EWRI CURRENTS
VOLUME 17, NUMBER 4
FALL 2015

ESTIMATING FLORIDA STATEWIDE AGRICULTURAL IRRIGATION DEMAND (FSAID) USING ECONOMICS AND ENGINEERING MODELS

Valerie Seidel, Ray Scott

Despite receiving more than 50 inches of rain annually, Florida faces issues of long-term water security to support its economy. Over the past decades, Florida has been involved in litigation over water supply between water suppliers within counties, between counties within the state, and with other states. Hence, long-term water supply is an important public policy issue that requires coherent and defensible approaches to planning. In Florida, despite dense urban development, 40% of the total water use, or about 2,551,000 Million Gallons per Day (MGD) results from agricultural irrigation (Marella 2014). In recognition of this large consumptive footprint amid heightened water scarcity, The Balmoral Group recently developed a model for the entire state of Florida, showing the prediction potential for a large geographical context. A large-scale model was developed to predict future irrigation demands based on the combination of physical and economic factors that impact water use in agriculture.

Over the past twenty-five years, U.S. researchers have noted agricultural irrigation practices in western states shifting eastward; more intensive agricultural irrigation has accompanied a decline in overall agricultural land. At the same time, adoption of increasingly efficient technology has slowed the increase in total water use from rates seen in prior decades. Responses to market conditions, including land use constraints, urbanization pressures and energy costs, are reflected in the crop mix and irrigation decisions made by producers.

The Florida legislature recently adopted new provisions for agricultural water supply that require the Florida Department of Agriculture and Consumer Services (FDACS) to develop geographically specific water use estimates that incorporate metered and other water use data into a 20-year horizon, across the entire state. In the past, Florida's five water management districts (WMDs) used their own individual models to estimate agricultural water use separately for each region. As a result, statewide estimation was fraught with inconsistency. For example, a crop in one district might be said to require 70 percent more water than the same crop ½ mile away, but in another district, due to differences between estimation approaches. To overcome this type of inconsistency, The Balmoral Group was tasked with estimating agricultural water use for all the farms across the state; this is the Florida Statewide Agricultural Irrigation Demand (FSAID) project.

The Balmoral Group's model was completed as four related steps. First, a dataset of all agricultural lands was prepared in a geographic information system (GIS), and irrigated lands were identified. Water use estimates were developed using econometric techniques to link current and historical biophysical factors, irrigation water use data,

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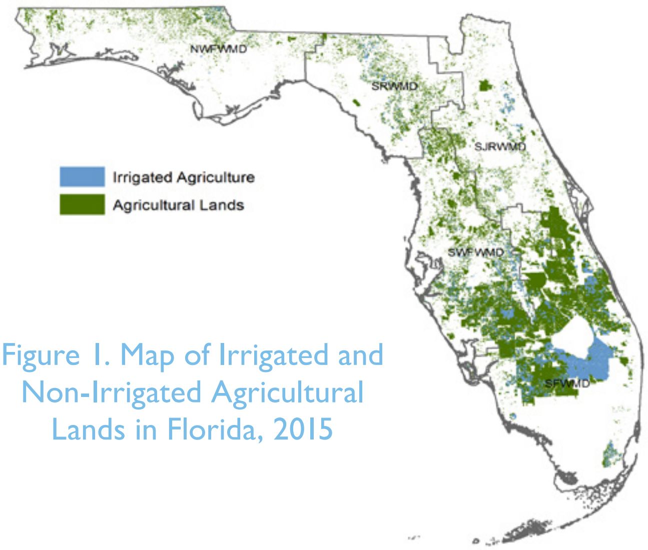


Figure 1. Map of Irrigated and Non-Irrigated Agricultural Lands in Florida, 2015

HELP EWRI WELCOME OUR NEW PRESIDENT FOR 2016, **DAVID DEE**

Inform, Inspire and Engage- these are actions I promised I would do for our members if elected to the governing board to help us all continue to work toward achieving EWRI's vision. This column gives me the opportunity to do so.

Let me first inform you of some of our outstanding volunteers and the changes that occurred to the Governing Board as of October 1, 2015. Paul Bizier, P.E., BCEE, F.EWRI, F.ASCE will serve the final year of his 4-year term on the Governing Board in the role of Past-President. Under Paul's leadership as President, he helped advance EWRI's strategic plan and initiatives, helped rejuvenate and revise the Member Services Council with new committees for younger members and students, and helped that Council refocus on the members it serves. A. Charles Rowney, Ph.D., P.Eng., D.WRE, F.EWRI, M.ASCE, will be rotating off the Governing Board. Charles has served two terms (six-years) as the Chair of the Technical Activities Executive Committee (TAC ExCom). In this role, he has helped refocus the TAC ExCom to becoming an efficient clearing house for our technical committees' activities, budgets, and products. Charles has also been an effective champion for Green Infrastructure and Low Impact Development and will continue advancing these practices in our organization. Scott Struck, M.ASCE, will also be leaving the Governing Board this year having served twice in the year-long role as the President-appointed Treasurer.

I would like to welcome the following members to the Governing Board. Congratulations to Cristiane Q. Surbeck, P.E., Ph.D., ENV SP, M.ASCE, who was elected as Vice President and begins her 4-year term on the Board. Welcome also to Victor Cook, A.M.ASCE, who will serve a 3-year term as the Chair of the TAC ExCom. And welcome to Eric Loucks, P.E., D.WRE, M.ASCE, who will serve as this year's President-appointed Treasurer. I look forward to working with these new Board members! Finally, I would like to welcome new EWRI staff member Barbara Whitten who will serve as the Program Manager of Technical Committees. She joins an outstanding staff consisting of our Director, Brian Parsons, Manager, Gabrielle Dunkley , Technical Manager, Barbara Whitten, Administrator, Maureen Maldonado, and Communications and Projects Coordinator, Veronique Nguyen.

To inspire you, I need only to highlight the efforts and research of EWRI member Daene McKinney, Ph.D., P.E., D.WRE, M.ASCE, who has spent the past ten years studying the effects of climate change on the high mountain lakes in the Himalayan Mountains of Nepal. So after the April 25th 7.8-magnitude earthquake struck the region, Daene's prior experiences helped him lead a research team on a two month mission to assess the increased risk of flooding to downstream villages from potential failures of these lakes, and also provide the region with better information on post-quake conditions. EWRI along with ASCE are among the many groups that provided financial support for the mission. You can read more about Daene's trip and efforts here: http://blogs.asce.org/two-months-in-nepal-asce-member-leads-post-earthquake-assessment/

To engage our members, I challenge you to reach out and get involved with one of the 26 domestic EWRI chapters that have been established as we continue with our strategic initiative of providing outreach to ASCE's Sections and Branches. There were a total of 5 new chapters formed this past year, including a chapter from my home state of Maryland, the Chesapeake Bay Environmental & Water Resources Institute Chapter, led this year by President Rosanna LaPlante, PE, M.ASCE. I have attended these meetings and find that the programs offered at the local chapter meetings are more geared toward technical content associated with the environment and water resources, thus attracting more water related designers, scientists and engineers than would go to a local ASCE meeting. If you feel so inspired, you could also help organize and form a new chapter in your area, and our Member Services Council, chaired by Sheila Carpenter-van Dijk, F.EWRI, M.ASCE, is available to assist you in those efforts. I also want to recognize our 2 international chapters established in North and South India, as well as our 5 Graduate Student chapters. As EWRI events take place around the country and globe, we will be reaching out to the local chapters in that area and inviting them to attend, learn about, and become more involved with EWRI National. This year our Council Weekend will be held during the month of February in Los Angeles and we will reach out to the local chapters to attend and get involved.

