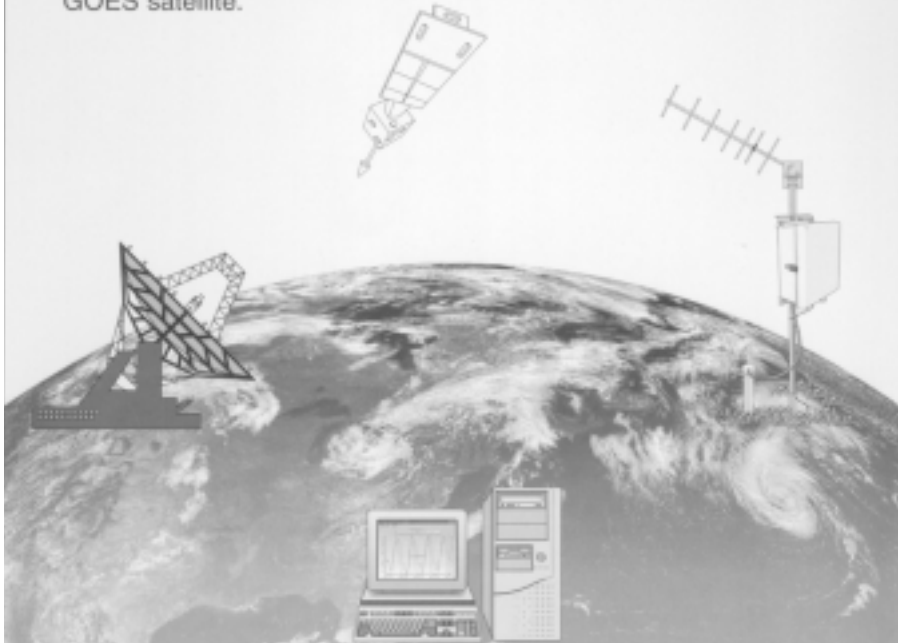


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BMP PERFORMANCE AND RECEIVING WATER IMPACTS

Jonathan E. Jones, Associate Editor
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The objective of this issue of IMPACT is to explore the linkage between urban stormwater best management practices (BMPs) design criteria/performance data and impacts to receiving waters. These articles reveal that our knowledge regarding this linkage is still quite limited. This subject is highly complex (and often times, counterintuitive) and much research remains to be done

Overview

2 BMP Performance and Receiving Water Impacts
Jonathan E. Jones (jonjones@wrightwater.com)

Feature Articles

3 Protecting Our Receiving Waters With BMPs

Ben R. Urbonas (burbonas@udfcd.org)
Explores the key question of how to utilize appropriate stormwater BMPs for the situation at hand.

7 Low Impact Development Creating a Storm of Controversy

Larry S. Coffman (lscoffman@co.pg.md.us)
Addresses commonly asked questions and concerns about "low impact development," or "LID."

10 Low Impact Development (LID): How Low Impact Is It?

Eric W. Strecker (estrecker@geosyntec.com)
Explores some of the beneficial aspects and concerns associated with low impact development, including the hydrologic effects.

16 Channel Protection

Ted Brown and Deb Caraco (Ewb@cwp.org)
Explores the topic of stream channel enlargement in response to urbanization such as how much will a channel enlarge, how many years will it take to do so, and what mitigation measures can be used?

20 Long-Term Experimental Watersheds and Urban Stormwater Management

James P. Heaney (Heaney@spot.colorado.edu)
Outlines reasons why a network of long-term experimental watersheds is needed to address significant urban wet weather flow issues, including the linkage between BMPs and receiving water effects.

24 Through the Pipe: Down the Creek!

Edwin E. Herricks (herricks@uiuc.edu)
Explores what is currently known and not known about adverse impacts to receiving waters associated with urban stormwater discharges.

28 Retrofit of an Extended Detention Basin in Denver, Colorado

Matthew J. Gavin (mgavin@wrightwater.com)
John T. Doerfer (jdoerfer@udfcd.org)
Summarizes the successful retrofit of an extended dry detention pond which was not functioning as originally designed.

32 BMPs and Receiving Waters: What is the Connection?

Michael L. Clar (mclar@smart.net)
Explores the highly relevant question of what definition of "receiving water" is appropriate to use to access the extent to which BMPs mitigate land development impacts.

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▲	Employment Opportunity	19
▲	Fellowships Available	23
▲	Future Issues of IMPACT	31
▲	President's Message	34
▲	AWRA Business	
35	A Tribute to Dr. John R. Donaldson	
36	Scholarships Awarded for 2001-2002	
36	October 2001 JAWRA Papers	
37	2002 Membership Application	
38/39	AWRA Proceedings Available	
▲	Water Resources Puzzler	40
▲	Water Resources Continuing Education Opportunities	
41	Meetings, Workshops, Short Courses Calls for Abstracts	

OVERVIEW: BMP PERFORMANCE AND RECEIVING WATER IMPACTS

Jonathan E. Jones

The objective of this issue of IMPACT is to explore the linkage between Urban Stormwater best management practices (BMPs) design criteria/performance data and impacts to receiving waters. Over the next 10 to 20 years in the United States and other countries, vast monies will be spent designing, constructing, and maintaining BMPs, such as retention and detention ponds, wetlands, vegetation-lined channels, infiltration basins, subsurface “vault-type” structures, and other facilities to remove pollutants from urban runoff, attenuate flows, and otherwise mitigate adverse impacts to receiving waters. Unfortunately, the attached papers reveal that our knowledge regarding the linkage between BMPs and receiving water impacts is still quite limited. The subject is highly complex (and often times, counterintuitive) and much research remains to be done.

As indicated in the following articles, there certainly are sufficient data to demonstrate that urbanization typically adversely impacts the quantity and quality of receiving waters. Urbanization is responsible for changes in hydrology, stormwater runoff quality, geomorphology, and biological systems. These changes can vary enormously from country-to-country, region-to-region, and site-to-site. Consider the differences between arid/semi-arid settings and wet (humid) settings for each of these four broad categories.

Many studies have assessed the impacts to stream aquatic life of varied levels of imperviousness. These studies normally find that the higher the impervious percentage of the watershed, the poorer the biological integrity of the relevant stream. However, despite the value of such studies, when they are examined closely, it is clear that investigators did not follow consistent protocols or attempt to couple data from various sources to develop linkages between observed effects and impacts. Declining biological indices between upstream and downstream stream reaches are not generally tied to the specific effects of urbanization. Moreover, there is typically not good linkage to the structural and nonstructural BMPs that are present in the watershed (if any), including such factors as: (1) percent of watershed area captured by BMPs, (2) hydrologic function, (3) design criteria, (4) frequency of bypass, (5) frequency of maintenance, and (6) extent to which traditional BMPs are supplemented with instream stabilization/habitat measures.

The articles by Ben Urbonas and Jim Heaney describe steps that can be taken, and research that can be conducted, to develop a better understanding of the linkage between BMP design criteria, performance and receiving water impacts.

A number of the articles (see, for example, the articles by Ted Brown and Deb Caraco, Mike Clar, and Larry Coffman) address the topic of stream channel instability, and habitat degradation in response to urbanization. It

has long been apparent that although there can be considerable argument regarding the impacts of elevated concentrations of chemicals in streams (see the article by Ed Herricks, in this regard), the evidence is quite clear that in the absence of thoughtfully designed detention facilities and stream channel stabilization measures, the physical integrity of streams will inevitably be compromised by urbanization. The hydrologic considerations associated with stream channel stability are addressed by a number of the attached articles.

A technique which shows considerable promise for ameliorating the negative effects of urbanization is “low impact development” or “LID.” Larry Coffman, one of the originators of LID, directly addresses concerns that some have raised regarding this topic including, for example, whether LID is based on sound engineering principles and whether there is “anything new” about the approach and scientific data regarding the effectiveness of LID. Another article, prepared by Eric Strecker entitled “Low Impact Development: How Low Impact Is It?” also addresses this technology, and the so-called “zero-impact development.”

Because so many of us are often faced with a need to retrofit or upgrade existing BMPs to enhance water quality performance, Matt Gavin and John Doerfer have prepared a case study which summarizes the difficulties that were experienced with an extended dry detention pond, and steps that were taken (during retrofitting) to overcome these problems

In conclusion, many outstanding urban water resource engineers, scientists, planners, attorneys and others are now devoting considerable effort to promoting our understanding of the linkage between BMPs and receiving water impacts. IMPACT readers are urged to stay abreast of the evolution of this topic, as it has enormous implications for the hundreds of thousands of public and private urban stormwater dischargers in the United States and internationally. My best regards to all of you who are reading this issue, and I certainly would enjoy further discussing this topic with you.

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PROTECTING OUR RECEIVING WATERS WITH BMPs

Ben R. Urbonas

ARE WE USING APPROPRIATE BMPs FOR STORMWATER MANAGEMENT?

Are we using appropriate stormwater best management practices (BMPs)? This is the question too often not being asked whenever stormwater management measures are being required by regulators or are being selected by engineers.

Often BMPs are chosen from a laundry list specified in local or state criteria, rules, regulations, or ordinances; a list that may have been developed without regard to what may be appropriate for the local meteorology, climate, geologic conditions, or the receiving waters that are supposedly being protected. Whenever local criteria are not clear, BMPs are often selected because a vendor has convinced a local reviewer that their product will meet the regulatory requirements. Either approach can be equated to having your mechanic choose from a list of very expensive parts to put in your car without first knowing why the engine will not run.

Clearly, we are on the verge of a massive structural and nonstructural BMP deployment throughout the United States; one that is often done without regard to what BMPs are really needed to protect our receiving waters. Is this what we, as a nation, should be doing in the name of addressing urban stormwater-caused receiving water "ills"? Probably not, but this is essentially what has been happening in many cases as the U.S. EPA, states, and the local jurisdictions respond to the 1987 provisions of the Clean Water Act and the separate stormwater discharge control regulations that followed.

The answer is not a simple one. In a perfect world we should know how effective each type of BMP is in mitigating various adverse impacts of urbanization on receiving waters, including their geomorphic stability and their aquatic ecology. Unfortunately, the basic science and technology has not progressed to a level where we can do so with confidence. At the same time, we have sufficient knowledge about many BMPs to draw inferences as to which ones may best help mitigate, at least in part, some of the observed impacts.

For example, if the concern is to reduce the impacts on receiving streams resulting from changes in hydrology that occur with urbanization, intuition tells us that BMPs that reduce rates of runoff and volumes for the large population of smaller storms (i.e., versus ones used for drainage design) should provide the best results. Why? Because it is this large set of much-increased runoff events that the receiving systems, physical and biological, have to now deal with where none (or few) runoff events existed from these small storms prior to urbaniza-

The universal use of structural BMPs is very expensive and, unless they provide a realistic level of protection for the receiving waters, their use could be a total waste of investment

tion. On the other hand, if controlling trash and debris is the goal, street cleaning, enforcement of antidumping ordinances, and the use of devices that strain out trash from water may be sufficient. If, however, fine sediment and associated pollutants silt in aquatic habitats and increase sediment oxygen demand (i.e., depress dissolved oxygen concentrations in the water column), use of BMPs that reduce the concentrations of total suspended solids, smaller than 100 microns in size, may be adequate. Rarely does a single issue have to be addressed, and the selected BMPs will often need to address the issues mentioned and others as well.

RECENT CONFERENCE ON BMPs AND RECEIVING WATER IMPACTS

Many excellent papers by some of the leading experts were presented on this topic at a conference held August 19-24, 2001, in Snowmass, Colorado. The American Society of Civil Engineers (ASCE) will publish this conference's proceedings late in 2001, and everyone is encouraged to study them when they become available. Several themes ran throughout this meeting. One is the need to mitigate flow rates and volumes to the maximum extent practicable to help reduce geomorphic changes and the aquatic habitat destruction created. Another was to use BMPs (i.e., treatment devices) that have the greatest potential for reducing concentrations of small sediment particles, even ones smaller than 10 microns. Yet another theme gaining considerable notice is that instream stabilization and habitat enhancement measures need to occur in parallel with the use of BMPs as areas urbanize.

Initial evidence was presented that, when compared to streams in urbanized watersheds without the use of BMPs, the use of extended-detention-type BMPs can have a measurable mitigating effect on impacts to aquatic biota. It was also concluded at this conference that much more work and research is needed before we have truly quantified the relationships between BMP systems in a watershed, their design parameters, and their effectiveness in mitigating impacts of urbanization. In the meantime, we will need to continue to draw on the emerging information and do our best job when selecting and using what we believe to be the most effective BMPs.

EXAMPLES OF RECENT DESIGN GUIDANCE

Following up on the themes of "the devil is in the details" and the "use of BMPs to help reduce impacts of urbanization on receiving waters," our own experience at the Urban Drainage and Flood Control District (District)

Protecting Our Receiving Waters With BMPs . . . cont'd.

has shown that a significant number of design, nuisance, maintenance, and performance problems were solved when we developed concise water quality capture volume sizing requirements; specific drain times for this volume; and a new outlet design for extended detention basins, retention ponds, and wetland basins.

Figure 1 is a photograph that shows a micro-pool at an outlet and a properly sized stainless steel well-screen-type trash rack with a perforated riser plate mounted behind the trash rack. This design virtually eliminated clogging and sediment accumulation problems at the outlet, permitting the detained volume to drain out within the 40-hour design period of time. Another design that the District introduced to address flow mitigation and water quality treatment is shown in Figure 2. It is a sand filter basin, with a water quality capture volume above the filter's surface. When sized and designed following the District's guidelines, such filter basins operate well, provide significant peak flow attenuation, are relatively trouble free, and have reasonable maintenance needs to stay in operation. AutoCAD™ details for these designs are available to download at the District's Web page: www.udfcd.org.



Figure 1. Extended Detention Outlet Installed in June 2001 and in Operation in August (18 hours after a storm's end). Note the partially submerged well-screen-type trash rack, the debris line that is near the bottom of the 10-year control orifice and the 100-year overflow on top. (This photograph was used by permission of the Urban District, Denver, Colorado.)



Figure 2. Sand Filter With Water Quality Capture Volume Above It, Installed in the Late 1980s. Note two inlet pipes and an overflow for larger storms.

Volumes below the overflow are filtered and, because site conditions permit, infiltrated into the ground. (Photo used by permission of Urban Drainage and Flood Control District, Denver, Colorado.)

COMPREHENSIVE RESEARCH PROGRAM NEEDED

The universal use of structural BMPs (i.e., treatment facilities) is very expensive. They are expensive to install, many BMPs require the dedicated use of expensive land areas, and their ongoing operation and maintenance will carry a significant price tag as well. If the selected BMPs provide a realistic level of protection for the receiving waters, the price may be worth it. If they do not, then much money has been sunk building facilities for naught. The only way to answer whether what we are installing and maintaining in our communities is effective, is to have the federal government, states, and local jurisdictions commit to a long-term national program of basic research. The research being suggested would help quantify the linkages between urban stormwater BMPs and their ability to mitigate the impacts of urbanization on receiving waters.

Protecting Our Receiving Waters With BMPs . . . cont'd.

Sufficient data and observations are in place today to show that urbanization does change the nature, quality, and quantity of surface runoff and ground water flows reaching the nation's receiving waters. These include changes in the rates, volumes, frequency, and quality of the surface runoff. All of these are attributed to the observed physical, chemical, and biological changes of the receiving water systems.

There have been several reported efforts to compile information on the effects of urbanization and impacts on receiving water. Many of these studies, although good to excellent in their own right, did not follow consistent protocols or attempted to couple data from various sources to develop linkages between observed effects and impacts. Namely, reporting that the Rapid Bio-Assessment Index showed degradation between upstream and downstream reaches of an urban area does not tie these degradations to specific effects of urbanization.

There were only very few attempts to link the performance of stormwater BMPs with their ability to mitigate the observed impacts of urbanization (e.g., State of Maryland; King County, Washington; Austin, Texas). Although studies by Maxted (1999) and Maxted and Shaver (1997) looked at the ability of retention basins and Horner *et al.* (2001) looked at extended retention basins to mitigate the impacts of urbanization on aquatic biota, none of those studies attempted to link specific BMP design parameters (i.e., various types, surface areas, and capture volumes relative to local mean runoff volume, release rates, etc.) to their effectiveness. None of them looked at entire systems of municipal BMPs that thoroughly cover the watershed and can operate simultaneously.

Although these efforts have been excellent in what they pursued and the knowledge they generated for each area of study, they did not involve a broad cross section of the scientific and engineering community. They were limited in scope, focused on limited areas of the United States, and were limited in the parameters evaluated and documented. As a result, there has not been a consensus as to the techniques used and how the findings may apply to different geographic, meteorological, and urban settings. In addition, the scarcity of these types of studies makes it premature to extrapolate conclusions beyond the few sites investigated.

Clearly there is a need to establish an approach that will permit the development of a nationwide quantitative evaluation. We need an effort that is designed to link the impacts of urban stormwater runoff on receiving waters to the performance of various types of BMPs and their design parameters such as type, size, volume, surface area, flow release rates, potential for infiltration, etc.

A SUGGESTED RESEARCH PROGRAM

A nationwide research program designed to answer the above-stated challenge has to be scientifically credible and defensible. Simply launching a series of "studies" to answer questions being raised (something that has become a norm), is insufficient. Studies can only assemble and interpret available scientific information and data that is available. Thus, to be credible, a research effort

that addresses and quantifies the linkages between BMPs and their ability, as part of a total municipal system, to mitigate impacts of urbanization on receiving water needs to:

- Involve the scientific and engineering community from many disciplines.
- Identify issues and complexities that will need to be dealt with to achieve stated goals.
- Identify the data and other information needs.
- Develop protocols for research, data acquisition and their evaluation.
- Whenever possible, quantify the relationships discovered.
- Point out the observed or suspected relationships that cannot be quantified.

