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Hunt describes benefits of rainwater harvesting BMPs

by Rhett Register

On April 1, a new chapter of the North Carolina Stormwater BMP manual was posted online for public comment. The rainwater harvesting, or RWH, chapter is an outgrowth of an existing section within the rooftop runoff management chapter.

Bill Hunt, professor in NC State University's Department of Biological and Agricultural Engineering and leader of the Stormwater Engineering Research Group, drafted the chapter. He spoke at the February NC Water Resources Association luncheon about the RWH chapter as well as his work on bioretention cells and downspout disconnection.

"There is a national stormwater rule that is right now under review by the Office of Management and Budget, Hunt said beginning his presentation. Hunt expects the rule, once finalized, will require any jurisdiction impacted by NPDES to capture something between the 85th and 98th percentile storm event. For the Piedmont, he estimates this will equal 1.2 to 1.5 inches that must be captured for infiltration, evaporation or harvested and used elsewhere.

What this absolutely means, he said, is that you are going to see an increase in non-pond technology.

Stormwater control measures are already required in much of the state with multiple programs run by state and local permitting authorities. An interactive map on the NC Division of Energy, Mineral and Land Resources website allows property owners to find which stormwater rules apply to them.

Most of the programs use a 24 percent built-upon area threshold that, when exceeded, causes the landowner to become responsible for managing stormwater onsite. Low Impact Development techniques, such as RWH, are one way of reducing or removing traditional onsite stormwater controls, such as retention ponds, that may take up space or be visually unappealing.

Hunt spoke at the NCWRA luncheon on upcoming changes to the stormwater BMP manual.

The new chapter on RWH systems includes information on design, siting, maintenance and construction. It also describes credits that can be earned by installing an RWH system. If designed in

continued on page 2

EMC Highlights

At its March 13 meeting, the NC Environmental Management Commission defined gravel as it relates to stormwater control measures, officially began the comprehensive rules review called for by House Bill 74, and heard updates on the status of impaired waterbodies in the state and on the progress of the triennial review.

Temporary rule for gravel

A definition for gravel was needed after Session Law 2013-413 modified a statute that describes stormwater runoff rules and programs for the state.

The new law modifies the definition of "built-upon area" — the area used to calculate stormwater control measures needed for a site — to exclude "gravel." It does not, however, define what "gravel" is, thus leaving many in the regulated community scratching their heads.

Some rock used to cover trafficked areas can become compacted through use and the pores between pieces clogged, eventually making the area impervious to precipitation. If stormwater

continued on page 3

In this issue **January-March 2014**

Hunt *continued from page 1*

accordance with the information in the chapter — including having capacity to capture 86 percent of the annual rainfall — the owner will receive credits for 100 percent of the runoff volume from the design storm. They will also receive an 85 percent reduction of total suspended solids mass loads.

Credits also are available for areas with nutrient removal requirements. A permitted RWH system can account for up to a 35 percent reduction of the annual total nitrogen coming off of a property and a 45 percent reduction of total phosphorus mass loads.

Hunt noted dual goals for employing RWH systems — stormwater management and potable water conservation — are sometimes at odds. A full cistern, though available to offset potable water uses for things like irrigation, washing and flushing toilets, does not have room to capture precipitation from future events.

To address this issue, Hunt introduced the concepts of passive release and active management. In an experimental RWH system, Hunt and his group installed a valve midway up the side of the cistern. Permanently open and designed to resist clogging, the valve allows water to slowly drain out to a small infiltration area. In two to five days, the area above the valve is available to catch a storm event and the area below is available for non-potable water uses. This is passive release.

Hunt gave examples of active management of RWH systems. In one, managers of an Australian bus terminal use harvested rainwater to wash buses. They monitor levels using a computer interface, choosing which cistern gets used based on capacity.

Another example is closer to home. At Tryon Palace in New Bern, Hunt is testing an automated system designed by the firm Geosyntec that makes room for precipitation. The device uses an Internet connection to monitor National Weather Service predictions for the area. When precipitation is predicted, the system

This cistern has a passive release valve. Photo courtesy of NCSU BAE.

moves water into an adjacent rain garden in preparation for the event.

Passive release and active management both are included in the system requirements in the new Stormwater BMP manual chapter.

Hunt also noted his work testing undersized bioretention cells. In areas where standard-size cells are not an option, smaller cells can still achieve statistically significant volume and load reductions.

