A Comparison of Infiltration Observations for Dry Basins in Lake Tahoe

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ACRONYMS

BMP	Best Management Practice
BMP RAM	Best Management Practice Rapid Assessment Methodology
CASQA	California Stormwater Quality Association
CHP	Constant Head Permeameter
CSLT	City of South Lake Tahoe
EDC	El Dorado County
EPA	Environmental Protection Agency
FSP	Fine Sediment Particles
NPDES	National Pollutant Discharge Elimination System
NRCS	Natural Resources Conservation Service
RAM	Rapid Assessment Methodology
SNPLMA	Southern Nevada Public Lands Management Act
Tahoe RCD	Tahoe Resource Conservation District
TMDL	Total Maximum Daily Load
TN	Total Nitrogen
TP	Total Phosphorous
UPC	Urban Planning Catchment

EXECUTIVE SUMMARY

The Lake Tahoe National Pollutant Discharge Elimination System (NPDES) permit was developed by the Lahontan Regional Water Quality Control Board to help implement the Lake Tahoe Total Maximum Daily Load (TMDL) to improve Lake Tahoe's deep water transparency. The permit requires that local California jurisdictions reduce pollutant loading of fine sediment particles (FSP), total nitrogen (TN), and total phosphorous (TP) to Lake Tahoe. As part of this permit, local California jurisdictions in the Tahoe Basin are required to monitor the performance of all "key and essential" Best Management Practices (BMPs) through the use of Rapid Assessment Methodologies (RAMs). In the fall of 2014, Tahoe Resource Conservation District (Tahoe RCD) staff tested three different methods for evaluating infiltration in dry basins as part of the BMP RAM measurements. The methods were tested in the City of South Lake Tahoe's Urban Planning Catchment (UPC) B14 and El Dorado County's UPC04 and included constant head permeameter (CHP), single-ring infiltrometer, and California Stormwater Quality Association (CASQA) 48-hour basin draw down time. This was an effort to provide BMP RAM data to these jurisdictions, and to evaluate each method's results and the efficiency with which the observations were obtained.

CHP is currently the recommended method for conducting BMP RAM on dry basins. However, CHP **does not evaluate infiltration at the soil surface, where infiltration nautrally occurs in a dry basin.** CHP punches a hole through the surface of the dry basin, the area that is prone to sedimentation and subsequent clogging,and measures saturated hyraulic conductivity in the subsurface. Single-ring infiltrometer and CASQA 48-hour basin draw down time both focus on infiltration at the soil surface and therefore may be more indicative of a dry basin's ability to infiltrate stormwater runoff.

Conducting CHP and single-ring infiltrometer measurements require similar amounts of staff time, while the **CASQA 48-hour basin draw down time took roughly 10% of the staff time required by the other two methods**. The main disadvantage of the CASQA method is that it is weather dependent, which creates scheduling difficulties. However, in basins where CHP/infiltrometer measurments are not possible (i.e. rock lined basins), CASQA may be the only viable option.

CASQA provides BMP standards that are nationally recognized. Due to the substantial decrease in required staff time, along with CASQA's reputation for setting the industry standard, the Tahoe RCD recommends that the CASQA 48-hour draw down time be used for BMP RAM on dry basins.

