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**Solicitation Name:** P3 Award: A National Student Design Competition for Sustainability focusing on People, Prosperity, and the Planet; **Sorting Code:** 2004-P3-S7 (Water)

1. **Title:** University of Arizona Cross-border Water Technology Collaboration

2. **Faculty Advisor:** Dr. James Washburne, Asst. Adj. Prof. of Hydrology & Water Resources and SAHRA Asst. Dir. of Education

3. **Institution:** University of Arizona, Tucson, AZ 85721-0011

4. **Project Period:** Sept. 15, 2004 to Sept. 14, 2005

5. **Project Amount (EPA):** $10,000

6. **Total Project Amount:** $10,000

7. **Project Summary:**

   We propose a partnership with the Northern Sonora community of El Ejido del Desierto, MX (pop. ~2500) to improve their drinking water quality. This collaborative effort is based on ideas generated in graduate seminar course in Advanced Topics in Semi-arid Hydrology (HWR 696L) with input from one or more campus groups experienced in cross-border capacity building. The preliminary design concept is to evaluate point-of-use solar distillation technology to produce purified water that will dilute local groundwater, which has naturally high concentrations of arsenic. Equally important to this design concept is a community-based needs assessment, development and implementation approach that will be taken with the help of one or more campus-based collaborators. Preliminary discussions and letters of support have been secured from SAHRA (Sustainability of semi-Arid Hydrology and Riparian Areas), a NSF science and technology center focused on the sustainable management and scientific understanding of semi-arid water resources, BARA’s (Bureau of Applied Research in Anthropology) cross-border internship program, and the University’s Water for People (WFP) organization.

   **The following lists the points of information requested in the proposal:**

   (i) Access to clean drinking water is a basic human need that is not always available in rural communities. There are many possible sources of contamination, and one of the most prevalent is from low but unhealthy concentrations of naturally occurring metals, such as arsenic. While many treatment methods have been devised for this contaminant, very few are appropriate or sustainable in poor and rural settings. (ii) We propose a collaborative effort between University students, who can help select appropriate technologies, cross-border action groups, who can foster community participation and implementation and the communities themselves, whose quality of life will be improved. (iii) This challenge to rural residents’ water quality can be met by taking advantage of renewable solar energy throughout much of the Southwest and northern Mexico, by stakeholder participation in the process, and by adequate planning for the responsible management of any possible waste products. (iv) Funds will be allocated to the cross-border collaborators to conduct a follow-up survey and water quality testing will be done at regular intervals. (v) Students in this course and in collaborating programs will directly benefit from the practical application of basic concepts. The results will be more widely shared with the EPA and with other professional organizations, such as the American Geophysical Union.
E. Research Plan

1. P3 Project Description

1.1 Problem definition

The problem that we address in this grant proposal is water treatment in a small Mexican border community (El Ejido del Desierto), with emphasis placed on arsenic removal. This topic fits under the Water category of the grant application. The arsenic poses a challenge to the sustainability of the community. It affects the health of People and the treatment is an opportunity for Prosperity and the Planet.

Arsenic contamination of groundwater is a worldwide problem. Increasing world population is likely to increase the demand on groundwater. Recently, groundwater use in Bangladesh has created a health crisis. The World Health Organization estimates that more than 200,000 cancer deaths will result from arsenic in Bangladesh.1

The U.S. EPA issued a new rule on arsenic concentrations in drinking water on January 22, 2001. The new rule lowers the Maximum Contaminant Level of arsenic from 50ppb to 10ppb. The new standard reflects research that shows an increased cancer risk at levels below 50ppb. Our goal is to help small communities follow the new EPA guideline by utilizing techniques that are inexpensive and easy to implement.

Health Effects
The most common forms of arsenic in drinking water are inorganic. There are two forms, arsenite and arsenate. Arsenite is more toxic than arsenate and is more difficult to remove from drinking water. Arsenite is the most common form in groundwater.2

Arsenic is known to have severe health effects on humans. There are well-documented effects from long-term exposure at low concentrations. These can be divided into cancerous effects and non-cancerous effects. Non-cancerous effects of arsenic exposure are generally non-fatal, but still pose serious health risks. These include “cardiovascular, pulmonary, immunological, neurological and endocrine (e.g., diabetes) effects.”3 Exposure to arsenic is associated with several types of cancer. Lung and bladder cancers are the most common types of cancer associated with arsenic in drinking water. Other types of cancer linked to arsenic are skin, kidney, liver and prostate cancers.