Over the last five years, the Urban Water Resources Research Council of the ASCE has developed a database system to assemble BMP performance data in a consistent and repeatable manner. This work was funded by a grant from the U.S. EPA's Office of Wastewater Management. The database may be accessed through its own Web page at www.bmpdatabase.org. This project resulted in a suggested set of minimum standard parameters and information that needs to accompany each BMP evaluation data set. The study team is also developing a guidance manual, which should be released in 2001 or 2002, for the design of monitoring systems whenever BMP evaluation tests are being set up.

Based on what was learned during the development of the ASCE BMP database, it is possible to recommend a research program that eventually may be able to link various BMPs and systems of BMPs to their ability to mitigate receiving water impacts. Such an effort needs to:

- Identify the sources of currently available data and other related information.
- Postulate areas of knowledge and, more importantly, lack thereof.
- Obtain, consolidate, and organize currently available data.
- Examine available data, current thinking, and models on these phenomena.
- Develop a consistent protocol for further data and information acquisition and development.
- Launch a nationwide data acquisition effort to supplement currently available data.
- Evaluate information and data as it is developed and acquired.
- Adjust data, information needs, and protocols when "knowledge" gaps or additional needs become apparent.
- Attempt to quantify relationships in a manner that provides defensible and useable tools throughout various ecoregions of the United States.
- Suggest and modify protocols as better understanding is gained about this topic.

This effort will need to be aimed at defining which physical (i.e., hydrologic, geomorphic, stream power, sed-

imentation, erosion, etc.), chemical (i.e., toxicity, oxygen availability, etc.) and biological (i.e., numbers and types of species of flora and fauna, habitat, eutrophication, etc.) processes are at work and what may be achievable through the use of individual BMPs and systems of BMPs in urban areas to mitigate the effects of urbanization.

SUMMARY AND CONCLUSIONS

The universal use of structural BMPs (i.e., treatment facilities) is very expensive and, unless they provide a realistic level of protection for the receiving waters, their use could be a total waste of investment. What is needed is a nationwide research effort, funded to a large extent by the federal government, to quantify the linkages between urban stormwater systems of BMPs and their ability to mitigate the impacts of urbanization on receiving waters.

This scientific effort has a good start through the availability of the ASCE BMP database. In other words, some of the tools needed to begin the above-stated research effort are now in place. A follow-up program can start with this database, build on it, and add to it a set of receiving water parameters. It needs to be designed to help link, by geographic regions, BMPs and systems of BMPs to observed in-stream, in-lake, in-wetland, and in-estuary impacts offered by each. Comparisons will need to be made using areas not yet urbanized, urbanized areas without BMPs, and areas with BMPs. In addition, isolated tests are also needed to identify the effectiveness of a specific BMP design's ability to mitigate the impacts of urbanization. All of these field research studies have to be designed in order to minimize the influences of a very large number of confounding variables.

A word of caution about the use of computer models to develop the needed information. Computer models should be used to help with these studies but should not be relied on to give true answers on system performance. Models will only regurgitate what was built into them, along with all assumptions, equations, parameters, etc. One of the outcomes of such a research effort could be a much-improved computer model. Eventually, we may be able to do a much more credible job of predicting urban drainage system response and how the receiving waters may be affected using the improved computer models that would result from such a research effort.

While we wait for advances in science and information, we can be doing a better job of selecting BMPs. By selecting BMPs that help reduce flow rates, volumes of runoff, and concentrations of very fine suspended solids, we have the greatest chance of mitigating some of the impacts of urbanization on our receiving streams. Clearly, there are impacts other than those touched upon in this article that need to be addressed for the great varieties of receiving waters in United States. While the sciences improve, we should at least be discriminatory in our choices, using mitigation of physical and biological impacts of urbanization as our goal. On the other hand, choosing BMPs indiscriminately is misguided and a monumental waste of fiscal resources.

LITERATURE CITED

Horner, R., C. May, E. Livingston, D. Blaha, M. Scoggins, and J. Maxted, 2001 (in press). Structural and Nonstructural BMPs for Protecting Streams. Proceedings of the Conference on Linking BMPs and Their Ability to Mitigate Effects of Urbanization, ASCE, Renton, Virginia.

Maxted, J.R., 1999. The Effectiveness of Retention Basins to Protect Aquatic Life and Physical Habitat in Three Regions of United States. Proceedings of the Comprehensive Stormwater and Aquatic Ecosystem Management Conference, Auckland, New Zealand, pp. 215-222.

Maxted, J.R. and E. Shaver, 1997. The Use of Retention Basins to Mitigate Stormwater Impacts on Aquatic Life. In: Effects of Watershed Development and Management on Aquatic Ecosystems, L. Roesner (Editor). ASCE, Renton, Virginia, pp. 494-512.

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FEEDBACK! . . . Let us know what you think. We want to encourage dialogue. Write or e-mail your comments to the Associate Editor of this issue or to me. We appreciate everyone who has sent their comments to us so far and ask that you continue to do so. We would like to get everyone involved in some "conversation" on various topics.

Earl Spangenberg, Editor-In-Chief
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LOW IMPACT DEVELOPMENT CREATING A STORM OF CONTROVERSY

Larry S. Coffman

When I began my career as a public servant, over 27 years ago, all I wanted was to become a life-long local government bureaucrat, safe and secure in my administrative job and anxious to collect my retirement. Then, about 10 years ago I innocently started a new approach to stormwater management called Low Impact Development (LID). Since then, it seems I've been working 24 hours a day seven days a week on LID. About five years ago I began the conference circuit, explaining the lessons learned about the economic and environmental limitations of conventional management approaches and the possibilities of LID. I never imagined that my message would have been so enthusiastically embraced and so bitterly opposed. Who would have imagined – me, an old country biologist – embroiled in the mist of a national debate on advancements in urban stormwater management technology?

The demand on me to provide information on LID was so great that I helped establish the non-profit Low Impact Development Center to assist federal, state, and local governments with education, training, research, and demonstration projects on LID's source control principles and practices. So please call the LID Center for help to answer your questions – so I can get back to my eight-hour a day job conducting my favorite bureaucratic pass-time of cutting red tape lengthwise!

When I was asked to prepare an article on (LID) for this issue, I planned on providing an update on some exciting advances in LID technologies. I was going to discuss the efforts of U.S. EPA's Office of Research and Development to modify SWMM to model LID's multiple scale systems. I was going to discuss the Puget Sound Water Quality Action Team's first national conference on LID and Smart Growth (terrific event – well done!). I thought I might report on the proceedings of the first national LID roundtable with 40 national experts working on various aspects LID technologies. I was going explain how Washington, D.C., is using LID in their long term CSO control plan. I was going to let you know that the Chesapeake Bay Program's Executive Council (comprised of the governors of Maryland, Virginia, Pennsylvania, and the Mayor of the District of Columbia) issued a directive to their respective jurisdictions to include LID in their stormwater programs for greenfield and urban retrofit development. And, finally, that my County Executive, Wayne K. Curry, a strong supporter of LID, directed me to develop the ultimate LID greenfield development guidelines. He wants me to develop the "almost no impact" (at least to water quality) LID. There is no doubt LID is out of the bag and building a

critical mass for future major change in our approach to stormwater management and greatly expanding our tool box of techniques.

As one of many enthusiastic advocates of LID, it would have been easy and fun to let you know about the LID's successes. However, I thought it might be more interesting to comment on a few issues surrounding LID expressed by consultants and practitioners that remain skeptical, doubtful, suspicious, or misinformed about what LID is and its possibilities. It is interesting to note that since the release of our first LID local design manual in 1997 no one has challenged the technical merits of LID's decentralized micro-scale source control strategy. To challenge LID on a technical basis would require challenging our current basic scientific and engineering principles of hydrology, hydraulics, ecology, biology, etc. The criticism of LID is related to its practical application and long-term maintainability. Below are four commonly expressed issues.

ISSUE 1

There are detractors who say there's nothing new about LID; we've done it for years. Many have been misled by those who want to lump LID into the popularized Better Site Design and conservation design techniques. LID goes far beyond the goals of these impact mitigation schemes by providing many more tools to plan and engineer a site in a manner that maintains or restores the hydrologic and ecological functions necessary to support the integrity of receiving waters. LID requires strategic and customized use of conservation measures, multifunctional small-scale controls, and pollution prevention to address site-specific stormwater pollutant load, timing, flow rate, and volume issues. This is not the same as a broad-brushed set of generic site design or

conservation tools that only reduce impacts. LID's analytical methodology and organizing principles are designed to allow one to engineer a site's landscape in a manner that maintains the natural rainfall/runoff relationship, not just reduce impervious surfaces and minimize impacts. Don't let others tell you what they think LID is, find out for yourself. Get a copy of the easy to read National LID Design Manual from the web: <http://lowimpactdevelopment.org>.

ISSUE 2

Where is the scientific proof and data that LID works better than ponds at pollutant removal? This question I find systematic of the specialization, compartmentaliza-

LID has initiated new dialogue, opened up new areas of research, and caused us to question many of our past assumptions and approaches

Low Impact Development Creating a Storm of Controversy . . . cont'd.

tion, isolation, and parochialism that stormwater practitioners often exhibit. The LID principles and practices are based on what we have learned over the years about stormwater management and the transfer of technology from other fields of engineering and science, such as sanitary engineering, agriculture, forestry, soil science, phytoremediation, bioremediation, and ecology. As an example, take a look at the data on the 50-year history of successful land application and treatment of wastewater effluent (slow rate irrigation, overland flow, and high rate infiltration). Add to this the existing and growing body of data on the performance of bioswales, bioretention, filter strips, and turf from universities (Maryland, Virginia, and Washington State), Federal Highway Administration, EPA, and others. When you look at the entire body of related scientific data and engineering/environmental technologies, you begin to see the advantages and benefits of LID's multiple systems (treatment train) approach. Just looking at the monitoring data on bioretention (rain gardens) alone shows it to be far more effective than any other stormwater BMP.

Last year we began monitoring a paired watershed (conventional design versus a LID prototype design) for flow and found the LID site generates one-third less flow than the conventional site for small storm events. When you add the flow and frequency reductions that can be achieved with LID, you get the added benefits of reducing

total annual loads by reducing runoff volumes and erosion potential. We can't afford to wait 20 years to generate the data to absolutely prove LID works, you just need to use a little common sense and be open to embracing and learning from other fields of science and engineering. By the way, we have been collecting data for about 20 years on conventional BMPs and there are still questions about their efficacy.

ISSUE 3


Many people want to know what is the long-term viability of the LID systems? What's to stop property owners from filling in the rain gardens and cutting down the trees? This statement demonstrates the lack of understanding of the comprehensive nature of the wide array of practices used in LID. Many try to simplify LID by characterizing it as only relying on rain gardens and rain barrels. They fail to recognize or do not want to understand that LID is a systems approach using dozens and dozens of techniques that retain, detain, infiltrate, recharge, filter, use, modify runoff timing, and prevent pollution in order to maintain and restore an ecosystem's hydrology and water quality. LID's multiple systems have built-in redundancy and reduce the possibility of total failure. Many LID techniques have nothing to do with nor can they be significantly influenced by the property

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owner such as reducing the use of pipes, ponds, curbs, gutters, saving recharge areas, saving streams/drainage courses, infiltration swales, saving buffers, reducing impervious surfaces, disconnection, open space conservation, grading strategies, saving streams/wetlands/buffers, dispersing drainage, and using open drainage systems. LID's long-term success has much more to do with the knowledge, skills, intelligence and creativity of the site designer (planners, engineers, architects, and environmental scientists) than what the property owner does or doesn't do.

Furthermore, if one reads the LID Design Manual carefully, they will find that additional storage volume is added as a margin of safety to account for some losses over time (although we expect LID to work better over time). If one wants to raise their level of comfort about maintenance, they can use easements and maintenance agreements. In our experience, the use of smart designs works without any undo burden on the local government for enforcement – there is none. If you do not believe it, come see me and I will take you on the LID tour – you be the judge. There is no reason to rely on or accept speculation of what does or does not work form those who have never used LID.

After all shouldn't each property owner be responsible for the impacts associated with their property? Don't we want the public actively engaged in protecting our receiving waters? What better way than to design properties and landscaping to be a functioning part of the ecosystem rather than apart from it?

ISSUE 4

Detractors state that LID conflicts with state and local land use laws. In fact, it is just the opposite. LID is not based on modifying land use. However, conservation design and the popularized Better Site Design techniques often do conflict with land use laws as they require rezoning to clustering and change lot sizes/designs or limit the types of development. As a local government official, I want to preserve local government's right to determine zoning and land use. LID focuses more on changing building codes, with its emphasis on highly engineered multifunctional landscape techniques. LID requires revisions or waivers to some building codes, not zoning codes. LID leaves it up to the local communities to define the building envelope in the way they chose and consistent with resource protection laws.

LID has initiated new dialogue, opened up new areas of research and caused us to question many of our past assumptions and approaches. Innovation and change requires taking some risks, strong commitment, expending tremendous energy, and having great perseverance. I think advancements in our technology are worth the effort. I would not be in my tenth year of exploring and promoting LID if I did not truly believe it will help move us forward towards reaching our overall objective of fishable and swimmable waters. My advice to other program administrators and their engineering/environmental consultants is educate yourself on LID's new approach to determine its applicability to better meet your ecological

and economic goals. We owe it to the public we serve to provide them with the most sustainable solutions possible.

FIVE BASIC STEPS TO LID

1. CONSERVATION,
2. MINIMIZATION,
3. STRATEGIC TIMING,
4. INTEGRATED MANAGEMENT PRACTICES
5. POLLUTION PREVENTION.

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LOW IMPACT DEVELOPMENT (LID) How Low Impact Is It?

Eric W. Strecker

INTRODUCTION

Over the last several years there has emerged a number of techniques that applied in combination in a methodological way have been asserted to result in little or no stormwater impacts. Although many of these techniques have been utilized for a number of years, they recently have been given the name of Low Impact Development (Prince George's County, Maryland (PGC), 2000a,b). Some have gone so far as to call these techniques "Zero-Impact" development in discussions about adopting new standards and accepting alternative development patterns and designs (e.g., Tumwater, Washington, has been evaluating a "Zero-Impact" Development Ordinance). The author believes strongly that many of these techniques are very helpful in reducing impacts and should be encouraged. However, what is problematic is suggesting (as the name does) that these techniques will solve "the problem" without other watershed efforts, such as instream stability measures, and/or regional systems. The name that has been given to them, "Low Impact," infers that the downstream impacts would be expected to be minimal, when in fact, depending on a number of site, weather, watershed, receiving water type, design, and maintenance factors, this may not be the case.

There needs to be more evaluation as to the extent that these techniques can really reduce or eliminate impacts as well as their maintainability. In addition, the design criteria need to be evaluated and updated to ensure that they are not based upon improper applications of single event flood design methodologies that are inappropriate for water quality and hydrological controls designed to protect streams. A number of communities are adopting and/or encouraging LID techniques without assessing what the design criteria should be and what levels of environmental protection will result for their soil, vegetation, slope, hydrologic, and stream conditions. This could lead to another round of less than satisfactory environmental protection. Flood design methods, with built-in conservative saturation and rainfall distribution assumptions in almost all cases overpredict predevelopment (open land use) runoff more significantly than post-development (higher imperviousness) runoff. Therefore, the result is that the differences between pre- and post-development for most regular storm events are likely significantly underestimated. Merely demonstrating that the pre- and post-hydrographs are "close" for the design events is not an accurate portrayal of what would likely occur. In fact, for many sites and storm events the runoff amounts may

be many orders of magnitude larger in post-development conditions.

IMPACTS OF DEVELOPMENT ON HYDROLOGY AND WATER QUALITY

Changes in hydrology and water quality due to development are caused by a number of factors, but primarily are caused by:

- Removal/reduction of tree and/or shrub canopy and root systems.
- Removal or compacting of moisture adsorbing soils.
- Increase in landscaping consisting of shallow rooted grasses.
- New impervious surfaces including streets, driveways, roofs, sidewalks, etc.
- Direct connection of these surfaces to the stormwater systems.
- Activities and exposed materials in urban areas resulting in stormwater pollutantion.

Much of the recent literature on impacts due to development has focused almost exclusively on the level of imperviousness (or directly connected imperviousness) of a watershed as the factor that indicates the structural integrity of a stream or the health of it's aquatic species (May *et. al.*, 1997; Schueler, 1994; Booth and Jackson, 1997). In fact, depending on predevelopment conditions, the vegetation and soil layer changes in many cases are large factors as well, particularly for smaller storm events. The impervious factor does to some extent account for part of the change in canopy and soils, but not completely for those areas that are affected but remain unsurfaced (e.g., lawns, compacted soils, etc.). Low Impact techniques have recognized that the importance of other factors besides imperviousness via the suggestions for increasing nongrassed natural vegetation areas, and to be careful to preserve moisture-adsorbing soils.

LID techniques primarily function by routing stormwater from roofs, parking lots, and driveways to depressed areas and/or infiltration trenches

A schematic of the pre-hydrology (Curve 1) and post-hydrology (Curve 2) design storm changes with development from the Prince George's County (PGC) Manual (2000b) is shown in Figure 1. This figure portrays the well-understood phenomenon of increasing peak flow rates and volumes with the conversion of open land to urban uses. Note that in this schematic, although the represented change in peaks and volumes is large (somewhere in the 50 percent range), they are not nearly as large as often observed with real storms and antecedent conditions.