"We have been stuck with 'My bioretention cell has to be this size or else.' I call that the one-size-fits-all shackles. Well you know what? That's on the cusp of being broken," he said.

He also described some of his work looking at the effects of disconnecting downspouts as a way to encourage onsite infiltration of rooftop runoff.

"Downspout disconnection is a very effective practice," he said. "I think you are going to see a lot more of it."

Hunt's work on bioretention cells and downspout disconnection will be featured, he said, in upcoming Stormwater BMP manual revisions.

To view the proposed RWH chapter as well as the stormwater permitting interactive map, visit: portal.ncdenr.org/web/lr/stormwater. The new RWH chapter can be found under the link "Public Notice for LID & Storm-EZ." For inquiries, contact Annette Lucas with the NC Division of Energy, Mineral and Land Resources at annette.lucas@ncdenr.gov or (919) 807-6381.

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EMC *continued from page 1*

control measures are designed with the supposition that these areas are pervious, and they are in fact compacted and impervious, the measures may become overwhelmed or bypassed during storm events.

To clarify, the temporary rule proposed by the EMC defines gravel as:

> *"a clean or washed, loose, uniformly-graded aggregate of stones from a lower limit of 0.08 inches up to 3.0 inches in size."*

Rocks of this size, and graded in a prescribed way, will not, the commission says, become compacted, but instead will allow water to infiltrate. This allows graveled areas not to be included as impervious or "built upon" in stormwater control measure calculations.

Chairman Benne Hutson noted that the EMC rule might become moot as the matter could be taken up in May's "short session" of the General Assembly, where the statute could once again be modified. But, he said, the temporary rule is needed for immediate clarification, as well as to prevent a run on permits before the permanent rule is made.

The temporary rule went into effect on March 28 and will expire in 270 days, which is approximately mid December, or when it is replaced by another rule.

Rules review

The first package of rules came before the EMC as part of SL 2013-413 (H.B.74)-mandated rules review. Jeff Manning, Classifications and Standards/Rules Review Branch Chief with NC Division of Water Resources, presented rules 15A NCAC 02B, 02H, 02T and 02U describing the set of rules as "pretty much the heart of the water quality program."

Due to the referential nature of the rules, they are being reviewed as a group. Tom Reeder, DWR director, noted that there was no way to untangle one of the rules from the other because they all build upon each other.

According to Manning, in the division's analysis, none of the rules fell into categories that would allow for their being discarded or readopted without the rulemaking process. Instead, all of the rules are considered "necessary with substantive public interest," meaning they will need to go through the entire rulemaking procedure as if they were new rules.

The EMC unanimously approved them to proceed to public comment. To submit a comment, visit: rulesreview.ncdenr.gov/

Informational items

The EMC heard two informational items. The first was a summary by Campbell McNutt, DWR Modeling and Assessment Branch, of the new 303(d) list of impaired waters. He discussed some of the changes to how waters are assessed, as well as changes in listing for different water bodies.

Ways in which the streams are assessed changed as NC Department of Environment and Natural Resources is now trying to implement a 90 percent statistical confidence. The new technique will allow for more statistical confidence that water quality criteria are exceeded. By taking sample size into account, the technique reduces the chance of listing waters that actually meet criteria.

Changes from the 2012 assessment include:

- 152 water bodies that went from "Exceeding Criteria" to "Meeting Criteria" with 120 removed from 303(d) List all together.
- 173 water bodies went from "Exceeding Criteria" to "Data Inconclusive" with 138 removed from 303(d) List. This was due to the changes in assessment methods.
- 75 water bodies went from "Meeting Criteria" to "Exceeding Criteria" with 70 added to 303(d) List.

According to the report, North Carolina has 13,342 waterbodies. This year, 1,104 exceed at least one parameter of interest. This causes them to be listed and requires the creation of a TMDL or other management strategy to address the exceedance.

In the next presentation, Connie Brower with DWR went over proposed changes to the state's surface water rules 15A NCAC02B. These proposed changes were distilled from public comment as part of the state's "triennial review" responsibilities under the Clean Water Act.

Multiple recommendations were made during public comments including suggestions to retain chlorophyll *a* standards while making major changes to metals standards.

The hearing officer, Commissioner Steve Tedder, suggested DENR staff evaluate and address the recommendations and draft proposed regulations. The Water Quality Committee and the EMC could then consider them at their May 2014 meetings with the goal of getting the new rules to proceed to public hearing during the summer months.

