Construction Industry Coalition on Water Quality

June 19, 2009

Jimmy Smith, Supervising Engineer
San Diego Regional Water Quality Control Board
9174 Sky Park Court, Suite 100
San Diego, CA 92123

Public Comments Regarding Revised Tentative Order No. R9-2009-0002, NPDES No. CAS01087420 Waste Discharge Requirements for Discharges or Urban Runoff from the Municipal Separate Storm Sewer Systems (MS4s) Draining the Watersheds of the County of Orange, the Incorporated Cities of Orange County, and the Orange County Flood Control District Within the San Diego Region

Dear Mr. Smith:

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 San Diego Regional Water Quality Control Board (Regional Board) for the opportunity to offer this public comment on the revised tentative order (Tentative Order or Permit) No. R9-2009-002. This letter provides constructive suggestions that we have for the Tentative Order in addition to those we made to the Regional Board previously.

As currently drafted, we cannot support adoption of the Tentative Order because certain portions of the language can be misinterpreted to prohibit any discharge of surface water runoff. This is inconsistent with CICWQ positions made known during months of discussions in which we agreed with the principal permittee and co-permittees that the private and public development community should maintain the ability to employ a variety of Low Impact Development (LID) best management practices (BMPs) in MS4 permitting efforts in southern California (notably in Ventura and north Orange Counties). We have consistently advocated for flexibility to use the full range of LID BMPs to handle the design storm volume, not just those that hold all the water on-site. And as we point out below, this redefinition of LID and narrow interpretation of LID BMP implementation is not a technically or economically feasible alternative and has serious implications for redefining California water law. Moreover, that the 5% effective impervious area (EIA) numeric standard also applies in the hydromodification control section is duplicative, unnecessary, and will lead to widespread confusion among project developers about which LID standards apply. This is all the more so because of the fact EIA is being applied here incorrectly.

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 Tentative Order, as are thousands of construction employees and builders working to meet the demand for modern infrastructure and housing in Orange County. Our organizations support efforts to improve water quality in a cost effective manner. Our comments and suggestions on the Tentative Order 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. 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 consideration of site-specific feasibility considerations.

II. Preliminary Statement

The language in the Tentative Order, while specifying a volume capture approach to sizing LID BMPs, introduces a narrow definition of LID through restrictive application of BMPs to only those that infiltrate, harvest and use rainwater, and/or evapotranspire all of the captured water (See Section F.1.d.(4)(c)). In other words, permit language now requires that projects would be limited to zero discharge of a design storm volume with no cross-boundary runoff whatsoever allowed.

Unless the Tentative Order is better clarified, the draft provisions seemingly rule out the use of LID BMPs for filtration – and instead require that no storm water (except in the largest rains) can ever leave a developed or redeveloped parcel unless an infeasibility analysis is performed. If this is intended, it is a radical measure that should not be undertaken. It would violate millennia (literally) of civil law concerning the unconstrained flow of rain water (called "diffuse surface water"). Specifically, the law in California – which itself is derived from the laws of the Roman Empire –favors what is called the "***natural flow doctrine***," which states that diffuse surface flows should be permitted to flow to their natural water course. *See Gdowski v. Louie*, 84 Cal.App.4th 1395, 1402 (2000) ("California has always followed the civil law rule. That principle meant 'the owner of an upper … estate is entitled to discharge surface water from his land *as the water naturally flows*. As a corollary to this, the upper owner is liable for any damage he causes to adjacent property *in an unnatural manner*…. In essence each property owner's duty is to leave the natural flow of water undisturbed.'" – emphasis added by the court, quoting *Keys v. Romley*, 64 Cal.2d 396, 405-06 (1966)).

The "natural flow doctrine" has been altered by the California courts in recent decades – in order to facilitate reasonable land development and protect local governments and land owners. Replacing the natural flow doctrine is a ***modern reasonableness test***. Property owners (both public and private) may alter the natural flow of diffuse and/or discrete surface water, but only if they are reasonable when doing so and downstream owners can effectively trump the reasonable efforts of the upstream owner only if they (the downstream owners) in turn take reasonable defensive steps. *See, e.g.*, *Locklin v. City of Lafayette*, 7 Cal.4th 327, 337 (1994). However, the natural flow doctrine – which seeks to *maintain the natural flows* of diffuse and discrete surface water – is the doctrine that conforms best to the federal Clean Water Act's overarching objective to "restore and *maintain*" the natural integrity of waters.[1] *See* 33 U.S.C. section 1251. Accordingly, we would, of course, expect the Board and the non-governmental organizations that purport to defend natural resources to strongly prefer the *natural flow doctrine*, and to deviate from it (if at all) only as reasonably necessary to accommodate competing societal goals.