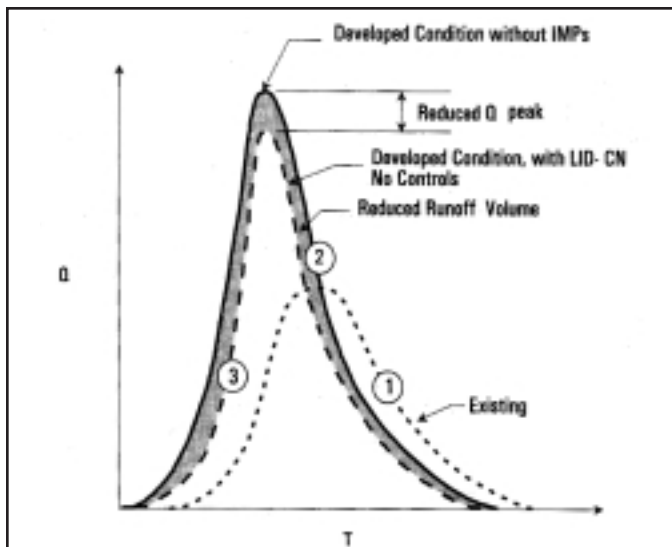


Figure 1. Predevelopment (Curve 1), Post-Development With No Controls (Curve 2), and Post-Development With Curve Number (CN) Reductions (Source: PGC, 2000b).

There have been numerous studies on the sources and magnitudes of urban runoff pollution (USEPA, 1983; Pitt *et al.*, 1995; Driscoll *et al.*, 1989) that LID attempts to address. This paper will primarily focus on the hydrological and hydraulic effects of these techniques.

LOW IMPACT DEVELOPMENT STORMWATER MANAGEMENT TECHNIQUES

LID techniques primarily function by routing stormwater from roofs, parking lots and driveways to depressed areas and/or infiltration trenches. These areas (raingardens, retention areas) usually consist of organic mulches, soils, and/or sand layers (PGC, 2000a). In soil conditions with poor infiltration, they often include an underdrain for discharge to storm systems. The techniques also emphasize leaving significant areas in natural state (e.g., the manual shows one-acre lots, with many deeper rooted vegetated areas and undisturbed soils).

The suggested techniques reduce impacts via: (a) temporarily ponding runoff and slowly discharging, (b) soaking water up into the “sponge” (soils, vegetation) and allowing evapotranspiration to occur, and/or (c) infiltration. The results of the successful application of these techniques to a site are that stormwater runoff is reduced and slowed. If volumes of runoff can be reduced and slowed, impacts downstream can be reduced. The hypothesis is that these techniques reduce runoff changes to levels that would result in no or little significant impacts. In stream systems, reducing runoff volumes and peak flows could result in less habitat damage due to physical hydrologic changes and for all water bodies a reduction in pollutant loads. However, peak reductions via controlled releases by themselves can sometimes lead to increased channel degradation (MacRae, 1996).

LOW IMPACT DEVELOPMENT METHODOLOGY

The low impact development methodology utilizes the following flood control design hydrological approaches to determine the sizing and effectiveness of low impact BMPs (PCG, 2000b): (1) curve number reduction, (2) maintain time of concentration, (3) retention (no surface release, and (4) detention (slow release).

Figure 2 highlights a schematic of a storm that might actually occur as opposed to the typical flood design hydrographs. Along with showing the higher post-development runoff, it also shows the potential problems with peak rate control (detention is used to control peak flows in LID methodology and in many communities there is a small-storm peak flow control to protect streams). In extending the duration of what were previous peak flows, significantly beyond the duration of predevelopment peaks, MacRae (1996) highlighted this problem in peak matching. He found that the policy of matching flood control design hydrographs with smaller storm events (e.g., two-year events) from pre- and post-development conditions was flawed because the result was an extended duration of channel forming/effecting flows. This approach has caused more damage in many streams than letting these flows pass. Low Impact techniques do attempt to address the runoff volume issue, but also include detention to allow peak flows to be matched.

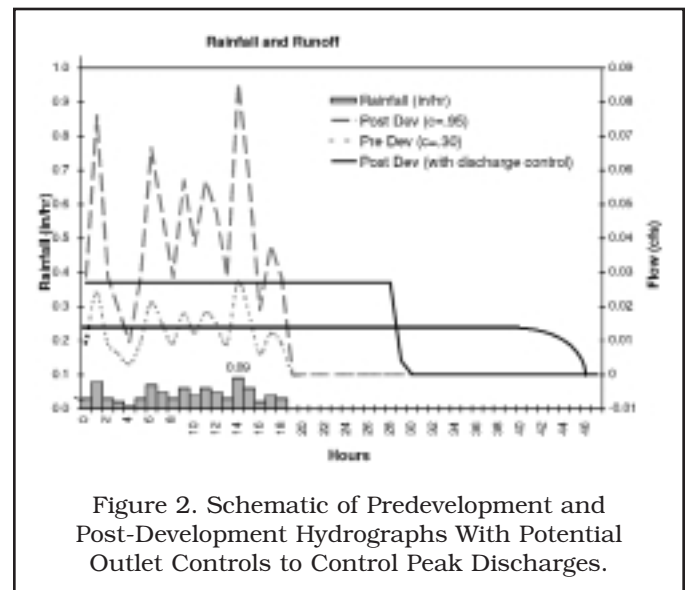


Figure 2. Schematic of Predevelopment and Post-Development Hydrographs With Potential Outlet Controls to Control Peak Discharges.

Another problem with matching post-development flow rates to predevelopment hydrographs is that the predevelopment flow rate is typically very overpredicted, as compared to the post-development using traditional flood design approaches (as mentioned above). The SCS (Soil Conservation Service; now the Natural Resources Conservation Service) approach for developing flood design hydrographs is to select a large rainfall depth over some period (typically 24 hours) (McCuen, 1998). This selection is usually based upon a desired return period (typically 2, 5, 10, 25, 50, and/or 100 years). As it is well understood, the observed runoff rates are actually dependent

Low Impact Development (LID): How Low Impact Is It? . . . cont'd.

on much more than the rainfall depths. How the rainfall arrives, prestorm soil and surface moisture/saturation levels, the effects of soil compaction and impervious surfaces, vegetative canopy level, etc., also impact runoff hydrographs; each runoff hydrograph from each storm will in reality display unique characteristics. Because of these effects, the resulting peak flow rate that occurs in a stream is rarely of the same return period as that determined from the rainfall analysis alone. Flood design methods that assume higher saturation levels and assume that the rainfall arrives in a very peaky shape, almost always over-predict flow rates such that the return period of the resulting peak flows are much higher. This level of increase is usually much larger for predevelopment conditions (Strecker and Reininga, 2000).

The shape of SCS flood design hydrographs are also quite problematic when used for water quality and/or smaller storm analyses that are trying to address impacts. They were developed by combining the analyses results of larger (24 hours) and shorter (to 15 minutes or less) duration rainfall frequency distributions, such that a 24-hour storm would also have the resulting rainfall from 15-minute and higher durations of the same return periods (McCuen, 1998). In that way, it was assumed that the storm could be applied in all types of catchments for design conveyance systems and would be conservative enough to result in large flows from different sized catchments (a one storm size fits all approach). This has resulted in peak flows that are likely much larger than would be expected for any given return period. The problem is then that peak matching is happening at some pretty large flow rates that in reality must be much smaller to actually match predevelopment conditions.

Low Density Development = Sprawl?

The first approach listed in the PGC manual in their methodology description is reducing imperviousness. There is no question that this approach could result in lower impacts and should be pursued. However, this should be approached within the context of reducing imperviousness without necessarily encouraging more urban sprawl. For example, if an area zoned R10 (10,000 square foot lots, which is about 4.3 houses per acre), was modified to move to a technique that reduces imperviousness via the use of one-acre lots (an example size given in the PGC Manual), then to fit the same number of households into a development would require 4.3 times the land area. Figure 3 displays the potential differences of 15,000 vs. 5,000 square-foot lots in concentrating impact areas. Larger lots would spread impacts to more areas and would require more roadways (some of the imperviousness reduction achieved in this way would likely be lost to more arterial roadways).

Cluster development techniques could also encourage more sprawl if it were the case that the developer could put the same, more compact density over the whole site and therefore accommodate more people. In effect, this would be "clustering" the developments within urban areas (e.g., within Urban Growth Boundaries) such that there would be less need to move further out from City

centers. Figure 4 shows how "urban clustering" could reduce impacts to some streams dramatically over even project clustering by showing one scenario where impacts are spread out over the entire area while in the second they are concentrated. In some LID approaches, the first case would show larger lots throughout the whole area. The State of Oregon has had urban growth boundaries for over 25 years and others are adopting similar approaches. Urban growth boundaries in Oregon have resulted in 5,000 square-foot lots for single-family homes, where it would be more difficult to preserve natural soil and vegetative conditions. The benefit to Oregon has been that urban sprawl has been more contained. There is a potential conflict between this aspect of the LID technique and containing sprawl. The point here is that one needs to consider potential ramifications on an urban and watershed scale of on-site standards.

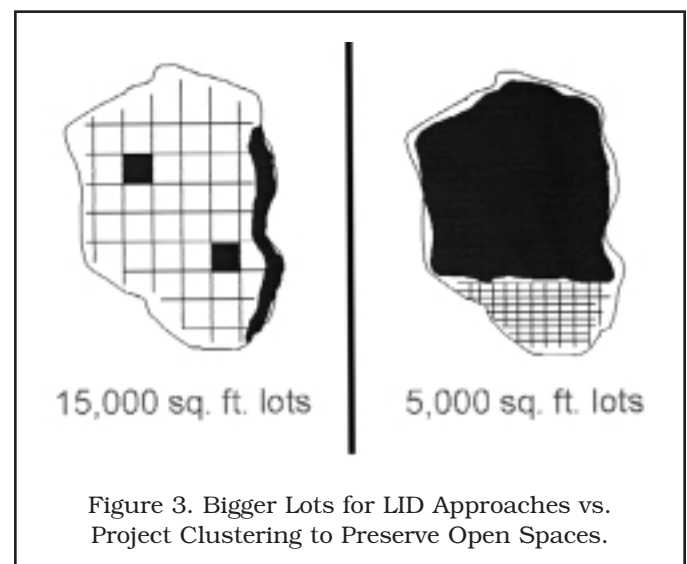


Figure 3. Bigger Lots for LID Approaches vs. Project Clustering to Preserve Open Spaces.

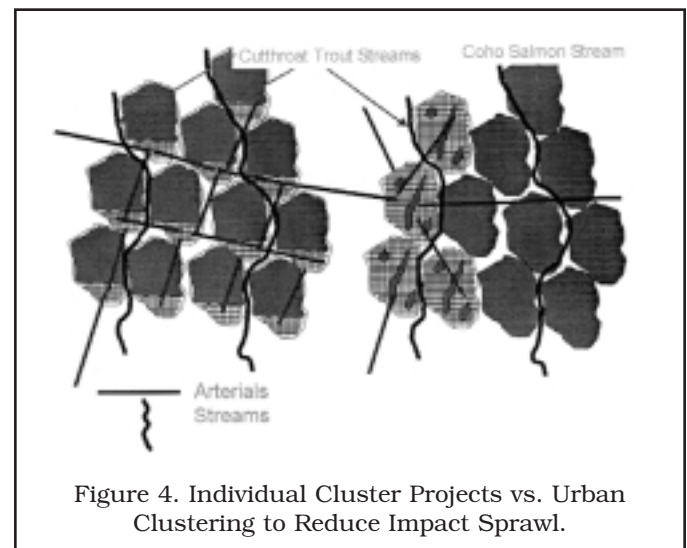


Figure 4. Individual Cluster Projects vs. Urban Clustering to Reduce Impact Sprawl.

The key to impervious limits being successful is to try to achieve the reduction in imperviousness without enlarging development sizes and encouraging sprawl

Low Impact Development (LID): How Low Impact Is It? . . . cont'd.

(unless, it can be demonstrated that with more sprawl, overall impacts are lower – a hard sell in this day and age). The goal of reducing runoff by preserving trees and soils is a good one. It does become more difficult in denser developments. Perhaps another approach might be to have the soil loosened up and planted with trees and shrubs once the project is complete. This will achieve the goals of low impact development while taking into consideration the difficulty of preserving existing soil and vegetative conditions during construction in denser developments.

Single Event vs. Continuous Simulation Analyses

The reality of pre- and post-development conditions when converting land from forested to a developed state is that runoff hydrology changes are much greater than that predicted by single-event flood design hydrology methods. Although these design methods tend to over-predict all runoff flows, they typically overpredict to a much greater extent predevelopment conditions. An example of this is shown in the modeled hydrographs in Figure 5. A calibrated model was applied to a basin in Eugene, Oregon, and then the predicted predevelopment, existing, and built-out conditions were modeled for a rather large storm event of 2.5 inches (about a two-year, 24-hour event). From the chart, it is evident that the pre-development peak flow is about 10 percent of the expected built-out flow rate. The volume difference is about 1000 percent. This contrasts starkly with the flood design approaches that would have likely resulted in about a 40 to 60 percent peak and volume difference. It would be much easier to show a match under the flood design approach vs. what is a more realistic analysis of site or basin hydrology. Today, when there are plenty of computing resources available (Donigian and Huber, 1991) for assessing hydrology on a continuous basis, there is really no reason for using flood design approaches to assess impacts to streams or water quality, other than tradition.

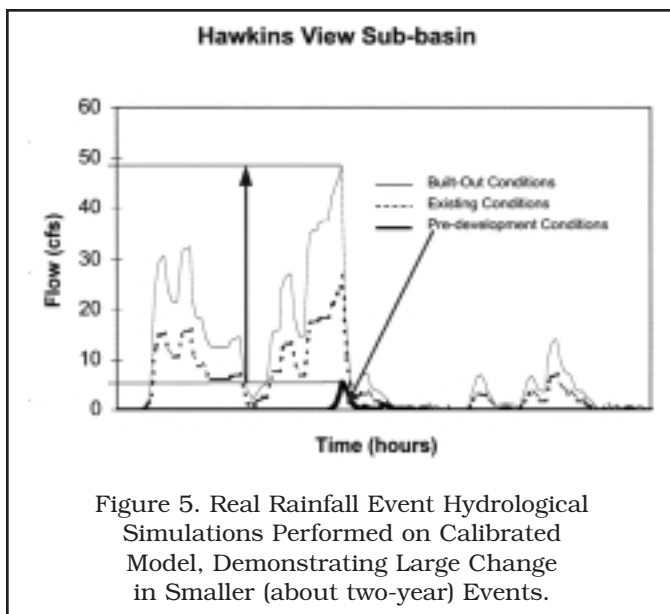


Figure 5. Real Rainfall Event Hydrological Simulations Performed on Calibrated Model, Demonstrating Large Change in Smaller (about two-year) Events.

LONG-TERM FUNCTIONING ISSUES

Some of the other issues with these techniques include the obvious ones, such as the potential for clogging from yard debris (landscaping management) as well as washing of soils into areas that could then diminish the ability of retention areas to infiltrate and/or filter runoff. There is also the potential for products such as fertilizers and pesticides to be improperly applied that could cause problems if there were not downstream BMPs to address these. As in all cases, homeowner education is critical. Other potential issues include homeowner regrading and/or paving of areas, converting natural areas into grass areas, and elimination of swales.

However, the author has observed conditions at some projects that utilized LID – like techniques in developments – including Village Homes development in Davis, California. This development has been in existence for over 25 years, has no piped conveyance systems, and utilizes deep-rooted vegetation swales to convey runoff. Residents reported that they have had no flooding problems and that it is rare that the development discharges to the city's drainage system. The system is in common areas that are maintained by a homeowners association, which may be one of the keys to its long-term success (i.e., the system is their landscaping and they take good care of it). This area does not have high infiltration rates, is very flat, and was likely grass land prior to development. This, combined with the deep rooted vegetation that keeps these soils "open," has resulted in what is likely to be "low impact." However, sites in steeper sloped areas that were forested prior to development would not have the same advantages in terms of being able to achieve "low impact."

WATERSHED ATTRIBUTES

A number of watershed and geographic attributes need to be considered when evaluating the potential effectiveness of LID or any other BMPs. These include: (a) weather patterns, (b) slope of terrain, (c) soil types, (d) depth to bedrock, (e) development densities, (f) street drainage, and (g) the overall watershed imperviousness of the stream being affected.

Weather patterns could greatly influence the potential effectiveness of LID measures. In the west coast for example, the weather patterns are dominated by whether the high-pressure ridge (which block storms from coming onshore) is present or not. When it is not there, a series of storms track in. This may leave little time for low impact systems to "recover" prior to the next storm arriving. Continuous simulation modeling would address this potential issue.

Another potential issue is whether the site has steep or flat topography and whether introduction of runoff (which will be much greater after development) can be safely introduced into the subsurface. The predominance of soil types (e.g., clay or sandy) will also affect how well these potential techniques will work. Another consideration is whether the streets are addressed, including arterials.

What also must be considered is that many watersheds in urban areas (if not most) are beyond the impervious thresholds that have been observed for stream health (5 to 10 percent imperviousness). In these watersheds, the only improvement in runoff control over existing conditions would come from retro-fits of existing systems. LID techniques could help reduce the level of further degradation. However, it is the author's opinion that the tradeoff between installation of LID methods in new or retro-fit situations or any other on-site techniques should be considered against the costs of providing additional structural and habitat integrity to the stream through the use of instream measures such as log and rock weirs, etc. (Sovern and Washington, 1996). The key here is providing the wisest uses of limited resources to restore and protect stream health.

RECOMMENDED NEXT STEPS

The next steps in evaluation of Low Impact Development techniques should be to perform a series of evaluations of potential effectiveness of these systems via the use of continuous simulation modeling. One thing that will be key is to ensure that the canopy layer reduction effects can be accounted for in any modeling. This parameter is among the tougher ones to evaluate and adequately account for in simulations. The simulations should address the following:

- Conduct long-term model simulations of sites (entire developments) with applied low-impact techniques to compare pre- and post-development hydrology (i.e., with and without low impact techniques).
- Conduct the evaluation on a number of sites nationally, with varied climatic and watershed conditions.
- Compare hydrologic and energy responses (stream energy) of pre- vs. post-no control vs. post-LID control approaches.
- Assess potential instream energy reductions via an assessment of different stream conditions, including steep and low slope streams, soft and hard bottomed streams as well as stream bank stability conditions.