The next EMC meeting is scheduled for May 8. To look at agendas and presentations from this and other meetings, visit: ncdenr.gov/web/emc/home.

Sensing the future: a new technique to monitor water quality

A new technique developed by François Birgand and his lab at NC State University may revolutionize how water quality is monitored. In a paper published in the journal, *Limnology and Oceanography: Methods*, Birgand and his team describe an automated technique they developed to monitor water quality in tidal marshes. The method gives researchers a high-resolution view of changes in water nutrient levels by using sensors to take readings at 15-minute to 1-hour intervals. WRRI contributed funding to the project as did North Carolina Sea Grant.

Current techniques

Marshes often are restored in areas between agricultural lands and water bodies, where the marshes absorb some of the fertilizer that may be present in runoff from the farmland. Marshes are a dynamic place, however. Tides, storms, wind and evaporation all contribute to making water quality in marshes difficult to quantify.

Unlike the continuous data that is available for flow and precipitation, scientists do not have a similar understanding of what is happening chemically in the water of marshes or in any other aquatic system.

"All of our understanding of the hydrologic cycle and the climate is based on the fact that we have had access to this continuous data, which gives us the dynamics, which gives us so much information," Birgand says. "Well, for water quality, we have remained in prehistory at the same time. We have just been blind all along."

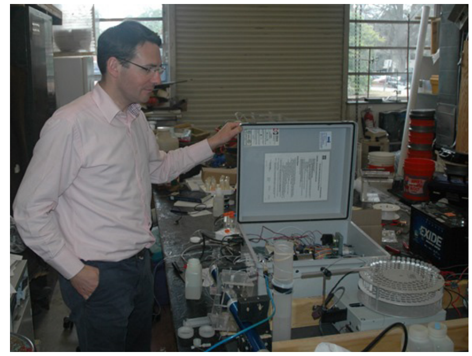
Current techniques for studying how marshes process nutrients often involve taking a limited number of water samples and extrapolating data to show how a system functions over longer periods of time. The problem with this method, according to Birgand, is that short-term fluctuations and unpredictable events, such as storms, are not quantified in terms of their contribution to nutrient fluxes within the system.

"If you are measuring every two months for 50 years, you will get the true tendency," he says of the marsh system. "But if you are measuring every two months over the next three or four years, in my opinion, the chances for your conclusions to be wrong are very, very high."

New technique

The technique Birgand and his colleagues are developing gives researchers a clearer view of what is happening in the water without having to monitor it for 50 years. It combines using UV-Vis spectroscopy — shining ultra-violet and visible light through a water sample and recording how it is absorbed — with a statistical technique called partial least squares regression, or PLSR.

Birgand was inspired by a new generation of UV-Vis spectrometers that are manufactured to monitor water quality. These metal tubes, nearly two feet long and two inches in diameter, are made to be submerged where they take measurements and provide data in situ. Wastewater treatment plant managers put them near their intakes to understand the quality of water coming into their system. State agencies use them to monitor drinking-water reservoirs. A few studies have looked at their use in the ocean and in streams, but none have tested their use in tidal marshes.



Birgand shows how the sampling system can be configured to sample from up to 12 locations.

Birgand and his team saw the sensors as an opportunity to look at how water quality changes at 15-minute intervals in a restored salt marsh. As part of the testing, the group developed a method that expands upon the sensor's advertised capabilities. The journal article details how the method can be replicated in other systems so that researchers can get a nearly continuous estimate of changes in water quality.

Expanding capabilities

Water constituents such as nitrate, dissolved organic carbon and total suspended solids have unique absorbance signatures that UV-Vis spectrometers can detect. The sensors that Birgand was working with advertised that they could identify these constituents. But after looking at the data they generated, he saw an opportunity to do more.

"I was convinced from day one that the raw data in there was very, very rich and there was a lot of potential to extract a lot more than what people were advertising for," he says.

Birgand contacted the manufacturer, but they were unable to share the proprietary algorithms the

continued on page 5

Sensing the future *continued from page 4*

sensors use to identify the constituents of a sample. Through reading and talking to statisticians, he eventually hit upon using the PLSR statistical technique to identify the absorbance signature of the constituents he wanted to identify.

Each of the constituents in a water sample has an absorbance signature — a part of the spectrum that only they, or a limited number of other constituents, absorb. But if there are a lot of constituents in the sample, it can be hard to find that signature within the data.