Regional
The southwestern United States and northern Mexico depend upon groundwater for much of their drinking water. Even though several large cities receive supplies from the Colorado River, many small communities and private homes depend solely upon groundwater. Water samples from the region have shown arsenic levels above 50ppb in some wells. Many more wells show

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levels between 50ppb and 10ppb. These communities are not large enough to qualify as Community Water Systems. Therefore, they are not required to enforce the new EPA standard for arsenic in drinking water. It is unlikely that such communities will treat their water to “safe” arsenic levels. In addition, most treatment methods require the use of various chemicals and technical expertise that is unavailable in rural areas. According to the World Health Organization, these technologies are “inapplicable in some urban areas of developing countries and in most rural areas world-wide.” This region also faces a problem with water loss due to treatment. Conventional methods of arsenic removal may produce only one gallon of treated water for every ten gallons of influent water. Any technology implemented in the region should be conscious of the water scarcity. It is therefore necessary to develop a cost effective arsenic-removal technique for small arid communities.

Arsenic removal also poses a problem of waste disposal. Most removal techniques produce concentrated brines or chemical precipitates high in arsenic. The brine itself poses a health risk and an environmental risk. There is a lack of free-flowing streams in which to discharge the brine. Discharge into groundwater would further increase the arsenic concentrations. Any water treatment method must include a proper method for waste disposal in order to be sustainable.

Project Site
As our project site, we have selected the village of El Ejido del Desierto. This community lies a few miles south of the Arizona-Mexico border. Their wells have shown arsenic concentrations in the range of 80ppb. The Tucson chapter of Water for People is active in the village. They are working to expand the water distribution system. The expansion in the distribution system is likely to increase the number of people drinking the contaminated water, thus increasing the need for a treatment program.

Constraints
El Ejido del Desierto does not have the financial resources to install a conventional arsenic treatment facility. It is our goal to assist the residents in selecting a new treatment technology. Any technology must be low cost and operable by the local residents. Our project design is bound by the desires of the community population. Without their participation, the project will surely fail.

The groundwater in El Ejido del Desierto also has high fluoride concentrations. The fluoride has negative health impacts and it may affect the treatment efficiency for arsenic. There also is a need to design a waste disposal method for the brine or chemical precipitates with minimal environmental impacts. Low-cost arsenic removal is a developing technology and as such there are limited resources available to us in the research stage of the project.

1.2 Innovation and Technical Merit

The success of our design hinges on its ability to reduce arsenic to safe levels at a low cost. This is an active area of research, since communities all over the planet urgently need to decrease the

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impact of arsenic contamination on their health and their economies. While the prohibitive cost of known treatments is felt even in the U.S., the problem is most acute in developing nations, which often lack not only the funds but also the expertise needed to operate the treatment facilities. Furthermore, communities in developing nations are increasingly suspicious of outsiders wanting to provide solutions to health and environmental problems without the input of those responsible for maintaining the systems. Whether or not this attitude is present in El Ejido del Desierto, it is prudent to seek community participation for the sake of sustainability. Thus, our design will seek community acceptance in both technical and social terms, i.e. the goal is to devise a system that is simple to operate and simple to integrate with local customs, (and simple and inexpensive to maintain) and the people should feel a certain amount of ownership of the solution.

In order to meet these technical and social constraints, a unique combination of engineering and social science expertise is required. Our team will work in close consultation with partners experienced in implementing engineered solutions in developing communities. The organizations we have targeted for partnerships have demonstrated their ability to identify and include local experts and decision-makers, to educate the public, and to incorporate residents’ concerns and feedback at the earliest possible stage. Water for People already is consulting with the local water committee in El Ejido del Desierto and has helped us in the development of this proposal. For its part, the University of Arizona’s department of Hydrology and Water Resources is home to SAHRA, a leading authority on semiarid hydrology and a sponsor of most of our team members. Much of the success of our final design will depend upon our creation of an effective alliance to exchange interdisciplinary expertise.