SUMMARY

ZERO AND LOW IMPACT DEVELOPMENT?

Low impact development tools are certainly ones that should be considered and implemented as appropriate, but with the recognition that the hydrology and resulting downstream energy will still likely change in many or most cases. Therefore, additional instream or other regional measures may still be necessary to protect habitat, water quality, and the physical integrity of streams and other receiving waters. This article has reviewed the potential problems with the analysis used to develop the design procedures. It also presents an example from Oregon data where more "accurate" example event simulation modeling based upon continuous simulation techniques was performed to compare "real" pre- and post-hydrographs.

It is the author's opinion that these techniques should be titled Reduced Impact Development (RID) or hydrologic source control (HSC) rather than Low Impact Development to reflect the fact that more comprehensive watershed management planning and implementation measures will likely be required in many cases to protect and maintain beneficial uses of streams. It is recommended that a national approach to performing an assessment of the benefits of low impact development techniques in reducing impacts be used to determine where these techniques are truly low impact and where they result in lower impact development.

The labeling of these techniques is problematic in the author's view. The danger is that with terminology such as this, it would be easy for decision makers (City Councils, etc.) to opt out of tougher (and in my view much needed) watershed-based approaches to solving habitat and water quality issues in urban streams. Part of the allure of this approach is that it places the burden on developers rather than on watershed managers and existing residents, as well as developers. In addition, as we will likely discover down the road that these techniques do not solve all the problems, we will again be as guilty as when we put forth wet ponds and other BMPs (best management practices – another unfortunate term) as "the solution."

The techniques themselves have much merit in that they can reduce impacts. Watershed planning that incorporates the appropriate level of technical analyses (e.g., continuous simulation) will be required to find the balance of appropriate on-site controls and public efforts, including instream measures as well as LID like techniques. Given the amount of money that is expended by both the public and private sectors in construction and maintenance of stormwater conveyance systems, this level of effort is warranted.

LITERATURE CITED

- Booth, D.B. and C.R. Jackson, 1997. Urbanization of Aquatic Systems-Degradation Thresholds, Stormwater Detention, and Limits of Mitigation. *Journal of American Water Resources Association* 33(5):1077-1090.
- Donigian, Jr., A. and W. Huber, 1991. Modeling of Nonpoint Source Water Quality in Urban and Non-Urban Areas. U.S. Environmental Protection Agency, Environmental Research Laboratory, EPA/600/3-91/039.
- Driscoll, E.D., P.E. Shelley, and E.W. Strecker, 1989. Pollutant Loadings and Impacts From Highway Stormwater Runoff. Analytical Investigation and Research Report, FHWA-RD-88-008, U.S. Dept. of Transportation, Vol. III.
- MacRae, C., 1996. Experience From Morphological Research on Canadian Streams: Is Control of the Two-Year Frequency Event the Best Basis for Stream Channel Protection? *In: Effects of Watershed Development and Management on Aquatic Ecosystems*, Larry Roesner (Editor). American Society of Civil Engineers, Snowbird, Utah, pp. 144-162.
- May, C.R., R. Horner, J. Karr, B. Mar, and E. Welsh. 1997. Effects of Urbanization on Small Streams In the Puget Sound Lowland Ecoregion. *Watershed Protection Techniques* 2(4): 483-494.
- McCuen, R.H., 1998. *Hydrologic Analysis and Design* (Second Edition). Prentice Hall, New York, New York.

Low Impact Development (LID): How Low Impact Is It? . . . cont'd.

- Pitt, R., R. Field, M. Lalor, and M. Brown, 1995. Urban Stormwater Toxic Pollutants: Assessment, Sources and Treatability. *Water Environment Research* 67(3):260-275, May/June (discussion and closure in Vol. 68(4):953-955, July/August, 1996).
- Prince George's County Department of Environmental Resources (PGC), 2000a. Low Impact Development Design Manual. Department of Environmental Resources, Prince George's County, Maryland.
- Prince George's County Department of Environmental Resources (PGC), 2000b. Low Impact Development Hydrological Analysis. Department of Environmental Resources, Prince Georges County, Maryland, 39 pp.
- Schueler, T., 1994. The Importance of Imperviousness. *Watershed Protection Techniques* 1(3):100-111.
- Sovern, D. and P. Washington, 1996. Effects of Urban Growth on Stream Habitat. *In: Effects of Watershed Development and Management on Aquatic Ecosystems*, Larry Roesner (Editor). American Society of Civil Engineers, Snowbird, Utah, pp. 163-177.
- Strecker, E. and K. Reininga, 2000. Integrated Urban Stormwater Master Planning. Proceedings of the National Conference on Tools for Urban Water Resource Management and Protection, EPA/625/R-00/001, pp. 132-146.
- U.S. Environmental Protection Agency, 1983. The Nationwide Urban Runoff Program, Report to Congress. U.S. EPA, Office of Water, Washington, D.C.

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CHANNEL PROTECTION

Ted Brown and Deb Caraco

INTRODUCTION

It is widely accepted that urbanization can alter the geometry and stability of stream channels. Both anecdotal evidence and field research support the notion that the larger and more frequent discharges that accompany watershed development cause downstream channels to enlarge, whether by widening, downcutting, or a combination of both (Figure 1). Channel enlargement severely degrades the quality of instream habitat structure and sharply increases the annual sediment yield from the watershed. These two factors, in turn, are often correlated with the sharp drop in aquatic diversity frequently observed in urban streams (U.S. EPA, 1997).

Despite the large body of research available, many questions about the channel enlargement process in urban and suburban streams remain to be answered. For example, how much development can occur before a stream response is observed? Exactly how much will a channel enlarge, and how many years will it take to do so? Finally, what stormwater management strategies can engineers use to mitigate the amount of future channel enlargement?

While it is not easy to predict the absolute degree of channel enlargement caused by watershed development, it is clear that enlargement will occur in the absence of stormwater controls (Figure 2). Therefore, the challenge facing the engineering community is to develop and adopt stormwater management criteria that will provide adequate channel protection to minimize the extent of future channel enlargement.

OPTIONS FOR CHANNEL PROTECTION CRITERIA

Historically, efforts to control channel erosion through stormwater management have been largely unsuccessful. The failure has, in part, been the result of an oversimplification of geomorphological processes. In the past, engineers reasoned that if natural channels are largely formed by "bankfull" storm events that occur on average once every one or two years (Leopold *et al.*, 1964), then stormwater ponds should detain the post-development peak discharge for the two-year storm to the predevelopment level (i.e., two-year storm control). There are two problems with this approach. First, while the magnitude of the peak discharge may not change from pre- to

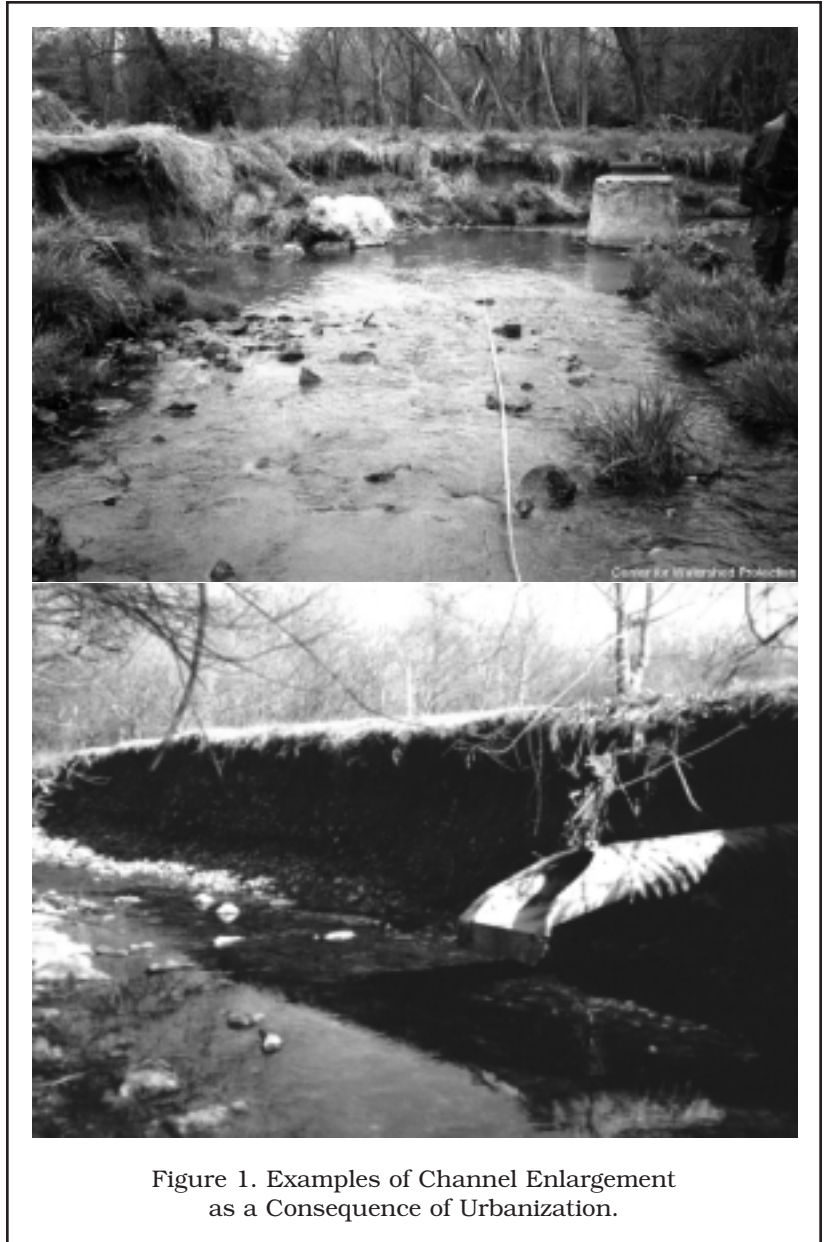


Figure 1. Examples of Channel Enlargement as a Consequence of Urbanization.

Channel enlargement in urbanizing streams can have significant economic and ecologic implications, from impacts to infrastructure

post-development with two-year control, the duration of erosive flows increases (Figure 3). This may actually exacerbate channel erosion since banks are exposed to a longer duration of erosive bankfull and subbankfull events (MacRae, 1993, 1996; McCuen and Moglen, 1988). Second, with increased development and associated increased runoff, the bankfull event often shifts to rainfall events smaller than the two-year return frequency. Consequently, the total

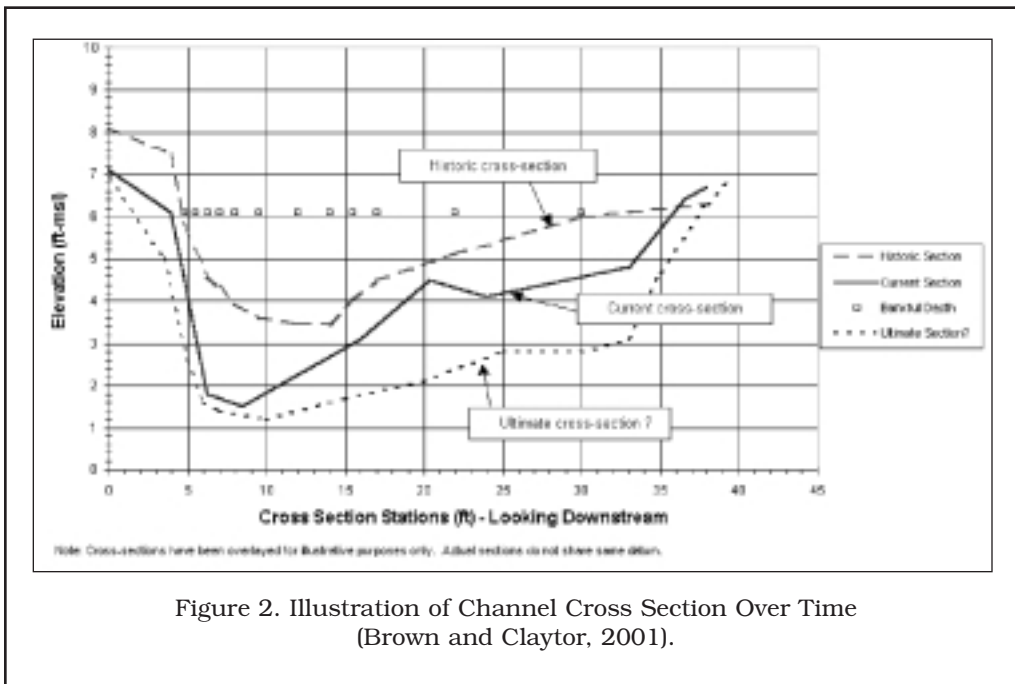


Figure 2. Illustration of Channel Cross Section Over Time (Brown and Claytor, 2001).

based on hydrologic and hydraulic modeling of streams. In addition, the limited field data that have been collected for some of the methodologies are favorable and support the use of these methodologies to protect channels from accelerated channel erosion. Generally speaking, the newer methodologies require more control (i.e., a larger required storage volume) than traditionally has been allocated to channel protection. One of the challenges of the more advanced channel protection approaches is to develop design methodologies that are relatively easy to apply. Three of the more promising approaches are described below briefly.

Two-Year Over-Control

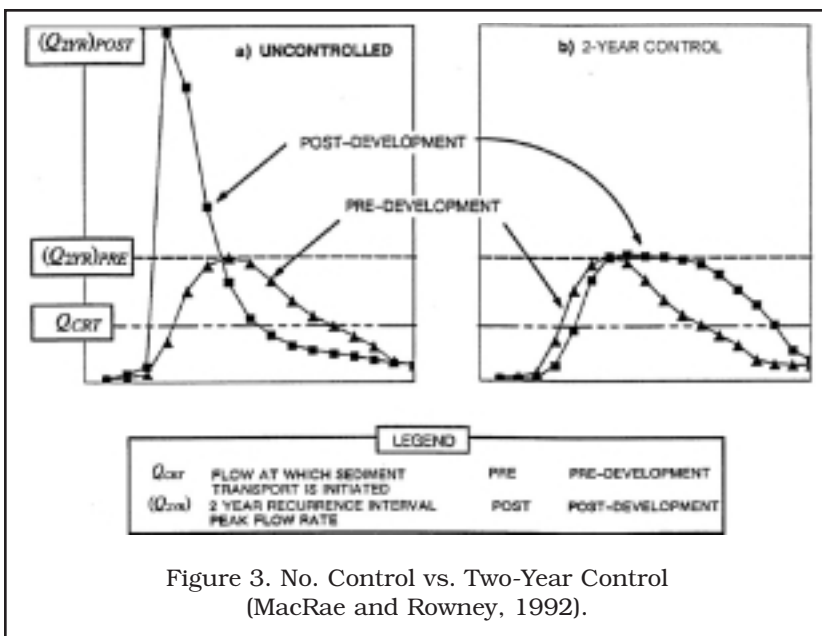


Figure 3. No. Control vs. Two-Year Control (MacRae and Rowney, 1992).

This method (initially proposed by McCuen, 1979) is based on controlling the post-development peak flow rate to 50 percent or less of the predevelopment level. Another common numerical approach is to control the two-year post-development discharge rate to the one-year predevelopment rate, using the 24-hour storm event. Subsequent analysis by MacRae (1993), however, indicates that this design criterion is still not fully capable of protecting the stream channel from erosion. Modeling suggests that, depending on the bed and bank material, the channel may either degrade (downcut where soft boundary material is present) or aggrade (build up where firm boundary material is present) with over control.

Distributed Runoff Control (DRC)

energy available to transport bed materials can actually increase when two-year peak discharge control is used.

The choice of two-year storm control neglects the increased frequency of bankfull and sub-bankfull flows in urban watersheds. For example, Leopold (1994) observed that the average number of bankfull flow events in an urbanizing watershed near Washington, D.C., increased from two to seven times per year between 1958 and 1987.

Over time, practitioners have developed a better understanding of the key parameters to provide adequate downstream channel protection. With the advent of more sophisticated computer software, much of the analysis of channel geomorphology and protection criteria has been

This method was developed by MacRae (1993) and is proposed for adoption in Ontario, Canada (Aquafor Beech, 1999) and on a limited basis in the State of Vermont (VTANR, 2001). The DRC method involves detailed field assessments and hydraulic and hydrologic modeling to determine the hydraulic stress and erosion potential of bank materials. The methodology is based on the premise that channel erosion is minimized if the erosion potential of the channel bank materials remains the same as in predevelopment conditions over the range of flows at which sediment transport of bed or bank material begins (i.e., mid-bankfull to bankfull flow events). While the method holds great promise and has been applied and tested recently in Ontario, it requires some detailed field work at each site. The DRC hydrograph attempts to mimic the predevelopment hydrograph for the area above Q_{cr} (flow at which sediment transport is initiated) shown in Figure 4.

