Construction Industry Coalition on Water Quality

April 10, 2009

Ms. Tracy Woods
Los Angeles Regional Water Quality Control Board
320 W. Fourth Street, Suite 200
Los Angeles, California 90013

RE: Tentative Order 09-XXX (NPDES Permit No. CAS00402) Waste Discharge Requirements from Stormwater and Non-stormwater Discharges from the Municipal Separate Storm Sewer Systems within the Ventura Watershed Protection District, County of Ventura, and Incorporated Cities Within

Dear Ms. Woods:

On behalf of the more than 3,000 member companies of the Construction Industry Coalition on Water Quality (CICWQ), we would like to thank the Los Angeles Regional Water Quality Control Board (Regional Board) for the opportunity to offer this public comment on the Draft Ventura County Municipal Separate Storm Sewer System Permit, Tentative Order No. 09-XXX (Draft Permit). We also appreciate the Regional Board's participation in the series of permit stakeholder meetings that we have had over the past three years and staff's willingness to meet with us at various times.

This letter and attachments provide constructive suggestions that we have for the Draft Permit, and defines our positions on planning and land development provisions (most notably Low Impact Development (LID), hydromodification control, and construction site best practices requirements) that have been discussed and debated thoroughly within a stakeholder group framework since the Draft Permit was first released in December 2006. We also comment on the introduction of numeric limits for treatment control best management practices.

I. Introduction

CICWQ is comprised of the four major construction and building industry trade associations in Southern California: the Associated General Contractors of California (AGC), the Building Industry Association of Southern California (BIA/SC), the Engineering Contractors Association (ECA) and the Southern California Contractors Association (SCCA). The membership of CICWQ is comprised of construction contractors, labor unions, landowners, developers, and homebuilders working throughout the region and state.

These organizations work collectively to provide the necessary infrastructure and support for the region's business and residential needs. Members of all of the above-referenced organizations are affected by the Draft Permit, as are thousands of construction employees and builders working to meet the demand for modern infrastructure and housing in Ventura County. Our organizations support efforts to improve water quality in a cost effective manner.

Our comments and suggestions on the Draft Permit as well as our active involvement in the stakeholder process reflect our commitment to protect water quality while at the same time preserve our member's economic viability in this difficult economic environment. Please know that our membership has invested significant resources into developing sound engineering approaches for LID stormwater management techniques and for hydromodification control, facilitating the appropriate application of these valuable approaches to water quality management. Our comments reflect this commitment to sound engineering practices and principles and consideration of site-specific feasibility considerations during and following project construction.

II. Preliminary Statement

Our comments are directed at the content of the Draft Permit. Section E. Planning and Land Development Program and Attachment C. Treatment BMP Performance Standards. We share the common goal of moving the Ventura County program in the direction of using LID Best Management Practices ("BMPs"). and we appreciate the need to avoid hydromodification impacts to sensitive stream channels. We agree that conventional stormwater BMPs should not be used as the primary BMP approach for a site unless it is plainly infeasible or undesirable due to ecological or other societal considerations to use LID BMPs. We also continue to favor the consideration and use of regional and other "scaleable" BMPs and off-site solutions when they can be demonstrated to achieve a high environmental benefit. recognizing at the same time that these options cannot be mandated when they are not generally available. and may not be for some time. Fundamentally, we support more engineering rigor in selecting and sizing LID BMPs. Finally, we support the Draft Permit's consistency with the State of California General Construction Permit for stormwater discharges.

Given these over-arching issues. we have the following remaining concerns:

Effective Impervious Area (EIA) Restrictions Must Be Replaced By Volume Capture LID BMP Sizing Standards

The term "EIA" lacks a common, understandable and implementable definition. and is too vague and ambiguous to be used as a logical standard without assigning a volume capture requirement to it. In other words. EIA is not a stand-alone standard and must use a hydraulic-based translator to have any relevance to LID BMP sizing.

There seems to be willingness on the part of the Regional Board and the NGOs to consider a capture volume approach, without the complication and confusion created by appending EIA to it. The NGOs have acknowledged that EIA lacks meaning without a design storm volume specified and clear criteria of what would be considered non-effective impervious area. This is an important acknowledgement, which we appreciate, as it tends to show that EIA as a stand-alone concept falls short as a performance standard.

CICWQ has often pointed out that a limitation on EIA as a performance standard for sizing LID BMPs has created widespread confusion and misunderstanding in the development and building industry with respect to its definition, what this standard would require, and the reason for it. Proposing EIA as a performance standard has also created confusion among stormwater professionals from the principal permittee and co-permittees and consultants who support them and within Regional Board staff as well. It is quite clear that EIA does not have an agreed upon. logical definition and its suitability across all development project scales raises serious concerns about unintended consequences (such as limiting infill and redevelopment and promoting sprawl). We

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strongly question its utility in many project site contexts such as hillsides. bluffs, soils with restrictive layers such as hard pans, or high water tables. It may be a valid scientific concept under uncontrolled conditions (where there are no BMPs), and one that has meaning on a watershed scale where its definition first appeared, but it's utility is hampered by confusion and the need for a clear hydraulic sizing translator, such as design storm volume capture.

In recent correspondence, the U.S. Environmental Protection Agency (EPA) appears to be accepting of alternative engineering approaches other than EIA (such as volume capture), which importantly is being considered in draft permits or is found in guidance documents in several states. BIA/SC communicated with the EPA regarding their intent in using EIA as a performance standard in designing and implementing LID BMPs. While EPA supports the use of "clear, measureable, and enforceable requirements" for LID performance, such as limitations on EIA, EPA's letter to BIA/SC dated July 31, 2008 (Attachment 1) clearly states that "use of the 5% EIA requirement is not the only acceptable, quantitative approach for incorporating LID into renewed MS4 permits in southern California." The EPA further states that "we are open to other quantitative means for measuring how LID tools reduce storm water discharges." Finally, EPA recently commented on the North Orange County MS4 permit (March 24, 2009) and stated that "EPA has not determined that EIA is not necessarily the only or always the best method to implement LID" and that they are supportive of a volume capture approach.

All LID BMPs Must be Available for Use to Collect and Treat the LID Storm Capture Volume

The current Draft Permit in section 5. E. III.1 (d) appears to allow infiltration, rainfall harvest and use, or vegetated LID BMPs to collect and treat the design storm volume that is used as a hydraulic translator for the 5% EIA standard. This apparent flexibility is found in an explanation of how to render an impervious surface "ineffective." However, in the preceding section 5.E. III.1 (c), the permit states that all structures built to render surfaces ineffective must be properly sized to infiltrate or store and use rainwater up to the water quality mitigation criteria value. This somewhat contradictory permit language and a recently surfaced Ventura County City Manager-NGO proposal both attempt to narrow developer choices in selecting and sizing LID BMPs by restricting BMPs to only those that infiltrate or store rainfall for beneficial use. In other words, each project would require zero discharge of a design storm volume with no runoff whatsoever allowed.

The US EPA defines LID as follows:

*A comprehensive stormwater management and site-design technique. Within the LID framework, the goal of any construction project is **to design a hydrologically functional site that mimics predevelopment conditions**. This is achieved by using design techniques that infiltrate,* **filter**, *evaporate, and store runoff close to its source.* (emphasis added)

http://cfpub1.epa.gov/npdes/greeninfrastructure/information.cfm#glossary

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Mandating the complete on-site retention of any sizable storm volume (i.e. runoff that never leaves as surface flows) is not a reasonable approach and the City Manager-NGO proposal attempts to redefine the allowable site design elements necessary to implement LID. This proposal if adopted may implement LID in a way that is contrary to the EPA definition of LID by restricting BMPs to those that only achieve zero discharge—not allowing any BMPs that appropriately "filter" runoff, such as bioretention cells or other vegetated LID BMPs. Total, 100 percent retention remains impractical and unwise in most circumstances, and is not a goal that can be achieved for most projects within reasonable costs, despite best efforts. Moreover, such a mandate abandons the goal to mimic predevelopment conditions to the extent practicable, as EPA encourages.

We are providing, in Attachment 2, a comprehensive analysis done by Geosyntec Consultants of the feasibility of implementing rainfall and stormwater harvesting systems and the utility of these systems in achieving pollutant load reductions from stormwater runoff as compared to use of all types of LID BMP features. This document and follow up correspondence with Geosyntec show that harvesting alone may result in poor water quality treatment performance relative to a well designed system of LID BMPs that includes all types of BMPs—including filtration, not just those that capture and retain stormwater. This document also identifies the current institutional barriers (code requirements) that will need to be adjusted long before total rainwater capture systems can be considered feasible in any practical sense.

To CICWQ, the retention BMPs of infiltration, harvesting, and evapotranspiration ("ET") may be described as a preferred tier of LID BMPs for use wherever practical; but they should not be universally mandated to the exclusion of all other options. As the EPA definition of LID indicates, biofiltration, bioretention, filter strips, and other BMPs based on using vegetation to promote stormwater treatment via filtration are fundamental to LID implementation. These BMPs may be specified as additional secondary options (although they best mimic pre-development conditions), but project proponents should have considerable discretion to use these BMPs, and should not be required to apply for a feasibility exception to do so.

The use of conventional BMPs (structural treatment installations) as the principal approach for stormwater management should be a last resort, available only when objective infeasibility criteria are satisfied, and when off-site, scaleable, opportunities are not readily available. When LID BMPs are infeasible, and nearby off-site options are not available, the use of conventional BMPs that have been demonstrated to be effective on the pollutants of concern should be a compliance option.

The NGOs assert that the Draft Permit is too permissive in its application of LID BMPs or in the volume of water that must be collected. Moreover, they point to other locations around the U.S. where these more constrictive BMP measures are required and where larger volumes of water are presumably collected in them. A review and analysis of the documents referenced by NRDC in a recent comment letter regarding the Orange County MS4 permit was prepared by Geosyntec Consultants (Attachment 3). This review shows that, in all cases, none of the LID BMP sizing provisions targeted by NRDC appears in an adopted permit, so the actual utility, practicability, and on the ground results of the permit conditions remains to be seen. In addition, these programs do not: a) generally mandate zero discharge through application of only infiltration or rainfall harvest and use LID BMPs. and b) require large volumes of water (in excess of 1-inch for example) to be collected in infiltration or harvest and use LID BMPs regardless of feasibility. We recognize and appreciate that these programs may provide approaches for consideration, yet their direct transfer to permit content for Ventura County is inappropriate. Also included for the Regional Boards consideration as Attachment 4 is a critical evaluation requested by the US EPA concerning the content of the Draft Technical Guidance on Implementing Section 438 of the Energy Independence and Security Act. None of the documents cited by NRDC constitute permits adopted for implementation.

Off-site Mitigation and Development Credit Programs Must Be Simple and Flexible

We are concerned about the current mitigation program requirements, in lieu fee program, and master planning and redevelopment provisions known as RPAMP (Redevelopment Project Area Master Plan). The current mitigation program for implementation of LID and conventional treatment control BMPs lacks coherence, detail, and specificity, and the in-lieu mitigation funding program lacks a clear connection between a determination of impracticability and exactly what is being determined to be impracticable. CICWQ suggests that only that volume of excess water that is not collected and treated at a project through the use of a preferential selection of LID BMPs (infiltration, harvest and use, evapotranspiration, and vegetated/biofiltration) and through the use of clear engineering feasibility criteria (geotechnical concerns, high ground water, pollutant plumes, etc.) be subject to off-site mitigation requirements. Then, that excess volume of water may be mitigated off-site using a similarly broad suite of LID BMPs.

The Draft Permit Section III (b) mentions use of "stormwater mitigation credits" but provides no indication on what such a program would entail beyond the establishment of a mitigation funding program. CICWQ is supportive of a "credit" program that would reduce the amount of stormwater requiring on-site installation of LID site design features. Potential development contexts where credits are immediately applicable in this permit term include (but are not limited to) those listed in Section E. IV. 3. (g). The final adopted Permit should reflect greater clarity on the details of this program (see Attachment 5 for potential permit language).

