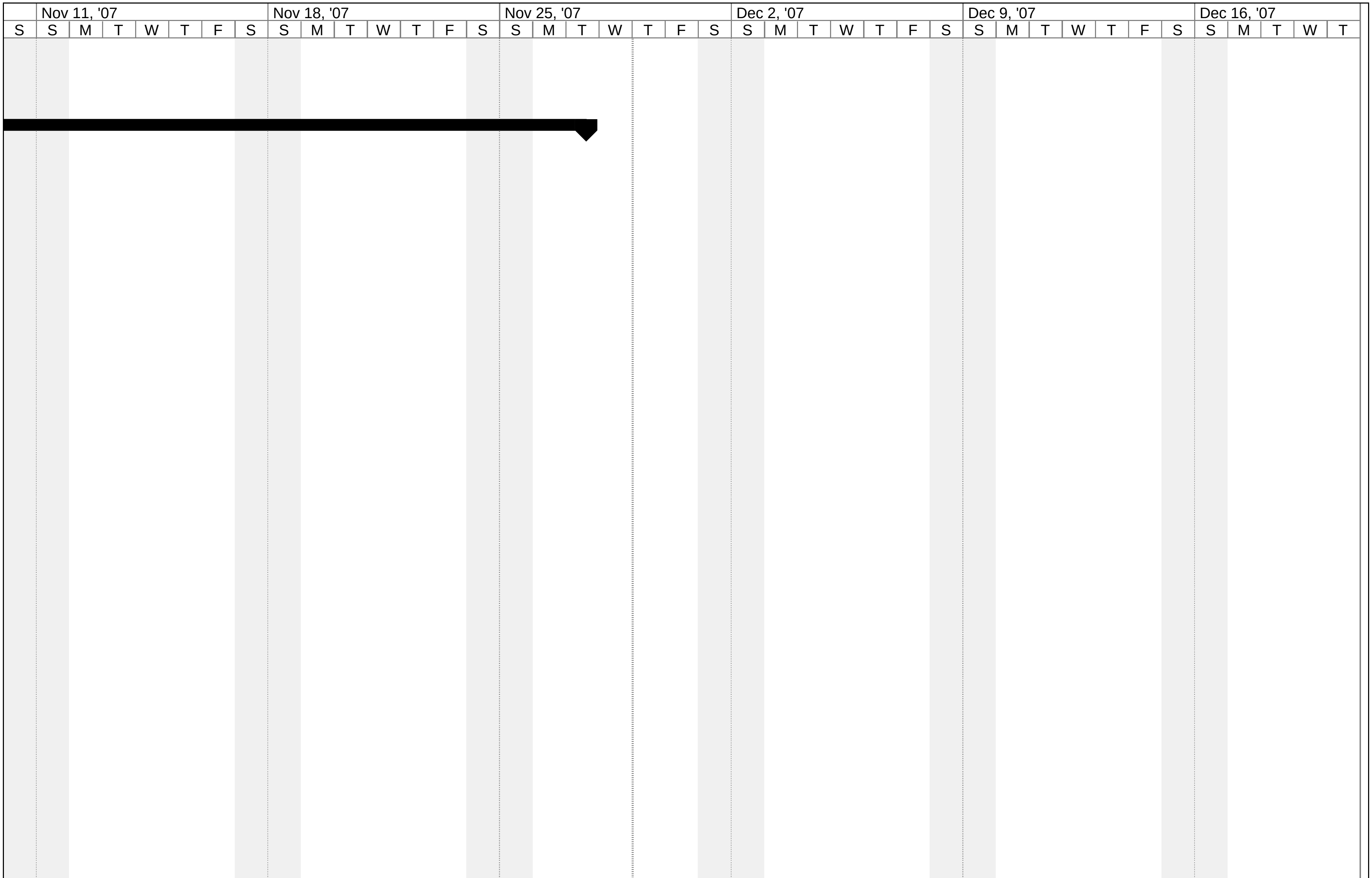
Summary

Project Summary

External Tasks

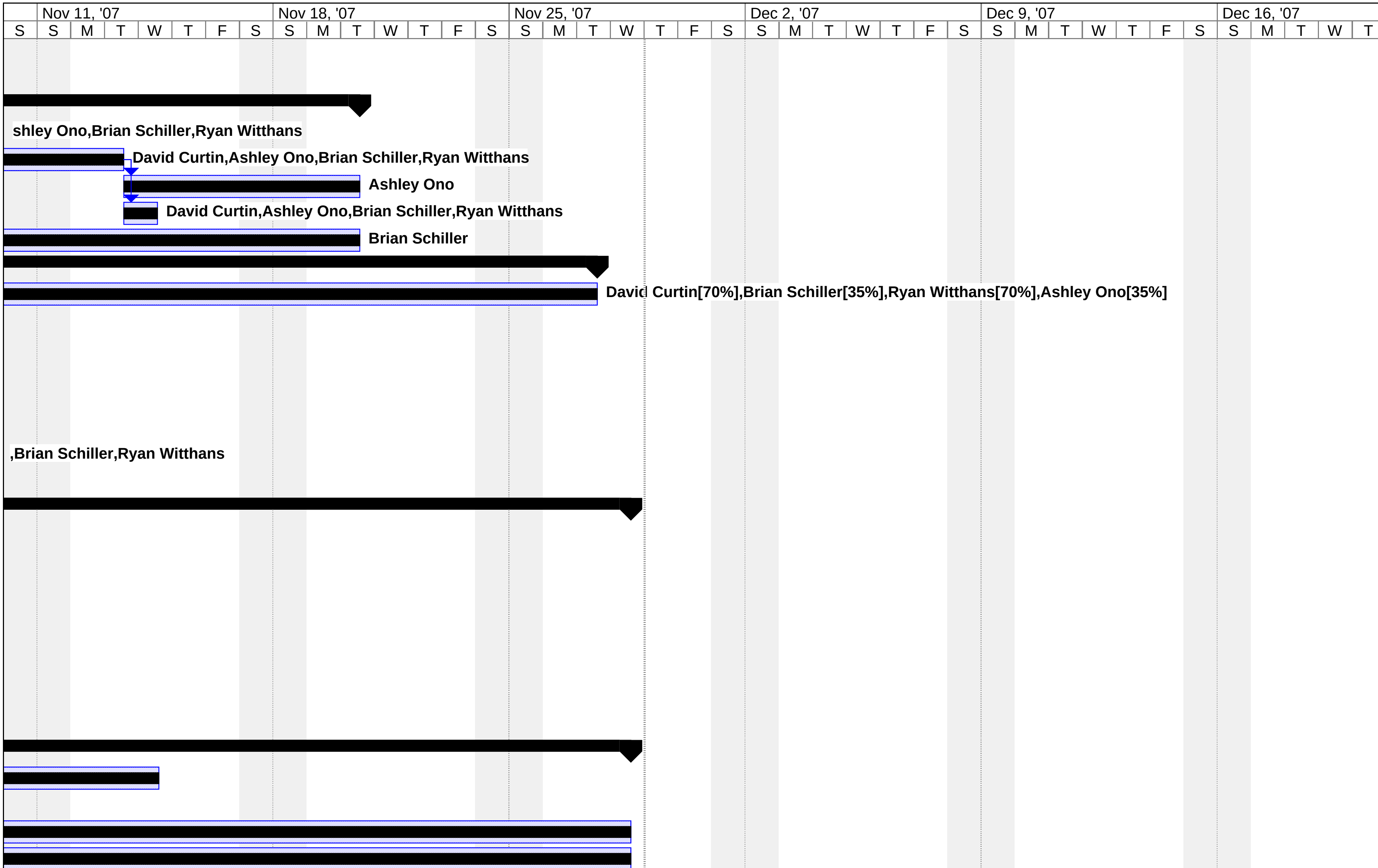
External Milestone

Deadline



Project: water-timeline-2-DNU
Date: Thu 11/29/07

Task		Milestone		External Tasks	
Split		Summary		External Milestone	
Progress		Project Summary		Deadline	