Our initial research aim is to establish a range of treatment alternatives appropriate to El Ejido del Desierto and to analyze the tradeoffs. To do this, we will gather detailed information for new or under-studied technologies to compare with established technologies. Recognizing that our research might lead in new directions, we will initially concentrate our efforts on the possibility of solar distillation. This process has received little attention due to its limited output capacity, but we believe under certain circumstances this may be an ideal treatment. In particular, low output is not a problem where demand is low (e.g. small villages). Although most solar distillation systems have been abandoned due to low output, the technology has been demonstrated and actually applied using several different designs in India, the Middle East, Mexico, and a few industrialized countries\(^5\). Barrera developed a type of solar still in Mexico which he calculated to be “3.5 times more economical than chemical water acquisition”\(^6\). The purpose of these systems has mostly been desalination, but analytical tests have shown them to be capable of total removal of impurities such as nitrates, chlorides, iron, and dissolved solids\(^7\). There is every reason to believe the same would be true for heavy metals, i.e. arsenic.


\(^7\) M. Zein, Al-Dallal., 1984. Solar desalination correlation with meteorological parameters. 2nd Arab International Conference, p. 288.
In addition to solving many problems at once and costing very little (a simple still design is slightly more advanced than a greenhouse), the approach is technically favorable in El Ejido del Desierto because the Sonoran Desert has abundant sunlight and geothermal activity has produced groundwater in village wells with temperatures as high as 37°C (98°F).

A successful application in Mexico holds the potential for transfer of the solution to places around the world where low-cost arsenic treatment options are urgently needed. Applied to rural communities in the United States, solar distillation could potentially provide cleaner water than most large cities enjoy.

One of the primary benefits of a distillation process for treating water is that it completely removes heavy contaminants – not just a few targeted ions or compounds. In the case of El Ejido del Desierto, this aspect is particularly appropriate since the groundwater also contains high TDS (Total Dissolved Solids). Although high TDS does not pose a serious health risk, residents may not be willing to drink water treated by a method that does not also sharply reduce the concentration of bad-tasting dissolved solids. Combined with dilution from other sources not affected by high arsenic -- harvested rainwater perhaps -- solar distillation could very well offer water of sufficient quantity and quality to out-compete any other alternative.

Tiwari et al. surveyed the state of the art in solar distillation in a 2003 paper and the following was among their conclusions:

The double slope [fiber reinforced plastic] conventional solar still is the most economical solar still to provide drinking water for domestic applications at decentralized level. This is due to the fact that it is simple in design and fabrication, easy to handle (unskilled manpower is sufficient) along with longer life, low unit cost and low cost of water per liter. Further, due to low operation and maintenance cost it is most suitable in rural areas of remote regions.5

Tiwari’s lifetime body of work on the subject will be an invaluable resource; at the same time, there is great potential for innovation and improvement of existing designs (his own 2003 paper noted no less than 14 suggestions by others for increased efficiency). It is the nature of low-tech solutions to be easily adapted according to conditions and thus improved. The combined expertise in hydrology, chemical engineering, and anthropology assembled between the team and its partners will hopefully spur the kind of innovation that will successfully apply a solution in line with the residents’ needs, preferences, and limitations.

Despite our high hopes for solar distillation, we recognize that the ultimate analysis of technical, economic, and social factors may not show that it is the most appropriate solution for the particular village we have chosen to study. In such a case it would be non-sustainable and probably immoral to urge residents to experiment with an inferior solution. Therefore, at every stage we aim to compare alternatives with a most critical eye, and specifically to resolve the questions: (1) is a central treatment facility preferable to point-of-use treatments, and (2) what is the most appropriate combination of chemical treatment, physical separation (filtration), and distillation?
One challenge that exists for most of the available methods is the concentration of fluoride in the groundwater of the village. However, depending on the capacity for harvested water or the availability of other sources, dilution to safe levels may be feasible. Indeed, the same contaminants are not likely to be found in rainwater and treated groundwater, so the two sources could be used to dilute each other. By considering the entire system for water distribution (which requires expansion anyway) and not just the treatment component, we leave the door open for the necessary innovation to guarantee the people of El Ejido del Desierto a healthy and sustainable supply of water.

