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**World Water Forum College Grant Program  
2007 Grant Proposals**

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**College**

University of Redlands (1)

**Faculty**

Dr. Max Baber

**Project**

Developing a GIS-Based Suitability Model for  
Rural Water Supply in Rwanda

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# **Developing a GIS-Based Suitability Model for Rural Water Supply in Rwanda**

A faculty-student project to be carried out in collaboration with the Millennium Villages Project and the National University of Rwanda in the summer of 2008



***Submitted by***

University of Redlands College of Arts and Sciences and  
The Redlands Institute  
1200 E. Colton Ave  
Redlands, CA 92373

***Submitted to***

Metropolitan Water District of Southern California  
700 North Alameda Street  
Los Angeles, California 90012

**Important Note:** a letter of support is forthcoming from the Millennium Villages Project Staff. It will be forwarded as supplemental documentation to this proposal once it is received.

A.

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Make Check Payable To:	University of Redlands

B.

Applicant	
First Time – Local Project	
First Time – Global Project	X
Existing Project – Local Focus	
Existing Project – Global Focus	

C.

Student Project Manager	TBD
Undergraduate or Graduate	Undergraduate
Department	Environmental Science / Master's of GIS
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D.

Faculty Project Manager	Dr. Max Baber
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<b>Department</b>	<b>Geographic Information Science</b>
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## **E. ORGANIZATIONAL BACKGROUND**

The University of Redlands (U of R) has an undergraduate degree program in environmental science, an applied research group known as the Redlands Institute (RI) and a one-year intensive Master's degree program in geographic systems (GIS). These three programs are designed to work in complementary and synergistic ways to enhance students' knowledge of environmental issues and to facilitate applied learning through exposure to 'real world' projects. The subject of this proposal is to use funds from the World Water Forum Grant to provide students from the U of R and from National University of Rwanda (NUR) an opportunity to apply their studies in environmental sciences and GIS to a 'real world' problem of rural water supply in eastern Rwanda.

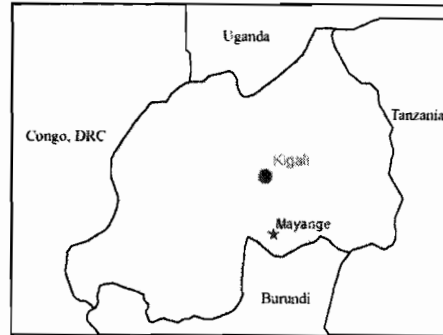
In recent months, the University of Redlands, in partnership with Loma Linda University (LLU), has begun a dialog with the National University of Rwanda's GIS Centre and a network of non-profit organizations operating throughout that country on economic development, environmental conservation and educational programs. The GIS Centre is an applied research group affiliated with the National University and is located near the main campus in Butare, approximately 120km southwest of the capital, Kigali. A representative from the NUR's GIS Centre visited the U of R and LLU in June of this year for a series of high level meetings. More recently, a team from the U of R and LLU that included the U of R's Dean of the College of Arts and Sciences and the LLU's Chancellor traveled to Rwanda to continue this dialog and to forge partnerships with other organizations.

During this visit, the U of R/LLU team met with representatives from the Millennium Villages Project (MVP). Millennium Villages are established as models for combining the best scientific, technical and local knowledge to solve issues of extreme poverty in Africa. 79 Village projects are in operation throughout the world. In Rwanda, the MVP team consists of international experts and local staff working in the Mayange Sector of Rwanda, a region that is highly prone to water shortages and disease caused by poor access to ample, clean water. An outcome of these meetings was an agreement that the U of R/LLU team would work with MVP staff to identify opportunities to collaborate. There was particular interest in lending the U of R's expertise in GIS along with its faculty and student resources to leverage MVP's ongoing projects in Mayange. Chief among MVP's needs are student and faculty assistance to use GIS to evaluate community water supply, demand and quality. Related to this is a pressing need to train local Rwandan students and young professionals to use GIS.

