Water Resources Management
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SUBJECT: Model Bioretention Soil Media Specifications

Dear Dale,

The two Technical Memoranda and Annotated Bibliography are important initial steps towards a better understanding of what is required to achieve effective storm water treatment using bioretention "facilities"; however, they fall short in several very significant areas including:

- The submittals only address the "***life of the Facility***" (bioretention system) and did not address the "***life of the Regulated Project***" (development project).
- Sizing of "facilities" at the minimum rate of infiltration of 5-inches/hour assures that the "facilities" will violate the MRP treatment requirement shortly after the initial storm event.
- The proposed media will result in the release of nutrients from bioretention "facilities" and have a high potential for creating damaging impacts to beneficial water uses because of changes in clarity of San Francisco Bay Estuary and further contributing to the impairment of creeks.
- Literature cited is very limited and does not address field data developed by others and long-term pollutant removal effectiveness of the bioretention "facilities".

Several of these shortfalls can be attributed to the lack of specificity of the Municipal Regional Permit (MRP) and need to be addressed if the Regional Board is going to rely on bioretention "facilities" to comply with discharge prohibitions, receiving water limitations and hydro modification requirements over the "***life of the Regulated Project".*** The Regional Board could in part address this important issue through Provision C.3.h.iii. and iv. by requiring monitoring and detailed reporting of facility inspections.

<u>"Life of Facility" vs. "Life of Regulated Project"</u>

BASMAA recommends that soils for bioretention facilities have a minimum rate of infiltration of 5-inches per hour during the ***"life of the facility"*** and the technical memoranda refer to a "***long-term***" infiltration rate. These carefully worded qualifications raise immediate questions about what is the "***life of the facility***" and what is "***long-term***". The MRP Provision C.3.h.iii. requires that storm water treatment systems be operated and maintained for the "***life of the Regulated Project***". BASMAA's submittal must address the "***life of the Regulated Project***" and the following issues:

- Criteria and/or testing methods to determine when the bioretention facility no longer provides effective treatment i.e. reducing pollutants to the MEP standard and/or has become clogged and not maintaining the minimum infiltration rate of 5-inches per hour and does not maintain the hydro modification requirements.
- Guidance and criteria for rehabilitation or replacement of bioretention media and/ or reconstruction or replacement of the bioretention facility.

The criteria must at least address loss of infiltration and percolation capacity due to clogging, reduced cation exchange capacity and accumulation of pollutants posing a human or watershed health risk[1],[2], [3].

The performance of infiltration systems (swales, bioretention, infiltration basins, etc) degrades through normal operation as suspended and settleable solids in storm water runoff plug or clog the infiltration surface. WERF[4] did an extensive study and field survey on the performance and whole life costs of BMPs. It found a wide variation in levels of maintenance of these systems and the systems tend to fail within a period of 2 to 7 years. WERF reported that even the best storm water agencies lack funding for BMP maintenance and that inadequate and deferred maintenance results in expensive rehabilitation or reconstruction of the BMPs.

Livingston[5] reported that only 50% of infiltration practices surveyed in Maryland were considered to be working. Studies on the performance and maintenance of swales found that over 75% of the 33 biofiltration swales surveyed in King County in1995 to be in fair to poor condition having little or no vegetation or extensive channelization. Dr. Gary Minton in 1996 performed an extensive survey of swales in the Pacific Northwest and reported “These results raise concerns about bioswales as a viable treatment BMP”. Recent personal observations of swales in the Northwest and reports on the operation of swales have documented the poor condition of swales due to the destruction of vegetation requiring extensive and expensive reconstruction.

The City of Portland (ref 2 and 3) is conducting a performance evaluation of a number of its storm water BMPs including eco roofs, street planters (green streets) and vegetated infiltration (bioretention) basins. The City conducts five types of monitoring: infiltration testing, flow metering, flow testing, water quality sampling and sediment/soil sampling. Portland has found significant sediment accumulation in street planters and rain gardens requiring temporary removal of vegetation to remove sediments, frequent maintenance and clogged drainfields. They also found soil clogging due to formation of hard crusts on the soil, accumulation of large amounts of soil, leaves and debris from streets requiring cleanout up to six times per year. Initial sediment/soil sampling found PAH levels that have exceeded California’s human health exposure guidelines and levels of lead approaching California’s TTLC[6]. The City’s program provides an excellent model for the monitoring needed to assess the long-term sustainability of storm water BMPs that have been installed in the Bay Area.