1.3 Sustainability

Water distillation is one method to remove salts and metals from drinking water for small communities. Solar water distillation has low energy and low operational costs. Thus, solar distillation is an ideal technique in desert areas where solar energy is not a limiting factor. Research, development and implementation of this technique is applicable in both developing and developed countries. Appropriate user communities can be found in developed countries, such as Native American communities in the U.S., and in developing countries, such as the border communities of Mexico. The success of the present project will provide clean drinking water for healthier future generations.

People
Poor water quality can have particularly negative affects on the youngest members of a community, which is the base for the future economic success and growth. While, the implementation of a solar distillation plant in a community will provide metals-free water for all, the children will benefit the most.

The success of the present project will not only help to provide the basic need of quality water to one border town, but will lay the foundation of a new treatment plan that can be scaled up to many towns with similar socio-economic and climatic conditions. As mentioned before, many rural border pueblos have an immediate and long-term need for improved drinking water quality because of high concentrations of arsenic and fluoride. This technique will provide an affordable procedure which is easy to implement and provides good quality water to all the population. The short-term effect will be a reduction of internal cancer rates and fluorosis of bones and teeth, and the growth of a healthier future generation.

Prosperity
Currently, a majority of the population of El Ejido del Desierto relies on expensive bottled water for their drinking water needs. Any technique developed to reduce (or eliminate) arsenic, fluoride and/or salts from water must be sustainable, affordable to the community, and environmentally and politically appropriate to the community’s needs. Solar distillation fulfills these requirements, with minimal energy costs, with no chemicals required, and can be easily managed by local people. Solar stills can be built with local and regional materials (glass and cement), easily encountered and replaceable, while always respecting certain quality standards. The use of these materials will reduce implementation and maintenance costs and promote long-
term sustainability. The acceptance and understanding of the proposed design by the community is critical in the initial and future implementation and operation of the system.

**Planet**

Solar distillation is relatively efficient in the Sonoran Desert region, which typically experiences 350 sunny days per year, more daylight hours and high solar radiation. These factors will assure an energy input sufficient to operate the system without damaging the environment with non-renewable energy inputs. The higher temperature of the groundwater (due to the natural geothermic gradient) will further reduce the energy needs of the distillation process, possibly allowing for greater output than otherwise achievable.

The waste residues generated by the solar still could be added to the irrigation water after a natural aeration and oxidation process that naturally reduces the arsenic concentration to a level that is safe for agricultural purposes. This possibility will be under study.

The success and further spread of the present project will result in improved public health in the economically and technically challenged border towns.

**1.4 Outcomes and Implementation:**

Both short-term and long-term factors will be evaluated in determining the success of this effort. The project objective is to provide safe drinking water to the inhabitants of El Ejido del Desierto, which should reduce all types of water-related illnesses, particularly cumulative arsenic and fluoride poisoning. The success of the project will be measured in two ways. First, we will assess the quantity and quality of drinking water made available to the local populace. Second, we will evaluate the long-term sustainability of the system.

The results of technical and social challenges will be measured in different ways. Certain aspects of the technical performance can be measured quantitatively, such as water quality and amount of water per capita produced per week. Other aspects, relating to the implementation of the system in the community, can only be evaluated qualitatively. Nevertheless, adequate objective indicators will be used in order to make a performance assessment. Overall, the most important point is to ask to what extent this plan provides a safe and sufficient drinking water source and to what extent the community is able to handle its daily operation and long-term maintenance. We will evaluate that effectiveness of the transboundary collaboration between our partnerships and the awareness and education achieved through the activities described in the following section.

In order to evaluate the results and the degree of success of the project, the following indicators will be used when making assessments of the project:

Indicators to evaluate technical performance: (WFP & U of A)

- Percentage of arsenic removed
- Percentage of fluoride removed
- Percentage of TDS removed
- Average amount of water per person produced per week
• Amount of waste generated per volume of safe water produced
• Frequency of repairs needed

Indicators to evaluate integration of the system in the community and its sustainability:
Population acceptance survey: (BARA, WFP)
• Do they like the taste and odor of the water?
• Do they use the water for both drinking and cooking?
• Do they feel comfortable using the system?
• Do they understand how the system works?
• Do the people trust the created water commission?
• Does the water commission perform the ordinary maintenance correctly?
• Are the spare parts easily available in the local market?
• Does the water commission know who to talk to when facing a problem they cannot solve?