Imagine trying to identify specific voices in a room crowded with yelling people. PLSR allows researchers to separate the voice of the constituent that they are interested in from the cacophony of voices that are found in a sample of brackish marsh water.

To test the ability of the technique to identify constituents in the sample and their concentrations, Birgand used automated water samplers to take physical water samples at the same time and in the same place that the spectrometer made its reading. Samples were collected and analyzed in the lab and then compared with the sensor data.

Laboratory analyses confirmed that the technique not only identified nitrate, DOC and TSS but also TKN, PO4, TP and salinity.

"Uncertainties on our values are comparable to those we would get in the lab," Birgand says.

The error on the 'worst' predicted parameter, namely orthophosphate, equates to a potential deviation of about 10 micrograms per liter — small enough to allow researchers to still get a fairly accurate idea of what is happening in the water in this environment and for local ambient concentration levels.

Taking the sensors out of the water decreases fouling of the optics. Photo courtesy of Randall Etheridge.

Infrequent sampling can tell a radically different story from what is really happening in the water Birgand says. Simulating six-hour sampling cycles, an interval which is already considered rather small, Birgand said, "we would have possibly under or over estimated by 70 or 130 percent the nitrate retention over that 10-day period. That's just over 10 days. Imagine for a year."

To quantify how much nitrate nitrogen the marsh might retain, the researchers attempted a mass-balance, a measurement that compares how much of a substance goes into a system with how much exits. For over 20 months, they took 15-minute measurements of flow and nutrient concentrations at two stations 2,100 feet apart in the marsh.

"We found that we got about 10 percent removal for marsh area," Birgand says referring to the nitrate retained by the marsh. This is somewhere between the removal rate of streams and wetlands. This makes sense, he says, as marshes sometimes behave like streams and sometimes like flooded wetlands.

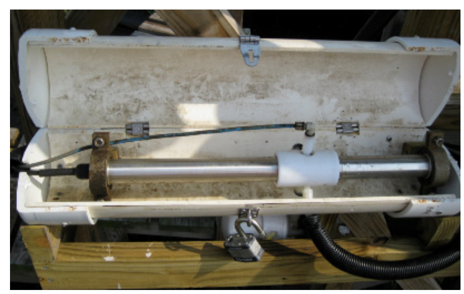
The 10 percent absorbed by 2,100 feet of stream would be added to absorption by the marsh areas further downstream, potentially removing up to 30 percent of the nitrate generated from the upstream agricultural lands.

Problems

One of the biggest problems the researchers encountered using these sensors to monitor water quality in marshes was fouling. Algal growth and chemical deposition due to electrolysis often clouded the optics.

To prevent electrolysis and reduce fouling, Birgand and his team removed the sensor from the water and instead pumped water from the marsh to the sensor. They then cleaned it with tap water, thus lowering exposure time of the sensor to the brackish water.

Additionally, because the probes also are expensive, Birgand and his team developed a technique for pulling water through tubes from multiple locations in the stream, thus allowing one sensor to sample from up to 12 locations.



A UV-Vis spectrometer in the field. Photo courtesy of Randall Etheridge.

Next steps

These sensors and their expanded use are revolutionizing water-quality testing, Birgand says. He would like to see more deployed in the field to revisit questions that have lacked sufficient data. Their expanded use, he says, will generate data that will require water-quality models to be revised. He also notes that nutrients are not the only thing that has absorbance spectra.

"There are so many other parameters out there that are of interest — all the heavy metals, all the pesticides, all the organic matter. The list," he says, "is endless."

New report gives an overview of the academic literature of rainwater harvesting

Population growth, climate change and more frequent water supply shortages have caused rainwater harvesting, or RWH, systems to increase in popularity as an alternative water supply.

A new report released by WRRI and written by Kathy DeBusk, now of Longwood University's Department of Biological and Environmental Sciences, and William Hunt, of NC State's Department of Agricultural and Biological Engineering, pulls together the academic literature on the subject.

Rainwater Harvesting: A Comprehensive Review of Literature examines the global research on rainwater harvesting and groups its findings into seven topic areas: water quality, microbial characteristics, systems modeling, reduction of potable water consumption, economic and social aspects, stormwater management, and legislation and incentive programs that promote RWH.

"This is basically a go-to guide for what has been done in the field," says DeBusk who wrote the report with Hunt as part of her doctoral dissertation at NC State University.