We maintain great concern regarding the Alternative Post Construction Storm Water Mitigation Program known as RPAMP. In general, we view it as cumbersome and unduly complicated, and it favors large redevelopment or master planning efforts over smaller or more spatially diverse redevelopment and infill efforts across all development settings. We feel the program as constituted could stifle infill and redevelopment projects in urban areas as well as potentially excellent green field development, rather than accelerate it because of its complexity and the inherent barriers (e.g. two layers of regulatory body approvals) it creates for medium to small developers. Here too we recommend using alternative mitigation program requirements as identified in Attachment 5.

Establishing Effluent Concentrations as Median Values for Treatment BMP Performance Standards are Precursors of Numeric Effluent Limits

We strongly oppose the inclusion of treatment BMP performance standards in Appendix C (we read this table as numeric effluent limits) and suggest that the Regional Board re-think its approach to achieving better treatment BMP performance through specification of unit-based process design principles for selecting and sizing treatment control BMPs. We recommend that Table 3 be either deleted or redirected for use as a design goal. and instead require the permittee to develop design criteria for treatment control BMP performance and include these criteria in an updated version of the Ventura County Stormwater Design Manual. The values given in Attachment C are in essence indirect metrics of performance and require translation into design criteria to have any meaning. For example. unit based process design principles such as the amount of runoff to be captured (design storm). expected forms and concentrations of influent pollutants of concern. BMP length to width ratio. drawdown time. and other hydraulic and pollutant criteria must be integrated in a design approach for these values to have any meaning in properly designing treatment control BMPs. Moreover. we ask that the Regional Board provide more information about how the values in the table were developed from the WERF-ASCE/US EPA International BMP database. We are concerned specifically about which version of the database the Regional Board used and how the statistics were derived in the table including number of data point. number of individual BMPs. and number of non-detects.

III. Specific Comments on the Draft Permit

What follows are our comments. organized into two sections and supported with attachments where noted: (A) comments on Section E: Planning and Land Development Program and (B) comments on treatment control BMP performance standards (Draft Permit Attachment C).

A. Comments on Section E: Planning and Land Development Program (pages 52 of 121 through 65 of 121)

Part III. New Development/Redevelopment Performance Criteria, No. 1 (b) and (c)

CICWQ is unsupportive of EIA as an LID BMP sizing standard as previously discussed in our Preliminary Statement. and we ask that you strike Part III, No. 1 (b-d) in favor of a volume capture approach. We urge the Regional Board to consider using the following as an equivalent performance standard:

(b) The goal of the New Development and Redevelopment Standards shall be to capture and treat the water quality mitigation criteria volume defined in Section E. Part III. No. 3. through the use of an LID BMP implementation hierarchy described below in Section E. Part III. No. 1. (c).

(c) The selection of LID principles shall be prioritized in the following manner (from lowest to highest priority: (1) Preventative measures (these are mostly structural

measures, e.g. preservation of natural features to the maximum extent practicable, minimization of runoff through clustering, reducing impervious areas, etc.) and (2) Mitigation (these are structural measures such as infiltration, harvesting and use, bio-treatment, etc. 'The mitigation or structural site design BMPs shall also be prioritized (from highest to lowest priority): (1) Infiltration (examples include permeable pavement with infiltration beds, dry wells, infiltration trenches, surface and sub-surface infiltration basins); (2) Harvesting and use (e.g. cisterns and rain barrels); and (3) Bio-treatment such as bio-filtration/bio-retention.

(d) *Any excess surface discharge of the storm water runoff that is not captured or treated in LID BMPs shall be mitigated in accordance with Section E. Part III.No.3.*

Part IV. Implementation, No. 3. Alternative Post Construction Storm Water Mitigation Program

CICWQ views the redevelopment project area master planning process (RPAMP) as cumbersome and unduly complicated, and it favors large redevelopment or master planning efforts over smaller or more spatially diverse redevelopment and infill efforts across all development settings. We recognize that appropriate mitigation options will need to be available to those infill and redevelopment projects that cannot feasibly treat the design storm water quality volume with LID BMPs. We also recognize that certain types of development projects or development contexts should be afforded waivers or credits from LID BMP and/or hydromodification control requirements for various reasons.

One of CICWQ's principal concerns with the Alternative Post-Construction Storm Water Mitigation Program and the mitigation funding program defined in Part IV. Implementation, No. 4, is inconsistency of the Draft Permit program provisions with other programs defined in adopted or pending MS4 permits elsewhere in southern California. We believe there are more straightforward programs under consideration currently in MS4 permitting contexts. For example, we include as Attachment 5 alternative mitigation program and water quality credit program requirements cited in the second draft of the Orange County Areawide MS4 permit, dated March 25, 2009. CICWQ supports the framework, procedures, and opportunities for mitigation and credits described in the Orange County draft permit.

B. Comments on Treatment Control BMP Performance Standards (page 36 of 121 and Attachment C, page C-2 of 2)

The Draft Permit introduces numeric effluent limits which appear to be intended to assist in engineering design of treatment control BMPs, presumably both conventional and LID. Six specific BMP classes are given effluent limits for sediment, nitrate, copper, lead, and zinc, with the data extracted from the WERF-ASCE/US EPA International BMP database for those classes of BMPs where data is available. The full extent to which these numeric targets are applied to other types of treatment control BMPs is unclear, as is the ultimate intent of introducing numeric limits in this manner. We can only imagine that these values will be translated into end of pipe (BMP) numeric effluent limits at some point.

Therefore, we suggest deleting Attachment C and its implementing Draft Permit provision in Part 4. Storm Water Quality Management Program Implementation. No. 3 in favor of requiring the permittee to develop design criteria for treatment control BMP performance and include these criteria along with other key unit-based process design criteria in an updated version of the Ventura County Stormwater Design Manual. These criteria would include design principles such as the amount of runoff to be captured (design storm), expected forms and concentrations of influent pollutants of concern, BMP length to width ratio, drawdown time, and other important design principles. We must note as well that the WERF-ASCE/US EPA International BMP database has been updated with additional BMP studies since 2007. We recommend that you use the values in the published June 2008 statistical summary report on the BMP database website, or clearly describe what version of the database was used and how the statistics were derived including the number of data points, number of individual BMPs, and number of non-detects.

IV. Summary

CICWQ is pleased that an inclusive stakeholder process has ensued since the Draft Permit was first released in December 2006. The process has shed significant light on areas where all stakeholders have common interests and common plans for tackling the pressing water quality improvement issues we all face. We will be an active participant in this group moving forward, and we trust that the Regional Board will continue to promote and engage in this process leading up to permit adoption. If you have any questions or want to discuss the content of our comment letter, please feel free to contact me at (909) 396-9993, ext. 252, (909) 525-0623, cell phone, or mgrey@biasc.org.

Respectfully,

Mark Grey, Ph.D.
Technical Director
Construction Industry Coalition on Water Quality

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
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July 31, 2008

Mark A Grey
Director of Environmental Affairs
Building Industry Association of Southern California
1330 South Valley Vista Drive
Diamond Bar, CA 91765

Andrew R. Henderson
Vice President and General Counsel
Building Industry Association of Southern California
1330 South Valley Vista Drive
Diamond Bar, CA 91765

Dear Dr. Grey and Mr. Henderson:

This is in response to your July 1, 2008 letter to Alexis Strauss regarding the incorporation of Low Impact Development (LID) provisions into Municipal Separate Storm Sewer System (MS4) permits in southern California.

Your letter refers to your email communications with Ms. Strauss, as well as to testimony provided at the February 13, 2008 San Diego Regional Water Quality Control Board Hearing by Dr. Cindy Lin and to the April 1, 2008 comments to the Colorado River Basin Regional Water Quality Control Board by Mr. Doug Eberhardt. Your letter asks several questions about the U.S. EPA Region 9 Water Division's positions regarding the incorporation of LID provisions into southern California MS4 permits.

Nationally, U.S. EPA has formally recognized the benefits of LID (also termed "Green Infrastructure") in several policy documents. EPA is advocating green infrastructure as an approach to wet weather management that is cost-effective, sustainable, and environmentally-sound. On April 19, 2007, EPA and four national groups signed an agreement to promote green infrastructure as an environmentally preferable approach to storm water management, and on August 16, 2007 EPA issued a memo encouraging the incorporation of Green Infrastructure into NPDES storm water permits. Ongoing efforts are described in the January 17, 2008 Action Strategy for Managing Wet Weather with Green Infrastructure. All of these materials regarding EPA's policy on green infrastructure can be found at:
http://cfpub.epa.gov/npdes/greeninfrastructure/information.cfm#greenpolicy.

In EPA Region 9, we are promoting LID strategies that infiltrate, evapotranspire, capture, and reuse storm water to maintain or restore natural hydrologies and improve water quality. We are encouraging permitting agencies across Region 9 to incorporate LID provisions into MS4 permits as clear, measurable and enforceable requirements.

The next round of MS4 permits in the coastal Regions of southern California will be the fourth generation of these permits. It is our expectation that these latest permits be strengthened to take advantage of lessons learned from previous permits, and to contribute to the restoration of impaired waters impacted by MS4s. These new MS4 permits should include quantitative requirements to enable all parties to clearly identify performance expectations for LID implementation.

Your letter asks several questions about our position regarding permit provisions which call for LID implementation to attain a standard of no more than 5% Effective Impervious Area (EIA). Such provisions are included in the current draft (April 29, 2008) MS4 permit for Ventura County proposed by the Los Angeles Regional Water Quality Control Board, and the February 15, 2008 guidelines provided by the Central Coast Regional Water Quality Control Board to those in the Central Coast Region enrolling under the State's Phase II general MS4 permit. We support the inclusion of the 5% EIA provisions for new development and redevelopment projects in both of these examples as clear, measurable, and enforceable requirements. Use of the 5% EIA requirement is not the only acceptable, quantitative approach for incorporating LID into renewed MS4 permits in southern California. As noted in Mr. Eberhardt's April 1, 2008 letter, and his May 13, 2008 follow-up letter to the Colorado River Basin Regional Water Quality Control Board, we are open to other quantitative means for measuring how LID tools reduce storm water discharges.

Your letter asks about our use of a paper by Dr. Richard Horner concluding that the achievement of a 3% EIA standard for development in Ventura County is feasible. Dr. Horner's paper is one of many we have before us. Our positions have been informed by many documents germane to the management of municipal storm water, including the January 21, 2008 paper by your organization entitled "Integration of Low Impact Development Measures and CEQA Approvals." EPA has also considered numerous publications, case studies and guidance manuals in its consideration of LID/Green Infrastructure as a cost-effective, preferable alternative to storm water management. A partial list of these materials may be found at http://cfpub.epa.gov/npdes/greeninfrastructure/research.cfm.

While we cannot attribute our position on future MS4 permits to a single report or analysis, our views on these permits have been most comprehensively informed by the nearly 50 audits of Region 9 MS4 permits we have conducted over the past seven years. These audit reports can be found on our website at http://epa.gov/region09/water/npdes/ms4audits.html#report. Twenty of our audits have been conducted in southern California. These audits have highlighted the need for quantitative, measurable requirements in MS4 permits to ensure effective implementation of storm water controls.

I hope this has answered the questions in your July 1, 2008 letter. If you would like to discuss this further, please call me. here in EPA's Southern California Field Office, at 213-244-1832

Sincerely,

John Kemmerer
Associate Director.
Water Division

cc: Executive Officers, RWQCBs Regions 1-9
Tam Doduc, Chair SWRCB
Dorothy Rice, Executive Director, SWRCB
(all cc's transmitted electronically)

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Memorandum

Date: 9 April 2009

To: Mark Grey, Director of Environmental Affairs Building Industry Association Of Southern California

From: Eric Strecker, Aaron Poresky, and Daniel Christensen

Subject: Rainwater harvesting and reuse scenarios and cost considerations

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SUMMARY

The purpose of this memo was to investigate two hypothetical scenarios involving rainwater harvesting and reuse in newly developed residential neighborhoods in Orange County, California. These scenarios include an on-lot harvesting and re-use and community-scale harvesting and re-use. The community system was also modeled using SWMM to assess its potential benefits using some simplifying assumptions, and general findings are presented in a brief discussion. Lastly, the Appendix, prepared by Dr. Mark Grey, provides an analysis of the institutional and building code issues for constructing rainwater harvesting and resuse systems in California.