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 .

Mandating the complete on-site retention of any sizable storm volume (i.e. runoff that never crosses any property boundary as surface flows) is not a reasonable approach. The Tentative Order seemingly seek to 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 on-site 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 provide, in Attachment 1, a comprehensive analysis done by Geosyntec Consultants of the feasibility of implementing rainfall and stormwater harvesting systems and the utility of

[1] *See* S. Rep. No. 92-414, 92 Cong. 2d Sess., 2 U.S. Code Cong. & Adm. News '72 3668, 3674 (1992) ("The Committee believes the restoration of the natural chemical, physical, and biological integrity of the Nation's waters is essential."); H.R.Rep. No. 92-911, p. 76 (1972) (""the word 'integrity' ... refers to a condition in which the natural structure and function of ecosystems is [are] maintained.").

these systems in achieving pollutant load reductions from stormwater runoff as compared to use of all types of LID BMP features. This document shows that attempts at 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, 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 preferred LID BMPs, 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 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 perform a feasibility analysis to do so.

III. Specific Comments on the Tentative Order

Section D - Municipal Action Levels

The Tentative Order establishes Municipal Action Levels (MALs) for selected pollutants (pH; TSS; chemical oxygen demand; total Kjedahl nitrogen; nitrate & nitrite; total phosphorous; and total cadmium, chromium, copper, lead, nickel, zinc, and mercury). In comparison, the Ventura County Tentative Order MALs are set for only those pollutants that were identified as pollutants of concern by the Ventura Program. Such an approach avoids using public resources unwisely and inefficiently by not requiring actions to address pollutants that are not resulting in local water quality concerns. The revised Ventura County Tentative Order includes MALs only for the following pollutants of concern: TSS; nitrate & nitrite; and total copper, lead, and zinc. If MALs are to be included in the South Orange County Tentative Order, they should be revised to include only those pollutants that are of particular concern in southern Orange County.

Section F.1.d(6)(g) – Treatment Control Requirements

The Revised Tentative Order states:

"Not be constructed within a waters of the U.S. or waters of the State"

The sentence should be modified to be consistent with the statement on page 14 of the Order regarding federal authorization as follows: "*<u>Without federal authorization (e.g. pursuant to Clean Water Act Section 404)</u>, not be constructed within a waters of the U.S. or waters of the State*."

Section F.1.h (3)(c)(i) – Hydromodification Control Waivers, lack of discharge-caused hydrology changes

The hydromodification control waivers contained in this subsection should expressly include waivers for projects that do not increase the potential for hydromodification impacts over the existing site conditions, or that discharge to a receiving water that is not susceptible to hydromodification impacts. Suggested edits are as follows:

(c) On-site hydromodification control waivers: Copermittees may develop a strategy for waiving hydromodification requirements for on-site controls (not site design BMPs) in situations where assessments of downstream channel conditions and proposed discharge hydrology clearly indicate that adverse hydromodification effects to present and future beneficial uses are unlikely. The waivers must be based on the following determinations:

(i) Lack of discharge-caused hydrology changes: Waivers may be implemented where the total impervious cover ~~on a site is increased by less than 5% in new developments and decreased by at least 10% in redevelopments~~ within the site's watershed at planned build-out is less than 5%. ~~These~~ This numeric criteria may be revised to be consistent with findings from reports from the Storm Water Monitoring Coalition and Southern California Coastal Waters Research Program. Alternatively, directly-connected impervious area or effective impervious cover may be used as an indicator, provided that numeric criteria for the indicators are used and are based on hydromodification studies conducted in southern California.

Waivers may also be implemented for the following projects that do not increase the potential for hydromodification impacts over the existing site conditions:

(A) Projects within a natural watershed where a geomorphically-based watershed study has been prepared that establishes that the potential for hydromodification impacts is not present.

(B) Significant redevelopment projects that do not do not increase impervious area or decrease the infiltration capacity of pervious areas compared to the pre-project conditions.

