IPRO 323
Low-Cost Water Pump Design/Testing to Serve Rural Villages
Midterm Project Report

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1. Background

1. Sponsors

There is a great need for potable water supply systems in rural areas of Mexico. Our specific focus is on Monterrey, Mexico. Previous research has been conducted and supplied to IIT by Monterrey Institute of Technology. They determined the typical water needs of a community and the water resources available. In addition to this collaboration, this project is being sponsored by NCIIA and EPA p3 grants.

2. User Problems

The regions surrounding Monterrey face an intermittent water supply as a result of the inconsistent performance of windmills. The lack of a sufficient supply of wind, and the inability to reach a depth with uncontaminated water limits the reliability of the current water distribution system. The community does not have the resources to procure more common and reliable methods to obtain water.

3. Technological Implications

Many methods exist that require manual operation to retrieve water, such as hand pumps. More modern technologies utilize engines to provide a consistent supply of water, though these require additional resources such as gasoline or diesel fuel. The desire to increase efficiency and decrease the impact on the environment has caused alternative energy supplies, such as solar power, to be pursued. In addition, the use of solar power is attractive due to the low levels of maintenance required.

4. Historical Success and Failures

Previous attempts to solve the water crisis have been in the form of wind turbine technology. This technology relied upon wind movement to create enough electricity or generate enough mechanical motion to power the well pumps to extract water. However, due to the rapid change of wind directions in Mexico the turbines have sustained consistent damage, making repairs costly and frequent.

5. Cultural and Scientific Issues

The location of the project site is in Mexico, which implies both language and cultural barriers that will have to be considered in designing the system. Because the Federal government owns all ground water in Mexico, caution must be exercised in following all local regulations.

6. Costs of the Problem

Without a consistent source of potable water, communities reach an economic standstill, losing the ability to sustain livestock and agriculture. This forces water to be imported, which is costly over time.

7. Details of a Proposed Implementation

Through research and consultation with professionals, a list of possible solutions will be considered. The best solution will then be tested in the form of a scaled down test model to understand and predict full-scale operation. The assembly of a full-scale prototype is the final goal of the IPRO.

2. Solar Water Pump Systems

Solar powered water pumping systems are often used in agriculture, but have not been widely implemented in developing rural areas. The objective of this IPRO is to determine the appropriate components for a system to meet the needs in Monterrey, both in terms of performance and cost. Monterrey Institute of Technology previously completed a similar cost-benefit analysis, which showed that solar powered pumping systems outperformed diesel and wind powered systems.

3. Project Goals and Objectives

The students of IRPO 323 will explore the possibility of using solar water pumps to access groundwater, particularly in areas which do not have easy access to water resources. The solar water pumps need to be cost effective, easy to design, install, and maintain, as well as fulfilling the water requirements. However, in order to fully understand the system and its limitations, a test model will be constructed. The set objectives, therefore, are:

- Evaluate water sources and water demands of the target community
- Design and construct a small-scale test system to approximate the performance of a full-scale system
- Design a full-scale solar powered water pumping system
- Research available components and perform cost-benefit analysis

The test models will take place in the form of a small-scale model to perform tests of the roof of Farr Hall, and a larger scale model pending access to a test site in Kankakee and external funding sources.

4. Methodology

1. Problems

The existing problems that must be overcome in the final design are getting access to groundwater in Mexico, supplying a sufficient amount of water to fulfill the needs of the community, and providing the power to extract that water.

2. Solving the Problem

The information needed to determine the water requirements and assistance in gaining access to the groundwater will be gathered through consultation with Monterrey Institute of Technology, which will help alleviate the distance between IIT and Monterrey. The pumping system will then be designed based on criteria such as ease of use and maintenance, cost, and ability to supply enough water.

3. Testing of Solutions

Once possible solutions have been determined, small-scale systems will be constructed near IIT. Data will be gathered from these systems to approximate expected performance relative to manufacturers ratings. This will help to determine the performance of the full-scale systems as well as evaluating the performance of each possible solution.

4. Documentation of Solutions

The data gathered will be presented as justification for the performance of the final pumping system design. A cost-benefit analysis will be provided as further justification of the cost. The final, full-scale design will be documented with required system components, assembly method, and operating instructions.

5. Analyzing Solutions

Possible solution will be analyzed based on the performance of the solution relative to the system cost, ability to consistently provide the required water, ease of use, and maintenance requirements.