Minton[7] reports that soil gradually clogs decreasing infiltration and is due to accumulation of sediment, growth of bacteria, natural formation of crusts from chemical changes of the soli, growth of algae and impact of raindrops. He also observes that BMP manuals do not take into account this gradual clogging and that with the first storm event the actual infiltration rate immediately begins to decrease below

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[1] Wisconsin Department of Natural Resources, Bioretention for Infiltration, (1004), 07/06
[2] Bureau of Environmental Services, City of Portland, 2006 Stormwater Management Facility Monitoring Report, Sustainable Stormwater Management Program, September 2006
[3] Bureau of Environmental Services, City of Portland, 2008 Stormwater Management Facility Monitoring Report, Sustainable Stormwater Management Program, December 2008
[4]Water Environment Federation, Performance and Whole Life Costs of Best Management Practices and Sustainable Urban Drainage Systems, Final Report 2005
[5] Eric Livingston, August 1997, Operation, Maintenance & Management of Stormwater Management, Watershed Management Institute, Inc.
[6] Anne Jones-Lee, G. Fred Lee, Stormwater Runoff Water Quality Newsletter, Volume 9 Number 9, September 25, 2006
[7] Stormwater Treatment Northwest© Vol. 12, No. 3, August 2006

design values and that infiltration systems should be sized using an infiltration rate that is truly "long term".

Wisconsin DNR (ref 1) indicates that use of bioretention sytems for infiltration should consider that the longevity of engineered soil is decreased by clogging, reduced cation exchange capacity (CEC) and accumulation of sodium. The DNR reported that clogging problems can be reduced by limiting input of sediment (pretreatment) and cation exchange capacity be rejuvenated by replacement of the engineered soil.

Bioretention facilities fail as early as the initial year of operation with very high rate failure rates within 5-7 years. Plugging of the infiltration surface and loss of percolation capacity by fine and coarse sediments, reduced CEC resulting in the breakthrough of heavy metals, accumulation of toxic and hazardous pollutants on the infiltration surface will require replacement and rehabilitation multiple times during the "**life of the Regulated Project**".

Recommendation: That the Regional Board in the implementation of MRP Provision C.3.h.iii. :

- Develop a program that will ensure that bioretention facilities are sustainable for the ***"life of the Regulated Project".***
- The program must require permittees:
  - Provide a complete inventory including location and design criteria of all bioretention BMPs that have been installed since the inception of the storm water programs and the installation of all future bioretention BMPs.
  - Require rehabilitation or replacement of the bioretention media of facilities that have been in operation for more than five years and every five years thereafter. **OR** Implement a biannual monitoring program that documents compliance with the 5-inch per hour minimum infiltration rate and approved media specifications for cation exchange capacity.
  - During the rehabilitation or replacement of the bioretention media use media that complies with the final approved media specifications.
  - Require all new and rehabilitation or replacement projects include a storage area or alternative media to achieve reduction in discharges of nutrients.
  - Monitor at five year intervals the accumulation of toxic and hazardous pollutants on the infiltration surface and require replacement of hazardous sediments.

Sizing of Facilities

Application of the MRP Provision C.3.d.i.(2)(c) flow criteria of 0.2 inch per hour intensity and Provision C.3.c.i.(2)(b)(vi) 5-inches per hour stormwater runoff surface loading rate results in the sizing of bioretention facilities at 4% of the tributary impervious area[8]. Minton (ref 7) observes that BMP manuals do not take into account gradual clogging of the infiltration system; that infiltration systems are sized assuming clean soils; and, treatment goals are not achieved because infiltration rates begin to decrease below the design value with the first storm. Minton suggests application of correction factors to relate short-term to long-term infiltration rates and account for saturated soil conditions.