## F. PROJECT DESCRIPTION

### Rationale and Need for Proposed Work

The Millennium Village in Rwanda is located in Mayange sector in Bugesera district, Eastern Province. The area is almost completely deforested and receives ~800mm of intermittent annual rainfall. Crop failures due to lack of rainfall are increasingly common and drinking water supplies are scarce and often dirty and unreliable. Women and children bear the major burden of water collection, traveling long distances, almost always on foot. Pumps and faucets are often neglected or broken and conservation measures are essentially non-existent. Access to water tables deeper than about 50 meters is not possible in most areas due to lack of power for motorized pumps.



*Shallow protected well (courtesy Susan Doll)*

In Mayange there are challenges for all aspects of water use: access and availability, quality, ownership and upkeep of water access points, environmental degradation and water source contamination. One of the major goals of the Millennium Villages Project is to increase access to clean drinking water. Current sources of water include the following:

- piped water system
- boreholes
- shallow protected and unprotected wells
- rainwater from puddles
- rainwater harvesting from rooftops
- collection of rainwater and surface runoff in water ponds

### Project Objectives and Outcomes

The objective of the proposed work is to assist MVP to use GIS and global positioning system (GPS) technologies to identify ways to improve community water access points in Mayange. The term 'water access point' is used to refer generally to a variety of ways to improve community access to water. These improvements may be as simple as fencing off a spring to prohibit access by livestock, to engineered solutions such as extension of the piped water systems, installation of shallow wells or deeper



*Shallow unprotected ground water (courtesy Susan Doll)*

bore holes.

MVP's challenge is to identify the environmental and social/cultural conditions that contribute to ample, clean water supplies. Once understood, this information can be used to make targeted interventions to improve existing water sources and to identify new ones. To assist MVP in this endeavor, the joint U of R/NUR Team will work with MVP's Infrastructure Coordinator, Dr. Susan Doll and her staff to develop a GIS model that will identify factors and locations associated with good water quality and quantity. The model will also help MVP to better diagnose problems with existing sources so that they can take action to improve them.

The premise behind the model is simple: information about known locations of high quality, reliable water can be used to predict other locations where a good water source is likely to be found. Moreover, that same information can be used to diagnose the limitations of existing water sources. To develop the model, environmental and social/cultural information for existing 'good' sites will be compiled and formatted for use in a GIS. Characterizations of these sites will then be developed and compared. This assessment may reveal, for example, that a good site has vegetated land cover, be within a short distance from a perennial stream, have a positive recharge to extraction ratio, a particular soil and geomorphologic profile, be on communally owned property and be excluded from livestock grazing. Once developed, these characterizations will be applied to other geographic locations using a GIS technique called multi-criteria evaluation (MCE). The degree to which those locations are similar to good sites will determine their suitability as a water access point. The results can be expressed on a map, where each location is coded according to its suitability score. The locations of other 'less good' water access points can then be plotted on the resulting map and compared to good areas. The model will allow the team to better diagnose problems at 'less good' sites and to identify new areas that may prove to be suitable locations for water source improvement projects.

The team will rely primarily on data previously collected by MVP through surveys of household water use and water sources in one section of Mayange. Additional data on environmental, demographic, topographic, hydrogeologic and climatic conditions will be provided by the GIS Centre in Butare. These data will be incorporated in a GIS database and used to develop the model. Analysis will be carried out by the U of R team, their GIS Centre counterparts, students and MVP staff. Maps, tables and other documentation summarizing the outcomes of the analysis will be provided to MVP and included in the final project report.

The principal outcomes of the work will be:

1. Improved approaches to analyzing rural water supply through use of GIS/GPS technologies;
2. Information that will assist MVP to plan and implement water source interventions in Mayange; and
3. Trained Rwandan and American students to use GIS and GPS technologies in water resources planning and management

## **Business Plan**

The following describes a general scope of work to be carried out by the joint U of R/NUR/MVP team in Rwanda during the Spring and Summer of 2008.