In order to evaluate the transferability of the method, which is expected to be high – other communities with similar problems and other chapters of Water for People or similar non-government organizations will be approached. New problem scenarios will be analyzed in order to see to what extent the same system methodology can be applied. Feedback from the present project will be a key element to decide what should or should not be improved or modified.

The implementation strategy will give an important role to the involvement of the community and the partnerships in the project. The contributions of entities that understand the social and cultural challenge of the project in the setting of a developing country – such as BARA and Water for People – are critical. An effort will be made to help the community identify their water problems and all the possible solutions. A town committee will be created, composed of social communicators and relevant people, in order to represent, organize collaboration and ensure community involvement during the development of the project. Community involvement should be as high as possible so that anything that can reasonably be provided by locals, such as manpower, material resources, food and hospitality to visiting workers, should be included in the project.

Community participation and the town committee should guarantee the continuity and functionality of the project in the long-term. Depending on the general acceptance and on Mexican laws regarding this issue, possibilities for the implementation of a communal “tax” collection system for water use could be studied to help ensure the maintenance and spare parts acquisition capacity for the system.

2. Implementation of P3 concepts as an educational tool

This section is divided into two parts. The first focuses on the educational impact on students, the second focuses on the projects impact on the community.
Students

People
Scholastically, the project was initiated and developed by students in a seminar class about semi-arid hydrology and sustainability at the University of Arizona. If this project is funded, there will be a seminar every semester dedicated to this project. The seminar allows for a broader audience in which ideas are shared among students with varying backgrounds. This particular seminar has also taught valuable grant writing skills. It has taught the students to cooperate on the writing of this proposal, which is an important team building skill. In addition to the seminar, the students will be presenting their ideas and work at national meetings such as the American Geophysical Union (AGU) and the SAHRA annual meeting. This will allow an even broader dissemination and discussion of project ideas.

There is also an important international aspect to the project in terms of education. As the students working on the project are in the United States and the community of interest is in Mexico, the students will get an opportunity to learn about the social aspects of their science as well as be exposed to a different culture. The difference goes far beyond the language and into the very fundamental fabric of the society and what is important to them. It will give the students an opportunity to step outside of themselves and approach a problem from a different point of view. The opportunity to interact on a social and scientific level with people from outside of the United States and the university will allow them to learn important lessons that cannot be taught in the classroom.

Prosperity
The project is also an educational tool in applying the principles of hydrology taught in classes to a practical, applied problem. This type of problem solving will be important in the development of skills needed by students after graduation. The problem of arsenic removal in groundwater involves all the main aspects of hydrology: surface water, water chemistry, groundwater, and water policy. This will require the application of these techniques to a real community with particular needs. As many hydrology students pursue careers in consulting, this will help them prosper in any firm in which they choose to work.

Planet
The study and application of hydrology helps contribute to the health of the planet in the subsurface and surface waters. In this project, the remediation of the site in Mexico is one step in the process of educating the students on the physical and social science of cleaning up contamination of the Earth’s most precious resource, water.

Community
This project is an excellent topic for educational purposes in the community and will have two main areas. The first is education in health, including the adverse health effects of high levels of arsenic and fluoride in their drinking and bathing water. Promoting the involvement of local teachers to play their role in water and sanitation education and hygiene promotion in the community will be a key element to ensure a real and a long-term impact in the community.

The other is the education in how to operate and maintain the technical aspects of the removal. As the community is crucial in deciding the method of contamination removal, they are also crucial in the installation and daily maintenance. Once the technique has proven to be a success,
the community can then help educate other rural towns by serving as a model as well as possibly physically working with other community groups, SAHRA and Water for People in other rural towns in Mexico who would like to implement similar systems.

The effective clean up of arsenic, fluoride and total dissolved solids will make the community a much more desirable place to live. This will improve the living conditions for the people currently living there as well as encourage more people to move in. This will create an increased local economy. The clean up will also improve the health of the people thus allowing for fewer medical bills, which will also increase the local economy.