[8] Contra Costa Clean Water Program, Stormwater C.3 Guidebook, Stormwater Quality Requirements for Development Applications, Fifth Edition, October 20, 2010

The MRP in Provision C.3.c.i.(2)(b)(vi) requires that the soil media specifications and soil testing methods verify a ***long-term*** infiltration rate of 5-10 inches per hour; however, the MRP did not define ***long-term***. Provision C.3.h.iii. requires that treatment systems and hydro modification controls be operated and maintained for the "***life of the project***". It is not clear from the MRP, MRP Fact Sheet or record whether the 10-inches per hour infiltration rate is intended to establish an upper limit for infiltration. The MRP needs to clarified and an upper limit must be established that addresses excessive high rates of infiltration where there is insufficient filtration and retention of pollutants attached to particles, time for adsorption of pollutants through cation exchange or hydro modification requirements are not achieved.

BASMAA's submittal must also address the issue identified by Dr. Minton where infiltration systems are sized assuming clean soils and at the minimum 5-inches per hour rate of infiltration. Alternatives that should be considered include doubling the size of the facility when using the 5-inches per hour criteria or using the City of Portland's 6% of the "drainage area" criteria.

Release of Nutrients From Bioretention "Facilities"

The Pulse of the Estuary[9] alerted the Bay Area to an increase in phytoplankton abundance in the Bay and a potential for nutrient pollution to cause problems associated with excessive algal production. This is attributed to a shift from a system where photosynthesis by phytoplankton was limited in the Bay's past murky waters to an increase in clarity from reduction in erodible sediment input. The Pulse of the Estuary[10] further indicates that stream monitoring found that elevated nutrients are among the stressors affecting stream biota during ambient flow conditions. It also described results of nitrate and phosphorous sampling in Bay Area creeks and noncompliance with USEPA's proposed nutrient criteria and the SWRCB's Nutrient Numeric Endpoint approach that may offer an alternative criteria. Based on monitoring in the Regional SWAP it has recommended monitoring of nutrients and chlorophyll as an indicator of algal growth, but perhaps more important that restoration projects should be encouraged to keep nutrients and other pollutants out of streams.

Multiple studies and monitoring of bioretention facilities with compost amended media have documented minimal removals to significant increases in the discharge of nutrient concentrations from that in the storm water surface runoff[11], [12], [13], [14], [15], [16], [17], [18].

[9] San Francisco Estuary Institute, 2009, The Pulse of the Estuary: Monitoring and Managing Water Quality in the San Francisco Estuary

[10] San Francisco Estuary Institute, 2010, The Pulse of the Estuary: Linking the Watersheds and the Bay

[11] Richard A. Claytor and Thomas R. Schueler, The Center for Watershed Protection, Design of Stormwater Filtering Systems, December 1996

[12] Robert Pitt, etal, Infiltration Through Disturbed Urban Soils and Compost-Amended Soil Effects on Runoff Quality and Quantity, March 30, 1999

[13] Shirley E. Clark, etal, WERF, Infiltration vs. Surface Water Discharge: Guidance for Stormwater Managers,2006

[14] Caltrans, Compost Stormwater Filter System Monitoring – State Route 73, CTSW-RT-03-036, June 2003

[15] Les Lampe, etal, WERF, Performance and Whole Life Costs of Best Management Practices and Sustainable Urban Drainage Systems, 2005

[16] Eric Strecker, etal, WERF, Critical Assessment of Stormwater Treatment and Control Selection Issues, 2005

[17] Geosyntec Consultants, Inc and Wright Water Engineers, Inc, International Stormwater Best Management Practices (BMP) Database Pollutant Category Summary; Nutrients, December 2010

[18] Geosyntec Consultants, Inc and Wright Water Engineers, Inc, International Stormwater Best Management Practices (BMP) Database, Overview of Performance by BMP Category and Common Pollutant Type, June 2008

The WRA report identifies nutrient leaching from compost and notes that total phosphorus and total nitrogen removal in biofiltratiion is good compared to other storm water treatment practices. This may be true for the particulate forms of phosphorous and nitrogen and where biofiltration facilities do not have underdrains; however, in the Bay Area most sites are going to require underdrains because of the extensive Group C and D soils. References 10-17 provide much greater insight regarding the effectiveness of bioretention facilities to reduce concentrations of all forms of phosphorous and nitrogen which is required to reduce the potential for excessive algal production.