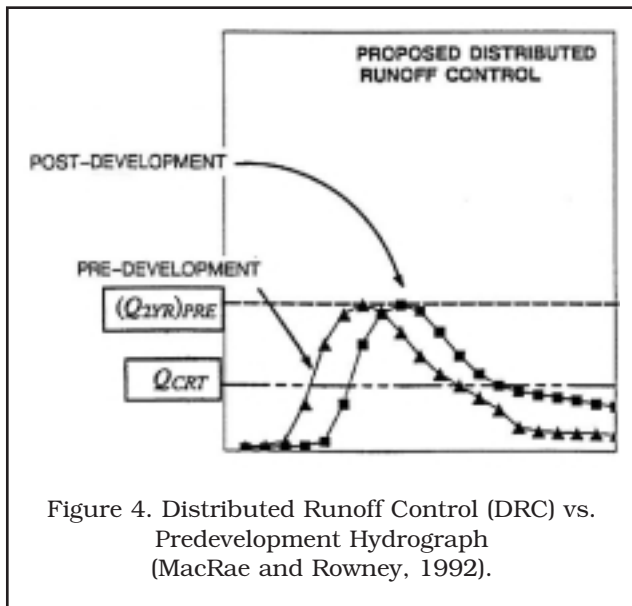


Figure 4. Distributed Runoff Control (DRC) vs. Predevelopment Hydrograph (MacRae and Rowney, 1992).

24-Hour Extended Detention of the One-Year Storm

This design method calls for holding the runoff volume generated by the one-year, 24-hour rainfall to be gradually released over a 24-hour period (MDE, 2000). The rainfall depth will vary depending on location and can be determined from intensity-duration-frequency [IDF] curves or other regional rainfall frequency analyses (e.g., NOAA Atlas 2 or TP 40). The premise of this approach is that runoff will be stored and released so gradually that critical erosive velocities will seldom be exceeded in downstream channels. Modeling based on a Maryland development site demonstrated that 24-hour extended detention approximated DRC well for storms less than the two-inch rainfall (Capuccitti and Page, 2000). The required storage volume needed for 24-hour detention of the one-year storm is not trivial; it is roughly comparable to the storage volume for ten-year peak discharge control.

It is of note that the 24-hour extended detention of the one-year storm event has been adopted in Maryland as the base channel protection criteria and is proposed for adoption in the states of New York, Vermont, and Georgia. The advantages of this approach over the DRC are that it is relatively easy to apply (in terms of computing the runoff volume and storage requirements), it is conducive to regional or statewide application, and it does not require extensive field measurements.

LIMITATIONS TO CHANNEL PROTECTION REQUIREMENT

From a programmatic and design standpoint, there are practical limitations on how broadly a channel protection criterion can be applied. Namely, there is a minimum site size at which the required orifice or weir sizes become too small to effectively operate and maintain. In addition, channel protection is generally not needed where sites discharge directly to a river (e.g., fourth order or greater), lake, reservoir, or estuary.

In addition, in streams where channel erosion is already occurring, it may be necessary to supplement the upstream channel protection storage with some form of in-stream channel protection controls. Representative practices range from robust bank protection measures such as imbricated riprap, boulder revetments, and root wads to grade control practices such as vortex weirs, cross veins, and step pools to “softer” bioengineering practices such as live fascines and coir fiber logs. A study by Brown (2000) indicates that most stream restoration practices work reasonably well in urban stream systems when sized, located, and installed correctly. The efficacy and longevity of these in-stream controls tends to improve when they are used in combination with upstream storage controls.

CONCLUSION

Channel enlargement in urbanizing streams can have significant economic and ecologic implications, from impacts to infrastructure such as culverts, sewers, bridges or pipelines to impacts on water quality and biology such as increased sediment loads, habitat loss and fish barrier creation. Consequently, there is a heightened need for stormwater engineers and managers to develop and assess stormwater design criteria that directly address the channel enlargement problem. While there are some promising approaches that are being applied in different regions of the country, more research is needed to determine how well these new criteria prevent or minimize the channel enlargement process.

LITERATURE CITED

Aquafor Beech Ltd., 1999. Final Stormwater Management Planning and Design Manual (Draft). Ontario Ministry of the Environment. Available at http://www.ene.gov.on.ca/envision/env_reg/er/documents/stormwatermanual/index.htm.

Brown, E. and R. Claytor, 2001. Watts Branch Watershed Assessment Study. Prepared for City of Rockville, Maryland. Center for Watershed Protection, Ellicott City, Maryland.

Brown, K., 2000. Urban Stream Restoration Practices: An Initial Assessment. Center for Watershed Protection, Ellicott City, Maryland.

Capuccitti, D and W. Page, 2000. Stream Response to Stormwater Management Best Management Practices in Maryland. Maryland Department of the Environment, Final Deliverable for a U.S. EPA 319 Grant.

Leopold, L.B., 1994. A View of a River. Harvard University Press, Cambridge, Massachusetts.

Leopold, L.B., M.G. Wolman, and J.P. Miller, 1964. Fluvial Processes in Geomorphology. W.H. Freeman and Company, San Francisco, California.

MacRae, C., 1993. An Alternate Design Approach for the Control of Instream Erosion Potential in Urbanizing Watersheds. In: Proceedings of the Sixth International Conference on Urban Storm Drainage, Marsalek and Torno (Editors). Niagara Falls, Ontario, pp. 1086-1091.

MacRae, C., 1996. Experience From Morphological Research on Canadian Streams: Is Control of the Two-Year Frequency Runoff Event the Best Basis for Stream Channel Protection? In: Effects of Watershed Development and Management on

Channel Protection . . . cont'd.

- Aquatic Systems, Larry Roesner (Editor). Engineering Foundation Conference Proceedings, Snowbird, Utah, August 4-9, 1996, pp. 144-160.
- MacRae C. and A. Rowney, 1992. The Role of Moderate Flow Events and Bank Structure in the Determination of Channel Response to Urbanization. 45th Annual Conference. Resolving Conflicts and Uncertainty in Water Management. Proceeding of the Canadian Water Resources Association, Kingston, Ontario.
- MDE (Maryland Department of the Environment), 2000. Maryland Stormwater Design Manual. Baltimore, Maryland, Vol. 1.
- McCuen, R., 1979. Downstream Effects of Stormwater Management Basins. Journal of the Hydraulics Division, American Society Civil Engineers 105(HY11).
- McCuen R. and G. Moglen, 1988. Multicriterion Stormwater Management Methods. Journal of Water Resources Planning and Management (114)4.
- U.S. EPA, 1997. Urbanization and Streams: Studies of Hydrologic Impacts. Office of Water, Washington, D.C., 841-R-97-009.
- VTANR (Vermont Agency of Natural Resources), 2001. Vermont Stormwater Management Manual – Public Review Draft. Waterbury, Vermont.

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LONG-TERM EXPERIMENTAL WATERSHEDS AND URBAN STORMWATER MANAGEMENT

James P. Heaney

INTRODUCTION

The purpose of this paper is to outline reasons why a network of long-term experimental watersheds is needed in order to address significant issues regarding urban wet-weather flows. Under the U.S. Environmental Protection Agency's (EPA's) stormwater permitting program, cities are facing unprecedented costs to comply with regulations to protect urban stormwater quality. Reliable information on the long-term effectiveness of controls, and their impacts on receiving waters, is essential if this large regulatory effort is to proceed in a cost-effective manner. Current funding for urban stormwater research comes from the U.S. EPA, the Water Environment Research Foundation (WERF) and a variety of state and local governmental agencies. It is essential to evaluate the urban water budget at time steps as short as a few minutes in order to understand the dynamics of changes in water quantity and quality that occur as stormwater and its associated contaminants move through urban areas. In the first part of this article, the key research issues are identified. Then, experimental watershed programs for evaluating agricultural forested, and natural systems are described with a view towards lessons learned from them and whether they might serve as models for an urban experimental watershed initiative. Lastly, specific recommendations for an experimental watershed research program in urban areas are described.

A fundamental research need is to establish and maintain, for at least a decade, a suite of experimental catchments in urban areas

ments of the nation's water quality also look at the receiving waters but are limited by the lack of a consistent data collection and analysis methodology from state to state (U.S. EPA, 2000). Its results do indicate that urban runoff is a significant contributor to water quality problems. The American Society of Civil Engineers (ASCE) BMP database provides cross-sectional data on BMP effectiveness, but it does not include process-level analyses for individual BMP sites that would permit more definitive conclusions as to its performance and variability (<http://www.bmpdatabase.org/>). Receiving water impacts are outside the scope of the ASCE's BMP project.

Only a few studies have jointly evaluated BMPs and receiving water impacts. Given the relatively large number of combinations of urban stormwater pollutant sources, e.g., highway runoff, shopping center runoff, BMPs, and ways to categorize receiving water impacts, many gaps remain in filling in the matrix of wet-weather loadings, BMPs and receiving water combinations. Previous research needs assessments have described the need to support long-term experimental urban catchment monitoring and modeling (Heaney, 1986; Heaney *et al.*, 1998, 1999). Unfortunately, this recommendation has not been implemented. This greatly restricts our ability to make significant progress in this critical area.

In sharp contrast, the Agricultural Research Service (ARS) has maintained numerous long-term experimental sites for evaluating agricultural practices. Similarly, the National Science Foundation (NSF) has supported ecosystem monitoring since 1980 through its long-term ecological research (LTER) program. Two of the LTER sites are in Baltimore and Phoenix. However, neither of these monitoring efforts addresses urban runoff and its control. The impacts of forestry at the watershed scale can be evaluated using the long-term data from Hubbard Brook, an experimental watershed. These programs are described below with a view towards using them as a framework for a long-term urban wet-weather research effort centered around experimental catchments.

RESEARCH NEEDS IN URBAN STORMWATER

Heaney *et al.* (1998, 1999) presented a list of research needs in urban wet-weather flows based on a national assessment under sponsorship of WERF. The results of the assessment were organized into ten categories. An expenditure of \$20-40 million per year is estimated to be needed to address the high-priority research needs. With the notable exception of the ongoing \$30 million Best Management Practice (BMP) evaluation program of the California Department of Transportation (CALTRANS), no major research efforts have been conducted on the subject of BMP effectiveness and receiving water impacts since EPA's Nationwide Urban Runoff Program (NURP) of over 20 years ago. The U.S. Geological Survey's National Water Quality Assessment (NAWQA) program results offer strong evidence that urban streams are receiving significant stress from urban runoff both in the water column and the sediments (USGS, 2001). However, NAWQA has not addressed landside source characterization other than rough estimates of land use and water quality relationships. The EPA's 305(b) biennial assess-

LONG-TERM EXPERIMENTAL WATERSHEDS

ARS Program

The ARS' National Research Program in Water Quality and Management is partitioned into three components (<http://www.nps.ars.usda.gov/programs>): (1) Agricultural Watershed Management, (2) Irrigation and Drainage, and (3) Water Quality Protection and Management Systems.

Long-Term Experimental Watersheds and Urban Stormwater Management . . . cont'd.

While the Water Quality Protection and Management Systems component is most directly relevant to the wet-weather flow problem, the other areas also are germane because they permit a more holistic evaluation of the problem. For example, the most cost-effective solution to non-point pollution may be to use less fertilizer. The core of this national program has been the long-term experimental watersheds in several diverse regions in the United States including outdoor laboratories. While the focus of the research being conducted on these experimental watersheds has changed over time, the fundamental data can be used for many purposes by a wide variety of researchers. General watershed research is being conducted at 19 ARS sites across the United States under the following seven categories:

1. Climate and Weather Uncertainties, Risks, and Extremes
2. Watershed Characteristics, Processes, and Responses
3. Watershed Hydrology, Erosion, and Sediment/Contaminant Movement
4. Riparian Streams and Wetlands Ecosystems
5. Water Scarcity and Drought Mitigation
6. Watershed Management and Flood Control
7. Watershed Management and Decision Making

Research on irrigation and drainage is being conducted at 20 ARS sites across the United States under the following eight categories:

1. Economical Irrigation Crop Production
2. Precision Irrigated Agriculture
3. Water Conservation Management
4. Irrigation and Drainage in Humid Areas
5. Waste Water Reuse
6. Erosion on Irrigated Land
7. Salinity and Trace Element Management
8. Drainage Management

Lastly, the research being conducted under the Water Quality Protection and Management Systems program is being performed at 34 sites nationally across five pollutant and three methodological categories as listed below:

Pollutant Categories

1. Nutrients
2. Pesticides and Other Synthetic Chemicals
3. Pathogens
4. Erosion and Sedimentation
5. Trace Elements

Methodological Categories

1. Model Testing, Evaluation, and Improvement
2. Integrated Field, Farm, and Watershed Management Systems
3. Environmental and Economic Risk Evaluation

With regard to spatial scale, ARS research takes place at laboratory, field, farm, and watershed scales. Interest in more macro issues such as global climate change is stimulating research at these larger spatial scales.

NSF LTER PROGRAM

The LTER Network is an NSF-sponsored collaborative effort involving more than 1,100 scientists and students investigating ecological processes over long temporal and spatial scales (<http://lternet.edu/>). This program began in 1980 and has expanded over the years to its present level of 24 sites that represent diverse ecosystems and research emphases. The research efforts at these sites focus on ecological processes and do not include evaluation of engineered control systems such as structural BMPs.

HUBBARD BROOK

The Hubbard Brook Experimental Forest (HBER) is a 3,169-hectare reserve located in the White Mountain National Forest in New Hampshire (<http://www.hbrook.sr.unh.edu/>). It was established in 1955 by the U.S. Department of Agriculture (USDA) Forest Service as a major center for hydrologic research in New England. The Hubbard Brook Ecological Study (HBEF) was initiated in 1963 to study linkages between hydrologic and nutrient flux and recycling in response to natural and human disturbances such as forest cutting, land use changes, and climatic factors. In 1988, HBEF was designated as an LTER site. Cooperative efforts among educational and private institutions, government agencies, foundations, and corporations have resulted in one of the most extensive and longest continuous data bases on the hydrology, biology, geology, and chemistry of natural systems. Ten small watersheds within Hubbard Brook are under study. For example, one small watershed was clear-cut in 1970. The database allowed researchers to document how peak runoff rates increased and how the area recovered over the next six years.

SUGGESTED URBAN ANALOGUE TO THE EXISTING EXPERIMENTAL WATERSHED PROGRAMS

The next section of this paper provides a preliminary description of some aspects of this recommended experimental watershed program.

Spatial Scales

Spatial scale is a critical component in designing a research program. Smaller spatial scales permit direct measurement of more components of the system. Also, current interest in source control of wet-weather flows as illustrated by the low impact development initiative, call for monitoring at individual property, and small neighborhood scales (Wright and Heaney, 2001). Smaller spatial scales are also appropriate for evaluating individual BMPs that receive runoff from homogeneous land uses of

the scale of one to ten hectares. Hubbard Brook is a nice example of using multiple spatial scales within a single larger watershed with a range in sizes from 12.1 ha to 3,169 ha.

Temporal Scales

The only long-term precipitation data available across the United States is 15-minute data from the early 1970s and hourly data from 1948. Precipitation data should be collected at frequencies such that the travel time through the study area is at least five times the frequency of the key input data such as precipitation. This suggests collecting precipitation data at one to 15-minute intervals for these smaller study sites.

Climatic Regions

The climatic regions of the United States can be divided into as few as three categories, (i.e. eastern, midwest, and west). However, much finer categories would be better. The ARS water quality research is being conducted at 34 sites nationally. The NURP used 28 sites.

Land Uses

It is more instructive to monitor specific functional land uses such as streets, roofs, parking lots, and lawns as opposed to the more popular descriptors such as residential, commercial, and industrial. The other major partitioning of runoff is directly connected versus non-directly connected impervious areas. Directly connected impervious areas are the most serious water quality threat since they generate runoff from nearly all storms. Pervious areas contribute runoff much less frequently. With smaller storms contributing 70-80 percent of the annual runoff volume, directly connected impervious areas are the more critical areas to evaluate.

Pollutants

The selected suite of pollutants should correspond to the suspected sources in the study area of interest. Siltation, pathogens, nutrients, oxygen-demanding substances, metals, and pesticides are the leading causes of impairment for rivers and streams (U.S. EPA, 2000). Sufficient individual pollutant loading data exist to make a good estimate of its expected characteristics for a specific land use such as rooftops.

Effectiveness of BMPs

The CALTRANS BMP evaluations provide the most up-to-date basis for selecting the mix of BMPs to be evaluated. This large effort provides an excellent starting point for a more refined evaluation. The results of the ASCE BMP database project also provide useful insights into the areas where additional research will be most productive.

Receiving Waters

This long-term experimental catchment evaluation should focus on the following smaller scale receiving environments that will permit the essential data to be gathered in a cost-effective manner.

- Streams – First and second order.
- Lakes and Ponds – Wet detention basins and small ponds.
- Groundwater – Sensitive aquifers with high water tables that would tend to interact with the nearby streams.

Funding

Required funding for this effort would be in the range of \$10-20 million per year. Probably the biggest challenge is to secure a long-term commitment to continue this activity. The ideal model is similar to the ARS network or Hubbard Brook wherein the basic and applied science aspects of the experimental sites are studied cooperatively.

SUMMARY AND CONCLUSIONS

A fundamental research need is to establish and maintain, for at least a decade, a suite of experimental catchments in urban areas. This program could be modeled after the ARS, Hubbard Brook, and LTER experimental watershed programs. Required funding levels of \$10-20 million per year are needed to support this activity. Long-term research is essential to answer pressing questions regarding urban wet-weather flows. In order to evaluate the impact of a new development, it is necessary to monitor and model the study area before, during, and after construction. Without at least a decade of measurements, it is difficult, if not impossible to make definitive recommendations regarding the sustainability of proposed innovative design practices such as low-impact development. The behavior of individual BMPs can be evaluated but the overall impact of a system of BMPs, and land use practices, can only be evaluated by monitoring and modeling the entire system on a longer-term basis. Nowhere are the stakes higher than in urban areas where the estimated control costs for urban runoff are in the hundreds of billions of dollars. The ASCE Urban Water Resources Research Council is pursuing this idea. If you are interested in participating, please contact the author.