For the on-lot scenario, a 1000 to 1300 gallon tank would capture 0.8 inches of runoff depending on the impervious area used to fill the tank. Depending on the assigned water usages (outdoor or indoor + outdoor), the drawdown time of the tank could vary from 7 to 21 days. A single house rain harvesting system for this scenario would cost approximately $4,900. For the 100 acres neighborhood scenario, a 1.3 million gallon storage basin would capture 0.8 inches of runoff from 60% of the total area of the catchment (impervious area). Depending on the assigned water usages (outdoor or indoor + outdoor), the drawdown time of the basin could vary from 10 to 45 days (longer drawdown time due to inclusion of street runoff). This system would cost approximately 1.65 million dollars. The cost estimates found herein are for new developments and are rough guesses due to unaccounted items and other ancillary costs.

For the same neighborhood scenario, long-term (40 year period) modeling results show that 32% of the total runoff could be captured and used if only toilet flushing were used. If toilet flushing and outdoor irrigation were used, the system could capture and reuse about 55% of the total runoff. Under both usage scenarios, significant volumes of runoff would bypass the storage tank (or cause overflow) from 50 to 70 percent of the runoff or more would be expected to bypass.

BACKGROUND

Stormwater storage and re-use is a general description referring to the capture and storage of runoff and subsequent re-use of that water. Such a system could take a variety of forms. In the case of urban residential development, the typical storage component consists of some form of an enclosed tank or "cistern" that accepts runoff from roof drains or neighborhood storm drains. Some level of treatment (e.g. screening, filtration, etc.) is typically required upstream of the cistern to prevent the introduction of debris into the system. In addition, some form of treatment would be required, depending on the planned use. Potential re-use demands in residential neighborhoods are generally limited to irrigation of lawns and landscaped areas and/or to meet non-potable demands in homes such as toilet/urinal flushing (EPA 2008). The list below outlines the general materials needed for a reuse system for a single family household.

- Downspouts/Piping to Cistern: Typically a cistern is located near or directly under the downspout and minimal piping is needed. However, if driveway, patio and walkway water is to be collected on a lot, then additional collection and piping systems would be needed. The tank in this case would likely require deeper burial to be able to accept ground level runoff.
- Collection Filters: Fine mesh can be placed over the downspouts to prevent debris from clogging gutters and downspouts and entering the cistern. Filters with finer particle extraction capability, also known as "roof washers", can also be placed at top of the downspout to filter finer particles. (Figure 1a). For inlets from other areas such as driveways, filter materials can be integrated with the inlet and in fact would be more critical than for downspouts as debris quantities would be expected to be larger from ground level.
- First flush diverter: Typically this is a vertical pipe located before the cistern that traps the first flush volume using a ball float helping to prevent built-up contaminants entering the tank. The length and size of the vertical pipe determine the amount of water that will be diverted. A weep hole at the bottom of the vertical pipe empties the trapped first flush water. (Figure 1b). Another option would be to allow the tank to fill and then either divert via an overflow in the incoming pipe system or via a tank overflow.
- Tank/Cistern: Structure receives and stores impervious runoff (typically from roofs) and is design to store a certain volume of runoff to meet water use demands. (Figure 2a).
- Insect tank screens: Any open entrance to the tank should be covered with a fine mesh insect screen to prevent mosquitoes and pests from entering the cistern. (Figure 2b)
- Pump: A pump is used to force water to treatment system as appropriate and then toilets and/or irrigation system.
- UV treatment: Some regulations may require UV treatment for indoor non-potable water reuse or if water is re-introduced into a pressurized irrigation system. Another option would be to have a separate non-pressurized (low-pressure) irrigation system.
- Piping: Additional pipelines (purple lines) inside the house and to the irrigation system are needed to ensure the non-potable water does not mix with potable water.

- Backflow valve: This valve is a safety measure to ensure non-potable water does not mix with the potable water lines. An air-gap may also be used or in addition to a backflow valve.
- Potable water use failsafe system: A potable water line should be in place as a backup in case the non-potable reuse system fails or empties. This requires a double-line system and all measures should be taken to prevent non-potable water from mixing with potable water lines.
- Stencils: All non-potable water outlets should be clearly labeled as a "non-potable" source.

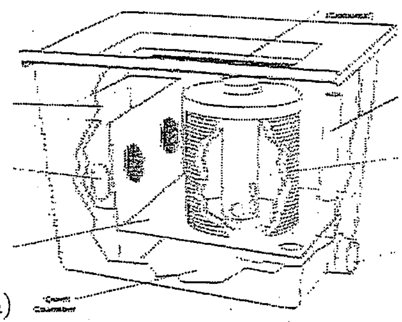
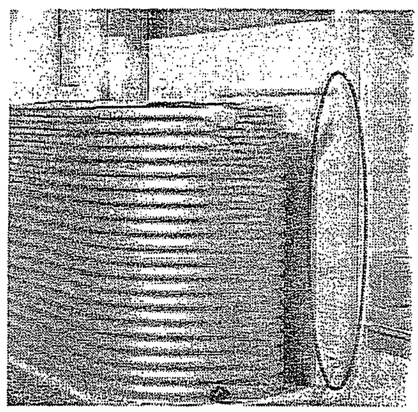
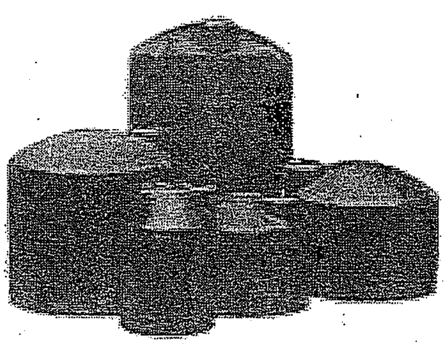

a) b)


Figure 1. a) Downspout filter or "roof washer"; b) First Flush Diverter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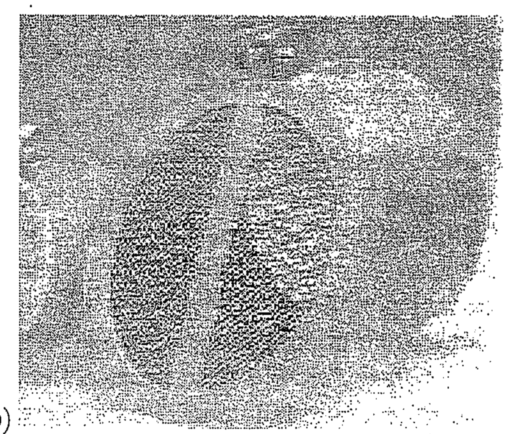

Figure 2. a) Cisterns; b) Insect screen

The critical factor in performance of storage and re-use systems lies in the integration of the magnitude and pattern of inflows and outflows with storage volume. For example, if inflow and outflow are well-matched and fairly constant, the system will require a small storage volume. If inflows and outflows are well-matched in total volume but come at different times, a larger storage volume may be required to match supply with demand. In the case of storage and re-use as a means of "disconnecting" impervious area, the most important requirement is that cistern has sufficient capacity and ability to regenerate this capacity, such that the system captures a significant portion of runoff on an average annual basis. If demand for harvested water during the period of high runoff is small compared to the overall runoff volume, then the system may not be able to perform its intended function of capturing a significant volume of runoff.

Two scenarios that were used for a general analysis are presented below. The first is a single family home scenario and the second is a 100-acre residential development. For the single family home scenario, two situations are analyzed: 1) only runoff from the roof-top drains to the cistern, and 2) runoff from the roof and additional impervious areas (driveway and patio) drains to the cistern. For the 100-acre residential development, runoff from the entire catchment, including the streets, sidewalks, driveways and roofs and pervious area was considered. The second scenario was also modeled using SWMM to ascertain long-term hydrology benefits.

HYPOTHETICAL SINGLE HOUSEHOLD SCENARIO

A simple single household example of rainwater harvest and reuse is provided to outline rough estimates of water demand and tank drawdown times that could be expected from a typical reuse system on a newly developed residential lot found in Orange County. This analysis uses the simple rational method to calculate runoff volumes and require tank size following the methods outlined in the "New Development and Significant Redevelopment" chapter in the DAMP. Runoff coefficients dependent on imperviousness found in the DAMP document were used in the runoff calculations. A total lot area of 0.1 acres with 69% impervious area was assumed. This imperviousness is based on 2,400 sq ft of roof area, 600 sq ft of other impervious area (driveway, sidewalks and patio), and the remaining 1,356 sq ft of pervious area. A rainfall depth of 0.8" was used to size storage units. This depth represents approximately the 85th percentile, 24 hour rainfall depth for large parts of Orange County. Two storage rainwater collection and storage scenarios were analyzed: 1) only runoff from the roof of the house drains to the cistern, and 2) runoff from the roof and additional impervious areas (driveway and patio) drains to the cistern.

Two reuse demand scenarios were considered: 1) reuse for internal demand only (i.e. toilet flushing), and 2) reuse for internal and external (i.e. irrigation) demand combined. Demand for toilet flushing and outdoor use per household were assumed to be 65 gal/day and 77 gal/day, respectively. The estimate for toilet flushing use was derived from an estimate of 18.5 gal/person/day (AWWARF 1999) and an assumed average occupancy of 3.5 people per house. For outdoor demand, the average use rate for May, September and December was estimated to be 113 gal/day for 2000 square feet of landscape area in the Irvine region (IRWD 2009). Since the majority of rain in Orange County occurs between November and March, the average of May, September and December demand likely over-estimates the demand for harvested rainwater during the months when rainwater is available for harvesting. The average outdoor demand (113 gal/day/2000sqft) was linearly scaled to the equivalent outdoor demand for the assumed 1,356 square feet of pervious area per lot used in this study, yielding 77 gal/household/day.

Based on the capture and storage scenarios and re-use scenarios described above, approximate average drawdown rates were estimated. Drawdown rates are important to the performance of stormwater BMPs because they affect how much storage capacity can be regenerated to capture runoff in subsequent storms. Table 1 shows the characteristics of the hypothetical lot and resulting cistern volume and drawdown times.

Table 1: Single household rainwater harvesting system attributes used for analyses.

	Roof Runoff	Roof + Other Impervious area	
Lot Characteristics			
# houses	1	1	
Total lot area	0.1	0.1	acres
Impervious area of roof	2400	2400	ft2
Other impervious area	600	600	ft2
Pervious area	1356	1356	ft2
% total impervious area of lot	69%	69%	
% of impervious area to cistern	80%	100%	
Runoff Coeff. for impervious area	0.9	0.9	
Storage Tank Sizing			
Storm Depth	0.8	0.8	inches
Vol Cistern	144	180	ft^3
	1,077	1,346	gal
	0.0033	0.0041	acre-ft
Demand Calculations			
People/ house	3.5	3.5	
Toilet use/capita	18.5	18.5	gal / day
Toilet use/house	65	65	gal / day
Outdoor / house	77	77	gal / day
Drawdown Times			
Toilets only	17	21	days
Both Toilets & Outdoor uses[1]	7.6	9.5	days

Per the calculations reported in Table 1, the drawdown time of a household cistern is expected to range from approximately 8 to 21 days. Note that these calculations assume that outdoor demand is immediately present following a storm event; likely an over-estimate due to rainfall soaking of landscaped areas and the prevalence of back-to-back storms in Southern California. From a runoff reduction perspective, a user would like to empty the cistern relatively quickly so

[1] Outdoor demand assumes that irrigation demand is immediate; more sophisticated modeling could be completed to more accurately characterize irrigation demand, but for purposes of this analyses, it has been assumed to be immediate. This likely significantly overstates the demand for irrigation.

that adequate storage is available for the next storm. Conversely, from a water reuse perspective, a user would likely desire the tank to empty slowly so that demand could be met for a longer period with the captured stormwater.