6. IPRO Deliverable Generation

The final IPRO deliverables will consist of the research to determine the water needs of the community, test system performance data, expected full-scale system performance, documentation of the selected components, assembly method, and operating instructions.

5. Results to Date

1. Solar Water Pump Test System:

The images depicted below are simulation drawings of the water pump test system. (Figure 1A and 1B) The solar panel is not shown in the figures as it is not yet configured to the test system.

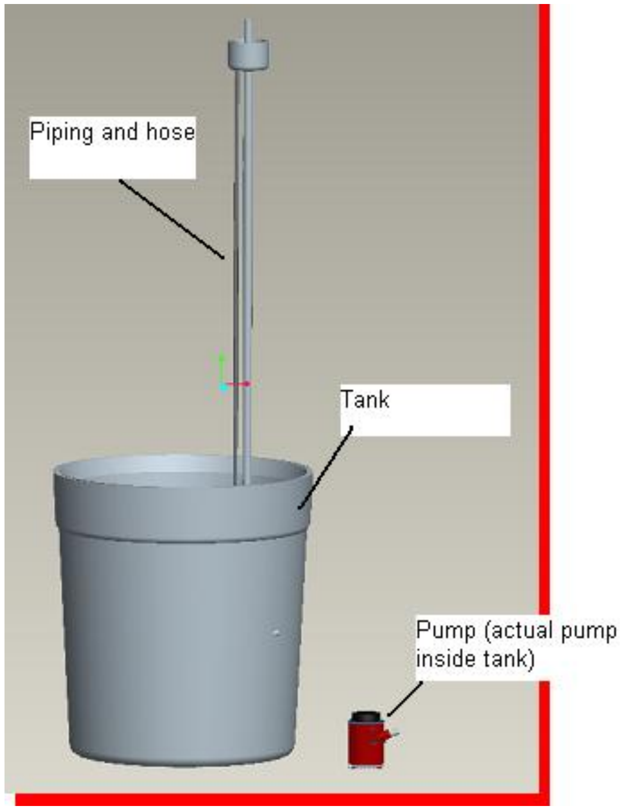

Figure 1A: Computer Drawing of Test System

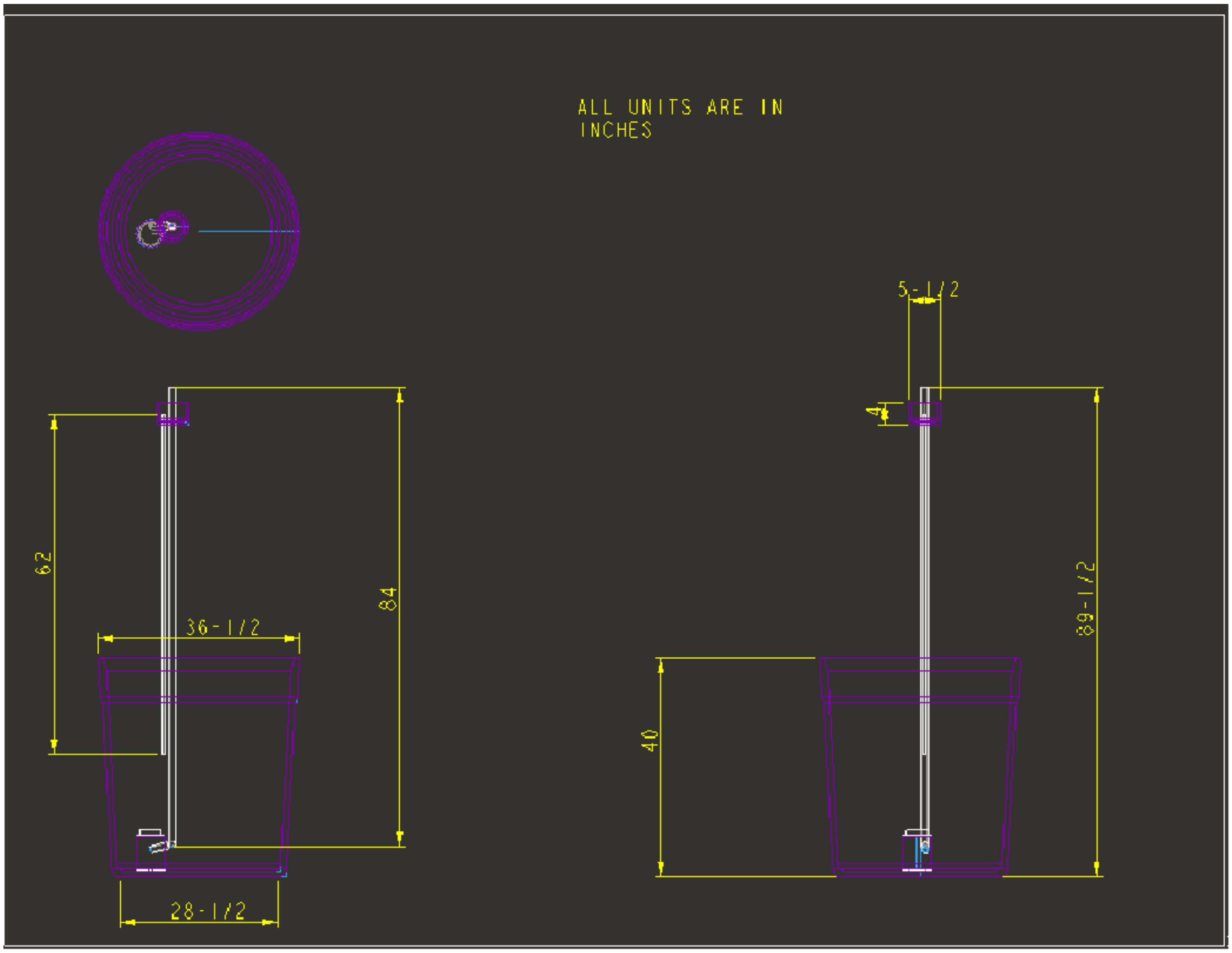

Figure 1B – ProE schematic drawing w/dimensions

The test system is composed of a Rubbermaid forty four gallon trash can (depicted by the gray cylinder), enclosed within the trash can is a submersible pump - Dankoff solar well (red and black device, rated 8gpm and 55-110W), and connected to the trash can is a pipe and tubing assembly made of ½ inch diameter tubing, 3/4 inch diameter PVC pipe connected to a 6 inch diameter cup at the top.

Deliverables: The pump, pipe, and storage components can be readily assembled and are ready for final delivery. Currently the model is pending ordering and testing of larger panels that can power the pump based on empirical testing of the smaller panel.

2. Results of Solar Water Pump Test System:

The pumping component of the system was tested to see if it would match manufacturer specifications. The pump output was measured both as a factor of flow rate in gallons per minute and the achieved head rate of the pump. The testing of the pump was successful but limited due to limitations in the electric component.

Data from testing a consistent range of operation between 3 gallons per minute to 4 gallons per minute at 11 Volts and 9.7 Amps around the manufacturers suggested values.

Potential Outputs:

More testing of the correlation between power and flow rate will become available once the required equipment is delivered.

3. Pumping:

Pump: The pump selection was done based on availability of product and the ability to meet the minimum specifications of 3 gallons per minute, a 5 feet pump head, submersible design, and DC powered.