Finally, I point out that EWRI has financial surety and continues to operate with good financial health. This allows us to fund ideas and activities associated with advancing our strategic initiatives. If you, or your committee or task committee has an idea along these lines, pass it on to your Technical Services Council or Member Services Council. I am looking forward to giving back to my profession by serving this year as your President.

David D. Dee, Jr., P.E., D.WRE, M.ASCE
President, EWRI

EDITORS CORNER

As your new Editor of Currents, I would like to begin by thanking John Weiland for his five years of excellent service as Editor. His leadership has been instrumental in providing the quality newsletter you and approximately zzz of your colleagues receive each quarter. I promise to do my best to live up to the standards John and his predecessors have set over the years.

Putting together Currents is truly a team effort. In addition to John, other key team members include: Catherine Soistman, Mike Buechter, Mary Fickert Thomas, David Renetzky, Bill Ritter, Brian Van Weele, and ASCE EWRI Project Coordinator Veronique Nguyen.

In this issue there is a broad variety of articles combining engineering, economics, and international water issues. Keeping with recent issues of Currents that have included cutting edge technology, there is also an article explaining cloud computing. Overall, I hope you find this Fall issue of Currents to be both informative and enjoyable.

To provide relevant content in future issues of Currents we need your articles. Please contact me at CDrummond@geosyntec.com or Veronique Nguyen at VNguyen@asce.org with any article suggestions or questions you may have regarding article submission. Either of us would be glad to help you through the process of getting published.

Chad Drummond, PE, D.WRE, BCEE

(continued from pg. 1)

and crop prices at the farm level. Revenue projections were then used to simulate future conditions. Finally, auto-regressive techniques were used to identify areas of growing and declining irrigated acreage, and generate projected irrigated area and water use.

Development of Irrigated Lands and Agricultural Lands Geodatabases

GIS databases of all agricultural lands in Florida, as well as irrigated lands, were created for the FSAID project as a first step. The benefit of a geodatabase with individual fields is that it can be utilized at any scale, facilitating refinements to reflect temporal changes and controlling for crop differences. An Irrigated Lands Geodatabase (ILG) was populated for 2015 conditions, using data from a number of sources. Agricultural areas were identified as irrigated or non-irrigated through manual and automated processes. The GIS was used to visually review and compare aerial photography (NAIP and Google Earth), USDA's Cropland Data Layer (CDL) , and permit data (reading permit documents to extract crop type, irrigation system, and irrigated area), to correctly classify field geometry, crop type, and irrigation system. The resulting GIS mapped an estimate of 1.8 million acres of irrigated area in 2015, and about 9 million acres of total agricultural land as shown in Figure 1.

Irrigation Estimates

Once the current irrigated and non-irrigated agricultural areas were established, the next step was to estimate current water use. About one-third of farms in Florida have metered water use, and this data is reported to the WMDs. Data were obtained for each District for three full years of irrigation, allowing for comparison of irrigation practices under a variety of climatic and market conditions. Demand for irrigation water was then modeled in an econometric regression linking total annual water use to biophysical factors, climate and market factors (see Table 1). For each farm, this included compiling data for each of the three years, including metered water use records, which varied by District but fell within 2007 – 2013. The model included variables representing the crop mix, field size, irrigation equipment used, and weather conditions observed for each year having measured water use. The coefficients in the model were used to replicate actual results at the farm level for the 3,200 farms with usable metered data, and a good fit of modeled water use compared to measured water use was achieved. The results were applied to the entire ILG to spatially distribute irrigation water use across the state.

Table 1. Regression Variables

Variable	*Measure; all at farm field level*
NP	*Crop-specific annual revenue; approximately 70 crops, aggregated to 9 crop categories*
Soils	*Soil type, aggregated to 8 broad soil categories*
PERIRR	*Percentage of permitted acreage that is irrigated*
IRR	*Type of irrigation system*
FF	*Variable for freeze protection*
L	*Vector of location attributes; including latitude/longitude coordinates and Water Management District variables*
RF	*Mean annual rainfall, based on nearest rain station*
ET	*Evapotranspiration, based on satellite data*

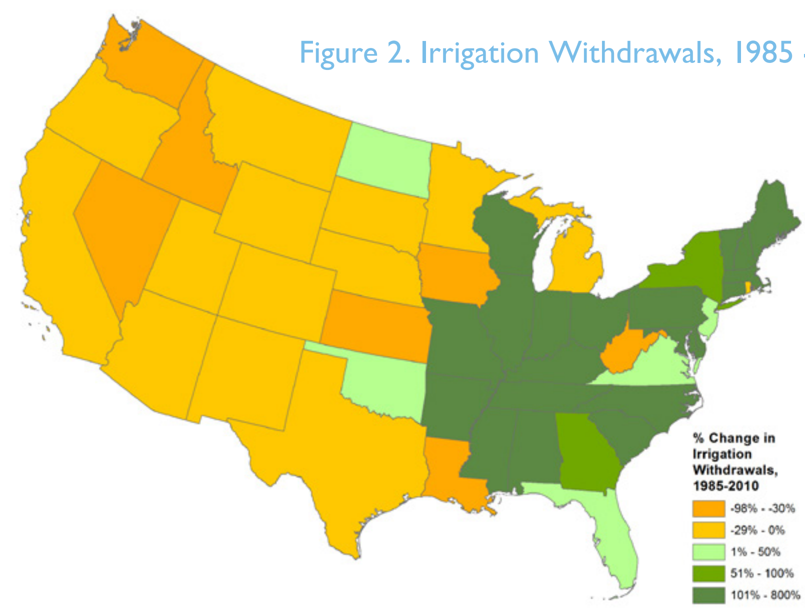
The model estimated that overall, agricultural lands are irrigated at about 16 inches/year. Historic estimates of Florida irrigation, as prepared by the water management districts, reported demand of about 21 inches/year. The model developed from the metered data estimated that farmers were actually using about 27% less overall water than previously thought.

Agricultural Acreage Projections and Associated Water Requirements

With estimates of current demand in hand, the challenge was to project irrigation behavior 20 years in the future, in a rapidly urbanizing state. The State required forecasts of both water use and its spatial location. Data were analyzed to define trends for projecting future water needs; behavior, a central theme of the study, is defined by needs. Agriculture is an inherently risky operation, and management behavior takes a variety of risks – from prices to labour shocks to weather - into account. Previous econometric modelling has identified spatially-varying trends in behavior including irrigation intensity, crop mix changes, and land use conversion.