According to DeBusk, researchers, policy makers, stormwater management officials and homeowners all will find aspects of the report beneficial. In addition to containing results from studies on the subject, each section also contains a list called "Future Research Needs" that highlights gaps in the academic knowledge of RWH.

"We were regularly receiving proposals to study one or another aspect of rain water harvesting, but a clear connection to prior work and the state of existing knowledge was missing in most of these," says David Genereux, associate director for research at WRRI. "Given the importance of the topic, we felt it would be a valuable service — to researchers and others interested in the topic — to have a comprehensive, critical review of existing work. This will help investigators prepare stronger proposals that would move the field farther along."

Water quality

The section on the quality, or the chemical composition of harvested rainwater, notes that heavy metals and nutrients may be present. These constituents can be introduced by the precipitation itself, or from particulates in the atmosphere or on roof surfaces. The pollutants may also come from materials used in construction of the RWH system. The report includes a list of features such as debris filters, first-flush diverters and high-grade PVC that can be used to maintain good water quality in the system.

Microbes

Microorganisms such as fecal-indicator bacteria, pathogens and viruses also can live in harvested rainwater. The review notes that the primary source of bacteria and pathogens in an RWH system is often wildlife. Insects, birds, small mammals, reptiles or amphibians can be swept into the system during rain events or make their homes in or near the system. Other sources that can introduce microorganisms include rainwater, roof surfaces, or improper handling of the water or system components. To combat these risks, the authors list suggestions for siting and maintaining the systems.

Modeling the system

RWH systems are not typically monitored for output of water or constituents in the water. Instead, models are

Using an RWH system to offset potable water use. Photo courtesy of NCSU BAE.

used to determine how a system will function. A section on modeling looks at the various approaches for RWH systems, presents metrics of how systems might be evaluated, summarizes studies concerning RWH system modeling, and discusses how systems can be designed based on the results of various models.

Reducing potable water consumption

The report notes that reduction of potable water consumption is one of the main reasons for use of RWH systems. The authors grouped research into site-scale and municipal- or regional-scale reductions. They found that most site-scale studies show that RWH can effectively be used to offset a large portion of a building's water needs. Reductions for a city or a region depend on the intersection of favorable rainfall characteristics with low-water demand. The report notes that RWH may not be feasible in high-density cities, such as Beijing, that have highly variable rainfall.

continued on page 7

New report *continued from page 6*

Promoting RWH through legislation and incentive programs

Along with technical features, the report examines social aspects of RWH. A section on legislation and incentive programs looks at how legislation can be crafted to promote the use of RWH systems. It gives the components of legislation that promote its use as well as examples of laws that can hinder RWH implementation.

Economic and social aspects

Economic considerations and public perception determine the widespread use of RWH systems. According to the review, numerous reports have found that RWH is not economically beneficial.This may be due to an imbalance between the price of potable water and the true cost of its production due to government subsidies on public water supplies. Apart from economics, the review found that independence from public water supply systems, environmental stewardship and reduction in potable water usage are some of the reasons people choose to install RWH systems.

Stormwater management

RWH systems also manage stormwater. According to the report, RWH systems effectively reduce the volume and rate of stormwater entering the storm-sewer network. The authors discuss models that can optimize RWH systems for stormwater control. The role that RWH systems can play in managing stormwater is reflected in the newly-updated chapter on RWH systems in the NC Stormwater BMP manual discussed in the first article of this newsletter.

To view the full report, visit: go.ncsu.edu/11-12-W

Upcoming Events

Sediment, Erosion and Turbidity Control Workshop and Field Day

May 13, 2014
Booth Field Learning Lab
Raleigh, NC

More information available at:
www.cvent.com/events/sediment-erosion-and-turbidity-control-workshop-and-field-day/event-summary-679aa03a92154af0bd4be99110b09947.aspx.

NEW! Low Impact Development & StormEZ Workshops

May 7-8, 2014
Watauga County Ag Conference Center
Boone, NC

May 14-15, 2014
James B. Hunt Jr. Library, NCSU Centennial Campus
Raleigh, NC

May 21-22, 2014
New Hanover County Center
Wilmington, NC

Check for the call for abstracts and other information at:
www.bae.ncsu.edu/stormwater/training/storm_ez.html.

2014 Water Education Summit: *Think Globally - Act Locally*

September 8-10, 2014
Crowne Plaza Resort
Asheville, NC

Check out the site below for additional information:
www.h2osummit.org.