HYPOTHETICAL 100 ACRE NEIGHBORHOOD SCENARIO

A newly developed neighborhood example of rainwater harvest and reuse is provided to outline rough estimates water demand and tank/basin drawdown time that could be expected from a larger centralized reuse system found in Orange County that would capture runoff from the entire catchment (including streets, driveways, and pervious areas if they are contributing). This analysis uses the simple rational method to calculate the runoff to size the volume for storage system following the methods outlined in the "New Development and Significant Redevelopment" chapter in the DAMP 2003 to size the cistern volume. A total tributary area of 100 acres with 60% impervious area was assumed. Assuming the same 0.1-acre lots as above at a density of 4.5 du/ac, the total acreage covered by residential lots would be 45 acres. This leaves approximately 27.5 ac of roads and 27.5 ac of common areas, parks and open space to yield 60 percent neighborhood-wide imperviousness.. Based on 1,356 sf of pervious area per lot and 450 lots in the neighborhood, 14 acres of pervious area would be located on private lots and the remaining 36 acres of pervious area would be contained in parks, open space, and greenways. A rainfall depth of 0.8" was used to size the neighborhood storage unit as this depth represents approximately the 85th percentile, 24 hour rainfall depth for large parts of Orange County.

The same water demand estimates as the lot scenario were used to develop the neighborhood scenario. Off-lot pervious area was assumed to be irrigated at the same rate per square foot as on-lot pervious area. Table 2 shows the characteristics of the neighborhood tributary area and resulting cistern volume and drawdown times.

Table 2: Neighborhood rainwater harvesting system attributes used for analysis.

Tributary Area Characteristics		
# houses	450	
Impervious area	60	acres
Pervious area	40	acres
% impervious	60%	
Composite Runoff Coeff. C	0.60	
Storage Tank Sizing		
Storm Depth	0.8	Inches
Cistern / Basin Volume	174,000	ft^3
	1,300,000	Gal
	4.00	acre*ft
Reuse Demand Calculations		
People per house	3.5	
Toilet use per capita	18.5	gal / day
Toilet use per house	65	gal/ day
Outdoor demand per 2000 sf of pervious area	113	gal / day
Total toilet demand	29250	gal / day
Total outdoor irrigation demand	98500	gal / day
Total toilet + irrigation demand	127750	gal / day
Drawdown Time		
For Toilets	45	Days
Both Toilets & Outdoor[2]	10	Days

BASIC COST CONSIDERATIONS

Cisterns may take a variety of shapes and forms, thus costs may vary substantially by project. Likewise, the appurtenances required to convey water to the tank and supply the building demand are likely to be affected by project-specific factors. Finally, there are a variety of treatment systems that could be considered. Therefore, only a rough estimate of costs for storage and re-use systems in newly developed houses or neighborhoods can be made herein. The basic cost items that will be considered include: collection tanks, filters, UV treatment, 1st flush

[2] Outdoor assumes that irrigation demand is immediate: more sophisticated modeling could be completed to more accurately characterize irrigation demand, but for purposes of this analyses, it has been assumed to be immediate. This likely significantly overstates the demand for irrigation.

diverters, inlet piping and filters; pumps and appurtenances; the incremental cost of a dual plumbing system, and installation. The limited implementation of storage and re-use systems of the sort being considered herein allows limited basis for comparison to actual projects. Table 3 shows an itemized cost list for rainfall harvesting items.

Table 3: Rainwater harvesting items and prices

Item	Description	Cost	Reference/Source
TANKS			
Galvanized steel	200 gal	$225	Fairfax County, 2005
Polyethylene	165 gal	$160	Fairfax County, 2005
Fiberglass	350 gal	$660	Fairfax County, 2005
Plastic	800 gal	$400	Plastic-mart.com
Plastic	1100 gal	$550	Plastic-mart.com
Plastic	1350	$600	Plastic-mart.com
Plastic cone	1500 gal w/metal stand	$1500	Plastic-mart.com
Plastic	2500 gal	$900	Plastic-mart.com
Plastic	5000 gal	$3000	Plastic-mart.com
Plastic	10000 gal	$6000	Plastic-mart.com
Dry Det. Basin(1997)[3]	$C = 12.4V^{0.760}$; for 1 ac-ft	$41,600	stormwatercenter.net
Below Ground Vault[4]	$C = 38.1\ (V / 0.02832)^{0.6816}$	$55,300	fhwa.dot.gov
Concrete	1,000,000 gal above g. (O&P)	$548,000	RSMeans
Steel	1,000,000 gal above g. (O&P)	$467,000	RSMeans
TREATMENT			
UV (house-scale)	Whole system - 12 gpm	$700-$900	rainwatercollection.com
UV bulb	Life: 10,000 hrs or 14 months	$80-$110	rainwatercollection.com
UV (neighborhood-scale)	Whole system - 200 gpm	$10,000	Bigbrandwater.com
Downspout filter	Placed in Gutter	$20 - $500	many online
1st Flush Diverter	Vertical pipe w/ ball float	$50-$100	raintankdepot.com
PUMP	1 hp (all in one package)	$575 - varies	rainwatercollection.com

[3] This dry detention cost equation is based on Brown and Schueler, 1997, where C is the construction, design and permitting cost and V is the volume (cu-ft) need to control the 10-year design storm. In this case, the 0.8" storm runoff volume was used in place of the 10-yr design storm volume.

[4] This below ground storage vault equation is based on Weigand et al., 1986, where C is the construction cost estimate in 1995 dollars and V is the runoff volume (cubic meters) of the maximum design event frequency, taken to be the 0.8" storm for this study.

Item	Description	Cost	Reference/Source
PIPING (Purple)			
to Tank (lot)	PVC: 2"-6" (O&P)	$2-$12 / LF	RSMeans
to House (lot)	PVC: 2"-6" (O&P)	$2-$12 / LF	RSMeans
to Tank (neighbor.)	Concrete: 6" – 18" (O&P)	$15-$30 /LF	RSMeans
to House (neighbor.)	HDPE- 4" – 10" (O&P)	$11-$27 / LF	RSMeans
to Irrigation	PVC: 2"-6" (O&P)	$2-$12 / LF	RSMeans
Backflow prev. valve	Each	$100-$200	web
STENCILS	Non-potable water	----	
INSTALLATION	Percentage of material cost	40 % – 50%	

A rough cost estimate for the hypothetical examples can be developed using the table above. Table 4 summarizes the potential costs for the single household (lot), and Table 5 summarizes the potential costs for neighborhood. For the neighborhood scenario, the pipe (purple) lengths were estimated using measurements along the centerline of streets from a similar size neighborhood in Irvine.

According to Table 4, the total cost of the single household rainwater harvest and reuse system would be approximately $4900, not including design, permitting, and contingency costs which could run from another 30 to 70 percent of the material and installation costs. Table 5 shows the total cost for the neighborhood scenario is approximately $1.65 million, not including design, permitting, and contingency costs which could run from another 30 to 70 percent of the material and installation costs. This would equate to roughly $3660 per house, most of the saving being found in the total cost of the tanks verse a large central storage unit.

Table 4: Rainwater harvesting materials cost for single household scenario

Item	Description	Cost
TANKS		
Plastic	1100 gal and 1350 gal	$550
TREATMENT		
UV	Whole system - 12 gpm	$800
UV bulb	Life: 10,000 hrs or 14 months	$80-$110
Downspout filter	Placed in Gutter	$250
1st FLUSH DIVERTER	Vertical pipe w/ ball float	$100
PUMP	1 hp (all in one package)	$575
PIPING (Purple)		
to Tank (lot)	PVC: 2"-6" (O&P) 20ft	$8 / LF
to House (lot)	PVC: 2"-6" (O&P) 50ft	$8/ LF
to Irrigation	PVC: 2"-6" (O&P) 50ft	$8 / LF
Backflow prev. valve	each	$200
STENCILS	Non-potable water	----
INSTALLATION	40% of material cost	$1400
TOTAL		$4,900

Table 5: Rainwater harvesting materials cost for neighborhood scenario

Item	Description	Cost	Units Assumed
TANKS			
Dry Det. Basin(1997)	$C = 12.4V^{0.760}$	$119,000	174,000ft^3
Below Ground Vault	$C = 38.1 (V / 0.02832)^{0.6816}$	$142,000	174,000ft^3
TREATMENT			
UV - neighborhood	Whole system - 200 gpm	$10000	
Catch basin filters	1 every 2 acres	$2000	50 catch basins
PUMP		$50,000	
PIPING (Purple)			
to Tank (neighbor.)	Concrete: 6" – 18" (O&P)	$15-$30 /LF	$23 - 14000 ft
to House (neighbor.)	HDPE- 4" – 10" (O&P)	$11-$27 / LF	$19 - 14000 ft
to Irrigation	PVC: 2"-6" (O&P)	$2-$12 / LF	$8 - 60 ft /house
Backflow prev. valve	each	$100-$200	$200 per house
STENCILS	Non-potable water	----	
INSTALLATION	40% of material cost	$470,000	
TOTAL		$1,650,000	

Note that there would also be on-going operation and maintenance costs for operation of both neighborhood and on-lot systems. These costs would include electricity, filter maintenance, operator for the neighborhood system, on-going training for home operators or contract maintenance and other on-going costs (periodic replacements/repairs, etc.).

ASSESSMENT OF HYDROLOGIC IMPACTS OF CISTERNS FOR NEIGHBORHOOD SCALE

Four community-scale residential re-use scenarios were analyzed based upon the above description of the 100-acre residential catchment. The four scenarios included:

A. Storage sized for 0.8" storm event and water reuse for toilet flushing only,
B. Storage sized for 0.8" storm event and water reuse for toilet flushing and outdoor uses,
C. Storage sized for 1.6" storm event and water reuse for toilet flushing only,
D. Storage sized for 1.6" storm event and water reuse for toilet flushing and outdoor uses,

Each scenario was modeled over a long period to better understand the potential hydrology performance of runoff storage and re-use systems in Orange County, California. Simplified representations were used for catchment runoff, cistern storage and re-use demands from toilet flushing and irrigation.

The Laguna Beach rainfall gage was used as a representative rainfall record for large parts of Orange County. The Laguna Beach gauging station is located in the City of Laguna Beach. The gauge elevation is 210 ft above mean sea level (AMSL). Reuse demand inputs were generated from IRWD estimates of indoor demand and irrigation demand. Results of this effort include the overall stormwater capture efficiency achieved in each scenario and the portion of residential demand that could be supplied by rainwater harvesting (RH).

METHODOLOGY

This section describes the methodology used to estimate system performance.

Model Selection

The EPA Stormwater Management Model (SWMM) Version 5.0 was used for continuous simulation analysis of the various facility configurations. SWMM is a dynamic rainfall-runoff simulation model used for single event or continuous simulation of runoff from primarily urban areas. The model accounts for various hydrologic processes that combined to produce stormwater runoff from urban areas. The model also contains a flexible set of hydraulic modeling capabilities used to route runoff and external inflows through the drainage system network of pipes, channels, storage/treatment units and diversion structures (USEPA, 2008). SWMM was selected because of its proven capabilities in simulation of urban hydrology and hydraulics, and its flexibility in representing the proposed systems. Although in this case, SWMM was used with some simplifying assumptions, it could be used with in a more sophisticated modeling approach to account for such factors as irrigation demand based upon available evapotranspiration rates, etc. that would allow for a more accurate analysis of irrigation demand then conducted in this simplified analysis.

Model Input Parameters

Table 6 shows the input parameters used to represent the tributary area to the re-use facilities. In addition, information from Tables 1 and 2 was used to characterize the attributes of each of the scenarios.