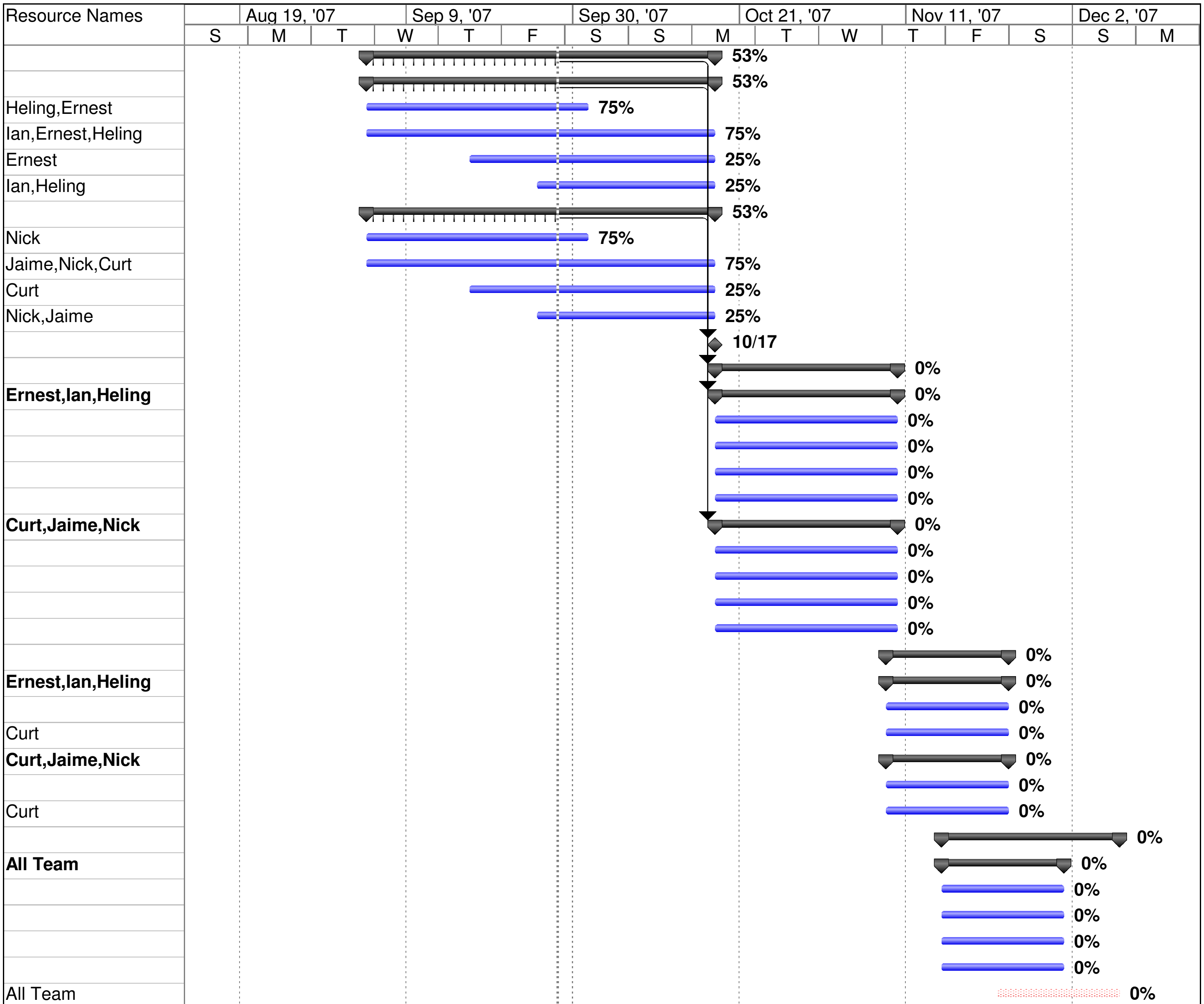
Project: water-timeline-2-DNU
Date: Thu 11/29/07

Task		Milestone		External Tasks	
Split		Summary		External Milestone	
Progress		Project Summary		Deadline	