Projections were developed for future agricultural water use in five-year increments for 20 years. Future scenarios were modeled using two parallel threads of information: future crop revenue expectations, and long-term trends in land use change. Land use change

Figure 2. Irrigation Withdrawals, 1985 - 2010



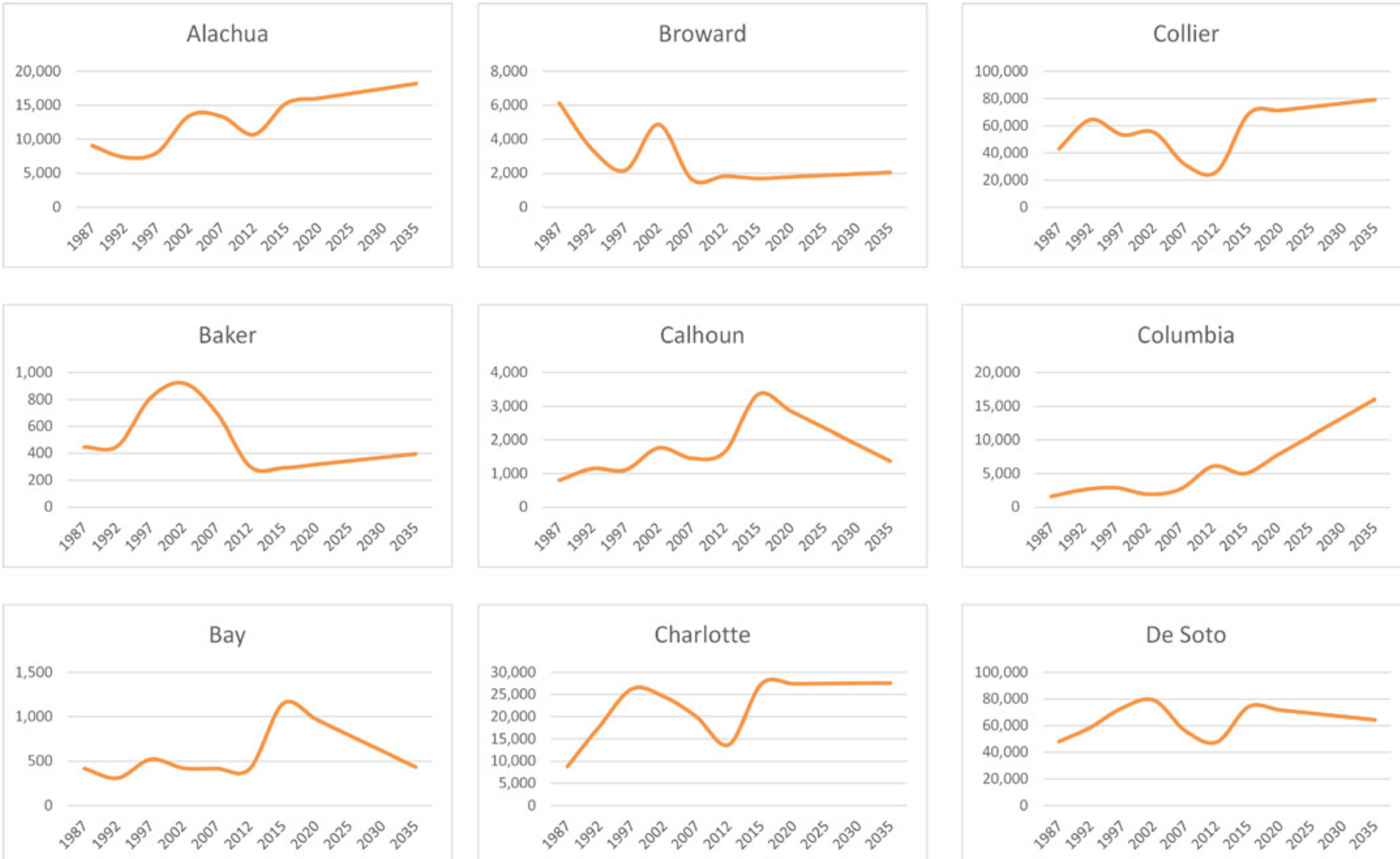


Figure 3. Selected long-term county trends, Irrigated area

was tackled first. In some parts of the state, such as the Miami metro area, agricultural land is likely to be smaller in twenty years, whilst in others – namely the northern parts of the state – substantial tracts of agricultural land are currently unirrigated. Irrigation practices from the western parts of the U.S., namely Texas and California, have shown evidence of migrating eastward over the past 30 years, as shown in Figure 2. Some areas of Florida that have traditionally been dry-land farming have seen new operators install sophisticated irrigation systems, and harvest two or more crops in fields that were historically single crop.

Using agricultural census data that is collected every five years, an analysis was conducted at the county level to identify long-term trends. The trend of interest is the share of agricultural land that is irrigated, rather than total agricultural land – which is generally declining. Techniques to detect the best-fitting trends were applied and used to identify how much agricultural land is likely to be irrigated in each county, twenty years into the future. Areas where irrigation was projected to be added or removed were identified in GIS. R script was developed to automate the process. Figure 3 shows selected counties with the long-term irrigation trends, based on activity since 1987.

Once the areas identified for likely future irrigation were identified, future water use was estimated. Long-term global revenue projections by crop type were used to estimate future crop returns. The econometric model was used to simulate future conditions, substituting long-term average weather trends for climate factors, and projected revenues for crop returns. Crop mixes have shifted in recent years as growers respond to subsidies, market shifts, and structural agronomic changes. In areas projected to be newly irrigated, prevalent irrigation equipment and crop mix in the local vicinity, and supported by local soil capacity, were used to assign categories and in turn, estimate crop area and water use.

Table 2 provides the estimates by WMD. For ease of viewing, only three time periods are shown – 2015, 2025 and 2035. While net water use in the state is expected to increase 17%, some areas see increases of 40%, whilst others are relatively flat at 7%. Projected behavioral changes in conservation measures, and frost-freeze protection, were also forecast and included in the report. Overall, increased efficiencies are expected to offset a significant share of the increased demand. Figure 4 shows the relative magnitude of changes across the state in MGD. The results reflect a combination of data-intensive modelling with national and local long-term trends.

Going forward, further refinements to the process are underway to accommodate projections without intensive farm-level data collection. Sufficient data may have been collected to support VAR methods (Vector

Auto Regression) going forward; if so, similar forecasts could be completed with substantial accuracy and considerably less modeling time. These and other alternatives are being explored to allow areas with less available data to capitalize on the work completed for this project. To accommodate stakeholder needs for ongoing detailed data availability, projection data by crop, location and time period are fully accessible through an online interface developed at www.fsaid2.com.