Table 6. Baseline SWMM Inputs - Hydrology

Parameter	Value	Units	Source/Rationale
Rainfall	Laguna 2 NCDC record (1952-1993)	in/hr	Representative of rainfall pattern at project locations: long period of record: good resolution: minimal missing data
Imperviousness	60	%	Consistent with hypothetical scenarios described in memo.
Slope	0.03	ft/ft	Includes roofs. lawns. streets. and sidewalks.
Impervious Roughness	0.01	-	Literature[1] (not sensitive to analysis)
Pervious Roughness	0.1	-	Literature[1] (not sensitive to analysis)
Impervious Depression Storage	0.02	inches	Literature[1] (sensitive to analysis. selected conservatively)
Pervious Depression Storage	0.10	inches	Literature[1] (sensitive to analysis. selected conservatively)
Ksat	0.15	in/hr	Literature[1] (representative of B/C soils) (moderately sensitive to analysis
IMD	0.25	in/in	Literature[1] (representative of B/C soils) (moderately sensitive to analysis. not highly variable)
Suction Head	8	inches	Literature[1] (representative of B/C soils) (not sensitive to analysis)
% of Imp area w/o DS	25%	-	SWMM default (moderately sensitive to analysis)
Path Length	500	ft	Typical of urban development
Routing	Imp and Perv routed directly to outlet	-	Conservative representation; in reality some imperviousness will be routed over pervious area. resulting in diminished volumes for small storm events
Dry Weather Flow	Assumed to be zero	cfs	Based on use of efficient irrigation methods

1 – Based on James and James. 2000.

Hydrology Validation

Average annual runoff coefficients recommended by the OC DAMP Table A-1 were compared to model results. For 60% impervious areas. the DAMP Table 1 recommends a runoff coefficient of 0.60. The SWMM model computed a long-term runoff coefficient of 0.58. This is believed to be adequately close for the purposes of this analysis.

Facility Representation

The storage and re-use systems were simulated as a simple underground storage feature (zero evapotranspiration) with multiple outlets to represent various types of re-use demand. The following assumptions were used:

- Storage volume was simulated per the hypothetical scenarios described in the memo. The baseline design storm depth was 0.8 inches for calculating the size of the storage facility. A scenario was also simulated that included twice as much storage (i.e. a 1.6 inch design storm).
- Toilet flushing was assumed to be the only indoor demand for harvested rainwater and was simulated as a constant use rate. It is acknowledged that toilet flushing will exert a time-dependent demand, most notably on a daily patter, however average rates were deemed acceptable for the modeling effort given the time scale of facility drawdown being considered (greater than 5 days).
- Irrigation demand was assumed constant within a single day, but to vary seasonally based on irrigation use data from IRWD's website (Table 2). The simulations did not account for reduced irrigation demands following wet periods that likely would significantly extend the storage drawdown times for irrigation use. Therefore, this analysis likely over predicts the effectiveness of the system in reducing runoff when irrigation is included.

Table 7: Landscape irrigation rates by month for IRWD service area (IRWD)

Month	Gal/mo per 2000 sf of landscaping	Gal/day per 2,000 sf of landscaping
Mar	3000	100
July	7500	250
Sept	5300	177
Dec	1900	63

Irrigation demand was interpolated between the monthly averages from Table 2 to yield monthly average values. The same yearly pattern of irrigation demand was assumed through the entire simulation period, though it is acknowledged that irrigation demand will vary by year (as well as following wet periods).

- An overflow weir was simulated to represent the condition in which the cistern is full and additional runoff bypasses the facility.

The simulation was run for 1952 through 1993 at 15-minute computational timesteps and one-hour reporting steps. Cumulative volumes were totaled and processed.

SUMMARY OF RESULTS

Table 3 provides a summary of key inputs and results for 42 years of continuous simulation.

Table 8: Key Inputs and Results

Key Inputs and Results	Units	Scenario			
		A	B	C	D
		Toilet Flushing Only. 0.8" design storm	Toilet Flushing + Irrigation. 0.8" design storm	Toilet Flushing Only. 1.6" design storm	Toilet Flushing + Irrigation. 1.6" design storm
Design Storm for Tank Volume	inches	0.8	0.8	1.6	1.6
Tank Volume	cf | ac-ft | MG	174.000 | 4.0 | 1.3		348,000 | 8.0 | 2.6	
Indoor Use Rate	cfs | gpd	0.0428 | 27,700			
Avg Ann Outdoor Use Rate (varies by month)	cfs | gpd	-	0.195 | 126.000	-	0.195 | 126.000
Average Annual Drawdown Time	days	47	8.5	94	17
Average Stormwater % Capture and Reuse	%	32%	55%	41%	68%
Avg Annual Volume of Stormwater Reused	MG | CCF	5.2 | 6,950	8.8 | 11,800	6.5 | 8,700	10.9 | 14.620

DISCUSSION

The modeling results illustrate several key concepts:

- Capture efficiency increases with higher use rate and larger volumes. Higher use rate serves to make more volume available for subsequent storms, while larger volume allows more water to be stored for use longer after the end of rainfall.
- The amount of runoff captured on an average annual basis by a DAMP sized cistern and used is on the order of 30 to 55%, and is likely closer to the 30 to 40 percent range due to optimistic irrigation demand assumptions. Therefore if no other treatment of runoff was provided. the system would leave about 60 to 70 percent of runoff untreated.
- Doubling the tanks size increases the percent capture, but at much less of a rate then the same percentage increase in size of the storage volume (i.e. double the volume with about a 10 percentage point increase in percent capture).

- Although the single lot scenario was not modeled. due to the fact that it does not include streets. the percent capture of runoff from a neighborhood with on-lot systems would be less overall than the community scenario due to street runoff not being included.

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APPENDIX – RAINWATER HARVESTING AND REUSE CODE ANALYSIS

Prepared by Mark Grey, Director of Environmental Affairs Building Industry Association of Southern California

The purpose of this document is to identify the California building codes that may govern design, installation and operation of rainwater harvesting and reuse systems (RHR) in new and redevelopment projects. This document may also aid in identifying relevant code sections for existing building retrofit to accept RHR.

Regulatory Background

California building and public safety codes do not explicitly recognize RHR or provide definitions for "rainwater" or "stormwater" and instead address plumbing and mechanical system criteria and use of appropriately treated wastewater effluent to protect public health. Plumbing and health and safety code adaptations to using treated wastewater effluent generally began in the early 1990s, with modifications made thereafter at various times. Neither the Uniform Plumbing Code nor the International Plumbing Code addresses the use of RHR.

Three California Code of Regulations sections govern direct reuse of treated wastewater effluent:

Title 24—Building Standards Code (plumbing code)

Title 22—Social Security (recycled water quality standards)

Title 17—Public Health (public water system cross-connection and backflow prevention)

Title 24 contains California building standards including the plumbing code (Chapter 16). Within Chapter 16, requirements for designing and installing dual-plumbed systems to accommodate treated wastewater effluent are found in Appendix J. Interestingly, Appendix J has never been formally adopted within Title 24 by the California Building and Standards Commission (CBSC) and serves as a guidance document. As of April 2009, the CBSC is considering incorporation of graywater recycling system installation standards into Appendix J. In any case, the mechanical design and installation of on-site (project level) or sub-regional or regional water treatment systems and their associated piping and pumping requirements would be governed under California plumbing code found in Title 24.

Title 22 contains the water quality standards for treated wastewater effluent used for dual plumbed systems within residential and commercial buildings and direct reuse of treated effluent for ground water recharge or for landscaping. Recycled water used within buildings for toilet flushing and urinals, or for most landscaping applications must meet disinfected tertiary recycled water standards. Less stringent disinfection standards are in place for other outdoor uses such as roadway landscaping. There are multiple water treatment technologies capable of meeting Title 22 requirements (CDPH. 2009). Two general classes exist: filtration and disinfection. Filtration technologies generally include granular media, cloth media, or membrane systems. Disinfection technologies include ultraviolet, pasteurization, or ozone/peroxide systems. An important project level planning consideration arises when capture and storage projects intend to use storage facilities in excess of 100,000 gallons or piping systems greater than 16 inches in diameter. Use of these large storage or conveyance systems triggers California Environmental Quality Act compliance.

Title 17 contains cross-connection and backflow prevention requirements where the treated wastewater effluent meeting Title 22 water quality standards is dual plumbed into potable water systems.

Integration of rainfall harvesting and reuse systems into existing California code structure

Given that state codes do not explicitly recognize rainfall or stormwater which is collected from roof areas or other impervious surfaces and stored and/or treated for use, discretion in plumbing and treatment system component approval will likely reside at the county or city level or both through local codes and ordinances. Few case studies are available for California, but available sources suggest multiple permits will be necessary from the local permitting authorities. These permits are required for installation of piping and mechanical systems (such as treatment) within the building footprint and envelope and below ground around the perimeter of the building site.

From a code transfer standpoint, California plumbing code (Title 24, Chapter 16) and cross connection/backflow system design standards (Title 17, Chapter 5) appear to be directly transferrable to RHR. Likewise, California Title 22, Division 4 Environmental Health standards would always apply to treated rainfall or stormwater serving dual plumbed systems (for toilet and urinal use within the building envelope). Title 22 standards for irrigation use also appear to be generally applicable; uncertainty arises for small single family homes or other buildings where only roof runoff will be collected and used for landscape supply only. Cross connection and backflow protection is always required whenever a recycled (presumably rainwater or stormwater) water source is integrated into the existing potable water system to meet indoor or outdoor demand.

Case Studies and National Code Guidance Documents on Rainwater Harvesting

City of San Francisco, California. The City of San Francisco amended its plumbing code in 2005 to allow individual property owners to direct rainwater to alternative locations such as rain gardens, rain barrels, and cisterns. Both landscaping and toilet flushing uses are allowed. To install such a system, an applicant must obtain a plumbing permit and a building permit, and if the system will include pumps, be located on a roof, or will be located underground, additional permits are necessary. If the rainfall collection system is not connected to the existing plumbing system, then permits are not necessary.

Oregon Building Codes Division. Oregon Smart Guide: Rainwater Harvesting. The Oregon Building Codes Division allows collection of roof runoff only for rainfall harvesting. A project applicant must obtain approval from the local authority having building code jurisdiction. Systems must be designed according to Appendix M.

Santa Fe County, New Mexico. Rainwater Catchment System Ordinance. This is a county ordinance that requires installation of rainwater catchment systems for all commercial and residential development from one to four dwellings. Cisterns are required to be designed to capture 1.5 gallons per square foot of roof area. Water collected must be directed to landscape irrigation.

Texas Water Development Board. Rainwater Harvesting Potential and Guidelines. The Texas State Board of Plumbing Examiners governs plumbing regulations in Texas. According to the document, most communities in Texas follow either the Uniform Plumbing Code or International Plumbing Code. Neither code structure addresses rainwater harvesting.

References Cited and Resources:

California Department of Public Health. 2009. Regulations Related to Recycled Water. Division of Drinking Water. 33 pp.

California Department of Public Health. 2009. Treatment Technology Report for Recycled Water. Division of Drinking Water and Environmental Management. 52 pp.

Oregon Building Codes Division, Oregon Plumbing Codes, Chapter 16, Part II

Oregon Smart Guide: Rainwater Harvesting. Undated.

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Memorandum

Date: 09 April 2009

To: Mark Grey, Director of Environmental Affairs Building Industry Association Of Southern California

From: Eric Strecker, Nichole Dunn, and Klaus Rathfelder, Geosyntec

Subject: NRDC comments on Draft NPDES Stormwater Permit for the County of Orange, Tentative Order No. R8-2008-0030

The Natural Resources Defense Council (NRDC) submitted comments on the Draft NPDES Stormwater Permit for the County of Orange, Tentative Order No. R8-2008-0030 (referred to herein as NRDC comments). As part of their comments, NRDC cites six numeric stormwater standards from jurisdictions nationwide as evidence that various jurisdictions have begun to implement numeric standards that require onsite retention, infiltration, and/or harvesting. Specific citations are included below in italics.

Geosyntec has reviewed the requirements of the stormwater standards cited by NRDC. Following each of the citations below, we provide of summary of the stormwater standards referenced. In particular, we focus on requirements for onsite retention and reuse and if and how these requirements consider site conditions. We have also attempted to characterize the current status of implementation of the requirements.