WRA identified increased media depth and a saturated anaerobic zone beneath the underdrains as two bioretention facility design improvements to reduce the release of nutrients. Storm water design manuals must be revised to require a 36-inch media depth and a 48-inch porous rock (double washed coarse aggregate #2 - ref 1) storage layer beneath the underdrains to reduce the discharge of nutrients.

WRA notes that composted media leaching may decline with age; however, this is not valid because composted media will likely have to be replaced on a five year cycle producing an ongoing source of nutrients over the "**life of the Regulated Project**".

Leaching of nutrients from compost amended media coupled with the growing concern about impairment of streams by nutrients and increase in phytoplankton abundance in the Bay raise major policy conflicts and questions about use of compost amended soils in storm water BMPs. This issue needs to be quickly addressed by the Regional Board to provide current guidance to the permittees. The possibility of a nutrient TMDL requiring mitigation of the release of nutrients from existing bioretention facilities should be of deep concern to Bay Area municipalities.

Recommendation: That the RWQCB:

- Closely follow the EPA-IX's development of nutrient standards and the SWRCB's Endpoint Project and the development of numeric nutrient standards in Florida and Chesapeake Bay because the latter may become the model for application of numerical nutrient standards to storm water runoff in the Bay Area.
- Require that BASMAA's submittal be amended to address the real potential for excessive algal production by nutrients leached from compost amended media.
- Require that current BMP manuals be amended to specify a 36-inch media depth and a 48-inch porous rock storage layer beneath the underdrains with a porosity of at least 40%.
- Require MRP permittees investigate and report on the use of alternative filtration media that would not increase the discharge of nutrients in storm water runoff;
- Require MRP permittees investigate and report on the use of alternative designs of filtration facilities that are more sustainable for the "**life of the Regulated Project**" and that can be more easily maintained and rehabilitated.
- Require that bioretention facilities with storage layers installed in areas with Group A or B soils conduct a site evaluation to address potential impacts on and mitigate any threats to ground water quality.

Literature Cited

The Annotated Bibliography is extremely limited for such an important project with many recent and readily available references not included. I can understand the MRP permittee's interest in reporting only on those studies favorable and most optimistic about the performance and effectiveness of biorentention facilities and media; however, that is not in the best interest of protecting the Bay's beneficial water uses and perhaps more important to the many entities that will have the responsibility for the operation, maintenance and rehabilitation/replacement of the bioretention facilities for the "**life of the Regulated Project.** Many of the references I have cited included references to many other studies that could contribute to a much better understanding of the design, operation, maintenance and sustainability of bioretention facilities for the "**life of the Regulated Project"**.

> Recommendation: That the RWQCB find that annotated bibliography incomplete and require that it be significantly expanded and include a peer review by professionals with experience in the sitting, design, operation, monitoring and maintenance of bioretention facilities.

Comments – Technical Memorandum, Regional Bioretention Soil Guidance & Model Specification , Bay Area Stormwater Management Agencies Association

The Introduction needs to clarify whether the 10-inches per hour is an upper limit designed to avoid excessive rates of infiltration where there is insufficient time for cation exchange to be effective and/or where the flow would move rapidly to the underdrain providing insufficient flow control. An initial study of LID practices in the Puget Sound area found the latter to occur requiring that the underdrains be plugged[19]. If the 10-inches is not an upper limit then the Technical Memorandum should recommend and justify an upper limit that would provide sufficient time for cation exchange to be effective and there would be sufficient retention of flow to insure that flow control goals are achieved.

Throughout the Technical Memorandum the terms "biofiltration" and "biroretention" are used interchangeably. The memorandum should explain the difference between the two terms or consistently use one or the other.

The Part 1 – Justification section of this Technical Memorandum must be expanded to discuss all the factors that influence the rate of infiltration of storm water through the surface interface of the bioretention facility and the subsequent percolation of the water through the underlying soil. In addition to those mentioned in subsequent sections of Part 1 it should also discuss the soil clogging process, reduced cation exchange capacity and clogging of the underdrain. This discussion should address how each of the factors can affect the longevity of the engineered soil and effectiveness of the bioretention facility and how the recommended soil mixes mitigate the factors. It would be helpful if the section also discussed the type and frequency of maintenance required to increase the longevity of the facilities that must be addressed by Provision C.3.h.iii. of the MRP.