### Task 1. Inventory and Evaluate Existing Data Needed for the Model

The U of R team will conduct a rapid inventory and assessment of available environmental and household datasets provided by the GIS Centre and MVP. The purpose of this task is to identify potentially relevant sources of information and to assess them in terms of their overall quality and usability. Results of this task will be documented in a Data Inventory Database. This database stores key attributes of existing datasets such as spatial scale, source, format, quality, whether they are current, etc. The types of data required for this kind of model include but are not limited to:

- Village locations, population size and distribution
- Surface hydrology
- Subsurface hydrology
- Land use/land cover
- Land ownership
- Topography and slope
- Rainfall
- Existing water access locations by type (i.e. surface water, bore hole, well, etc)
- Descriptive information about existing water sources, including daily extraction and recharge rates and anecdotal information related to quality and availability

### Task 2. GIS data conversion and database development

Once the required data have been assembled, the team will reformat these data as needed so that they can be incorporated into the GIS database. Required manipulations to these data may include spatial rectification, geocoding, attribute modification and where necessary, digitalization of hard copy maps and/or household survey forms. Once converted to GIS-ready format, the data will be imported to a geo-database. Simple maps will be generated to communicate the available information and to solicit feedback from MVP staff and others.

### Task 3. Design GIS-based suitability model

During this task, the U of R team will design a GIS model for evaluating 'good' site conditions for water access points. The design will be based on the MVP Infrastructure Team's understanding of water access siting criteria and parameters, which will be documented through a combination of questionnaires (administered remotely in the Spring of 2008) and through in-person interviews once the U of R team is on site in early summer. The outcomes of this task will be documented in a Geoprocessing Diagram

that graphically depicts the criteria, parameters, datasets, processing steps and model outputs. This diagram will be provided to MVP staff for review and comment. The team likely will produce several drafts of this flow diagram before a physical GIS model is produced.

#### Task 4. Implement GIS-based suitability model

In this step, the Geoprocessing Diagram will be implemented as a physical model using GIS software such as ESRI's ArcGIS ModelBuilder. The model will execute the spatial processing tasks, calculations, statistical summaries and map outputs specified in the design. Key parameters of the model will be exposed so that users can modify parameters such as buffer distance and suitability ratings, re-run the model and evaluate the results. Once the model is functional, MVP staff and others will be invited to explore and use the model in a workshop organized by the U of R team. This workshop will provide users a first opportunity to evaluate its quality and usability. It will also be the venue for creating multiple model outputs by modifying the input parameters. These outputs can then be compared by the group until agreement is reached on a map that adequately depicts water source suitability. Locations of existing water sources can be overlaid on this map to understand the spatial relationships between 'good' and 'bad' water sources.

#### Task 5. Preliminary Field Validation

Model outputs will be validated by field visits to the areas identified as having high water source suitability. Field teams will make observations of environmental conditions, water availability and speak to villagers about how and where they access water. GPS units will be used to record the locations of sites visited and be paired with survey forms developed by the team to collect standardized data about observed conditions. Results of the field visits will be used to corroborate or refute model results and to make adjustments to the model as necessary.

#### Task 6. Communicate Results and Measure Outcomes

The U of R team will host a final meeting with MVP staff and NUR students at the end of their visit to discuss the overall success of the project, needed enhancements to the model, and to identify opportunities for further joint research. Outcomes of this meeting will be documented for performance evaluation purposes. Final outcomes of the project will be documented in July-August in Redlands, culminating in a final report to be provided both to MVP and the Metropolitan Water District.

## Products

The following is a listing of anticipated products and their completion dates. These materials will be submitted both to MVP and MWD at the completion of the project.

Product	Completed By (2008)
Data Inventory Database	April
GIS database	May
Suitability Model Design Diagram	May
Draft Suitability Model	June
Final Suitability Model	July
Final Report	September

## Partnerships

This grant will help to forge new partnerships between the University of Redlands, the National University of Rwanda and the Millennium Villages Project. The benefits of this partnership are many. First, it meets an immediate MVP need to plan and implement water source improvement projects in Mayange. Second, it provides an opportunity for transfer of knowledge and skills between Rwandan students and faculty and their U of R counterparts. This will result in greater technical capacity in Rwanda, a commodity that is in very short supply as Rwanda works towards a national goal of creating a technology literate society. It will also be an invaluable learning experience for U of R students, preparing them professionally while raising their awareness about issues in developing countries and the role they can play in solving them. Finally, this partnership will directly support community based interventions that will improve people's access to a basic human need: clean, reliable domestic water.