Pipes: The PVC material of the pipes and assembly withstood the cold testing temperatures and was durable during construction and relocation of testing components.

Storage: The container selected for the experiment is sufficient for the water supply needed for the pump. The water heater ordered was not the correct heater and therefore is not being used for the test system. A new heater will not be ordered because the majority of final half of the semester will be focused on the Kankakee/Mexico systems.

4. Flow rate:

The flow rate of the solar water pump test system is currently fixed due to the dc regulator. New equipment or professional repairs will be required before a flow rate vs. power comparison can be made.

5. Issues and Observations:

Future Use:

The small-scale system has aided in understanding possible dilemmas of the larger full-scale project. Some of these include power requirements of the pump, orientation of the pump, operating water temperature, and dynamics of piping.

Framework:

The test data from both pump and solar panels will be used to help correlate the efficiency of larger scale equipment ordered.

Specifically the results will be used, the power to flow rate correlations in pumps and tested data to empirical data for solar panels will aid in ordering large scale products.

6. Solar Test System:

Figure 2 below can best summarize the data obtained for the solar test system. The voltage corresponds to the output of the solar panel whereas the time axis is segmented by .1 units of time relating to 2.4 hours of real time. Thus the graph shows the output of a solar panel in a 24-hour test period. The analysis of the peaks showed that the panel achieved the maximum voltage of the manufacturer's specifications and that the duration of sun time correlated with empirical sun data for the latitude.

There will be more data available as more tests are conducted. Currently a computer is continuously monitoring the solar cells output.

A new solar cell will be ordered to power the pump system, it is a Mitsubishi 110W max power rated panel and is approximately 4.7' x 2.1' and 2" thick. The max voltage rating is 17.1V.