Literature Cited

- Heaney, J.P., 1986. Research Needs in Urban Storm-Water Pollution. *Journal of Water Resources Planning and Management*, Vol. 112, No. WR1.
- Heaney, J.P., L. Wright, and D. Sample, 1998. Research Needs in Urban Wet Weather Flows. Water Environment Research Foundation Project Report 96-IRM-1, WERF, Alexandria, Virginia.
- Heaney, J.P., L. Wright, and D. Sample, 1999. Research Needs in Urban Wet-Weather Flows. *Water Environment Research* 7(2):241-250.

Long-Term Experimental . . . cont'd.

U.S. Environmental Protection Agency (EPA), 2000. The Quality of Our Nation's Water. EPA 841-S-00-001, Washington, D.C.

U.S. Geological Survey (USGS), 2001. The National Water Quality Assessment Program. USGS, Reston, Virginia.

Wright, L. and J.P. Heaney, 2001. Design of Distributed Stormwater Controls and Re-use Systems. *In: Stormwater Collection Systems Design Handbook*, L.W. Mays (Editor). Chapter 11, McGraw-Hill, New York, New York.

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THROUGH THE PIPE: DOWN THE CREEK!

Edwin E. Herricks



The public is being better educated about the infrastructure that makes our lives better, particularly the connections that exist between common features of built environments and stormwater, such as storm drains. The campaigns that paint “drains to stream” are part of the federally directed effort to better manage stormwater through both nonstructural approaches, such as education/awareness campaigns, and the construction and operation of facilities, such as detention basins (structural approaches). The education/awareness campaigns are directed at controlling the source of materials that impact streams and can be readily evaluated by assessing the change in pollutant concentration in stormwater from areas where educational campaigns have been implemented. The evaluation of the effectiveness of structural controls is more complicated. Structural control assessment, at a minimum, must consider design criteria and maintenance. This means that a performance assessment for structural controls can be conducted only for those parameters designed to be removed, and assessments will only be valid if the facility has been effectively maintained. A further complication for structural control effectiveness assessments is the need to expand the analysis from what is going through the pipe, to add what is happening down the stream (environmental impact)!

The impact of stormwater runoff can be related to physical, chemical, or biological/ecological alterations of the environment

An impact assessment begins with the analysis of stormwater flows from the initiation of runoff on a street surface, through the treatment processes in a grassed waterway, detention pond, or vortex separator, to measures of ecosystem integrity in receiving streams. In this analysis we must understand the sources, transport mechanisms, and mechanisms of removal for any pollutant. Impact is then assessed by evaluating how that pollutant harms organisms in the receiving system. Unfortunately, just as assessing control measures is complicated, assessment of the impact of stormwater on a stream or river receiving system is also complicated. The major complications arise from two factors. The first is that seldom does just one parameter produce an impact. The second is that seldom does the receiving system have only the stormwater control facility as a single cause for any observed impact. Impact is typically caused by the combination of physical alteration of habitat, chemical contamination, and the introduction of new organisms that challenge how ecosystems work. Further, stormwater runoff is seldom completely controlled by one facility; the observed impact in receiving systems can be produced by nonpoint runoff and changes in land use, which may add substantially to the effects of the control facility’s discharges, creating receiving stream impact independent of the facility’s effectiveness in pollutant control. The “big picture” then considers all watershed influences in relation to the control facility’s effluent.

To better understand both the causes of, and the solutions to, impacts produced by stormwater, it may be valuable to review common physical/hydraulic, chemical, and even biological causes for receiving system impact. The most common physical/hydraulic impact agent is associated with flow volume, flow duration and flow frequency. Floods and flooding are not unnatural events; in fact much is known about how stream channels adjust to normal flooding. Changes in the watershed alter rainfall to runoff relationships, changing volumes of flows and the duration and frequency of their occurrence. These changes initiate changes in channel form, channel substrate, and channel stability. The end result is the disruption of physical habitat, making it very difficult for critters to move to, and settle in, frequently changing habitats. If the only impact was produced by changing flow, the use of detention would provide a single practice to minimize impact. Unfortunately, altered habitat is only one of many agents that are implicated in stormwater impact analysis.

A second impact agent is the presence of polluting chemicals in stormwater. The impact of chemicals on receiving systems is most easily assessed in terms of the

Through the Pipe: Down the Creek! . . . cont'd.

toxic response of receiving system organisms. Toxic responses can range from death, as the most severe effect, to long-term disadvantage produced by health impairment and delayed damage caused by slowly developing conditions, such as cancer. The toxicity produced by stormwater is related to both the presence of contaminants and the ways those contaminants interact with organisms in the receiving system. What we do know is that toxicity is caused by the concentration of a contaminant, the time an organism is exposed to this contaminant, and the number of times that exposure is repeated. This is very important in stormwater impact assessments because the major focus of toxicity testing in the past has been directed to the effects of continuous, not intermittent, exposure to contaminants. Stormwater may have high but variable concentrations of contaminants that are present in the receiving system for only a short time. Further, the characteristics of the exposure regime of various contaminants may vary based on sources, transport, and any modification of contaminant characteristics in pipes or treatment practices. The result is a complicated cocktail of contaminants that is discharged to receiving systems with stormwater. Organisms will respond to all contaminants in this cocktail, but our understanding of toxic response to combinations of contaminants is limited because most of our attention has been directed to single chemicals, not complex mixtures. Added to this complicated picture is the fact that receiving system impact is assessed not only on the death or disadvantage produced in one species responding to one contaminant but also on the response of all of the species in the receiving ecosystem to the presence of multiple contaminants and changing physical conditions. In summary, although we can relate chemical presence to effect through toxicity, the presence of multiple contaminants, multiple organisms, and changing environmental conditions (e.g. physical habitat alteration) all conspire to complicate how we assess chemical impacts.

We have discussed physical and chemical causes of impacts. Although often subtle, changing biological conditions are known to alter ecosystems, producing impacts in receiving systems. To illustrate this potential for biological origins of impact, consider the fact that food, in the form of organisms, is cycled through the ecosystem. Normally a balance is maintained between production and consumption of food resources. When this balance is changed, the population of one or more species can explode. The high numbers of one, or few, species can overwhelm normal control mechanisms in the ecosystem and degrade the whole ecosystem. The most common response of this type can be found when a detention pond, which maintains large populations of algae, discharges into a stream. Suddenly the stream has more food. The stream biota will respond to increased food by increasing the numbers of organisms that eat algae, but the balance produced by this response may be tenuous. There are often critical lag periods between increased food availability and increased consumer populations. Further, a change in flow, or the presence of a contaminant, may limit the numbers of consumers so that normal ecosystem function cannot be maintained. The final result can

be similar to the discharge of untreated sewage where dissolved oxygen is depleted, further changing the capacity of organisms to operate in the stream and creating zones of reduced water quality downstream. The biological causes of stormwater impact are seldom as direct and as evident as the above example. It is more common to observe subtle changes in the receiving system ecosystem where changes in species composition alter the capacity of the ecosystem to function, thus altering the ecosystem's condition or integrity. Mechanisms of biological impact can range from contaminant addition that eliminates a species, through the alteration of ecosystem function by altering species survival in changing habitats, to the subtle effects produced by changing food resources.

In summary, the impact of stormwater runoff can be related to physical, chemical, or biological/ecological alterations of the environment. Considering the complicated mechanisms for physical, chemical, or biological impact agents operating alone (much less the complicated way that physical alteration, chemical contamination, and biological change act in combination), impact assessment is a complicated task. Answering the question "How can management practices minimize impact?" must involve analysis of the management practice, analysis of the receiving system, and careful integration to sort out

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control facility influences in complex environmental settings.

The assessment of impact reduction associated with the installation and operation of management practices is clearly a significant undertaking. First, we need to know a lot about the management practice and actual facility design. We need to understand that design criteria limit our assessment capabilities because those criteria identify what conditions or contaminants will be controlled by the practice. Next, the facility must be placed in an environmental setting where it is possible to assess how the facility affects physical/hydraulic conditions in the receiving system and contaminant exposure, considering how concentration, duration, and frequency are modified. Finally, we must determine how the facility is directly and indirectly related to effects on the ecosystem of the receiving waters. After considering physical, chemical, and biological/ecological impacts singly, it is then necessary to consider the facility's effect on any receiving system impacts where physical, chemical, and biological factors are considered in combination or all together. Finally, this facility-focused analysis must be expanded to consider the range of watershed influences that affect areas around, and downstream from the facility. The approach to this expanded analysis, which has been adopted based on experience with continuous discharges to the environment, is to assess the integrity of the receiving system upstream and downstream from the facility. The integrity assessment commonly uses multiple measures of ecosystem structure and/or function and establishes a quality rating based on comparison with an identified reference condition or stream segment. This integrity assessment/reference approach has the advantage of providing an excellent assessment of the ecosystem's state and condition, considering all of the factors together that produce an observed impact. Unfortunately, this method may or may not identify specific physical, chemical, or biological factors, acting alone or in combination, that produce an identified impact. The absence of specificity in the identification of the cause of impact makes it difficult, if not possible, to identify whether the facility is, or is not, creating impact, contributing to an identified impact, or having no impact at all! Another complication introduced by the integrity assessment/reference approach is that reference conditions are often selected as the goal of management programs or the basis for evaluating facility effectiveness. In urban and developing watersheds, establishing reference conditions as a goal for management may be unrealistic because landscape change may preclude reestablishment of truly natural conditions.

In conclusion, determining the value to ecosystem protection of stormwater management practices is an incomplete science limited by the complexity of analysis requirements. We are beginning to understand how physical/hydraulic, chemical/contaminant, and biological/ecological change can produce impacts in receiving systems. We are beginning to understand how facilities work and, based on an understanding of fundamental physical, chemical, and biological processes, how to design

specific treatment capabilities in best management practices. We have also developed excellent tools to assess the condition of receiving systems. As yet, we have done little to connect the treatment capability of management practices with a validated change in impact. We are simply limited in our capabilities to follow impact through the pipe and down the creek!

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Professor Edwin Herricks has direct and relevant experience in a number of areas related to environmental assessment and management. He has over 30 years experience with impact analysis and biological monitoring. His research analyzes and interprets the effects of contaminants and other environmental alterations on communities of organisms, including aquatic and terrestrial ecosystems. A focus is improvement of engineering design and environmental decision making. Specific areas include; (1) analysis of habitat factors that affect the ecological interactions; (2) development of the connections between engineering practice and environmental consequences; (3) the effects of wet-weather conditions on receiving systems; and (4) development of biological monitoring procedures for environmental decision making.



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RETROFIT OF AN EXTENDED DETENTION BASIN IN DENVER, COLORADO

Matthew J. Gavin and John T. Doerfer

INTRODUCTION

Stormwater quality facilities do not always function as hoped for by the designers. This was the case at Grant Ranch in Denver, Colorado, where an extended detention basin (EDB) designed to have a dry bottom instead remained inundated with stormwater for much longer periods of time than intended. This created nuisance problems that included permanent boggy conditions, inability to provide adequate maintenance, and mosquito breeding. The Urban Drainage and Flood Control District (UDFCD) was looking for a site to test its new EDB design standards and approached the Bowles Metropolitan District (Metro District) with an offer to retrofit that site with some of the new features being recommended for EDBs. In exchange for the rights to monitor the performance of the EDB, the UDFCD agreed to regrade and revegetate the basin's bottom, retrofit a micro-pool, and provide a new type of outlet.

BACKGROUND

The subject EDB is part of an overall stormwater treatment system consisting of three EDBs located in upland portions of the Grant Ranch residential development and one constructed wetland basin at the downstream extent of the watershed that treats the effluent from the EDBs. The system was designed to improve runoff water quality from the Grant Ranch residential development to comply with strict numeric limits established in a 1997 Agreement between the Metro District and the Bow Mar Homeowners Association. The Agreement was negotiated as part of development approval to protect Bow Mar's water supply and recreational reservoir.

To evaluate system performance, the Agreement required the execution of an extensive monitoring program, which began in the spring of 2000. Although analyses conducted in 2000 indicated that the system was functioning adequately, all parties agreed that the proposed retrofit would improve the system's ability to meet the performance goals established in the Agreement.

In 1992, the UDFCD published a criteria manual for stormwater best management practices (BMPs) (UDFCD, 1992). This manual was updated in 1999 based on the experience of implementing BMPs in the 1992 manual by local governments and private consultants. It was found that sediment from upstream sources (from construction activities, from landscaping activities by homeowners, or contained in urban runoff itself) would clog the gravel-pack screen at the outlets. Runoff would then pond and

lead to development of boggy conditions and growth of wetland species. Maintenance personnel, unfamiliar with the intended design, would respond by removing the gravel pack and enlarging outlet openings, thereby negating the hydraulic design of the EDB.

The UDFCD agreed to retrofit one EDB at Grant Ranch to conform with the new criteria published in the Urban Storm Drainage Criteria Manual (USDCM), Volume 3 (UDFCD, 1999), from which design and sizing spreadsheets and AutoCAD details can be downloaded at the UDFCD's Web page at www.udfcd.org. To evaluate the performance of the new EDB design, the UDFCD proposed to add an automated sampling station at the outlet of the basin. An automated sampling station at the inlet was already in place to satisfy monitoring requirements set forth in the 1997 Agreement. Water quality data from samples collected at these stations would allow the performance of the EDB to be assessed separately from the rest of the system.

On this basis, the UDFCD agreed to cover costs to retrofit the pond and install the new monitoring station. In addition, the UDFCD agreed to cover substantial costs for water quality analyses, which the Metro District was already obligated to perform according to the 1997 Agreement. In return, the Metro District agreed to share data and absorb the expense of operating the new sampling station. The retrofit of the facility was carried out in the spring of 2001.

*Stormwater
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ORIGINAL DESIGN

The stormwater treatment system at the Grant Ranch development was designed and built in 1997-1998 in accordance with criteria established in the 1992 version of the USDCM, Volume 3. The three EDBs were sized based on the watershed area and the water quality capture volume (WQCV), which is a function of the percent impervious area within a watershed and corresponds to the 80th percentile runoff event. The EDBs are designed to detain the WQCV for 40 hours. Low-flow channels were installed to convey base flows to the outlet structure. The outlet structures featured perforated standpipes with gravel jackets serving as trash racks. Above the standpipes, the outlet structures include orifices or weirs to convey larger storms (in this case the 10- and 100-year design storms) or runoff that occurs while the system is surcharged from a storm that occurred during the preceding 40-hour period.

After sedimentation in the EDBs, runoff is conveyed to the downstream wetland basin. The wetland basin was designed to detain the WQCV for an additional 24 hours,

Retrofit of an Extended Detention Basin in Denver, Colorado . . . cont'd.

bringing the total system detention time to 64 hours. The pollutant load is reduced in the wetland via filtration, infiltration, sedimentation, and nutrient uptake.

MODIFICATIONS TO THE EDB

Several modifications to the basin were required to bring the facility into conformance with the design criteria specified in the revised USDCM. These modifications included the installation of new outlet works, a micro-pool, and a sediment forebay as well as revegetation of the basin's bottom. Additional modifications carried out by the UDFCD included installing a groundwater collection system and regrading the pond's bottom.

OUTLET WORKS

Modification of the outlet works was the most significant change in terms of facility function. Prior to implementation of the updated design, the outlet consisted of a perforated standpipe with a gravel jacket serving as a trash rack. This design functioned adequately at first; however, as sediment accumulated, clogging of the gravel jacket interfered with the hydraulic function of the orifices on the standpipe. As a result, the pond's bottom was inundated with stormwater for longer periods than anticipated, ultimately killing the sod, as shown in Figure 1.



Figure 1. Before Modification Long-Term Inundation Killed the Sod Planted in the Bottom of the EDB and Created Boggy Conditions. [Photograph used with permission of Wright Water Engineers, Inc. (WWE).]

To address this problem, a new trash rack and orifice plate were installed (Figure 2). A flat aluminum plate (with orifices hydraulically equivalent to the previous design) mounted vertically to the inner face of the concrete outlet structure replaced the perforated standpipe. Stainless steel mesh mounted to the outside of the concrete outlet structure now serves as a trash rack.



Figure 2. Close-Up of the Well-Screen Type Trash Rack. An orifice plate (not shown) is mounted on the inside of the concrete wall behind the trash rack. Note the high-water mark and the fact that grass clippings did not plug the trash rack. [Photograph used with permission of Urban Drainage and Flood Control District (UDFCD).]

MICRO-POOL

A small permanent pool (micro-pool) was installed immediately upstream of the outlet works (Figure 3). Installation of a micro-pool helped to eliminate outlet clogging, which allows for proper hydraulic function of the outlet. Placing the small outlet orifices above standing water, as opposed to in the basin's bottom, minimized susceptibility to clogging with debris and sediment. The micro-pool surcharges rapidly, so that debris that may have accumulated in the trash rack at the permanent-pool level rises and may be dislodged by a pumping action. The new design criteria calls for a micro-pool volume of 5 to 15 percent of the WQCV, with a minimum depth of 2.5 feet. The pool is below the active storage of the facility, so no flood volume is compromised. At the request of the Metro District, a submerged bench was constructed around the edge of the micro-pool and planted with wetland species. The addition of a wetland bench, although not necessary for micro-pool function, might be considered to further enhance safety, visual appearance, wildlife habitat, and water quality.



Figure 3. Micro-Pool and Outlet Structure Following Modification. Note 10-year rectangular overflow orifice above the water quality outlet (see Figure 2), and 100-year overflow with sloping rack on top of structure. Submerged bench and wetland planting aspect in the foreground. [Photograph used with permission of Urban Drainage and Flood Control District (UDFCD).]