## Performance Evaluation

In order to measure the degree of success at achieving the stated outcomes, the U of R team will work with MVP and the GIS Centre to establish project performance indicators. These indicators will be defined in greater detail in Spring 2008 but generally will measure:

1. The degree to which GIS technology improves MVPs water intervention planning process;
2. Improvements to community water supply and quality as a result of MVP actions taken using the results of the GIS-based analysis; and
3. Improvements in American and Rwandan student capacity to use GIS to solve water source issues.

Indicator one (1) will be measured through in-person interviews and meetings with MVP staff at the end of the team's visit in Rwanda. Indicator two (2) will be measured by MVP staff through field observation and interviews with villagers. Results from this indicator will be time dependent on MVP implementation of water access projects. Nonetheless, preliminary observations of improvements to community water supply will be incorporated into the final report as they are available. Indicator three (3) will be measured through faculty and MVP staff evaluation of student work products. The outcomes of these evaluations will be documented in the final project report.

### Project Schedule

Upon receipt of grant funds in the Spring of 2008, the U of R team will contact MVP and the GIS Centre at NUR to make arrangements for joint work in Rwanda beginning in May. This will include making necessary logistical arrangements and identifying 2-3 Rwandan student interns who will be local counterparts to the U of R team. During April, the U of R and NUR students will begin an inventory and evaluation of available datasets and identify the required data conversion steps necessary to create a unified GIS database. This work will continue in May and will occur in tandem with design of the GIS suitability model. A first draft of that model will be completed in early June. Field verification will begin in the latter part of that month. In mid-June, the project team will have a final meeting with MVP staff to review the outcomes of the project and to assess its success. This information, along with the model documentation, will be compiled by the U of R team in July – August with a final report submitted both to the MWD and MVP in September. The following is a general schedule that reflects the planned sequence of tasks:

TASK	4/08	5/08	6/08	7/08	8/08	9/08
Task 1. Inventory and Evaluate Needed Data						
Task 2. GIS Data Conversion/Database Development						
Task 3. Design GIS Model						
Task 4. Develop/Refine GIS Model						
Task 5. Preliminary Field Validation						
Task 6. Communicate Results and Measure Outcomes						
Completed Project due to MWD						

## Relevant Experience

The Redlands Institute and the University of Redlands have successfully implemented more than 30 projects at the local, national and international scale. The University has a depth of faculty and professional staff who are well-qualified to provide support in areas such as GIS, information technology, and natural sciences. Our research combines science and technology to develop application prototypes for field data collection, desktop processing, and server/internet-based processing, to solve problems at the intersection of science, policy, and management. Relevant project experience includes:

- Salton Sea Database Program (SSDP): a congressionally funded, \$4.5M, five year project administered by the U.S. EPA, to (1) establish a decision support "infrastructure" of data management and analysis tools; and (2) support coordinated decision-making among stakeholders for restoration of the Salton Sea.
- Imperial Valley Spatial Data Infrastructure: a grant from the California State Water Resources Control Board to implement an integrated GIS database and web-based GIS application to support total maximum daily load (TMDL) requirements in the Salton Sea watershed in California's Imperial Valley.
- Maternal and Child Health Indicator Analysis, San Bernardino County: Conducted hotspot and other spatial analyses of health indicators for the Children and Families Commission's First 5 Program. Outcomes used by Commission to prioritize funding for community-based organizations offering prenatal care, health education and child welfare programs.