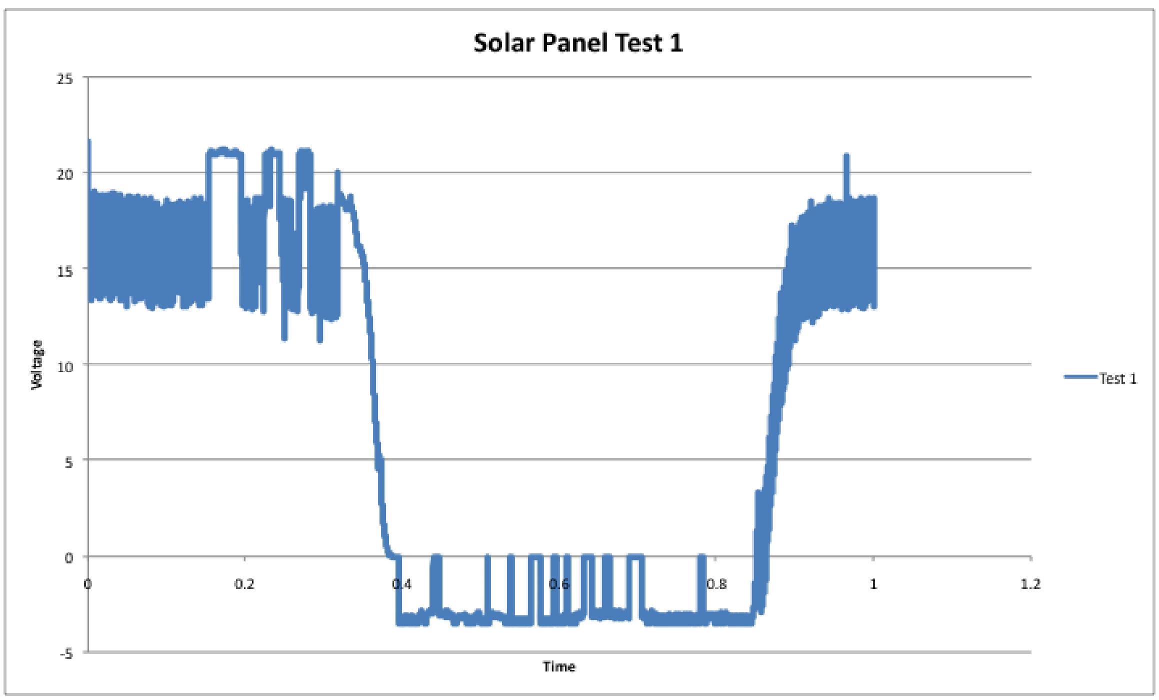

Figure 2: Voltage vs. Time of the Solar Panel Test

6. Revised Task / Event Schedule

<Insert Gantt chart>

The timeline has changed with the introduction of the Kankakee test site. An opportunity has been presented in designing a large-scale solar powered pump for a farm near Chicago. This opportunity would allow for testing of a model that will be used in Mexico allowing for real testing versus system simulations. This change has resulted in a change of time allocation between IPRO deliverables and a second phase of testing. This has also pushed off the Mexico project as the final objective with a submission of a water system proposal as the final deliverable of the IPRO this semester.

7. Task Assignments and Designations

1. Team Organization to Date
   No change to the team organization has been made at this point.

2. Subgroup and Individual Responsibilities.

   Subgroup: Piping
   Subgroup Leader: Not Applicable

   Subgroup Members: Brian, Bill

   General Tasks: Designing the piping system taking into account materials, stability, and requirements for the test model and for the full-scale models in Mexico and Kankakee.

   Individual Responsibilities:

   Name: William E. Pajak

   Responsibilities: Applying the necessary system equations to determine the piping options, and additionally purchasing piping and materials.

   Name: Brian Albee
   Responsibilities: Adapting the model design to the piping needs and also purchasing piping and necessary materials.

   Both will be participating in the construction of the test design as well as working on determining piping needs and construction parameters of the Mexico model.

   Subgroup: Pump and Control System

   Subgroup Leader: Joshua Sullivan

Subgroup Members: Katty Davila, Erick Leong, and Joshua Sullivan

General Tasks:

- Design and calculation of a) pump functional requirements and b) corresponding control system requirements.
- Selection of products in market that satisfy the functional requirements.
- Documentation of system dynamics for other subgroups to use in design. (e.g. flow rate and outlet size for pipe system and water storage groups; power requirements for solar group).
- Coordination with other groups over specification of test system measurements.