Table 2. Projected Water Use and Irrigated Area, 2015 – 2035

(Note: Dry MGD refers to a 1 in 10 dry year)

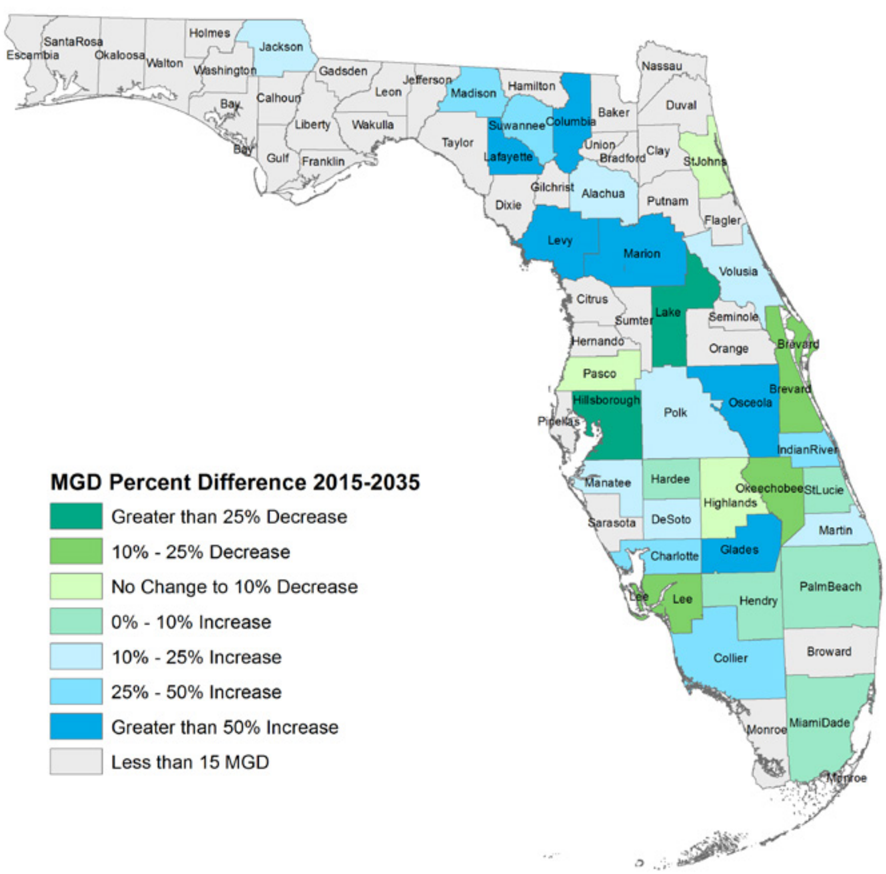
Water Management District	2015 Acres	2015 Avg MGD	2025 Acres	2025 Avg MGD	2035 Acres	2035 Avg. MGD	2035 Dry MGD	2015 - 2035 Difference	2015 - 2035 Difference
NWFWMD	56,829	46	61,879	52	66,713	59	67	9,883	17%
SFWMD	1,045,697	1,237	1,085,635	1,263	1,129,211	1,448	1,665	83,514	8%
SJRWMD	177,371	208	168,708	197	157,536	223	256	(19,835)	-11%
SRWMD	123,956	107	142,671	128	162,106	151	174	38,150	31%
SWFWMD	396,459	534	382,800	506	369,888	611	703	(26,571)	-7%
Total	1,800,312	2,132	1,841,693	2,146	1,885,453	2,491	2,865	85,142	5%

Conclusions

The statewide model with property-level data (all of which are maintained in a database) supports analysis at a variety of scales and enables the spatial distribution of results. The resulting database supports many applications such as demand projections, spatial identification of agricultural water use (including future scenarios), and evaluation of groundwater recharge analysis or reclaimed water opportunities, for example. The data is currently being used to evaluate costs and benefits of implementing BMP's (best management practices) for nutrient reduction, freeze protection, and alternative water supply sources.

The model provides a better understanding of Florida's likely future water scenarios. Exploration of alternative approaches, using the results of this project, is expected to identify opportunities to prepare water use forecasts in areas with less data-rich environments.

Figure 4. Map of Projected Changes in Relative Water Use



Grayed-out areas indicate Florida counties with less than 15 MGD in 2035 and account for less than 5% of total statewide water use.

Works Cited

Marella, R.L., 2014, Water withdrawals, use, and trends in Florida, 2010: U.S. Geological Survey Scientific Investigations Report 2014-5088, 59 p., http://dx.doi.org/10.3133/sir20145088.

Royal Consulting Services, Inc., and Soil and Water Engineering Technologies, Inc. 2013. Development of 1995 and 2010 Agricultural Geodatabases and Irrigation Estimates: August 2013.

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EWRI FELLOWS

The selection process for the 2016 Class of EWRI Fellows is well underway. A EWRI Fellow is someone who is recognized by the field, and their peers, as a leader in water resources and/or environmental engineering. Benefits of becoming a EWRI Fellow include:

- Recognition as a leader in the water resources, environmental, engineering, and sciences professions
- EWRI Fellows receive a distinctive wall plaque marking the achievement, as well as a EWRI Fellow lapel pin
- Recognition on the EWRI website and in the EWRI Currents Newsletter
- Fellows are honored with the F.EWRI credential

Applications will be accepted until January 18, 2016.

Fellow recipients will have their plaques and lapel pins mailed to them the beginning of April. The 2016 Class of EWRI Fellows will then be honored at a ceremony during the World Environmental and Water Resources Congress in May in West Palm Beach. For further information about eligibility requirements and the application process, please visit the EWRI Fellows webpage - http://www.asce.org/environmental-and-water-resources-engineering/ewri-fellows/

WATERSHED MANAGEMENT COMMITTEE SOLICITATION FOR SUGGESTIONS AND CONTRIBUTIONS

The Watershed Management Committee of the Environmental and Water Resources Institute, American Society of Civil Engineers is working with the USDA Natural Resources Conservation Service (NRCS) to prepare an update and modernize the Curve Number method as presented in several Chapters of the NRCS National Engineering Handbook.

The Curve Number method is used widely outside of NRCS, and this is the first attempt at revisions with general public inputs since its inception. The purpose of this notice is to solicit your suggestions.

The Curve Number method is taken to consist of the following elements, targeted on modeling direct runoff depth from event rainfall depth

- The equation $Q = (P-0.2S)^2/(P+0.8S)$ for $P>0.2S$; $Q=0$ otherwise.
- Q = runoff (in); P = rainfall (in); and S = potential maximum retention after runoff begins (in). This includes the assumption that Initial abstraction $(Ia)=0.2S$
- Hydrologic soils concepts and classifications (A,B,C,D)
- Tables and charts of CN (Curve Number) for soils and land use
- Antecedent moisture/runoff conditions (AMC/ARC) categories to represent variation

This work targets the Curve Number (rainfall-runoff) method only, and does not include the often-associated hydrograph procedures or many software packages. Coverage is limited to the following chapters in the existing NRCS National Engineering Handbook:

- NEH Part 630, Chapter 8, Land use and treatment classes
- NEH Part 630, Chapter 9, Hydrologic soil-cover complexes
- NEH Part 630, Chapter 10, Estimation of direct runoff from storm rainfall
- NEH Part 630, Chapter 12, Hydrologic Effects of land use and treatment

We urge you to consider and provide feedback on the following questions:

- Based on your professional experiences and observations what issues should be included and/or accented?
- Which – if any – topics or components of the methodology need priority attention?
- What problems have you encountered using the method as offered? For example, the Ia/S ratio, coverage of CNs from soils and cover, model departures from field observations, etc.
- What reasonable steps, enhancements, or inclusions might improve and modernize the method?