## G. PROJECT MANAGEMENT TEAM

The U of R team will serve as project managers and technical experts in the use of GIS and GPS, suitability modeling and GPS mapping. They also will contribute 4 GPS units and laptop computers equipped with GIS software for the duration of the project. Dr. Susan Doll and her colleagues at MVP will serve as domain experts on water resources appraisal and be closely involved in the design of the suitability model. Susan will also serve as an overall advisor to the U of R/NUR Team. MVP will also provide local accommodation near the site (Nyamata), transport during normal working hours in the village, some meals, use of some equipment such as GPS units and office space. NUR students will serve as GIS interns, community liaisons and interpreters for the U of R team. They will be hand selected by GIS Centre and MVP staff. The NUR GIS Centre will provide spatial data, general GIS technical support and use of their GIS lab as needed.

	NAME	TITLE	ADDRESS	PHONE & EMAIL
1	Dr. Max Baber	Associate Professor, GIS	Lewis Hall, U. of Redlands, 1200 E. Colton Ave, Redlands, CA 92374	909-748-8525 Max_Baber@redlands.edu

2	Dr. Susan Doll	Infrastructure Coordinator	Millennium Villages Project, Postal Address: BP 7393, Kigali, RWANDA Office Address: No. 2106, Rue du lac Mpanga, Kiyovu, Kigali RWANDA	USA Vonage: 646-290-6276 Rwanda: +250-03049162 sd2285@columbia.edu
3	Dr. Kurt Brassel	Director, Center for Geographic Information Systems	National University of Rwanda, P.O. Box 212 – Butare, Rwanda	250-08-606-208 kbrassel@cgisnur.org

### H1. SOURCE OF FUNDS

DESCRIPTION	AMOUNT	NOTES
GRANT FUNDS REQUESTED FROM MWD	\$10,000	
ADDITIONAL SOURCE OF FUNDS: Millennium Village Project/NUR CGIS	\$2,500 (estimated value)	DATE ISSUED (if applicable): Summer 2008. In-kind contribution of staff volunteer time, room, partial board and local transport in Rwanda.
ADDITIONAL SOURCE OF FUNDS: University of Redlands	\$7,500	DATE ISSUED (if applicable): Summer 2008. Support for U of R team travel and expenses to Rwanda.
PROJECT TOTAL	\$20,000	

### H2. BUDGET (for funds requested from MWD)

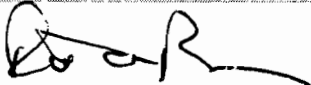
LINE ITEM	AMOUNT	DESCRIPTION
STIPENDS	\$5,000	Stipends for faculty and students: \$4,000 for Dr. Max Baber, U of R faculty and project manager; \$500 each for 2 U of R undergraduate student interns.
LAB FEES	none	
OFFICE SUPPLIES	\$300	
CONSULTANT	\$3,000	Support for student and staff consultants at NUR GIS Centre: \$500 each for 2 undergraduate

NUR consultants;

\$2,000 for staff consultants from  
the GIS Centre

OVERHEAD FEE	\$1,000
CONFERENCE REGISTRATION	none
EQUIPMENT	\$700
OTHER (Define)	none
<b>TOTAL</b>	<b>\$10,000</b>

**SIGNATURE BLOCK**

	NAME	SIGNATURE	DATE
Faculty Project Manager	Dr. Max Baber		12/14/07
Student Project Manager	TBD		
Member Agency Representative <sup>1</sup>	Benita Lynn Horn		

Note: On a voluntary basis, the Member Agency, has agreed to serve as the local partner for the college / university. As a non-fiscal partner, the Member Agency is not required to provide financial assistance for the Project. At their discretion and strictly on an as-needed basis, the Member Agency will provide in-kind resources and technical assistance for the college / university, pending availability of requested resources or personnel (subject matter experts). Excerpt from MWD-College Funding Agreement

<sup>1</sup> For a list of local water agencies (member agencies), log onto [www.mwdh2o.com](http://www.mwdh2o.com) or you may contact the Project Coordinator, Benita Lynn Horn at [waterforum@mwdh2o.com](mailto:waterforum@mwdh2o.com) or (888) 42-WATER.