ID		Task Name	Duration	Start	Finish
1		**Phase 1: Research**	**29 days**	**Tue 9/4/07**	**Wed 10/17/07**
2		**Solar Cooker**	**29 days**	**Tue 9/4/07**	**Wed 10/17/07**
3		Location Information	18 days	Tue 9/4/07	Mon 10/1/07
4		Current Solutions	29 days	Tue 9/4/07	Wed 10/17/07
5		Testing Parameters & Standards	21 days	Mon 9/17/07	Wed 10/17/07
6		Benchmark Selection and Defintion	15 days	Tue 9/25/07	Wed 10/17/07
7		**Conventional Cooker**	**29 days**	**Tue 9/4/07**	**Wed 10/17/07**
8		Location Information	18 days	Tue 9/4/07	Mon 10/1/07
9		Current Solutions	29 days	Tue 9/4/07	Wed 10/17/07
10		Testing Parameters and Standards	21 days	Mon 9/17/07	Wed 10/17/07
11		Benchmark Selection and Defintion	15 days	Tue 9/25/07	Wed 10/17/07
12		Midterm Report	0 days	Wed 10/17/07	Wed 10/17/07
13		**Phase 2: Design & Build**	**15 days**	**Thu 10/18/07**	**Fri 11/9/07**
14		**Solar Cooker**	**15 days**	**Thu 10/18/07**	**Fri 11/9/07**
15		Analysis of Benchmark	15 days	Thu 10/18/07	Fri 11/9/07
16		Analysis of New Prototype	15 days	Thu 10/18/07	Fri 11/9/07
17		Collection of Materials for Design Modifciations	15 days	Thu 10/18/07	Fri 11/9/07
18		Prototype Modification	15 days	Thu 10/18/07	Fri 11/9/07
19		**Conventional Cooker**	**15 days**	**Thu 10/18/07**	**Fri 11/9/07**
20		Analysis of Benchmarks	15 days	Thu 10/18/07	Fri 11/9/07
21		Design of New Prototype	15 days	Thu 10/18/07	Fri 11/9/07
22		Collection of Materials for Build	15 days	Thu 10/18/07	Fri 11/9/07
23		Prototype construction	15 days	Thu 10/18/07	Fri 11/9/07
24		**Phase 3: Testing and Analysis**	**10 days**	**Thu 11/8/07**	**Fri 11/23/07**
25		**Solar Cooker**	**10 days**	**Thu 11/8/07**	**Fri 11/23/07**
26		Obtain testing equipment	10 days	Thu 11/8/07	Fri 11/23/07
27		Testing Procedures	10 days	Thu 11/8/07	Fri 11/23/07
28		**Conventional Cooker**	**10 days**	**Thu 11/8/07**	**Fri 11/23/07**
29		Obtain testing equipment	10 days	Thu 11/8/07	Fri 11/23/07
30		Testing Procedures	10 days	Thu 11/8/07	Fri 11/23/07
31		**Phase 4: Conclusion**	**14.5 days**	**Thu 11/15/07**	**Fri 12/7/07**
32		**IPRO Presentation**	**10 days**	**Thu 11/15/07**	**Fri 11/30/07**
33		Abstract	10 days	Thu 11/15/07	Fri 11/30/07
34		Poster	10 days	Thu 11/15/07	Fri 11/30/07
35		Presentation Practice	10 days	Thu 11/15/07	Fri 11/30/07
36		Question and Answer Practice	10 days	Thu 11/15/07	Fri 11/30/07
37		Final Written Report	10 days	Thu 11/22/07	Fri 12/7/07

Project: EnergyProjectPlan
Date: Fri 9/28/07

Critical	Baseline Milestone
Critical Split	Milestone
Critical Progress	Summary Progress
Task	Summary
Split	Project Summary
Task Progress	External Tasks
Baseline	External Milestone
Baseline Split	Deadline



Project: EnergyProjectPlan Date: Fri 9/28/07	Critical	Baseline Milestone	
	Critical Split	Milestone	
	Critical Progress	Summary Progress	
	Task	Summary	
	Split	Project Summary	
	Task Progress	External Tasks	
	Baseline	External Milestone	
	Baseline Split	Deadline	