This is a rare opportunity to partake in a major improvement in applied hydrology. We seek your ideas, honest observations, creativity, experiences, and opinions. Please reply by email to any or all of the individuals below. Activity on this project should begin this fall following your inputs, and we welcome offers of assistance.

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CHINA'S AMBITIOUS SPONGE CITY INITIATIVE: A MONUMENTAL EFFORT FOR GREEN/GRAY INFRASTRUCTURE INTEGRATION

Shaw L. Yu, Univ. of Virginia and Haifeng Jia, Tsinghua University

Since the early 2000s the concept of Low Impact Development (LID) has gained widespread recognition as an ecologically sound and sustainable approach to stormwater management, especially in terms of urban stormwater runoff quantity and quality control. Currently in the United States, all levels (federal, state and local) of governments have either recommended or required the use of LID practices in new or retrofit urban projects. Similar trends have been enthusiastically picked up elsewhere, for example in Europe under the title Sustainable Urban Drainage Systems (SUDS), in New Zealand as Low Impact Urban Design and Development (LIUDD), and in Australia as Water Sensitive Urban Design (WSUD) , etc..

Figure 1. China 2015 Pilot Sponge Cities
Source: Jia Haifeng (2015)

In China, the rapid urbanization process in recent decades has led to a worsening "city syndrome" situation that exists in many urban areas such as urban flooding, water pollution, heat-island effects and ecologic deterioration, etc. As a result, in recent years much attention and efforts have been given to finding solutions to these and other environmental problems. Such efforts include government-sponsored initiatives on "low-carbon city", "green or ecological city", etc. A thorough review of the traditional urban drainage practices has also been underway and a new paradigm is emerging regarding system sustainability, which embraces many of the basic principles of LID technology.

In order to promote a sustainable urbanization strategy, the Chinese government announced in late 2013 a "Sponge City" Initiative (SCI) in building urban infrastructures. Deviating from the traditional "rapid-draining" approach, the new paradigm calls for the use of natural processes as part of the urban runoff control strategy. The "six-word" principle, which includes infiltrate, detain, store, cleanse, use and drain, forms the guideline for urban stormwater management.

In October 2014 the China Ministry of Housing and Urban-Rural Construction (MHURC) issued the "Guidelines for Construction Technology of Sponge City – The Establishment of Low Impact Development Stormwater Systems". In April 2015 the China Ministry of Finance, with support from MHURC and the Ministry of Water Resources, selected 16 cities, among more than a hundred applicants, as the first tier of Sponge City pilot sites (see figure 1). Each city receives between $63.5 million to $95.2 million from the government for three years with the total investment estimated to be about $14 billion. Local matching is required and public-private-partnerships (PPP) are encouraged. Cities will receive a 10% bonus from the central government if the PPP contribution exceeds a certain percentage of the overall budget.

In October 2015 the China State Department announced a major expansion of the Sponge City Initiative, which will be implemented nationwide. Recognizing the limitation of LID/GI facilities in controlling large or less frequent storm events, the government mandates the integration of green and gray infrastructures. The new SCI push also includes in its goals not only effective urban flood control, but also

Figure 2. Beijing Olympic Forrest Park
Source: Hu Jie (2014)

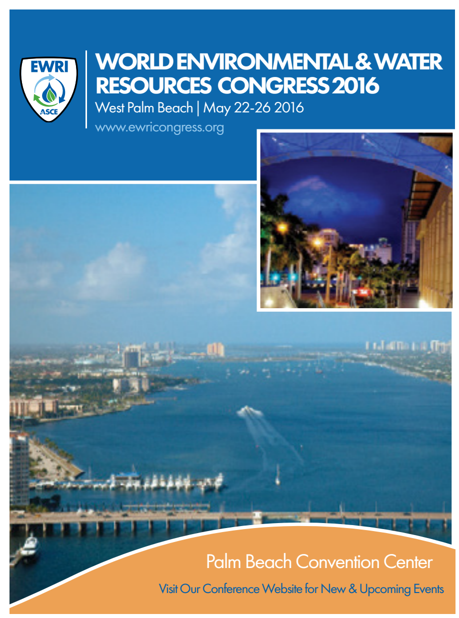
Figure 3. Infiltration Area and Swales in Foshan, China
Source: Shaw L. Yu

rainwater harvest water quality improvement and ecological restoration. For example, the current urban runoff control goals are set for 75% volume and 50% pollutant load reduction as an average. The use of LID/GI practices will be required for new development and retrofit sites, science and commercial parks, green spaces, non-mechanical vehicle roads, pedestrian walkways, etc. The estimated total investment is roughly 1.5 Trillion RMB for sixty cities nationwide or $400 million average per city. These figures correspond to about $28.6 million per impervious square kilometer or $120,000/per impervious acre.

China's represents an enormous and unprecedented undertaking by the government for achieving urban sustainability. MHURC officials recognize the success of the SCI will require a combined and coordinated effort by many government agencies such as landscape/architect planning, construction, municipal, water, transportation, finance, environmental protection and other stakeholders. How to finance all the sponge city projects is a real challenge. The government has listed some innovative strategies for fund-raising, which includes, in addition to government grants and subsidies, local matching and public-private partnerships. The government is also encouraging participation by financial institutions, and will allow qualified entities to issue construction bonds to finance the sponge city projects.

China will also host the first International LID Conference outside of the United States (See banner) in 2016. The conference will provide an excellent opportunity for LID/GI professionals in the Asia-Pacific region to exchange experiences, share results and implementation strategies with colleagues from North America, Europe and other parts of the world. Furthermore, presentations and discussions could be conducive to new ideas and innovation in the LID/GI technologies. International collaboration on LID/GI research projects and other efforts such as establishing an international "sponge city" alliance might be potential outcomes from the conference.

UPCOMMING CONFERENCES



EDEN HALL: AN IMMERSION IN SUSTAINABILITY

Djuna Gulliver

An Eden Hall student garden (for a wide range of experiments) sits next to a rolling meadow.

For future students that dream to learn about sustainability by "doing," Eden Hall is a rare campus that is built from the bottom up with sustainability in mind. A simple walk through the campus demonstrates that full sustainability takes more than the occasional solar panel and heat-efficient windows. Eden Hall incorporates a remarkable array of technologies that unite to make a self-sufficient campus.

Dr. Peter Walker pointed to a grassy hillside, where he plans to keep the goats with a protective llama. "It acts as kind of a guard dog against the coyotes," he explains. The backdrop of the grassy hillside is woodlands, where oyster mushrooms are cultivated. A neat garden sits alongside, with crops such as perennials, hops, even rye for Wigle Whiskey.