Individual Responsibilities:
The group as a whole coordinates cooperatively over all team responsibilities and there are not, nor does a need seem apparent for task specific delegations per team member.

Subgroup: Solar Panels

Subgroup Leader: Not Applicable

Subgroup Members: Juacinta, Ellen, Ryan, Nick
General Tasks:

- Selection of a small scale solar panel
- Creation of a test system to monitor the voltage potentials and variations from solar energy in Chicago
- Use of all available information and above data to select the optimal solar panels for the most efficient performance in Mexico

Individual Responsibilities:

Name: Jaucinta Burt
Responsibilities: Researching the solar panels, test system, and connections to be used and selecting what is best thereof and assembling and testing the efficiency of the panels.

Name: Ellen Rohde
Responsibilities: Creation of the test system for the Chicago test panel as well as looking into specific models to purchase.

Name: Ryan Yarzak
Responsibilities: Assistance in designing the test system and figuring out what is necessary to take to Mexico

Name: Nick Bailey
Responsibilities: Analyzing the solar panel data.

Subgroup: Water Storage

Subgroup Leader: Nicole Galbraith

Subgroup Members: Nicole Galbraith, Jinting Liu, Leon Chan

General Tasks: Responsible for the Kankakee and Farr Hall test system water storage design, selection, and implementation. The approximate timeline is as follows

Week of:	**Tasks:**
24-Mar	Visit Kankakee/Put test system together
31-Mar	Continue to test Farr Hall system and begin Kankakee building
7-Apr	Testing
14-Apr	Testing and begin Mexico proposal
21-Apr	Continue testing and Proposal
28-Apr	IPRO day on Friday - finish reports and presentations
5-May	Debriefing and proposal submittal

Individual Responsibilities:

The storage subgroup is broken up into Farr Hall and Kankakee groups. Nicole and Jinting will be primarily focused on the full scale Kankakee test system while Leon remains with the Farr Hall test system. All group members will be researching tanks for the full-scale systems and a method for installing the storage tank.

3. Role Changes:

Assigned Roles:

Meeting Minutes – Erick

Timesheets – Erick

Weekly Task List - Erick

iGroups Management – Erick

The shift in the plan from small scale testing to a larger scale testing has resulted in small changes of individual tasks. The differences include the storage subgroup changing design from pump storage to water storage. Also, the pipe subgroup must now design for a pipe system that transfers water to a storage tank instead of returning the water to the pump. The administration roles have remained unchanged.

4. Tentative Budget:

Item	Estimated Cost
Test Systems (Pumps)	$300
Test Systems (Solar Panels)	$300
Test Systems (Storage)	$50
Test Systems (Pipe)	$30
Test Systems (Other)	$100
Full Scale System (Pumps)	$2000
Full Scale System (Panels)	$1000
Full Scale System (Storage)	$1200
Full Scale System (Pipe)	$200
Full Scale System (Other)	$1000
Transportation	Varies on Plan
Well Construction	$5000
Total	$11180

The budget has slightly changed, mainly in a reduction of costs as the amount spent was less than expected for the completion of the small-scale project. The cost of the full-scale system pertains only to Mexico as funding for the Kankakee project will be obtained outside of the IPRO budget.

8. Barriers and Obstacles

1. Obstacles:
   Pipe: The pump purchased provided less head than the original pump specifications.
   Pump: The Electrical converter's adjustment potentiometer was damaged while in use.
   Solar Panels: The complexity of the first board oscilloscope was beyond the time available to decipher.
   Storage: The heating element did not provide enough warmth to the water in the storage tank to prevent freezing.
2. Resolution:
   Pipe: The pipe system was changed to fit the recommended vendor pump.
   Pump: Another dc converter has been ordered and more testing will commence once it arrives.

Solar Panel: Another board oscilloscope with available software was purchased.
Storage: The lack of heat is no longer a problem as the spring weather is raising temperatures above freezing.

3. Remaining Barriers:
   Team: Access to the Kankakee farm in order to study a larger scale solar powered pump.
   Solar Panel: Ordering solar panels for the small-scale pump based on the performance of the initial solar panel.
4. Solutions:
   Team: Sustain contact with the owners of the Kankakee farm and possible visits in order to understand the conditions.
   Solar Panel: Analysis of data is underway.

9. Midterm Power Point Presentation

<Attached power point file>