While the jurisdictions below may have begun implementing numeric standards with a focus on keeping and managing stormwater onsite, they generally recognize that this is not possible in all situations and allow for alternative measures in lieu of retaining all stormwater onsite.

Pennsylvania

Requirement: "*Capture at least the first two inches of rainfall from all impervious surfaces and retain onsite (through reuse, evaporation, transpiration, and/or infiltration) at least the first one inch of runoff" (NRDC comments/pg. 3)*

According to the Pennsylvania Stormwater Best Management Practices Manual, cited as the reference for the above information, "Pennsylvania laws and regulations do not directly manage stormwater at the state level, although some state level management occurs through the Stormwater Management Act and the NPDES permitting program." However, the 3/2009 Draft NPDES Stormwater Discharges from Small Municipal Separate Storm Sewer Systems (MS4s) General Permit (PAG-13) requires applicants to comply with a Model Stormwater ordinance approved by the DEP in 2005 or later, or the 2008 Pennsylvania Model Stormwater Management Ordinance (SMO). Counties that discharge to special protection watersheds are not eligible for the General Permit and must apply for an individual permit. The volume control requirements stated in the Pennsylvania Stormwater Best Management Practices Manual are required by the Draft 2009 Pennsylvania SMO. Therefore, the standards in the Pennsylvania Stormwater BMP Manual are a requirement in the Draft Phase II General Permit under development by the Pennsylvania Department of Environmental Protection. In addition, the standard cited by NRDC is one of two guidelines in the SMO. The standard selected by NRDC is one that is specifically independent of site constraints and it was stated that it should not be used when regulated activities are greater than 1 acre or for any project that requires design of stormwater storage facilities. Also known as Control Guideline 2 or the Simplified Method, this guideline requires:

- The first 2" of runoff from NEW impervious surfaces be captured.
- At least the first 1" of runoff from NEW impervious surfaces be permanently removed from the runoff flow through reuse, evaporation, transpiration and/or infiltration.
- Where possible, all permanently removed runoff should infiltrated; however, it is suggested that in all cases at least 0.5" should be infiltrated.

The other guideline, which was not cited by NRDC, is Control Guideline 1 or the Design Storm Method. This guideline is applicable to any size of regulated activity and requires that the post-development total runoff volume for all storms equal to or less than the 2-year/24-hour event to not increase. This guideline also requires modeling and requires that for the existing condition all pervious areas must be modeled as in good condition and 20% of the existing impervious area must also be modeled as pervious area in good condition.

The Pennsylvania Stormwater BMP Manual also calls out several Special Management Areas (i.e., Brownfields, Highways and roads, karst areas, mined lands, near supply wells, urban areas, surface water supplies and Special Protection Waters) that may require the above standards to be modified on a case-by-case basis due to site conditions. Neither the General Permit, nor the model ordinance specifically addresses the limitations of Special Management Areas, though they do address Special Protection Waters.

Since the General Permit and SMO are still in draft form it is unknown how the authorities will address situations where Control Guideline 1 is used and the onsite management of the first 1" of runoff from new impervious surfaces is not feasible, or where the site is in a Special Management Area.

Pertinent findings from our review of the Pennsylvania stormwater ordinance are:

- The requirements cited by NRDC are general requirements (SMO) of a Draft Phase II general permit via reference to the manual. The requirements are not specific conditions in the Permit.
- The requirements cited are applicable to sites of 1 acre or less or that do not require design of stormwater storage facilities. For larger sites, the Draft SMO requires no increase in runoff volume up to the 2-year/24-hour event, which implicitly considers the pre-development site conditions.
- The Draft SMO provides allowances for special site constraints.
- The application of the above is still proposed in a draft permit, so there are no cases studies or information about the practical implications of the requirements.

Anacostia, Washington, D.C.

Requirement: *"Retain onsite the first one inch of rainfall and provide water quality treatment for rainfall up to the two-year storm volume" (NRDC comments/pg. 3)*

The original requirement was published in Final Environmental Standards June 2007, by the Anacostia Waterfront Corporation acting on behalf of the District of Columbia. The Anacostia Waterfront Initiative was a Memorandum of Understanding (MOU) entered into by 20 District and Federal agencies that owned or controlled land along the Anacostia Riverfront. The partnership formed by the MOU was formed to help attain a vision for the waterfront areas, known as the Waterfront Revitalization Endeavor. The Anacostia Waterfront Corporation was created to oversee and implement the Anacostia Waterfront Initiative for the cleanup and redevelopment along the Anacostia River. Before being dissolved by the NCRC and AWC Reorganization Act of 2008, the Anacostia Waterfront Corporation published, "Final Environmental Standards" in June of 2007 that required retention of the first 1" of runoff for beneficial reuse. However, the standards allow for exceptions where infiltration or collection and reuse are not feasible for public safety or environmental protection. If an exception is required, physical and/or financial offsets may be applied. Physical offsets require 1.5 times the amount of the stormwater that is not retained on site to be reduced through the off-site use of greenroofs, potable water conservation, and LID measures. However, if potable water conservation is used as a physical offset only 25% of the annual volume saved is credited. Financial offsets consist of payments to the Anacostia River Trust Corporation, a subsidiary of AWC, for twice the cost of obtaining an equivalent reduction of the stormwater flow being offset. Since the AWC was rolled back into the Washington D.C. Office of Planning, the District Department of the Environment is responsible for the implementation of these requirements.

While these standards have gone into law, they will not go into effect until the regulations have been promulgated, which has not happened to date[1].

Pertinent findings from our review of Anacostia stormwater requirements are:

- The requirements do not apply to the entire geographic area of the city, but are limited to small special district of 3,070 acres in area along the waterfront.
- The requirements specify retention and infiltration as the preferred stormwater management control, followed by capture and reuse.
- The requirements provide for offsets in cases when site conditions limit feasibility of infiltration and reuse.
- Since the regulations have not been issued, there are no cases studies or information about the practical implications of the requirements.

West Virginia

Requirement: "*Retain onsite the first one inch of rainfall from a 24-hour storm preceded by 48 hours of no measurable precipitation" (NRDC comments/pg. 3)*

While the draft permit currently under consideration in West Virginia states that the first 1" of rainfall must be kept and managed onsite, it also allows for credits if certain types of development are used. The five development types that earn credits are:

- Redevelopment
- Brownfield redevelopment
- High Density (>7 units per acre)
- Vertical Density (Floor to Area Ratio of 2 or >18 units per acre)
- Mixed Use and Transit Oriented Development (within 1/2 mile of transit)

Each of the development types above earns a credit of 0.1" against the first 1" of rainfall. Therefore, it is possible that a site would need to mitigate only 0.5". Similar to the Anacostia standard, West Virginia allows for physical and/or financial offsets where on-site treatment of the entire amount of runoff is not possible or practical. However, the draft West Virginia permit allows offsets for a maximum of 0.4" of the original amount (i.e., if the entire first 1" of rainfall needed to be kept and managed then offsets would only be allowed for 0.4" and 0.6" would need to be managed onsite).

[1] Personal communication with Shane Farthing of District Department of the Environment. Phone. Apr. 06. 2009.

The West Virginia standard has not been implemented yet since the permit is still in draft form. Therefore, it is unknown how the regulators would address a situation where a developer was not able to keep and manage the entire amount of rainfall because of site constraints or feasibility.

Pertinent findings from our review of West Virginia stormwater requirements are:

- The requirements specify an array of options for meeting on-site retention requirements.
- Stormwater credit options provide incentives for high density development in Brownfield areas and transportation corridors.
- The requirements provide for offsets in cases when site conditions limit feasibility of infiltration and reuse; however, full offsets are not allowable, and some on-site retention will be required for all developments.
- It is a draft permit, so there are no cases studies or information about the practical implications of the requirements.

Georgia

Requirement: *"Treat the runoff from 85% of the storms that occur in an average year (i.e., provide treatment for the runoff that results from a rainfall depth of 1.2 inches)" (NRDC comments/pg. 3)*

Similar to PA, this standard is from the GA Stormwater Management Manual, which provides guidance on how jurisdictions in the state might address stormwater management. While the entire state has not adopted this standard, some local jurisdictions such as the Metropolitan North Georgia Water District have adopted model ordinances that direct their members to follow the guidelines in the Stormwater Management Manual. In either case, the standard merely requires treatment of the first 1.2" of rainfall; it does not require retention or infiltration of the stormwater.

Central Coast, California (RWQCB, Phase II)

Requirement: *"Limit effective impervious area ("EIA") at development projects to no more than 5% of total project area (interim criteria); establish an EIA limitation between 3% and 10% in local stormwater management plans (permanent criteria)" (NRDC comments/pg. 4)*

The above standard was set forth in a letter to small MS4s. Limiting the effective impervious area is an ambiguous task, as ineffective impervious area is not defined clearly. It is not clear if effective impervious area implies:

1. Total offsite runoff is limited to a volume that is equivalent to 5% impervious area. Essentially this requires that runoff generated by 95% of the project area. under most conditions be managed on site: or
2. Runoff that is not directly connected to the storm sewer. In other words. runoff from 95% of the site must be directed to pervious areas prior to collection in the storm sewer.

This is an interim criteria and it remains unclear as to what ineffective really means.

All Federal Buildings over 5,000 square feet (under EPA's draft guidance for implementation of the Energy Independence and Security Act of 2007)

Requirement: *"Manage onsite (i.e.. prevent the offsite discharge of) the 95th percentile storm through infiltration, harvesting, and/or evapotranspiration." (NRDC comments/pg. 4)*

According to H.R.6 Energy Independence and Security Act (EISA) of 2007. Sec. 438. Storm Water Runoff Requirements for Federal Development Projects include:

> "The sponsor of any development or redevelopment project involving a Federal facility with a footprint that exceeds 5,000 square feet shall use site planning, design, construction. and maintenance strategies for the property to maintain or restore, to the maximum extent technically feasible. the predevelopment hydrology of the property with regard to the temperature, rate, volume, and duration of flow."

In a presentation by Jennifer Molloy and Robert Goo from the USEPA in February 2009 to the Interagency Sustainability Work Group, they presented two options for meeting the Section 438 requirement of the EISA. Option 1 is to control the 95th percentile rainfall event by managing it onsite by using infiltration, evapotranspiration, and/or re-use. Option 2 is to preserve the predevelopment hydrology (rate, volume. duration, and temperature) by conducting hydrologic and hydraulic analyses for the 1, 2. 10. and 100-year 24-hour storm events. If Options 1 and 2 are not technically feasible due to site conditions or other factors, the agency/department must follow a process to employ onsite practices to the maximum extent technically feasible and document the design. Again, this stormwater management requirement recognizes that onsite management is not always feasible. The EPA guidance manual is still in draft form. Geosyntec has developed technical comments on the guidance manual and its methods and results regarding effectiveness.

Key points from Geosyntec's technical comments in regards to the EPA's numeric standards requiring onsite retention, infiltration. and/or harvesting include:

- That retention of the 95th percentile storm event may not be cost-effective for achieving the intended level of protection. This is not supported in the Draft Guidance. nor is it generally supported by the body of scientific knowledge.

- The requirement to retain the 95th percentile storm event does not account for the drawdown time of the captured volume. Therefore, if the capture system draws down slowly the storage volume remaining when the next storm arrives may not be adequate to capture the volume generated by the next storm, which would cause the second storm to bypass or partially bypass the retention system.

See attached comments on the draft manual submitted to EPA.

Discussion/Implications

Out of the six standards cited, the only one that does not specifically recognize that onsite management will not be possible in all cases is the Central Coast standard that is required to be incorporated into small MS4s stormwater management plans for them to be approved. However, this standard is also not as clear as the rest of the standards cited because it does not provide a clear definition of effective impervious areas.

Most of the jurisdictions cited above, recognize that it may not be feasible to manage the entire volume onsite and offer methods for improving the quality of the stormwater runoff within other means. Pennsylvania requires the first 1" of rainfall from new impervious surfaces to be permanently removed from the runoff flow. However, this regulation only applies when regulated activities are less than 1 acre and do not require stormwater storage facilities. In addition, the Pennsylvania Stormwater BMP Manual recognizes that when either of the control guidelines are applied to project, if the project is located in a Special Management Area, (i.e., brownfields, highways and roads, karst areas, mined lands, near supply wells, urban areas, surface water supplies and Special Protection Waters) the guidelines may need to be modified on a case-by-case basis.