"We've had many students interested in the Wigle project," comments Dr. Walker.

In addition to the goats and llama, the property will one day be capable of hosting 1,500 students, with 64 residents in the first dorm. The campus is Eden Hall, home to the Chatham University Falk School of Sustainability, of which Dr. Walker is Dean. Located just 30 minutes north of Pittsburgh, Eden Hall is a fully sustainable, almost off-the-grid campus, where students spend more time experimenting in the nearby woodlands and meadows than in the classroom. "I really don't want people in classrooms too much," says Dr. Walker. "You learn by doing. You learn by experiments."

Dr. Walker points, "I've never seen a sexy picture of a geothermal well."

What went into consideration when designing a campus completely around sustainability? Dr. Walker points at a white pipe sticking out of the ground. "I've never seen a sexy picture of a geothermal well," he shrugs. While the exposed pipe's charms are debatable, it accesses an impressive underground piping system that helps to maintain indoor climate control. In the summer, the fluid within the pipes extract heat from the buildings, and runs that heat deep into the ground, where the temperature stays at a constant 50 - 60°F. After the pipes are cooled to this below-surface temperature, the fluid is routed back to the buildings to extract more heat.

In winter, the system works in reverse, extracting the heat from deep underground and pumping warmed fluid back through the pipes to the chilly buildings. As the fluid is cooled, it is routed underground again to warm back up. Thus, to achieve the desired 72 °F

A wooden structure in the background houses a biofilm membrane that filters excess carbon from recycled water, while wetland crops absorb the excess nutrients.

indoors, the climate control system doesn't need to heat up the building from frigid winter temperatures; it needs only to raise the temperature from the 50-60 °F baseline.

Solar panels cover nearly every south-facing roof, generating the electricity that drives the heat pumps (for those last few degrees of winter climate control), the geothermal pumps, the lights and any electrical equipment. On sunny days, excess energy is sold to the grid, while on cloudy days and at night, energy is pulled back. This system currently has a net positive energy balance: more energy is generated than is used.

Water recycling undergoes an equally sophisticated process. Stormwater runoff and grey water first enters an underground holding tank. Next, the water trickles through a charcoal filter and then through a biofilm membrane. The water is then piped to marsh plants, where the roots absorb excess nutrients. Finally, the water is piped through a sand filter and blasted with UV radiation.

Unfortunately, while this water is safe to drink, regulation added a snag. "Even though we can produce water that is clean enough to drink on campus, regulations would require us to chlorinate it," Dr. Walker explains. In other words, Eden Hall would have to be regulated as a city municipal water treatment establishment before water could be consumed. "That seemed like overkill." Instead, the water treated on-site is recycled in the toilets and irrigation systems, and the drinking water is taken from the city supply.

Dr. Walker explains the permeable pavement in front of the main classroom building.

While this regulatory catch is the only thing keeping Eden Hall from being entirely off the grid, Dr. Walker is not discouraged. "I guess it goes with the territory of being pioneers," he says. "We are out ahead of the regulations!"

"If you think in a place with big views, you think big ideas," Dr. Walker declares. Wooden, asymmetric frames are all built below the tree line and incorporated with large windows to let in plenty of natural light. A dairy barn has been repurposed as a small coffee shop, which Dr. Walker is hoping will quickly become the neighborhood hot spot. And in the center of the campus sits a large outdoor amphitheater, which currently hosts performances ranging from bluegrass concerts to opera shows.

The campus is both aesthetically pleasing as well as practical. The pavements are permeable to reduce stormwater runoff. Buildings are certified at the highest standard of the US Green Building Council, LEED Platinum. The campus is not surrounded by traditional lawns, but with naturally growing meadows and wildflowers (to be kept trim by those goats). "I don't really believe in lawns," says Dr. Walker, referring to the constant need for watering, fertilizing, and mowing of the favored suburban turf.

A central part of the Eden Hall campus is the Food Studies program, which combines classroom learning with hands-on experimentation. "The Food Studies program has been operating out of Eden Hall campus part-time since its inception in 2010," says Dr. Alice Julier, program director of Chatham Food Studies program. "It is integrally tied to Eden Hall because we get to practice what we preach."

Students can take courses on grains, specializing in everything from crop science to culinary processes to fermentation. There are courses on sustainable meats that take you from pasturing to butchering. Students can practice from start to finish the process of making cheese, yogurt, and other dairy products. "Most recently, we developed a course on coffee," Dr. Julier adds. "Students look at both production and consumption with La Prima and other coffee roasters. Our cafe will likely feature our Eden Hall blend, but we will also do outreach workshops on small batch roasting and tasting."

A happy result of the prominence of the Food Studies program is a campus food system that offers a farm-to-table experience that would make even noted local chef Kevin Sousa green with envy. The goats on the grassy hillside will serve to both naturally keep the meadowland trim, and provide milk for cheese. Trout will be caught from the

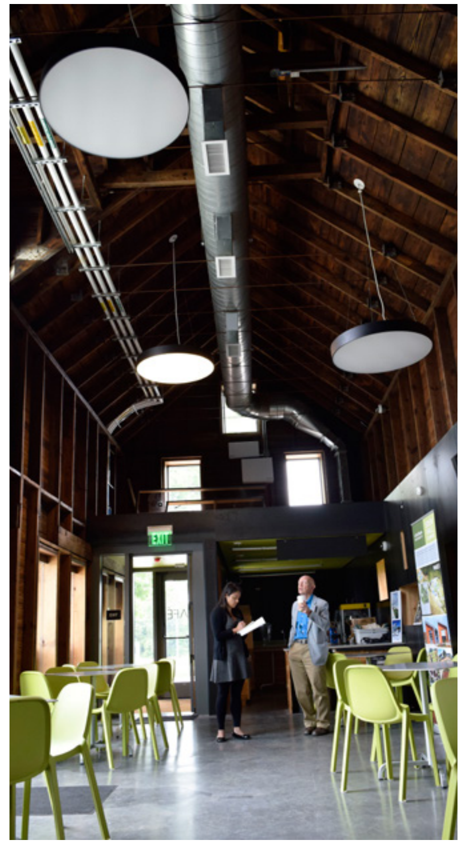
Crops in the solar tunnel get 12 months of a growing season and require little-to-no external heat.

aquaponics tanks set adjacent to the classrooms. Seasonal fruits and vegetables will come straight from the students' experimental garden, equipped with movable greenhouses to prevent overuse of the land. One large greenhouse, the "solar tunnel," is heated with solar panels and vegetables are grown year-round.

"That's the easy bit," says Dr. Walker about the first four sustainable systems. "What we're dealing with now is moving this project we've built into a social program." While designing and building a completely sustainable campus was an accomplished feat, perhaps the more important aspect of sustainability is changing people's behavior. The Falk School of Sustainability aims to go further than just encourage students to recycle. Student dorm rooms are equipped with sensors to warn students if they leave the windows open too long, allowing heating or cooling to escape the building. And all kitchen spaces are communal. This offers a chance for community bonding, but also saves on energy costs associated with individual hotplates and mini fridges. "The first group of students are really going to be pioneers," says Dr. Walker.