The references cited in this letter include the many factors that affect the rate of infiltration of storm water through the surface of bioretention facilities: sediments and especially fine (20-µm) particles, leaves, crusts formed by chemical changes, impact of rain drops, "scumutzdecke"; the factors affecting the rate of percolation of storm water through the underlying soil: fine solids driven into the media, small plately fragments in compost that orient themselves into an occlusion layer, biofouling algae and slimes; and, the factors affecting the performance of the underdrain system: biofouling and migration of mature compost that becomes sticky with fine humus, mulch that enters the facilities overflow pipe and rodents[20] and ref 2,3,5,7,12,13,14 and 24.

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[19] Curtis Hinman, Washington State University Extension, Flow Control and Water Quality Treatment Performance of a Residential Low Impact Development Pilot Project in Western Washington, 2009

[20] Personal communication with James Lenhart, Contech Stormwater Solutions, January 19, 2011

The discussion in section 1.0 Compost expressing various opinions and hypothesis on the role of fines and the design of the media makes it appear that this subject is an "emerging art" rather than based on sound science. This section should address this and suggest a monitoring program to obtain more precise design criteria. This section and BASMAA's December 1, 2010 transmittal letter refers to observations by municipalities and Contra Costa permittees of the performance of bioretention facilities. Apparently these are of recently constructed facilities because the NPDES Permit issued to the Contra Costa County program in 2006 required monitoring of five sites over a two year period yet that requirement was significantly reduced in the MRP and no report of the required monitoring has been found. Documentation of the installation dates, design criteria, actual observations, more detailed monitoring and monitoring of facilities installed at least five years must be obtained before accepting the observations as representative of the "**long-term**" performance of bioretention facilities since these types of facilities can be expected to fail within a five to seven year period.

The growing concern about impairment of streams by nutrients and increase in phytoplankton abundance in the Bay raise major policy questions about use of compost amended media in storm water BMPs. The possibility of a nutrient TMDL requiring mitigation of the release of nutrients from existing bioretention facilities should be of concern to Bay Area municipalities. Section 1.2 needs to be significantly expanded to include information from the references listed earlier under "Release of Nutrients From Bioretention Facilities". This expansion must include a discussion of what actions should now be taken to eliminate or reduce to the MEP the release of nutrients from existing and new facilities including BMP design changes, alternative media, rehabilitation/replacement of existing facilities, etc.

The Technical Memorandum would significantly benefit by adding a tabular summary comparing the specifications of compost that have been adopted by various states and organizations [21], [22] and [23] and discussing material differences between and experiences with implementing the specifications. Approximately four years ago Caltrans proposed a project to develop an improved design and specifications for biofilters and proposed monitoring of several test biofilter installations. BASMAA should investigate and include a report on the status and findings of that project.

Cationic exchange capacity (CEC) is one of the key factors in the ability of bioretention facilities to remove heavy metals and a new section needs to be added to address CEC's role[24] and [25] in removal of heavy metals and other pollutants of concern. This new section should develop a recommended CEC level in terms of milliequivalents/gram or centimoles/kg and recommend a CEC of the initial installed media that would assure effective retention of heavy metals and a lower limit which could be used to establish the "**life of the facility**". The section should also recommend a method to monitor the facility to determine when the media must be replaced because the facility is no longer effectively retaining metals. These criteria could be in terms of age of the facility, monitoring to determine the initial breakthrough of metals and/or measuring the remaining CEC of the media.

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[21] Low Impact Development Center Soil Amendment, Compost Specification, http://www.low impact development.org/epa03/soilamend.htm
[22] Stormwater Management Manual for Western Washington, Washington Department of Ecology
[23] Wisconsin Department of Natural Resources Specifications, S100 Compost, 10/04
[24] Water Environment Federation, Critical Assessment of Stromwater Treatment and Control Selection Issues, Final Report 2005
[25] Gary Minton, Stormwater Treatment, Biological, Chemical and Engineering Principles, 2002

There should be only one recommendation for percentage of fines in Section 1.4 and this should be based on long-term monitoring of clogging of bioretention facilities. If this data is not available then the more conservative value should be recommended and monitoring programs developed to obtain the data.