The draft permit proposed by West Virginia requires onsite stormwater retention between 0.1" and 1", depending on how many credits are issued for the type of development, but also allows offsets for up to 0.4" of that amount. However, they recognize that it may not be technically feasible to keep the entire amount of rainfall onsite and allow for deviations from that rule as long as there is a net improvement in the overall stormwater runoff for a particular sewershed/watershed.

Anacostia's standard is less stringent that West Virginia's standard only in that they do not limit the allowed offset (i.e., if needed the entire standard could be addressed by using offsets). However, Anacostia does not offer credit for different development types either. Similar to Pennsylvania, the EPA in their draft guidance for EISA Sec. 438 they offer two methods for preserving the predevelopment hydrology and if neither of those will fully address the problem, they have a process for implementing BMPs to the maximum extent technically feasible.

Georgia's stormwater management manual and associated ordinances merely require the treatment of the first 1.2" of rainfall. It recognizes that in critical or sensitive areas, additional requirements may be needed and the use of structural controls may need to be restricted to protect a special resource or address certain water quality or drainage problems.

Based on the information presented above, while various jurisdictions are moving towards implementing numeric stormwater performance standards that include retention, they recognize that numeric standards for retention are difficult to implement across all site conditions and allow alternative methods to improve the stormwater runoff quality. None of the jurisdictions cited above that clearly require implementation of retention and infiltration as the preferred method for addressing post-construction stormwater runoff have had their regulations go into effect. Therefore, there are no case studies or information about the practical implications of the requirements and how they are actually being applied.

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Memorandum

Date: 9 April 2009

To: Robert Goo, Nonpoint Source Control Branch, US Environmental Protection Agency

From: Eric Strecker and Aaron Poresky, Geosyntec Consultants

Subject: Comments on *Technical Guidance on Implementing Section 438 of the Energy Independence and Security Act*

PURPOSE

The purpose of this memo is to evaluate the content of Draft *Technical Guidance on Implementing Section 438 of the Energy Independence and Security Act* (referred to herein as the Draft Guidance) and provide recommendations for improvements to that document and further study. This review is based on the version of the Draft Guidance that was sent to Eric Strecker, Geosyntec, from Robert Goo, EPA, on March 16, 2009, noted as "Draft for discussion with ISWG".

SCOPE AND INTENT OF DRAFT GUIDANCE

Quoting from the Draft Guidance (p 1):

> Section 438 of [the Energy Independence and Security Act (2007)] establishes strict stormwater runoff requirements for Federal development and redevelopment projects. The provision reads as follows:
>
> > "Storm water runoff requirements for federal development projects. The sponsor of any development or redevelopment project involving a Federal facility with a footprint that exceeds 5,000 square feet shall use site planning, design, construction, and maintenance strategies for the property to maintain or restore, to the maximum extent technically feasible, the predevelopment hydrology of the property with regard to the temperature, rate, volume, and duration of flow."
>
> The intent of Section 438 of the Energy Independence and Security Act (EISA) is to require federal agencies to develop and redevelop applicable facilities in a manner that reduces stormwater runoff and associated pollutant loadings in order to protect or restore the waters of the U.S.

The stated intent of the Draft Guidance is "...to provide guidance and background information on Section 438." Quoting from the Draft Guidance (p. 2):

> "The document contains guidance on how compliance with Section 438 can be achieved, measured, evaluated, and reported. In addition, information detailing the rationale for the stormwater management approach contained herein has been included.
>
> The following information is presented within this document:
>
> **Part I: Implementation Framework**
>
> A. Background
>
> B. Benefits and outcomes of the new stormwater performance requirements
>
> C. How to meet the requirements of Section 438
>
> D. Applicability and definitions
>
> E. Complying with the performance requirement
>
> F. Calculating the 95th percentile rainfall event"

The Draft Guidance also contains case studies representing "...typical Federal installations... selected to demonstrate the feasibility of providing adequate stormwater control for a range of site conditions and building designs."

ORGANIZATION OF GEOSYNTEC REVIEW

This review is organized into the following sections and subsections:

- **Geosyntec Basis of Evaluation**: list of criteria used in reviewing the Draft Guidance
- **Review of Draft Guidance**
  - *Summary of Contents of Draft Guidance*: brief overview of the contents of Part I of the Draft Guidance
  - *Geosyntec Review:* key findings of our review
- **Review of Case Studies**
  - *Summary of Contents of Case Studies:* brief overview of the contents of Part II of the Draft Guidance
  - *Geosyntec Review:* key findings of our review of Part II with recommendations interspersed
- **Geosyntec Recommendations**: summary of recommendations

GEOSYNTEC BASIS OF EVALUATION

Geosyntec has approached this evaluation with the following general criteria:

- Guidance should result in project design features that protect receiving waters from stormwater impacts and do not have potential to cause unintended impacts.
- Guidance that results in protective designs that cost substantially more than other equally- or nearly equally-protective solutions, should not be encouraged.
- Guidance should consider the scale of the project and site-specific factors.
- Guidance should be based on the latest scientific findings and make use of accepted tools.
- Guidance should be reasonably simple to interpret and implement.

REVIEW OF DRAFT GUIDANCE

Summary of contents of Draft Guidance

The document recommends that an appropriate hydrologic standard for stormwater management would be based upon in part on either a design-storm or continuous simulation results. The proposed standard is based on either:

1. **Event-based:** Retention and infiltration, ET or reuse of the total volume from the 95th percentile, 24-hr storm event (days with <=0.1" removed), or
2. **Continuous simulation:** Matching the predevelopment rate, volume, duration and temperature of runoff for 1, 2, 10, 25, 50 and 100 year storms.

The first option is based on the stated assumption that natural watersheds produce runoff from only approximately 5% of storms. The document does not attempt to support this assumption or discuss the potential consequences if this assumption does not apply to a specific watershed or region. In areas of the country where storms arrive back-to-back, the assumption of only 5% of the storms contributing to runoff under natural conditions may not be true. This event-based option does not include requirements or guidance on drawdown (or re-use) time of retained water. This means that although the initial storm may be captured and either retained, that subsequent storms including even those smaller than the event based storm may cause discharge if the storage volume has not been recovered. The document provides guidance on how to calculate a locally-applicable design storm from daily or hourly rainfall data.

The second option is ostensibly based on the assumption that that it is protective to control events from the 1-yr to 100-yr return periods. Continuous simulation models would implicitly factor storage system drawdown (re-use or infiltraton) into evaluation of project design features. This option requires stormwater managers to select appropriate models and utilize them prudently. It also requires one to establish which storms in the record are "equivalent" to the design storms listed. In most areas of the country. there are about at most 65 years of hourly rainfall data. so identifying 100-year and even 50-year storms would be difficult at best.

Exceptions to these criteria would be allowed if infeasibility could be demonstrated by the project sponsor. If infeasibility were to be established. the two options above would be modified as follows:

1. **Event based:** Infiltrate, evapotranspire and/or re-use the maximum volume technically feasible on site and provide treatment and peak flow control for the remaining volume below the 95th percentile volume,

2. **Continuous simulation:** Provide treatment and match peak flow events where complete matching of peaks. volumes, duration and temperature cannot be achieved.

The document outlines the process to determine Maximum Extent Technically Feasible (METF). It seems that the cost of compliance is not a factor in determining MEFT.

<u>Geosyntec Review</u>

Geosyntec offers the following general findings:

1. Allowing two options for designing BMPs is consistent with the desires to make guidance suitable for various project scales and would be reasonably simple to implement if proper guidance is provided.

2. Both design options partially fulfill the criteria to consider site-specific factors. but do not sufficiently incorporate site specific factors as detailed below.

3. Our primary criticisms of the event-based design method are:

   a) The suitability of retention of the 95th percentile storm event to cost-effectively achieve the intended level of protection is not supported in the Draft Guidance and is not generally supported by the body of scientific knowledge. We feel it would be prudent to study the performance that would result for example projects using this standard to determine whether it generally achieves the intended purpose of the regulation. This could be done with continuous simulation modeling analyses (preferably calibrated) or possibly through research. Continuous simulation could be used to model over a long time period. how much runoff would occur. the amount infiltrated. the amount re-used. and the amount evapotransporated for both natural conditions and developed with the control in place. Various scenarios of infiltration rates. re-use rates (e.g. estimated actual irrigation. toilet flushing. etc.). etc. should be evaluated.

b) The methodology does not factor in drawdown time of captured volume, which is inextricably linked with long-term performance. For example, take the scenario where a 95th percentile, 24-hr storm (say 1.4 inches) and a 50th percentile, 24-hr storm (say 0.8 inches) are spaced by two days. Under the event-based sizing methodology in the Draft Guidelines, the first storm would be fully captured. If the drawdown time of this captured volume was less than 2 days, the entire volume of the second storm would surely be captured. However, if the drawdown time of the BMP was 10 days (say for re-use in irrigation or toilet flushing), only about 0.3 inches worth of storage would be made available in the two-day inter-event window, and thus about than 0.5 inches of the subsequent storm event would bypass. Either of these cases would be consistent with the Draft Guidelines as they are now written.

This effect is exacerbated by the fact that storms do not observe clock hours. If a storm is artificially divided by the change of day, there would effectively be no inter-event time. Storm events segregated by an inter-event time are typically larger than those segregated by the calendar day.

The Draft Guidance states that the intent of this requirement is to allow only 5% of events to discharge. The examples provided above essentially prove that unless the 95th percentile storm draws down relatively immediately, this standard cannot meet its stated intent. For this standard to result in consistent performance, it should be accompanied by a required drawdown time (and then an analysis to show that the drawdown time is requirement is feasible via either infiltration, evapotranspirtion, and/or re-use), or possibly have a sliding scale of design storm as a function of drawdown time. For example, a 1.4-inch design storm with 1-day drawdown time may result in the same overall performance as a 2.0-inch design storm with a 5-day drawdown time. These supposed relationships are provided to illustrate the concept and would depend on local rainfall patterns. We have found that in many cases, for re-use to be feasible, that the density of toilet flushers to impervious area must be fairly high. Irrigation use is limited by already soil saturated conditions following an event(s) and lower evapotranspiration rates during typical rainy periods in the southwest for example and much of the winter throughout the US.

4. Our primary criticisms of the continuous hydrology design method are:

a) The range of flows required to be controlled does not seem to be protective based on the body of knowledge. It has been widely demonstrated that flows less than the one-year average return interval may cause erosion and account for a major portion of the overall erosive work done on a stream. As written, the Draft Guidance may encourage designs that would result in extended discharge just below 1-yr flowrate, effectively increasing the duration of such flows. Extending low flows may result in channel erosion due to longer durations of erosive flows compared to predevelopment, and may result in habitat impacts by modifying the flow regime in ephemeral or intermittent streams (i.e. by increasing the duration of low flows that then results in conversion of open and typically dry creek beds in the southwest under natural conditions to willow or non-native vegetation thickets). Over-infiltration above natural levels can also increase the duration of groundwater discharges to streams potentially having detrimental habitat impacts. The Draft Guidance should consider all erosive flows, consider natural the water balance that includes groundwater recharge levels, and finally include considerations for changes to downstream flow regime, including smaller flows, from both surface runoff and groundwater discharges.

b) The standard does not account for potentially important sediment supply reductions in the watershed. If the standard was modified as suggested above to cover all erosive flows, theoretically the stream energy, and thus sediment transport, would be approximately balanced between pre- and post-development. However, if the stream is sediment transport limited, a change in the amount of sediment entering the stream may result in changes to channel geomorphology. If development activities result in stabilization (e.g. upland areas that become impervious or are landscaped that reduce sediment supply) or disconnection of areas that were major sediment sources in pre-developed conditions, this alone may result in channel down-cutting even if hydrology were perfectly matched. In areas of the Southwest, sediment supply from upland areas is substantial and needs to be considered. The standard should require at least a minimal sediment balance analysis in conjunction with flow control.

c) Finally, the continuous simulation hydrology standard should be accompanied by guidance on how to extract "design storms" (i.e. 1-yr, 2-yr… 100-yr) events from the continuous record. These may be defined in a variety of ways (i.e. independence criteria, statistical methods, etc) which could theoretically lead to different overall performance between projects based on assumptions used in design. Likewise, the estimation of storms with long return intervals is difficult where continuous periods of record are limited to less than the return interval of the event under consideration (i.e. estimating a 100-year event from a 40-year record).