Forging the fully sustainable campus was no easy task, and the project was initially estimated to cost $40 million. This fall, the new Eden Hall campus is finally open for business.

But perhaps the largest challenge is getting the word out to the targeted students that will appreciate the unique experience Eden Hall has to offer. The Eden Hall campus is not for the average student, as it does not yet have the social clubs and community that a larger campus can offer. Students looking for the college experience promised in movies like "Animal House"or "Rudy" may be better off taking classes elsewhere. However, for students that want complete immersion in sustainability, and want to learn in the pastures and woodlands as well as the classroom, Eden Hall may be a once in a lifetime opportunity.



A dairy barn is converted to a coffee shop to encourage student and community mingling.

The Eden Hall Barn is drafty, but makes for dramatic events and theater performances.

Photo Credits : All photos featured in this article are courtesy of James Gardiner

CLOUD COMPUTING: WHAT IS IT?

Sudhir Kshirsagar, Global Quality Corp., Covington, KY

Although "Cloud Computing" implies a web-centric implementation, a web-based solution is not always a cloud-based solution. In fact, web-based solutions have existed since the inception of the Internet but the cloud-based solutions have emerged just over the past decade. A simple web-server and a few lines of html can be used to implement a web-based application in a few minutes, but a cloud-based application is engineered differently and takes a significant amount of implementation effort that involves an emerging set of technologies. For the purposes of this article, cloud computing is defined as any and all activities that are carried out in a cloud platform. These platforms are available either as a commercial implementation such as the Microsoft Cloud (former known as Windows Azure) or as an open-source implementation such as the OpenStack. These platforms can be used in their large-scale public implementations or can be deployed as private clouds within enterprises. The following well-known acronyms can now be examined based on that definition of cloud computing.

Software-as-a-Service (SaaS): Software applications that are available (for a fee) in the cloud computing platforms. For example, SalesForce.com is a commonly used SaaS application. Note that it may be possible to further customize a SaaS application, or build a custom application using a SaaS platform application programming interface (API). There are very few environmental SaaS applications at present.

Infrastructure-as-a-Service (IaaS): Virtual Machines (mostly servers) hosted in a Cloud Computing platform. Most cloud computing platforms offer a variety of operating systems in a plethora of configurations. Most enterprises easily gravitate to these platforms to reduce their computing costs while improving the reliability of infrastructure.

Platform-as-a-Service (PaaS): A brand new architecture for storage and compute servers that are interconnected through a powerful geographically distributed secure and scalable fabric. This area offers the most opportunities for innovation because parallel computations that implement advanced analytics and massive distributed storage mechanisms that host "Big Data" can be used to explore areas that were previously impossible to examine without the use of massive supercomputing environments that were mostly available at a few large universities. The PaaS offering in the marketplace makes it extremely easy to start those research efforts without significant funding. For example, the Google App Engine and Microsoft Cloud provide such environments. Unfortunately, the PaaS has been and continues to be the least used cloud offering. The primary reason has been the costs involved in re-structuring and rewriting legacy applications are significant. Remember that a traditional web application is not a "Cloud Application" according to our definition. Those applications are not compute-scalable or storage-scalable. On the other hand, most of the cloud applications are implemented as web-facing applications that are consumed through a browser. So both a web-application and a cloud-application appear to be same thing to a user. Most users rarely think about how gmail is structured as a scalable cloud application, and they just consume it as a regular web application.

Migrating legacy applications to the IaaS environment is a typical first step for most enterprises. While that strategy makes sense in the short term, it is clear that applications that need to leverage "Big Data", generated by the Internet-of-Things (IoT) technology revolution, will need to be implemented as true PaaS cloud-based applications with scalability in computing and storage. The stormwater control application developed by OptiRTC is a good example of such an approach. Cloud-based environmental modeling applications can consume environmental data through web-services or through IoT gateways and interact with each other to share computational results. For example, the HydroTrek cloud-based stormwater calculator implements the US EPA SWMM engine in a public cloud and leverages the integration of field data through IoT event hubs. A large collection of such applications has the potential of becoming the most disruptive environmental technology change agent.

The IoT networks can be used for several purposes including monitoring, control, optimization and autonomous decision-making. The environmental applications of IoT hold a lot of promise given significant price drops in the sensors that can be deployed to provide the monitoring. The inexpensive open source platforms such Arduino and Raspberry Pi provide great sensor platforms for rapid development of software to integrate the measurements from the inexpensive sensors to build cohesive IoT networks that can interact with Cloud-based computing and analytics. Such platforms also provide great support for citizen science. These implementations can be coupled with Drones and other unmanned platforms to provide truly unmatched environmental monitoring and surveying capabilities.

To summarize, Cloud Computing and IoT provide a tremendous set of opportunities for environmental scientists and engineers, and not just to the auto-makers and other business enterprises of the world. The undergraduate curriculum of some of the top schools already provides an exposure to these technologies, but the widespread adoption of these technologies will require support and guidance from the key decision-makers.

This article is one of a regular series of reports on emerging and innovative technologies in the area of environment and water resources produced by EWRI's Emerging and Innovative Technologies Committee (EITC). If you are interested in contributing an article or becoming a member of this Committee, please contact Walter Grayman at wgrayman@gmail.com.

WATER-ALLIES: A COLLABORATIVE APPROACH TO SOLVE WATER & SANITATION CHALLENGES IN INDIA

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INTRODUCTION

India has around 16 per cent of the world's population and four per cent of world's fresh water resources at its disposal. Sizeable water resources is under tremendous pressure due to ever increasing population and unequal distribution of water. The current per capita water availability in India is around 1545 cu m/ person/ year which is below the global standard of 1700 cu thereby resulting in India being a water stressed country. The rural population of India comprises more than 700 million people (roughly 60% of total population) residing in about 1.42 million habitations. The lack of water availability and poor management practices have also manifested in poor sanitation facilities. World Bank estimates that nearly 21% communicable diseases in India are due to the unsafe water. Even though water supply coverage has improved in recent years, water quality continues to be a cause of concern and the health burden of poor water quality is enormous. Waterborne diseases affect nearly 37.7 million Indians annually, with 1.5 million children estimated to die of diarrhea alone and 73 million working days are lost due to waterborne disease each year. The 2011 Annual State of Education Report (ASER) reveals that only 73.5 percent rural government schools have drinking water facility

Poor and unreliable surface water supply has led to unchecked groundwater pumping as an ad-hoc adaptation mechanism. Roughly 92% of India's irrigation needs and 85% of its domestic water supplies comes from groundwater. India possesses about 432 billion cubic meters of groundwater replenished yearly from rain and river drainage, but only 395 bcm are utilizable. In addition these ground water sources are often contaminated with fluoride and arsenic. Fluoride problems exist in groundwater sources in 17 out of 29 states in India. The rivers also have high fluoride content, beyond the permissible limit of 1.5 ppm, which affects 66 million people nationwide. An estimated 5 million people are likely to be drinking water with concentrations of arsenic greater than the national standard of 50μg/l, principally in the state of West Bengal.