(C) Projects that discharge directly or via a storm drain to a substantially hardened channel, sump, a lake, area under tidal influence, or other receiving water that is not susceptible to hydromodification impacts.

Section F.1.h (3)(c)(ii)(b) – Hydromodification Control Waivers, degraded stream channel condition

The waiver for discharges into degraded stream channels has been removed in the Revised Tentative Order. As stated in the Supplemental Fact Sheet

"If requirements for currently degraded channels are removed, there will be a diminished opportunity for future restoration of Beneficial Uses of that receiving water due to the lack of hydromodification controls."

In areas tributary to channels that have been engineered as part of a Flood Control Master Plan that incorporated channel modifications and drop structures that control channel morphology and areas tributary to streams that are geomorphically unstable and have degraded to the point that controls on Priority Projects alone would not be effective in addressing impacts, projects should be allowed to contribute to in-stream or retrofit measures in lieu of onsite hydromodification controls.

Section F.1.h(6) – Interim Hydromodification Requirements

The Tentative Order includes an "Effective Impervious Area" (EIA) threshold requirement for Priority Projects as an interim hydromodification control requirement. The use of EIA as a regulatory metric for LID implementation is the subject of considerable debate and concern within the stormwater management and science community, as well as among urban planners and practicing landscape architects. Specific aspects of this concern include whether an EIA criterion should be used and, if used, if its application on a site-by-site basis is appropriate given its potential impact on urban redevelopment, smart growth, and sprawl. The use of an EIA requirement needs to be fully vetted to ensure that redevelopment of brownfields and infill development are not discouraged, but rather are encouraged, by the permit.

Although managing EIA is an important tool to achieving the goal of beneficial use protection, it should not be a goal in itself as it does not reflect the goals of the Clean Water Act. The origin of this measure is that it illustrated a threshold beyond which impacts could be identified in watersheds where treatment and hydromodification controls, including source controls, were generally not implemented. The adverse effects of impervious areas can be mitigated by a variety of tools including directing runoff to pervious surfaces, incorporating pervious material, or by controls located at the project scale, sub-watershed scale, or watershed scale. The issue is achieving beneficial use protection, not tool selection.

The volumetric control standards provided in section F.1.h(6)(a)(iii) are sufficient for interim hydromodification control. The inclusion of the EIA metric in F.1.h(6)(a)(i) is unnecessary and unwarranted.

Appendix C – Page C-3

The definition of Development Projects should clarify that for purposes of the Revised Tentative Order a land subdivision made for financing or legal purposes (i.e. without soil disturbing activities) is not considered a "Development Project." Modify the language as follows:

"Development Projects – New development or redevelopment with land disturbing activities: structural development, including construction and installation of a building or structure, the creation of impervious surfaces, public agency projects, and land subdivision (except for financing or legal purposes)"

Appendix C – Page C-4

The definition of "Effective Impervious Area" does not accurately reflect the studies in which the term was derived. The definition should be edited as follows:

"Effective Impervious Area (EIA) – that portion of the impervious area ~~or pervious area incapable of retaining design storm flow~~ that is ~~hydrologically~~ hydraulically connected via ~~sheet flow or~~ a discrete hardened conveyance to a ~~drainage system or a~~ receiving water body."

Suggested edits to the definition of "Erosion Potential" are as follows:

Erosion Potential (EP) ~~– is determined as follows~~ – A ratio calculated to estimate the likelihood of stream instability due to watershed land use changes. Ep is determined as follows: ~~The total effective work done on the channel boundary is derived and used as a metric to predict the likelihood of channel adjustment given watershed and stream hydrologic and geomorphic variables. The~~ A sediment transport or work index (W) under urbanized conditions is compared to ~~the work index~~ that under pre-urban conditions and expressed as a ratio (EP). ~~The effective work index (~~W~~)~~ is computed using applicable sediment transport or effective work equations, as appropriate to the channel materials and morphology. These equations quantify ~~as~~ the magnitude of excess shear stress ~~that exceeds a~~ exceeding the critical value for streambed mobility or bank material erosion, integrated over time, and ~~represents~~ thereby represent an estimate of the total work done on the channel boundary.

The effective work index for presumed stable stream channels under pre-urban conditions is compared to ~~stable and unstable channels~~ ~~under current~~ proposed urbanized conditions to evaluate the adequacy of proposed hydromodification BMPs. The comparison, expressed as a ratio, is defined as the Erosion Potential (Ep)[1] (MacRae 1992, 1996).