The term “no visual impact” for inert materials in Section 1.4 is insufficient guidance for municipalities based on the discussion on inert materials in Section 1.3. The inert materials specification should be <1% dry weight basis which is consistent with the Contra Costa County specification and with the Material Requirements of the Wisconsin DNR (ref 23).

A section needs to be added to Part 1 – Justification discussing the accumulation of toxic and hazardous materials such as oils, heavy metals (lead and those impacting plant health) and PAHs (benzo(a)pyrene) on the surface soils of bioretention facilities (ref 2 and3). A monitoring protocol must be developed to determine when these limits are reached requiring rehabilitation/replacement of the media or mulch.

Section 2.4 indicates that existing research does not warrant adding vermiculite, perlite, or calcined clay to the bioretention soil. The concern that compost amended media is adding nutrients to discharges from biofiltration facilities warrants a much more thorough investigation of alternative media. WERF (ref 24) suggests that other media may be more effective than or at least as effective as compost amended media that would not increase the discharge of nutrients.

Section 4.0 should also list the CEC test method to be conducted on alternative mixes.

Section 4.0 should define the qualifications and/or the professional certifications of a “qualified expert” and list the criteria of a “qualified soil analysis laboratory” ie. state certified.

The objectives for Soils for Bioretention Facilities and Soil Specification in Part 2-Guidance for Specifications should also include the maximum infiltration rate to insure that the facility does not drain too fast for support of the vegetation; provides sufficient contact time for adsorption of metals; and, achieves the flow reduction requirements.

The Soil Specification in Part 2-Guidance for Specifications should be mandatory rather than the permissive “should”.

The Soil Specification in Part 2-Guidance for Specifications must also specify that the compost material shall be free of pesticides and herbicides.

The 1.1 Submittals section of Soil Specification in Part 2-Guidance for Specifications and 1.3. B Compost for Bioretention Soil Texture should be limited to a state certified soil analysis laboratory.

A section needs to be added to Part 2-Guidance for Specifications of the 48-inch porous rock storage layer beneath the under drains required to control the release of nutrients. It would also be helpful to have a section on the design criteria(ref 1) for the under drain system since it will be an integral part of most Bay Area bioretention facilities or at least refer to other design criteria or BMP manuals.

The section on Mulch for Bioretention Facilities should specify that it “shall be nonfloating” to prevent the clogging of the under drain system and shall be free of pesticides and herbicides.

Comments – Technical Memorandum, Regional Bioretention Installation Guidance , Bay Area Stormwater Management Agencies Association

The Introduction needs to specify that the goal of the 5-inches per hour infiltration rate applies to the "**life of the facility**" and the upper limit of 10-inches per hour is a maximum infiltration rate to ensure that it doesn't drain too fast for support of plants; provides sufficient retention time for adsorption of metals; and, achieves the hydro modification requirements.

Wisconsin Department of Natural Resources (ref 26) has a number of recommendations for construction sequencing and oversight that should be considered as additions to the section on Installation of Bioretention Soils.

The verification of the underdrain installation should indicate that it complies with the facility's plans and specifications.

The Other Considerations section needs to address protection of biofiltration facilities throughout the construction period of the regulated project. This is now particularly important with long-term phased projects and where construction of buildings is undertaken by contractors that are different than the site grading and storm water management contractor[26]. Larger projects that were originally scheduled for completion during a short time frame are now being stretched out and in some cases in loan default leaving storm water treatment facilities vulnerable to high rates of failure and need to be completely reconstructed. These types of projects need to address interim storm water controls that do not rely on infiltration types of control measures.

I am available to discuss these comments and recommendations.

Sincerely,

Roger B. James
Senior Consultant

cc/ Tom Mumley, Shin-Roei Lee, Sue Ma, Geoff Broseau

[26] Gordon England, Implementing LID for New Development, Stormwater, July-August 2010