The lack of water, sanitation and hygiene has an unprecedented effect on India's economy. In a study undertaken by the Water and Sanitation Program (WSP), a global partnership administered by the World Bank, it was found that inadequate sanitation causes India 'considerable economic losses', equivalent to 6.4 per cent of India's gross domestic product (GDP) in 2006 (US$53.8 billion) (WSP, 2010). The health-related economic impact of inadequate sanitation was also $38.5 billion, which was 72 percent of the total impact. The study also highlighted that 40 percent of Indian water sources suffered bacteriological contamination attributable to poor sanitation (UNICEF, 2008). An important point regarding improved sanitation is that it is not enough to increase access to improved toilets—it is equally important to ensure the safe collection, conveyance, and treatment of sewage so that it can be safely released into the environment.

INTRODUCING WATER –ALLIES

Rising water demands due to population and economic growth are straining the already stressed demand-supply balance. It is estimated that if the current pattern of demand continues, about half of the demand for water will be unmet by 2030 (WRG 2009). Thus in a bid to contribute towards solving the water sanitation issues in India, the ASCE EWRI chapter of Richmond, Virginia instituted a program called "Water-Allies" in 2014. Based on the principle, Connect, Collaborate and Conquer- Water-Allies is an initiative to bring the information of all active non-profits and developmental, international organizations, working on infrastructure, water & sanitation issues, one location (web portal).

The primary objective of water-allies is to build sustainable collaboration between the water sanitation non-profits, institutional supporters, developmental organizations, professional chapters, social business group, and individual volunteers. To achieve this mission, water-allies showcases all the possible opportunities available within each organization. The opportunities can vary from being a case study or literature review on topics of wastewater treatment, groundwater contamination, storm water management to a fund raising opportunity for any current projects.

SUSTAINABLE & INNOVATIVE PRACTICES – AN OVERVIEW

The program also aims to create a resource directory of various economical, sustainable and innovative practices that can be replicated in other parts of the developing world. The EWRI team has studied more than 110 nonprofits and currently more than 30 such organizations are a part of the initiative. In this article, the authors would like to share the wok of few of these organizations in brief and the innovative approaches adopted by them in solving the water and sanitation challenges.

SEHGAL FOUNDATION: In 2015, Sehgal Foundation installed the world's first stainless steel bio-sand filter in Ghaghas village, Haryana, India. In comparison to the traditional concrete filters, which can weigh as heavy as 170 pounds, the stainless steel filter weighs only 10 pounds. These biosand filters can remove more than 95% of fecal coliforms and 75% percent of iron, manganese and arsenic content. The foundation has also been able to augment groundwater levels with the help of check dams, contour trenches, dug well recharging and pressurized recharge wells.

SUSTAINABLE SOLUTIONS: Sustainable Solutions, a NGO based in Virginia, has developed a sustainable enterprise rainwater harvesting model called Akash Ganga. The program is based on a public utility model, where every homeowner in the community with a roof is asked to lease the rights to harvest their rooftop rainwater. The homes are provided with the gutters, spouts and pipes that are connected to a network of interconnected underground storage reservoirs. Some of the rain water from these houses is channelized to a large reservoir of about 400,000 to 1 million liters to provide drinking water to those who live in houses with thatched rooftops that cannot be used for harvesting.

PROJECT WELL: Meera Hira Smith, a research specialist in the arsenic health effects research group of University of California, Berkeley, founded Project Well in 1996. Project Well is a sustainable community based mission that works in the arsenic affected villages of West Bengal where the drinking water is contaminated with more than 50ug/l of arsenic. In such Villages, the program constructs shallow concrete dug wells. The design of these wells differ from the traditional ones mainly by a layer of coarse sand of one-foot width that envelops the outer wall of the concrete cylinder that also acts as a filter, and by covering the wells and extracting water with hand pumps to reduce potential bacterial contamination. The annual average arsenic content of water from these shallow wells is approximately 11ug/l and the average fecal coliform count reduces from 100 to 26 units.

TOILET FOR PEOPLE (TFP): founded by Jason Kass in Brooklyn, TFP has designed and developed a sustainable, affordable and waterless composting toilet called "The CRAPPER" especially targeted for flood prone areas of the developing countries. The CRAPPER, aka the Compact, Rotating, Aerobic, Pollution-Prevention, Excreta, Reducer, consists of a horizontally mounted rotating drum which sits inside a box. The rotation mechanism maximizes aerobic degradation, eliminating pathogens and foul smell and also reducing the volume of the waste by 80%. In comparison to the traditional composting toilet that costs $1500, CRAPPER costs $200 per unit.

UNITED FOR HOPE: United for Hope is a nonprofit organization founded by Tara MaCartney who left her lucrative job at Microsoft and decided to work for a village in Uttar Pradesh, India. With her clean drinking water project, Tara with her team has succeeded in creating behavior change in the minds of the villagers. Adopting a social enterprise model, the team delivers clean drinking water to households at a very low price (3 cents per gallon).

GRAVIS: This non-profit works in drought affected Thar Desert of India and has succeeded in reviving indigenous rainwater harvesting systems in its last 30 years of existence. The team has designed and developed three major inlet structures that collect surface water from the desert catchment areas: percolation wells, underground tank, and village ponds. These structures have a capacity of storing more than 250,000 liters of water and Gravis has constructed more than 6,000 such structures.

GRAM VIKAS: The organization was founded by Joe Madiath in Orissa, India in the year of 1979. The majority of tribal communities that Gram Vikas works with are un-electrified. To bring 24-hours of piped water supply to un-electrified villages, Gram Vikas uses the principles of induced gravity flow and siphoning. Water from perennial springs are harnessed and diverted through pipelines, from as far as five or six miles. Gravity flow design for water-supply systems requires zero operating energy making the project financially attractive and easy to maintain.

BAREFOOT COLLEGE: The organization was founded by Mr. Bunker Roy in 1972 in Rajasthan, India and since then has successfully implemented various sustainable water solutions addressing the scarcity in rural communities. Solar powered reverse osmosis water desalination plants designed by Barefoot can reduce the total dissolved solids from 4,000- 6,000 ppm to only 450 ppm, making the water safe for drinking.

Water-Allies currently has established collaborations with 30 different WASH organizations and plans to increase this number to more than hundred in near future. To make this idea more impactful, a lot of groundwork, research and discussion are needed. The authors invite volunteers who would like to be a part of this initiative and make a difference in the lives of millions of people. Based on the scalability and success of this program, Water-Allies may be implemented in other under developed and developing regions of Asia and Africa.

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Meetings to Watch

8th International Perspective on Water Reso
the Environment
January 4-6, 2016 Colombo, Sri Lanka

World Environmental & Water Resources Congress 2016
May 22-26, 2016 West Palm Beach, Florida

International Low Impact Development Conference
August 29-31, 2016 Portland, Maine

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