5. There is not a consideration in the Draft Guidance for cases where infiltration may be feasible, but could create unintended consequences. For example, it is highly unlikely that pre-development evapotranspiration rates are matched in the developed condition and therefore infiltration to the extent that natural runoff rates are matched, would cause

infiltration to occur above natural rates. In some situations this could be problematic, resulting in base flows in intermittent or ephemeral streams where none may have previously existed or existed for shorter durations. In other cases, where aquifers have been drawn-down below natural levels, it could be a significant benefit to infiltrate more than natural. The effects on overall water balance, including infiltration and evapotranspiration as well as runoff should be included and considered in feasibility analyses.

6. Finally, the Guidance relies on previously-conducted case studies documented in *Reducing Stormwater Costs through LID Strategies and Practices* (EPA 841-F-07-006, December 2007 - available for download at www.epa.gov/nps/lid) to reach the general conclusion that the implementation of the types of BMPs required by the standard would results in cost savings over traditional stormwater management design. Geosyntec acknowledges that LID can result in substantial avoided costs and thus overall savings. However, we also believe that the conclusions of the above-referenced report may be taken out of context in estimating the cost of the proposed requirements.

   a) Out of the 17 case studies, only one provided the volumetric design criteria used for the case studies evaluated, and only three provided a narrative summary of performance. The Seattle SEA Streets study found that swales and bioretention with a design storm depth of 0.75 inch reduced runoff by more than 99 percent. Based on the 95th percentile depth of 1.6 inches that the Draft Guidance computes for Seattle, this level of performance is possibly an outlier due to very infiltrative soils or other anomalies in design and analysis. The cost of the facilities would certainly have been less when designing to a 0.75-inch design storm compared to a 1.6-inch design storm. There was also not assessment of impacts to the overall water balance from this system. As it is unlikely that pre-development and current evapotranspiration rates are the same, it is very likely that this system is infiltrating to the aquifer more water than natural. If this was done throughout the watershed, what would the consequences be? The other two studies that reported performance were Crown Street, Vancouver, British Columbia (90% volume reduction estimated through modeling) and Somerset Subdivision, Prince George's County, Maryland (20% reduction in frequency of discharge). It is believed that many of the studies contained in the above-reference document were based on design criteria less stringent than that proposed by the Draft Guidance. This would be an important comparison to make when relying on the findings of the above-referenced document.

   b) Some of the studies relied on BMPs such as narrowing street width and downspout disconnection that would not be widely applicable to higher-density projects. Of the BMPs that would likely be used to comply with the Draft Guidance for higher-density projects (bioretention, permeable pavement, green roofs, and cisterns), permeable pavement was considered in only two of 17 case studies, and green roofs were considered in only one of 17 studies (cost-benefit analysis showed substantially greater costs for this study). Cisterns with reuse were not considered in any of the 17 studies.

Overall, we believe that further study is needed to determine whether it is valid to use the above-referenced study to support conclusions about the cost and effectiveness of the requirements contained in the Draft Guidance.

REVIEW OF CASE STUDIES

Summary of Contents of Case Studies

Case studies were completed for 8 sites. The studies used various modeling methods to estimate the runoff volume from the 95th percentile storm, established fixed design criteria for a selected suite of BMPs, and identified ways in which the BMPs could be implemented on each site to achieve the event-based standard. Each case study was a volumetric exercise that did not consider routing or drawdown characteristics. Bioretention and porous pavement BMPs appeared to have been designed to ensure 24-hr drawdown in B soils, however designs were not adjusted for cases with C or D soils, which are typical of many urban areas. Regeneration of storage capacity (i.e. drawdown by ET and/or re-use) was not considered for greenroofs and cisterns which do not rely on infiltration to dispose of stored water. Given these limitations, the case studies generally showed that BMPs to capture the 95th percentile storm event could be installed on all sites. One of the primary conclusions of the case studies was related to the type of models that could be used to generate the runoff volume that needed to be capture. Modeling was not conducted to estimate long-term performance.

Geosyntec Review

Geosyntec offers the following general findings:

1. Runoff volumes were generally reasonable and the evaluation of different models to generate runoff volumes was informative. One criticism of all the methods used is that generation of runoff volumes did not consider antecedent conditions which may occur following a previous day with rainfall. The estimates assume maximum infiltration potential at the beginning of each simulation. Likewise, rainfall volumes were distributed evenly across all hours in the day, which would tend to smooth the intensity of rainfall and inherently produce less runoff in most models. We do not feel it is necessary to revisit this analysis as the variability between model results was not great.

2. The site development patterns appeared to be a reasonable cross-section of federal projects. While it would have been informative to see a case study for Southern California, the sites encompassed a range of geographic regions. Some gages in the coastal mountains of Southern California have significantly higher 95th percentile rainfall than the highest of the locations studied. For example, the 95th percentile, 24-hr rainfall depth is 2.5 inches at the NCDC gage in Newhall, CA (046162; 1948-Present).

3. The scope of the studies did not evaluate long-term performance that would result from the proposed suites of BMPs, thus only limited conclusions can be drawn. Hourly precipitation data are available for at least 20 years (and in most cases 30 to 50 years plus) in nearly all parts of the country. Therefore, sufficient data would be available to produce a meaningful simulation of the long-term performance that would account for antecedent conditions and ability to infiltrate, re-use water for irrigation, etc. While we understand the effort that such a study would involve, we believe it is minor compared to the cost of complying with this standard.

4. Some BMP design assumptions were developed with consideration for soil infiltration rates, which we believe was a well-considered element of the case studies. However, regeneration rates of greenroofs and cisterns were not considered in developing the design assumptions. This may have resulted in misrepresentative calculations of the spatial extent required for these BMPs. For example, the design retention depth of greenroofs was assumed to be 1 inch. However, during cold and wet months, ET can approach zero and even in Southern California falls to near 0.05 inches/day. As such, drawdown of 1 inch of retained water could typically take about 20 or more days in the times of year when the most rainfall occurs in Southern California (January/February; this will vary by location). Depending on whether cistern water is used for indoor uses (fairly steady demand) or outdoor uses (demand can be lowest during wettest/coldest times of the year) or both, and depending on the demand rate, a drawdown time on the order of 10 to 20 days would be typical for cisterns. It is questionable whether such a BMP could be considered to fulfill its intended function if the storage would not be re-established relatively soon after the end of rainfall.

   Additionally, BMP design for bioretention and porous pavement implicitly assumed 24-hr drawdown time based on infiltration rates characteristic of B soils. These were not adjusted for the scenarios that considered C or D soils. In such cases, it is likely that higher runoff would be generated from the watershed, and infiltration rates under BMPs would be slower. BMPs would have to be shallower (and thus more extensive) to draw down in the same amount of time. This consideration both introduces uncertainty into the case study findings and suggests that Draft Guidance possibly should account for existing condition runoff in calculating post-development requirements (i.e. a "delta volume" standard).

5. Other infiltration issues should be considered, including whether abnormal groundwater recharge could occur which could lead to geotechnical issues or habitat changes down gradient (i.e. extending duration of flows in ephemeral streams) and/or the presence of natural or man-caused plumes or soil contamination that could be further mobilized by increased infiltration. These factors may limit where infiltration is either feasible or advisable. In general, more assessment of the effects on overall water balance would be useful.

Overall, the case studies are useful in understanding how BMPs could be applied to various development times. However, they are limited in their findings of feasibility, and do not allow for conclusions about performance or cost.

GEOSYNTEC RECOMMENDATIONS

In summary of the above commentary, we offer the following recommendations.

1. Revisit and support or revise the assumption that 95 percent of storms do not generate runoff in the undeveloped condition, hence the rationale for selection of the 95th percentile storm as a design storm.

2. Revisit and support or revise the range of flows required for peak and volume matching when using the continuous simulation option; consider incorporating sediment balance and habitat changes into guidance for applying this method.

3. Evaluate selected case study scenarios with continuous simulation methods that include storage draw-down to assess whether 95th percentile storm surrogate provides approximately intended results.

4. Possibly develop surrogate event-based guidance that incorporates:

    a. Existing condition runoff potential (i.e. are soils B, C or D in existing condition).

    b. Drawdown time of proposed BMPs

    Such guidance would still not be truly site-specific, but would improve the validity and utility of the design storm method. It would likely require continuous simulation to support development.

5. Evaluate other alternatives for developing a design storm approach that would better ensure intended long-term performance.

6. Assess the potential for infiltration related to geotechnical, contamination, and/or potential for habitat changes down-gradient (due to lengthening of groundwater discharges to ephemeral streams).

7. Assess the potential and feasibility for water re-use for irrigation and other non-potable uses (i.e. toilet flushing, etc.) with regards to recovering storage in a cistern.

8. Revisit the relevancy of *Reducing Stormwater Costs through LID Strategies and Practices* (EPA, 2007) to support conclusions about the costs and effectiveness of BMPs under the proposed requirements.

E. ALTERNATIVES AND IN-LIEU PRC .AMS

1. Within 12 months of adoption of this order, the principal permittee, in collaboration with the co-permittees, shall develop technically-based feasibility criteria for project evaluation to determine the feasibility of implementing LID BMPs. This plan shall be submitted to the Executive Officer for approval. Only those projects that have completed a vigorous feasibility analysis as per the criteria developed by the permittees and approved by the Executive Officer should be considered for alternatives and in-lieu programs. If a particular BMP is not technically feasible, other BMPs should be implemented to achieve the same level of compliance, or if the cost of BMP implementation greatly outweighs the pollution control benefits, a waiver of the BMPs may be granted. All requests for waivers, along with feasibility analysis including waiver justification documentation, must be submitted to the Executive Officer in writing. Waivers shall only be granted with prior approval from the Executive Officer.

2. The permittees may collectively or individually propose to establish an urban runoff fund to be used for urban water quality improvement projects within the same watershed that is funded by contributions from developers granted waivers. The contributions should be at least equivalent to the cost savings for waived projects and the urban runoff fund shall be expended for water quality improvement or other related projects approved by the Executive Officer within two years of receipt of the funds. If a waiver is granted and an urban runoff fund is established, the annual report for the year should include the following information with respect to the urban runoff fund:

   a) Total amount deposited into the funds and the party responsible for managing the urban runoff fund;

   b) Projects funded or proposed to be funded with monies from the urban runoff fund;

   c) Party or parties responsible for design, construction, operation and maintenance of urban runoff funded projects; and

   d) Current status and a schedule for project completion.

4. The permittees may establish a water quality credit system for alternatives to infiltration, harvesting and reuse, evapotranspiration, and other LID BMPs and hydromodification requirements specified above. A summary of any waivers of LID, hydromodification and treatment control BMPs should be included in the annual report for each year. Any credit system that the permittees establish should be submitted to the Executive Officer for review and approval. The following types of projects may be considered for the credit system:

a) Redevelopment projects that reduce the overall impervious footprint

b) Brownfield redevelopment

c) High density developments (>7 units per acre)

d) Mixed use and transit-oriented development (within ½ mile of transit)

e) Dedication of undeveloped portions of the project to parks, preservation areas and other pervious uses

f) Regional treatment systems with a capacity to treat flows from all upstream developments

g) Contribution to an urban runoff fund (see 1, above)

h) Offsite mitigation or dedications within the same watershed

i) City Center area

j) Historic Districts and Historic Preservation areas

k) Live-work developments

In-fill projects