1 PURPOSE

The Lake Tahoe National Pollutant Discharge Elimination System (NPDES) permit was developed by the Lahontan Regional Water Quality Control Board to help implement the Lake Tahoe Total Maximum Daily Load (TMDL) to improve Lake Tahoe's deep water transparency. The permit requires that local California jurisdictions reduce pollutant loading of fine sediment particles (FSP), total nitrogen (TN), and total phosphorous (TP) to Lake Tahoe. The Lahontan Regional Water Quality Control Board also developed the Lake Clarity Crediting Program which requires California jurisdictions in the Tahoe Basin to monitor performance of all "key and essential" Best Management Practices (BMPs) through the use of Rapid Assessment Methodologies (RAMs). As of March 2015, the Lake Clarity Crediting Program Handbook offers the following regarding how "key and essential" is defined: "(a)s a rule of thumb, the complete absence or failure of an essential pollutant control could result in more than a 25% increase of the overall load from the catchment…" and "… the complete absence or failure of a key treatment BMP or source control could result in more than a few percent to a one third increase of the overall load from the catchment…". This study focused on dry basins because they are one of the most common infiltration BMPs in the Tahoe Basin. The purpose of this study is to (1) conduct BMP RAM assessments to be used by jurisdictions to evaluate BMP performance and to (2) evaluate the practicality, appropriateness, and amount of staff time needed to conduct BMP RAM on dry basins in El Dorado County (EDC) and the City of South Lake Tahoe (CSLT).

2 CATCHMENTS

BMP RAM was performed on dry basins for CSLT in Urban Planning Catchment (UPC) B14, and for EDC in UPC04 (Figure 1). CSLT UPC B14 contains three dry basins which overflow into a meadow and subsequently into Pope Marsh. EDC UPC04 contains eight dry basins; all runoff from EDC UPC04 catchment ultimately flows into Cold Creek before entering Lake Tahoe.

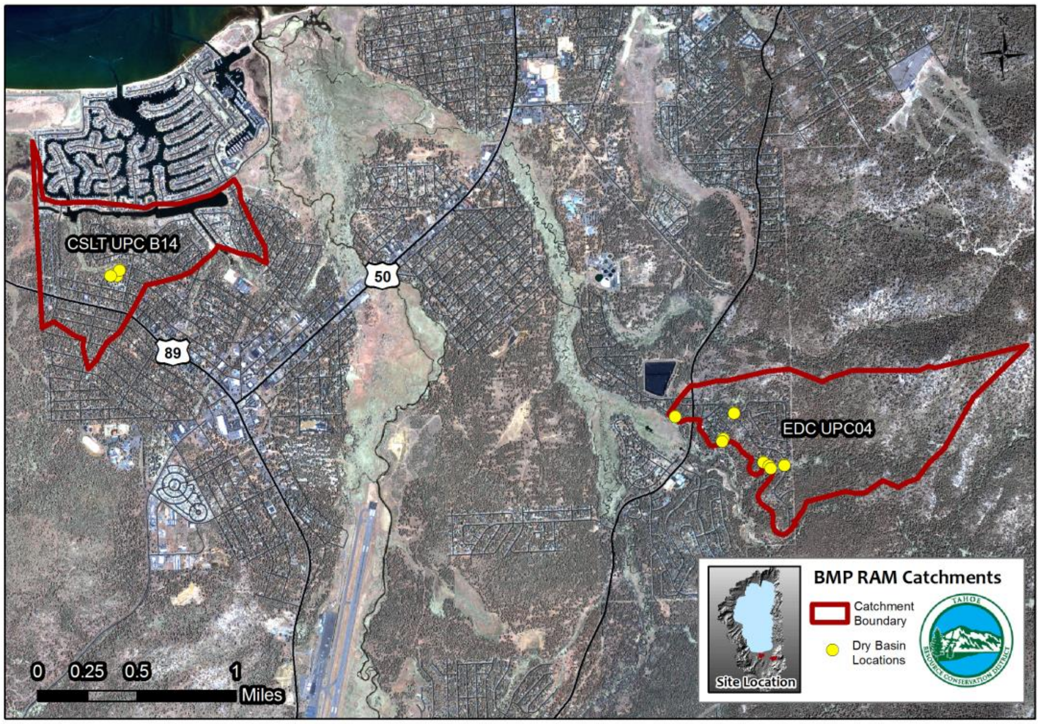

Figure 1 City of South Lake Tahoe's UPC B14 and El Dorado County's UPC04. BMP RAM measurements were conducted on dry basins within these catchments.