Where:
Wpost = sediment transport or work index estimated for the post-urban condition
Wpre = sediment transport or work index for the pre-urban condition.

IV. Summary

The Tentative Order for South Orange County contains some improvements over previous drafts, but concerns on our part remain because of the restrictive language that redefines LID narrowly and the confusion the hydromodification control provisions create. CICWQ urges the Regional Board to go beyond the technical arguments presented here and consider the cost and practical feasibility of these new permit provisions (zero discharge mandate, for example) that appear to be wholly unsupported. Given the restrictive conception of LID that the permit introduces, the net result of implementation we believe will fall far short of the Regional Board's expectations because development will be hindered, not enhanced by flexible permit provisions and water quality will not improve. 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,

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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)

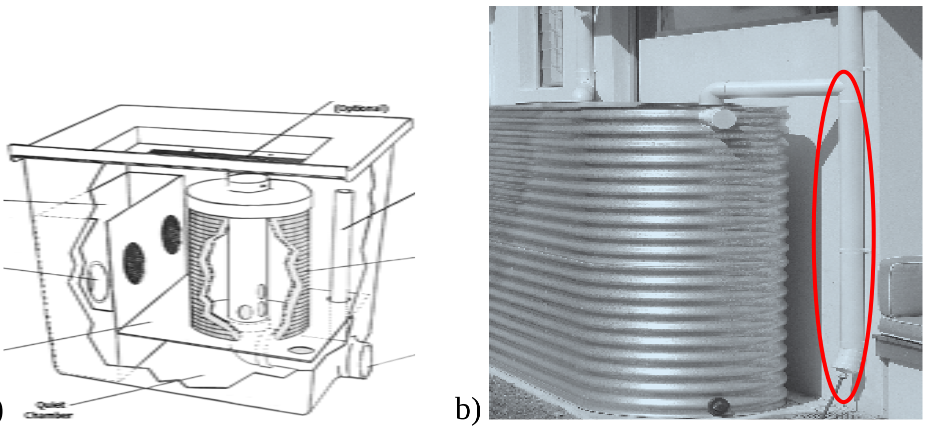

Figure 1. a) Downspout filter or “roof washer”; b) First Flush Diverter

a) b)

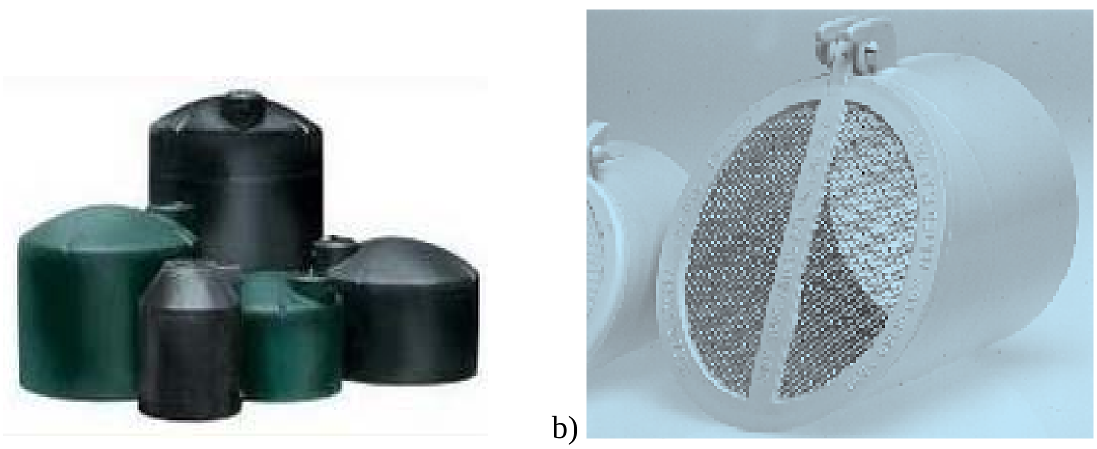

Figure 2. a) Cisterns; b) Insect screen

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: Toilet Flushing Only, 0.8" design storm	Scenario B: Toilet Flushing + Irrigation, 0.8" design storm	Scenario C: Toilet Flushing Only, 1.6" design storm	Scenario D: 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

<u>City of San Francisco, California.</u> 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

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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.

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