At the completion of the El Ejido del Desierto site clean up, the educated community can take what they have learned and help other communities. The remediation will create a cleaner environment in every community in which it is utilized and educated citizens to continue to keep it clean.

3. Project Schedule

In order to successfully implement the proposed project we must have a preliminary timeline on which we will base our progress. This timeline will be open to minor changes when warranted, however the milestones set forth in this schedule shall be regarded as the primary framework for our project. The following project schedule will outline the major milestones of the project and will also list the participants at each step.

_write Grant_

The first step toward the completion of our proposed project will be the writing of the P3 grant. This phase has been carried out by the members of a University of Arizona seminar class (HWR 696). This group along with future HWR 696 class members will serve as the core group for researching, developing, and implementing the project. The grant writing phase shall be completed by March 25, 2004.

Seek Partnerships and Support

During the grant writing phase of the project, all members of the HWR 696 class shall seek support from local organizations. We will seek out organizations that we feel will be capable of supporting the project with expertise, funding, and/or existing relationships with the targeted community. Partnerships shall be established by March 25, 2004.

Award Notification

Once the grant has been written, successful implementation of the project will hinge on whether the project gets funded or not. If the project gets funded we should receive award notification by August 2004.

Begin Research

Once we have received the award notification, we will begin the secondary phase of research. During this phase we will identify the actual process and technologies which we will use to remove arsenic from the water of El Ejido del Desierto. This research is in addition to the
preliminary research done during the grant writing phase. At this point we will identify the best possible solution to our problem. This shall be completed by December 2004.

**Begin Community Research**
Grant partners will begin assessing community needs, desires and capabilities during the fall and spring of 2004/2005. There will be close communication between the community and technical study groups to ensure adequate feedback between these two principle participants.

**Prototype**
Once we have established the best method for removing arsenic from the water supply of El Ejido del Desierto, the members of HWR 696 will develop and build a prototype of the proposed system. This will be done with the help of experts within the Hydrology Department at the University of Arizona. The prototype shall be installed at either El Ejido del Desierto or at a closer yet appropriate location to simulate the conditions at El Ejido del Desierto. The prototype shall be completed by May 2005.

**Reporting**
Two team members will attend the P3 Award Competition symposium in Washington, DC, May 2005. At least one other venue will be selected for sharing the results of this study with a wider audience.

**Implementation**
Once the prototype has proven to be a successful method for reaching our desired goals the HWR 696 team will work with Water For People and BARA to implement the system in El Ejido del Desierto. The working system shall be completed by September 14, 2005.

**Check and Maintenance**
System checks shall be performed at regular intervals once the system is up and running. These checks as well as the routine maintenance of the system shall be conducted by previously trained members of the El Ejido del Desierto community. Initial system checks will be conducted by University of Arizona team members. The initial check will be done within the first month of operation.

**Apply technology to other communities**
It is our hope that we will eventually be able to utilize the technologies applied in El Ejido del Desierto to other Mexican border communities. If there is funding to do so, we will identify other possible communities after six months of successful operation at El Ejido del Desierto.
4. Partnerships and Letters of Support

We have secured partnerships with three local organizations: SAHRA, BARA, and Water for People. Our partnerships with these organizations will strengthen the overall experience and expertise of the project team, as well as enable us to develop better relationships with the community of El Ejido del Desierto.

a. SAHRA (Sustainability of semi-Arid Hydrology and Riparian Areas) is a NSF science and technology center within the University of Arizona’s Hydrology and Water Resources Department. SAHRA is focused on the sustainable management and scientific understanding of semi-arid water resources.

b. BARA (Bureau of Applied Research in Anthropology) is a research institution within the University of Arizona’s College of Social and Behavioral Sciences. It is BARA’s mission to apply social science knowledge toward an enhanced understanding of real-world problems. We seek to work with the Bureau’s cross-border internship program.

c. Water for People is an international humanitarian organization with chapters in Tucson and within the University itself. Water for People was created by a group of water professionals from the American Water Works Association (AWWA) in 1991. This international, non-profit organization seeks to increase access to safe drinking water for communities in need.