SEDIMENTATION FOREBAY

Just downstream of the inlet to the EDB, a sedimentation forebay has been installed to remove larger particles. The criterion in the updated USDCM calls for a forebay volume of 5 to 10 percent of the WQCV. A rock berm separates the forebay from the main EDB. A vegetated berm with a buried riprap overflow spillway could also be considered for new construction. Base flows are conveyed to the low-flow channel via an eight-inch polyvinyl chloride (PVC) pipe, which penetrates the rock berm. The outlet was sized to provide approximately five minutes of detention time of the forebay's volume. The PVC outlet was offset from the main flow path to prevent short-circuiting during storm events. The forebay's bottom was constructed of concrete to facilitate easy removal of sediment. The sedimentation forebay can be seen in the foreground of Figure 4.

VEGETATION

Vegetation in the basin's bottom stabilizes the soil and improves water quality by filtering runoff. The grass seed mixture used at this facility consists of a blend of native and introduced species adapted to periodic flooding in a semiarid climate and includes species such as perennial ryegrass and hard fescue. Selection of an appropriate seed mixture for an EDB should be based on anticipated hydrologic conditions and consistency with the local setting.



Figure 4. After Modifications Healthy Grass Provides a More Attractive and Maintainable Bottom. Note sedimentation forebay and inlet in the foreground. [Photograph used with permission of Wright Water Engineers, Inc. (WWE).]

REGRADING BOTTOM SLOPE

To eliminate standing pools of water, the bottom of the EDB was regraded to maintain a positive slope toward the outlet. A minimum slope of 2 percent was provided. This modification improved hydrologic conditions for maintaining grass cover in the bottom of the EDB by eliminating saturated areas that persisted prior to the change. The 3-to-1 side slopes did not require regrading and are conducive to mowing. Figure 4 shows a dramatic improvement in vegetation resulting from regrading and removing the standing water from the basin's bottom as compared to Figure 1 taken before modification.

GROUND WATER COLLECTION SYSTEM

The UDFCD installed a seepage drain in the basin's bottom to drain ground water that was observed collecting in a specific portion of the pond. This modification was not intended to improve water quality; rather it was implemented to assure that the chemical analyses performed at the outlet were not influenced by the presence of ground water.

RESULTS OF RETROFIT

The upgraded facility had been operating for approximately three months at the time this article was written. Based on one very wet runoff season, operational problems associated with the previous design appear to have been entirely eliminated by the modifications. System performance will be tracked over the next several years to determine the effect on water quality. The modifications

Retrofit of an Extended Detention Basin in Denver, Colorado . . . cont'd.

at Grant Ranch not only improved facility function but also promise to add valuable data to the evolving field of stormwater management.

REFERENCES CITED

- UDFCD, 1992. Urban Storm Drainage Criteria Manual – Volume 3. Urban Drainage and Flood Control District, Denver, Colorado.
- UDFCD, 1999. Urban Storm Drainage Criteria Manual – Volume 3. Urban Drainage and Flood Control District, Denver, Colorado.

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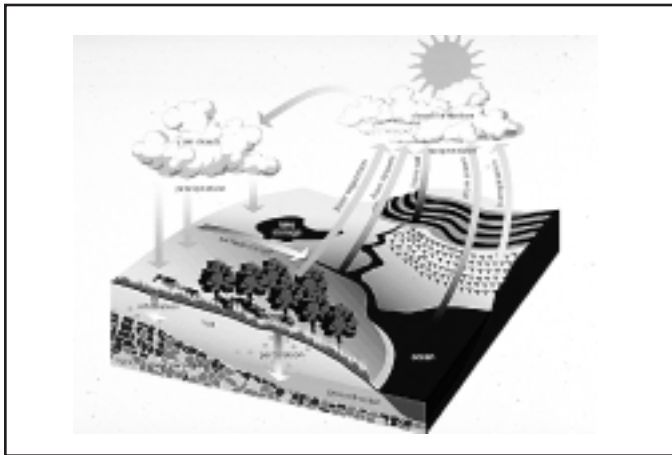
BMPs AND RECEIVING WATERS: WHAT IS THE CONNECTION?

Michael L. Clar

The focus of this issue is the relationship between land development impacts on receiving waters and the ability of best management practices (BMPs) to mitigate these impacts. The term receiving water was initially developed for use in conjunction with discharges of treated effluent from wastewater treatment plants and is often associated with the concept of the dilution capacity of a receiving water body, which has led to the following definition of receiving water: a body of surface or subsurface water which provides a dilution capacity for directly discharged pollutants (U.S. EPA, 2001). Examples of receiving waters generally used include streams, rivers, lakes, ponds, estuaries or the sea. Is this concept of receiving water appropriate for use with respect to land development impacts and the use of BMPs?

This article argues that is not a sufficient, or adequate definition of receiving waters. My position is based on the nature of impacts associated with land use changes and the scale of these impacts.

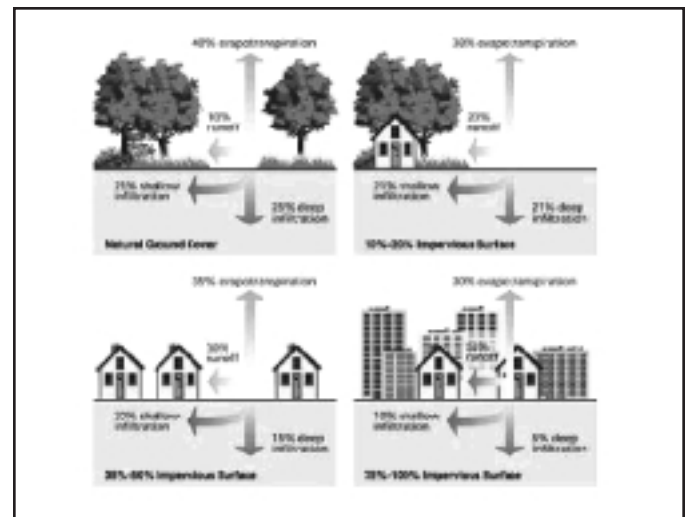
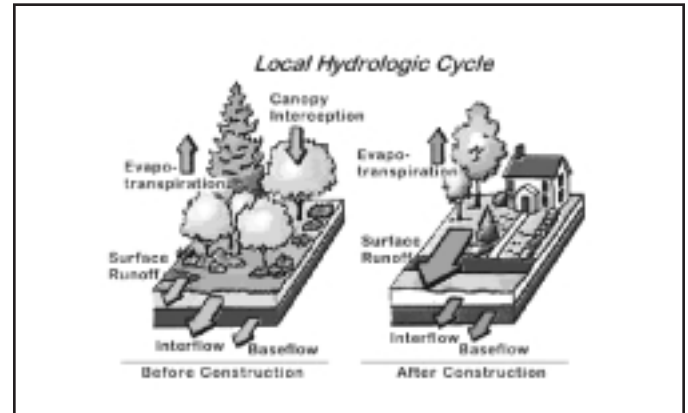
The hydrologic cycle is a good place to begin a review of the impacts associated with land use changes. The cycle illustrates the major components of the hydrologic budget which includes: precipitation, interception, transpiration and evaporation, infiltration, soil moisture and ground water, surface storage and runoff in streams, rivers, estuaries, lakes and oceans.



Land use changes can dramatically affect the components of the hydrologic cycle at the lot scale as well as the community scale as shown below (U.S. EPA, 2000).

These examples serve to illustrate the fact that the impacts resulting from land use changes go beyond the concept of water quality impairment and include quantitative impacts such as reducing ground water recharge and lowering local water tables. Another impact area is the corresponding increases in the frequency, duration and magnitude of surface discharges, including both volume

and peak flows. Clearly the definition of receiving waters needs to be expanded to include lot level impacts (scale) and ground water recharge issues (impact type).



... an appropriate definition of receiving waters must be extended to the very headwaters of the watershed to the point where rainfall first enters the soil surface

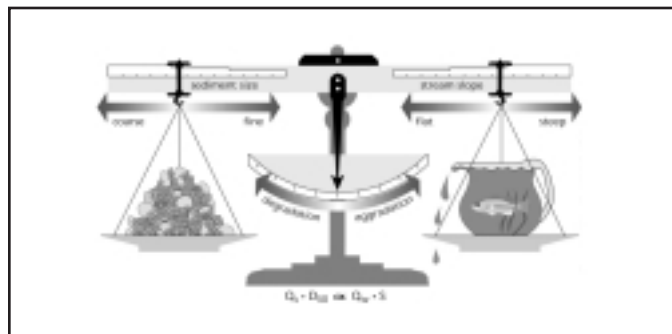
Another important consideration in arriving at an appropriate definition of receiving waters is the concept of watershed scale and stream order. Most BMPs serve and control small drainage catchments of approximately 25 acres or less. This size of drainage catchment coincides with the size of a first order stream as defined by Leopold (1994) for the Maryland Piedmont region.

BMPs and Receiving Waters: What is the Connection? . . . cont'd.



These first order streams are typically intermittent streams which flow in response to wet weather conditions. Stream biologists usually do not focus on these intermittent streams because they are more interested in perennial streams that support a greater range of biologic activity. However, the first order streams are linked with and can often directly influence the stability and biologic health of higher order streams. First order streams are the most abundant and account for most of the total area within a given watershed. These first order streams can range from 15 to 60 acres and are the most sensitive to land use changes due to their immediate

proximity to the source of the change. They can become rapidly stabilized and generate large volumes of sediment in response to altered hydrologic regimes associated with the land use change.



As illustrated by the Lane balance diagram (Lane, 1955) streams size themselves in response to their sediment load and discharge. These small first order streams are often subjected to increases in sediment load and discharge which can be three to four times larger than pre-development conditions. Their normal response is to enlarge their cross-sectional area to accommodate these increases in flow regime.

The destabilization of a first order stream can have a significant impact on a second order stream, which in



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BMPs and Receiving Waters . . . cont'd.

turn may impact a third order stream. The extent and magnitude of these downstream impacts will depend on the percentage of the total drainage area that is affected by land use changes.



Water quality impacts of land development, other than sediment, will not be addressed here, because they have been the overwhelming focus of past efforts and commentary on urban runoff and will no doubt be the focus of this edition.

In summary a brief review of both the nature of the impacts associated with land use changes, particularly land development, suggests that an appropriate definition of *receiving waters* must be extended to the very headwaters of the watershed to the point where rainfall first enters the soil surface. The definition must also be extended beyond water quality concerns to include physical impacts including groundwater recharge and changes in surface runoff including increases in runoff volume, duration, frequency and magnitude of peak flows. In

addition, special attention needs to be directed to the ongoing destabilization of first order streams and their resulting impact on the overall stream system.

LITERATURE CITED

- Lane, E.W., 1955. The Importance of Fluvial Morphology in Hydraulic Engineering. American Society of Civil Engineering Proceedings, No. 81, Paper No. 745, pp. 1-17.
- Leopold, L.B., 1994. A View of the River. Harvard University Press, Cambridge, Massachusetts.
- U.S. EPA, 2000. Low Impact Development Design Strategies: An Integrated Design Approach. Prepared by Tetra Tech, Inc., Fairfax, Virginia, for Prince George's County, Maryland, and the U.S. Environmental Protection Agency, Washington, D.C.
- U.S. EPA, 2001. Urban Drainage Glossary. Prepared by the Urban Watershed Management Branch, National Risk Management Research Laboratory, Edison, New Jersey (in press).

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Michael L. Clar, P.E., is President of Ecosite, Inc, Ellicott City, Maryland, and provides consulting services related to the assessment, development, and application of ecologically sensitive approaches to land development and watershed protection and restoration. He currently serves as the chair of the Urban Water Resources Research Council of the American Society of Civil Engineers, is president-elect of the Maryland Society of Professional Engineers, and is a member of the Maryland State Water Quality Advisory Committee.



▲ President's Message . . . John S. Grounds III, AWRA President, 2001

The Bush Administration has appointed Pennsylvania Governor Tom Ridge as the Director of Homeland Security to coordinate more than 40 federal agencies, including Immigration and Naturalization Service, Department of Transportation, Central Intelligence Agency, Federal Emergency Management Agency, Federal Bureau of Investigation, and the National Guard. With such a diverse collection of agencies each having a unique mission and jurisdiction, the task will be complicated and require substantial backing from the Office of the President and Congress in providing money and legislative support.

The United States does not currently have a national water policy. The task in creating a policy may be more problematic than that defined by our immediate need for a secure nation. The coordination of the United States Geological Survey, Environmental Protection Agency, Army Corps of Engineers, Federal Emergency Manage-

ment Agency, Department of Agriculture, Bureau of Reclamation, National Weather Service, and many other agencies – not to mention their state and local counterparts – appears staggering. The American Water Resources Association has taken on this challenge. We are planning, along with leaders within the agencies, a Water Resources Policy Summit that will engage senior staff at each agency and invite all stakeholders to participate in this dialog to provide guidance in developing their strategies and policies.

AWRA would appreciate your input on the key issues to be discussed at the summit and on individuals who could present their viewpoints on these issues. **To forward your input or to receive further information about the summit, please e-mail Richard Engberg, AWRA Technical Specialist at <dick@awra.org>.**



▲ Returning to the River: Watershed Leader Completes Life Cycle

A Tribute to Dr. John R. Donaldson

In life, and in death, water is a natural metaphor. As my father liked to ask people ... "Do you know where your watershed is?"

Salmon return to the headwaters of the rivers of their birth to spawn, passing on life to a new generation and enriching the mountain streams and related watersheds with their nutrients. Water was a central theme in the life of my father, Dr. John R. Donaldson, who died very unexpectedly last fall at the age of 71. In accordance with his wishes, we returned him to the watersheds of the Columbia River that meant so much to him, scattering his ashes last Father's Day at a beautiful, private spot, deep in the woods along the Salmon River, at the base of Mt. Hood in Oregon.

My father's accomplishments, including a PhD from the Univ. of Washington in freshwater limnology, ten years as a professor at Oregon State Univ., ten years as Director of Oregon's Fish and Wildlife Dept. and creator and director for nine years of the Columbia Basin Fish and Wildlife Authority, aren't as important as his life's spirit – the impact he had on others. Also, the story of how we honored his life, with water as the unifying element, may be of interest to others.

Open Space to Tap the Flow of a Life

In addition to the family ceremony we held last Father's Day, we organized a "Watershed Legacy" public tribute for my dad last winter. As he requested, this was done in the style of an "open space" meeting. My father took great joy, late in his life, in facilitating open space meetings focused on specific watersheds in Oregon and Washington, bringing together diverse groups that normally did not associate with each other, including environmentalists, ranchers, biologists, volunteers, leaders in government agencies, and Native Americans. People, not the fish, are the problem, he liked to say.

My father must have done something right in life – over 150 people attended his public tribute, including a former governor of Oregon, many former graduate students and employees for whom his mentoring meant so much, and two very senior Native American leaders in the Pacific Northwest, who sang traditional songs.

The tribute, which lasted over two hours, had water as a central theme. We gathered for the ceremony in a beautiful wooden hall at a forestry center in Portland, Oregon, sitting in a large circle. Each person, when they arrived, received a bottle of fresh water. In the center of the room were fir boughs, flowers, river rocks, and a beautiful ceramic bowl with water in it. Those who were moved to speak poured some of their water into the bowl at the center of the room, then picked up the "talking stick," symbolic in native cultures, before sharing a favorite memory.

Generations Hence Will Look back at Our Time

My dad's loss is a big one for our family, but also for our collective memory. As a young biologist, my dad hiked to the remote reaches of pristine rivers throughout the Pacific Northwest, walking up mountain streams in his waders, counting fish and taking notes on stream conditions. He drank from the cold water any time he grew thirsty. Later, before Interstate 5 was completed along the West Coast, he also had the job of interviewing Native Americans along the Columbia River who had fished in the traditional way, prior to the dams.

On our family hiking trips in Oregon, in my youth, we experienced the awesome beauty of wilderness – mountains, forests and streams. But we also learned not to drink directly from the water, for the backpacking boom had begun; with more and more people accessing the wilderness areas, the fragile nature of our ecosystems was exposed.

How, then, will it be in the future for my son, now age three? Permits and reservations will likely be needed far in advance to visit our parks and wild areas. Will we also find the deep communion with nature that my father did on the long wilderness hikes of his youth?

We will add tens of millions of new people to our country in the coming decades. It sickens the heart to see, throughout the U.S., landscapes and open spaces being dulled or destroyed by unaesthetic development based on the needs of automobiles and shopping malls, not nature or our natural spirits. Where there is no leadership and open space for watershed-wide awareness, there will be battles in the future over water, and, looking abroad, wars will be fought.

A Yellow Rose Rounds a Bend in the River

The ashes of my father – a human life actually generates a surprisingly small amount of ashes – quickly dissipated as we each took a turn scattering them out across the fast moving Salmon River. No one will know that we were there, for my father did indeed return to the rivers he loved. One of us did toss a yellow rose out into the current. I watched it as it slowly floated around the bend in the river. Someone likely saw that rose downstream and wondered about the story behind it. I would tell them this: our spirits can and do live on in others. And rivers carry a big part of our collective story, connecting us all in ways, even with our advanced technology, that we seem to barely understand.

John Donaldson is Manager of the International Section for the American Society of Association Executives in Washington, D.C. His brother, Peter Donaldson, an educator who works with schools throughout the Pacific Northwest, is creative director, and co-creator, with his father, of Watershed Legacy (www.watershedlegacy.com), a community of learners dedicated to enhancing watershed awareness among future generations.



▲ AWRA Awards Herbert Scholarships for 2001-2002

AWRA has selected the recipients for its 2001-2002 Richard A. Herbert Memorial Educational Scholarships. Over 30 applications from around the country and overseas were considered for receipt of the two \$1,000 scholarships (one graduate and one undergraduate).

CARL J. LEGLEITER of Colorado Springs, Colorado, is the recipient of the Richard A. Herbert Memorial Educational Scholarship, Undergraduate Student Category. Enrolled at Montana State Univ., Bozeman, Montana, Carl is pursuing a B.S. degree in Geohydrology and maintains a 4.0 GPA. His academic interests include surface and ground water resources, western water policy, stream ecology, statistics, and geographic information systems. He has received numerous honors and awards, among them the prestigious Barry M. Goldwater Scholarship. Carl has worked on field studies in Yellowstone National Park and Montana's Paradise Valley. Earlier this year he won the Water Resources Specialty Group's Student Paper Award for a paper he presented at the Association of American Geographers annual meeting. He plans to attend graduate school then work as a professor, "staying on the forefront of research and passing on knowledge to future students, hopefully



inspiring others to seek to understand and protect America's waterways."

CHRISTINE MAY of Albany, Oregon, is the recipient of the Richard A. Herbert Memorial Educational Scholarship, Graduate Student Category. Enrolled at Oregon State Univ. as a Ph.D. candidate in Fisheries Science, she maintains a 3.97 GPA. Christine received a B.S. in Natural Resources from Humboldt State Univ. where she twice received the Presidential Scholar Award and graduated Magna Cum Laude. Christine then went on to receive an M.S. degree in Forest Hydrology at Oregon State Univ. (OSU). During this time she received numerous awards and honors. Currently her research focuses on the routing and storage of water, sediment, and wood in headwater streams, allowing her "to do truly interdisciplinary research." Christine was a co-founder of Hydrophiles, the OSU Student Chapter of AWRA and currently is co-president. She has co-instructed a field course in Fisheries Biology and volunteers with a local school environmental education program for children. Christine hopes to become a university professor and "share her enthusiasm and knowledge with the next generation of students."



▲ October 2001 JAWRA Papers (Vol. 37, No. 5)

DIALOGUE ON WATER ISSUES

- Turbidity, Suspended Sediment, and Water Clarity: A Review

TECHNICAL PAPERS

- Watershed Scaling Effect on Base Flow Nitrate, Valley and Ridge Physiographic Province
- Impacts of Climate Change on Missouri River Basin Water Yield
- Parameter Estimation of the Nonlinear Muskingum Model Using Harmony Search
- Using Climate Forecasts for Water Management: Arizona and the 1997-1998 El Niño
- Effectiveness of Biophysical Criteria in the Hierarchical Classification of Drainage Basins
- Validation of the SWAT Model on a Large River Basin With Point and Nonpoint Sources
- Using Reference Sites and Simple Linear Regression to Estimate Long-Term Water Levels in Coastal Plain Forests
- Comparison of Parametric Tail Estimators for Low-Flow Frequency Analysis
- Accuracy and Consistency of Water-Current Meters
- Incorporating Uncertainty in the Design of Stream Channel Modifications
- Casa del Agua: Water Conservation Demonstration House - 1986 Through 1998
- Bankfull Discharge Recurrence Interval and Regional Hydraulic Geometry Relationships: Patterns in the Pacific Northwest, USA
- A Hydroclimatological Analysis of the Red River of the North Snowmelt Flood Catastrophe of 1997
- Water Supply Evaluation of Taiwan's Silicon Valley
- Effect of a Point Source Input on Stream Nutrient Retention
- An Integrated Approach to Water Resources Development of the Tehran Region in Iran
- A Survey of the Microbial Quality of Recycled Household Graywater
- Reservoir Trophic State Evaluation Using Landsat TM Images
- Effective Water Pricing
- Regression Model for Estimating Herbicide Concentrations in U.S. Streams From Watershed Characteristics
- Dynamics of Wetland Development and Resource Management in Las Vegas Wash, Nevada
- Fuzzy Iteration Methodology for Reservoir Flood Control Operation
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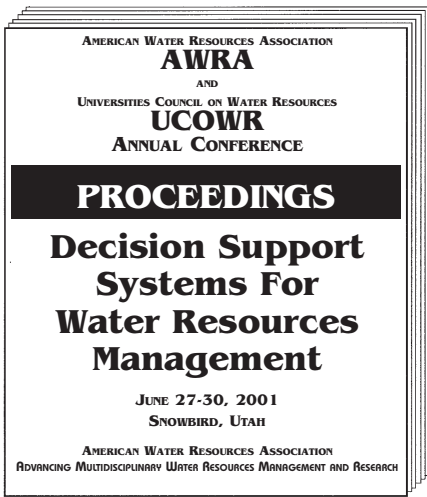
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As water resources managers struggle to satisfy society's growing demand for water, we rely increasingly on technology and information to increase the efficiency of our aging storage and delivery systems. Decision Support Systems (DSS) have matured during the past decade and become a way of life in water resources management. Integrated data collection and control systems are now widely used. Although DSS use was initially hampered by inadequate real-time data, some systems now suffer from information overload; data is received at a faster rate and volume than it can be processed and assimilated. Never has there been a greater opportunity or better reasons to exploit the use of DSS than now; and never has there been a greater need for research and development of DSS information technologies as applied to water resources management, and for education and training to support their proper use. A closer look at the splendid beauty and majestic peaks of the Wasatch Mountains exemplifies the problem. The snow pack is below normal again; this year makes several consecutive years of below normal winter precipitation and above normal temperatures in the mountain west. Yet, in the valley below – clearly visible through the mouth of Little Cottonwood Canyon – lays a thirsty metropolitan community bustling with growth. This desert community demands more water for culinary and industrial uses, wastewater treatment, and irrigation than ever before. It relies on hydropower generation as a significant source of electricity, and at the same time it appreciates the value of water as a recreational resource and is demanding higher reservoir levels and summer-time stream flows for fishing, boating, and swimming. It recognizes the environmental value of natural stream flows and natural stream channels, and is a community for which water is the source of both life and

controversy. The setting for the Conference could hardly be more fitting. It brought together a unique mix of water resources management practitioners and academicians focused on how to exploit information technology and the Internet in DSS.

This published proceedings represents a good sampling of presentations made throughout the conference. Author contact information appears on the first page of each paper and will allow interested readers to followup directly with authors, thereby propagating the dissemination of information beyond the conference and this published volume. Papers are included on the following topics: • Decision Tools for Integrated Watershed Mgmt.; • Information Mgmt. in Water Resources; • Innovative Approaches to Water Resources Education; • Watershed Mgmt. & TMDL Issues; • Water Quality Protection & Prediction; • Managing Water Resources for Divergent Political Interests; • Water Resources Mgmt. & Ecological Restoration; • Systems Approaches to Water Resources Mgmt.; • Innovative Ground Water Mgmt.; • Irrigation Mgmt. Systems; • Managing Floods & Floodplains; • Decision Support in Water Supply Systems; • Decision Support Systems for Managing Western Watersheds; and • Water Resources Mgmt. in the Middle East. (Proceedings includes several pages that have been printed in four-color.)

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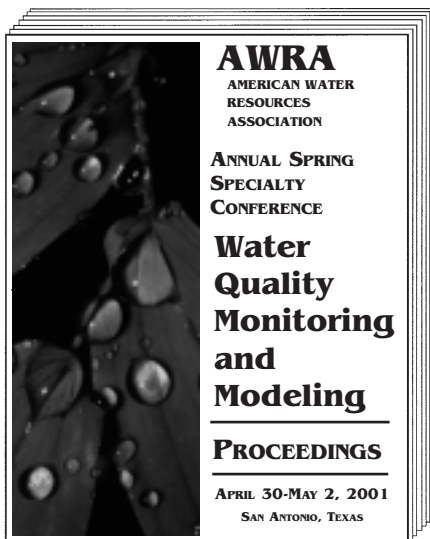
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The focus of this conference was freshwater quality, including both surface water and ground water. Presentations summarized monitoring studies, including both long-term and one-time synoptic field data collection efforts, along with strategies designed to support adaptive management restoration efforts. Presentations also covered modeling efforts, including all organized methods of data interpretation from statistical analysis through numerical simulation of hydrodynamics and associated water quality transformations. Finally, significant attention was also given to the relationship between monitoring and modeling in various studies.

The need to understand the current state of water quality has never been greater. Understanding is not merely reporting a water quality observation, but rather involves developing insight to explain its value. Specifically, our insight must help explain the relationships between human activities and desired water quality. A continued growth in population, coupled with increased expectations of acceptable water quality, places an ever-growing demand on this need to understand. The financial ramifications associated with limited understanding are increasing dramatically. It is, therefore, crucially important for us to be monitoring appropriate system attributes at correct spatial and temporal scales. Our interpretation (i.e., modeling) of collected data must capture true system functionality while clearly relating management alternatives to desired water quality goals. The drive to establish Total Maximum Daily Loads (TMDLs) for over 20,000 river segments, lakes, and estuaries across the United States highlights our need to better understand water quality and to do so soon.

This published proceedings represents a good sampling of presentations made throughout the conference. The volume is organized in the same manner in which the conference was held, by sessions. Author contact information that appears on the first page of each paper will allow interested readers to follow-up directly with authors, thereby propagating the dissemination of information beyond the conference and this published volume. Papers are included on the following topics: • Indices of Water Quality; • Basins & HSPF; • Surface Water Quality Monitoring Strategies; • Characterizing Ground Water Contaminant Plumes; • Techniques in Load Estimating; • Surface Water/Ground Water Interactions; • Assessment of Fresh Water Impacts on Estuaries; • Surface Water Quality Modeling Case Studies, • Uncertainties in Developing TMDLs; • Pesticides in Surface Water; • Characterization & Impacts of Urban Runoff; • Ground Water Quality; • Pathogens in Surface Water; • Defining Biological Resources; and • South-Central Texas Systems.

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▲ Water Resources Puzzler (answers on pg. 41)

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- 5 Zaharis or Ruth
- 8 landslide of wet debris
- 12 New Mexico art colony
- 14 moon of Jupiter
- 15 neap or spring
- 16 a pronoun
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- 1 bad service?
- 2 military rank
- 3 Henry's or Charles'
- 4 type of opera?
- 6 guide
- 7 boatswain
- 8 tops
- 9 tennis advantages
- 10 element with atomic No. 2
- 11 highland
- 13 Penn or Connery?
- 15 an aquatic bird
- 17 ooze
- 19 one of HOMES
- 20 warm
- 21 Fear or May
- 23 of the Earth's surface
- 25 type of cycle?
- 27 spayed
- 30 climbing supports
- 32 source of Powder River
- 34 fisherman
- 35 Nova _____
- 36 location of Laugatuck River
- 37 gumbo
- 39 the exile island?
- 41 part of a foot
- 42 type of bomb
- 44 sodium
- 46 shoe width
- 47 Old Iceland (abbr.)
- 49 selenium
- 54 location of Umpqua River
- 57 id est
- 58 a freshwater fish
- 59 not an acid

- 60 Asta's owner
- 62 style
- 63 wild onion
- 64 catcher's _____
- 66 teases
- 68 tenth president
- 70 ice pellets
- 71 Kingston _____
- 72 Mr. Preminger
- 73 followed by bake or shell
- 76 armed conflict
- 77 follows zeta
- 79 location of Chattahoochee River
- 82 printer's measure



▲ Water Resources Continuing Education Opportunities

MEETINGS, WORKSHOPS, SHORT COURSES

FEBRUARY 2002

18-20/USEPA SWMM & PCSWMM 2002 Stormwater Modeling Intro. & Advanced Workshops. Toronto, Ontario. **Contact** Lyn James, CHI, 36 Stuart St., Guelph, ON N1E 4S5 (519/767-0197; f: 591/767-2770; e: info@chi.on.ca; w: www.chi.on.ca/conf-sem.html)

21-22/Conf. on Stormwater & Urban Water Systems Modeling. Toronto, Ontario. **Contact** (see Call for Abstracts – due January 30, 2002)

25-March 1/IECA 33rd Annual Conf. Orlando, FL. **Contact** International Erosion Control Association, P.O. Box 774904, Steamboat Springs, CO 80477-4904 (970/879-3010; f: 970/879-8563; e: ecinfo@ieca.org; w: www.ieca.org)

MAY 2002

13-15/AWRA's Annual Spring Conf. – "Coastal Water Resources." New Orleans, LA. **Contact** AWRA, 4 West Federal St., P.O. Box 1626, Middleburg, VA 20118-1626 (540/687-8390; f: 540/687-8395; e: info@awra.org)

29-31/Ninth International Conf. on Hydraulic Information Management – HYDROSOFT 2002. Montreal, Canada. **Contact** Lucy Southcott, Conf. Secretariat, HYDROSOFT 2002, Wessex Inst. of Technology, Ashurst Lodge, Ashurst, Southampton, SO40 7AA, UK (+44(0)238-029-3223; f: +44(0)238-029-2853; e: lsouthcott@wessex.ac.uk; w:www.wessex.ac.uk/conferences/2002/hy02)

JUNE 2002

11-14/Allocating & Managing Water for a Sustainable Future: Lessons From Around the World. Boulder, CO. **Contact** Natural Res. Law Ctr., 401 UCB, University of Colorado Law School, Boulder, CO 80309-0401 (303/492-1272; fax: 303/492-1297; e: NRLC@spot.Colorado.edu; web: www.colorado.edu/law/NRLC/2002Conference.html)

JULY 2002

23-26/Integrated Transboundary Water Mgmt. Traverse City, MI. **Contact** EWRI of ASCE, 2002 Conference (UCOWR), 1015 15th St., NW, Ste 600, Washington, D.C. 20005 (202/789-2200; f: 202/789-0212; e: ewri@asce.org; w: www.uwin.siu.edu/ucowr)

28-Aug. 1/2nd Federal Interagency Hydrologic Modeling Conf. Las Vegas, NV. **Contact** Don Frevert, Co-Tech. Prog. Chair, USBR, P.O. Box 25007, M/C D-8510, Lakewood, CO 80225 (303/445-2473; f: 303/445-6351; e: dfrevert@do.usbr.gov); or George Leavesley, Co-Tech. Prog. Chr., USGS, Box 25046, MS 412, Lakewood, CO 80225 (303/236-5026; f: 303/236-5034; e: george@usgs.gov)

SEPTEMBER 2002

30-Oct. 4/6th Intern'l. Conf. on Diffuse Pollution. Amsterdam, The Netherlands. **Contact** (see call for abstracts – due January 1, 2001)

CALLS FOR ABSTRACTS

January 1, 2002 (Abstracts Due) – International Conf. on Diffuse Pollution. Sept. 30-Oct. 4, 2002. Amsterdam, The Netherlands. **Contact** www.nva.net/agenda/conference.htm or Govert Verstappen at G.G.C.Verstappen@riza.rws.minvenw.nl or r.r.kruize@inter.nl.net

January 30, 2002 (Abstracts Due) – Conf. on Stormwater & Urban Water Systems Modeling. Feb. 21-22, 2002. Toronto, Ontario. **Contact** Lyn James, CHI, 36 Stuart St., Guelph, ON N1E 4S5 (519/767-0197; f: 591/767-2770; e: info@chi.on.ca; w: www.chi.on.ca/confsem.html)

January 31, 2001 (Abstracts Due) – AWRA's Annual Summer Conf. – "Ground Water/Surface Water Interactions." Keystone, CO. **Contact** AWRA, 4 West Federal St., P.O. Box 1626, Middleburg, VA 20118-1626 (540/687-8390; f: 540/687-8395; e: info@awra.org)



FUTURE AWRA MEETINGS

MAY 13-15, 2002 • NEW ORLEANS, LOUISIANA
SPRING SPECIALTY CONFERENCE
"COASTAL WATER RESOURCES"

JULY 1-3, 2002 • KEYSTONE, COLORADO
SUMMER SPECIALTY CONFERENCE
"GROUND WATER/SURFACE WATER INTERACTIONS"

NOVEMBER 4-7, 2002
PHILADELPHIA, PENNSYLVANIA
"ANNUAL WATER RESOURCES CONFERENCE"

For additional information / info@awra.org

Solution to Puzzle on pg. 40

1	F	2	L	3	S	4		5	B	6	A	7	B	8	E	9		10	L	11	A	12	H	13	A	14	R		
A		15	T	A	O	16	S		17	I	O		18	T	I	D	E		19	I									
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22	L	E	23	G		24	P	A	R	25	T	N	E	R	S			26	H	27	A	G							
28	T	E	29	E	30	N		31	R	I		32	A	N		33	T	Y	34	P	E								
	35	P	O	E	36	M		37	E	38	A	39	S	T		40	C	O	41	D	E								
37		42	M	43	U	T	E	44	N	C		45	I	T	E	R		46	A										
47	K	48	N	O	T		49	L	50	A	G	51	O	N		52	H	O	53	S	T								
54	R	55	A	R	E		56	B	57	A	L	58	T	I	C		59	O	60	L	E	O							
A		61	P	R	O	62	A		63	E	I		64	H	65	I	L	O	66	M									
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73	R	74	A	I	D		75	M	A		76	O	R		77	S	I	L	78	T									
79	A	80	R	C		81	H	I	82	S	T	83	O	R	84	I		85	C	86	Z	87	A	88	Y				
89	M	90	P		91	W	A	T	92	E	R	93	T	A	94	B	L	E		95	N	L							
P		96	G	A	I	T		97	I	T		98	S	A	T	E		99	E										
100	S	101	N	A	R	L		102	M	O	O	R		103	M	A	N	O	104	R									

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(COMMENTS ON PREVIOUS ISSUES ARE ALSO WELCOME)

Water Resources IMPACT has been in business for almost three years and we have explored a lot of ideas. We hope we've raised some questions for you to contemplate. "Feedback" is your opportunity to reflect and respond. We want to give you an opportunity to let your colleagues know your opinions . . . we want to moderate a debate . . . we want to know how we're doing. Send your letters by land-mail or e-mail to Jonathan Jones (for this issue); or, if you prefer, send your letters to Earl Spangenberg (Editor-In-Chief). Either way, please share your opinions and ideas. Please limit your comments to approximately 350 to 400 words. Your comments may be edited for length or space requirements.

AWRA

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