2.1 BMP RAM MEASUREMENTS

BMP RAM for dry basins consists of the following four evaluations: (1) assessment of vegetation type, (2) infiltration capacity, (3) material accumulation, and (4) conveyance. BMP RAM protocol recommends using constant head permeameter (CHP) as a measure of infiltration in dry basins. Tahoe RCD staff attempted to conduct BMP RAM in the field in the fall of 2014 and immediately noticed issues with the recommended infiltration measurement. CHP is used to measure the subsurface saturated hydraulic conductivity (k_{sat}) of soil. The tip of the instrument is inserted into a vertical bore hole in the soil and water is allowed to flow into the soil while a constant pressure head is maintained. A bore hole depth of 4 inches was suggested in the BMP RAM User's Manual (2NDNATURE 2009), however the National Resources Conservation Service (NRCS; the agency that developed the CHP method) stated that the measurement should be conducted at a depth of 12 inches (William Loftis, NRCS, personal communication, October 2014). NRCS also stated that **CHP is not the correct measurement for infiltration in a dry basin because the measurement occurs below the surface**, and infiltration in a dry basin occurs at the **soil surface**. For these reasons, three types of infiltration measurements were investigated: CHP, single-ring infiltrometer, and the CASQA 48-hour basin draw down time. BMP RAM using CHP and infiltrometer readings was performed on three dry basins in CSLT UPC B14 over four days in early November. BMP RAM using the CASQA method was conducted in CSLT UPC B14 and EDC UPC04 in less than one day in late November on all eleven dry basins. **The CASQA method took roughly 10% of the time it took to complete CHP or single-ring infiltrometer measurements.** The results of the measurements taken in CSLT UPC B14 can be found in Appendix A, and the results of the measurements taken in EDC UPC04 can be found in Appendix B.

2.1.1 CONSTANT HEAD PERMEAMETER

In CSLT UPC B14, CHP measurements were taken at depths of 4 inches and 12 inches to compare the method suggested by the BMP RAM User's manual and the protocol developed by NRCS. CHP measurements were taken at both of these depths in three locations per basin: near the inlet, in the middle, and near the outlet. One of the first technical difficulties noted was that it is very difficult to keep the CHP upright at a depth of 4 inches.

The BMP RAM User's Manual calls for 3 CHP measurements per surface type. Each measurement took 15-20 minutes, so **each basin will take, at a minimum, 45 minutes to an hour to conduct RAM observations with 1 staff member** using CHP (assuming one surface type per basin). CHP uses about a third of a gallon of water per measurement, or a minimum of **one gallon per basin**.

BMP RAM User's Manual protocol requires that CHP measurements begin immediately after water begins to flow. However, the soil has not reached saturation at this time and thus the measurement yields a value that is not the true k_{sat} of the soil (NRCS protocol, on the other hand, requires that the user wait until the CHP has reached steady-state to before taking measurements). If the soil is not at saturation for each measurement there can be inconsistencies between measurements based on the antecedent soil moisture. However, allowing the soil to reach saturation before each measurement would require approximately 10 more minutes per measurement (30 more minutes per basin).

Figure 2 shows CHP measurements for the three dry basins in the B14 UPC. Measurements tended to have higher infiltration rates as well as larger variability between measurements at the 4" depth. Basin 1's CHP measurements ranged from 2.27 to 10.60 in/hr at a 4" depth – fairly slow to very fast CHP measurements. At the 12" depth Basin 1's CHP measurements were more consistent – ranging from 0.67 to 0.87in/hr (a very slow CHP measurement). In Basin 2 measurements ranged from 2.0 to 9.8in/hr, again, a range from fairly slow to very fast for CHP. Measurements at a 12" depth varied the most in Basin 2 – ranging from 0.20 to 6.27in/hr, which is a very slow to fairly fast CHP measurement range. Basin 3 had the most consistent CHP measurement at the 4" depth – ranging from 0.47 to 3.3in/hr – or very slow to fairly slow range of CHP measurements. CHP measurements at a 12" depth in Basin 3 ranged from 0.17 to 1.47in/hr – both very slow measurements for CHP.

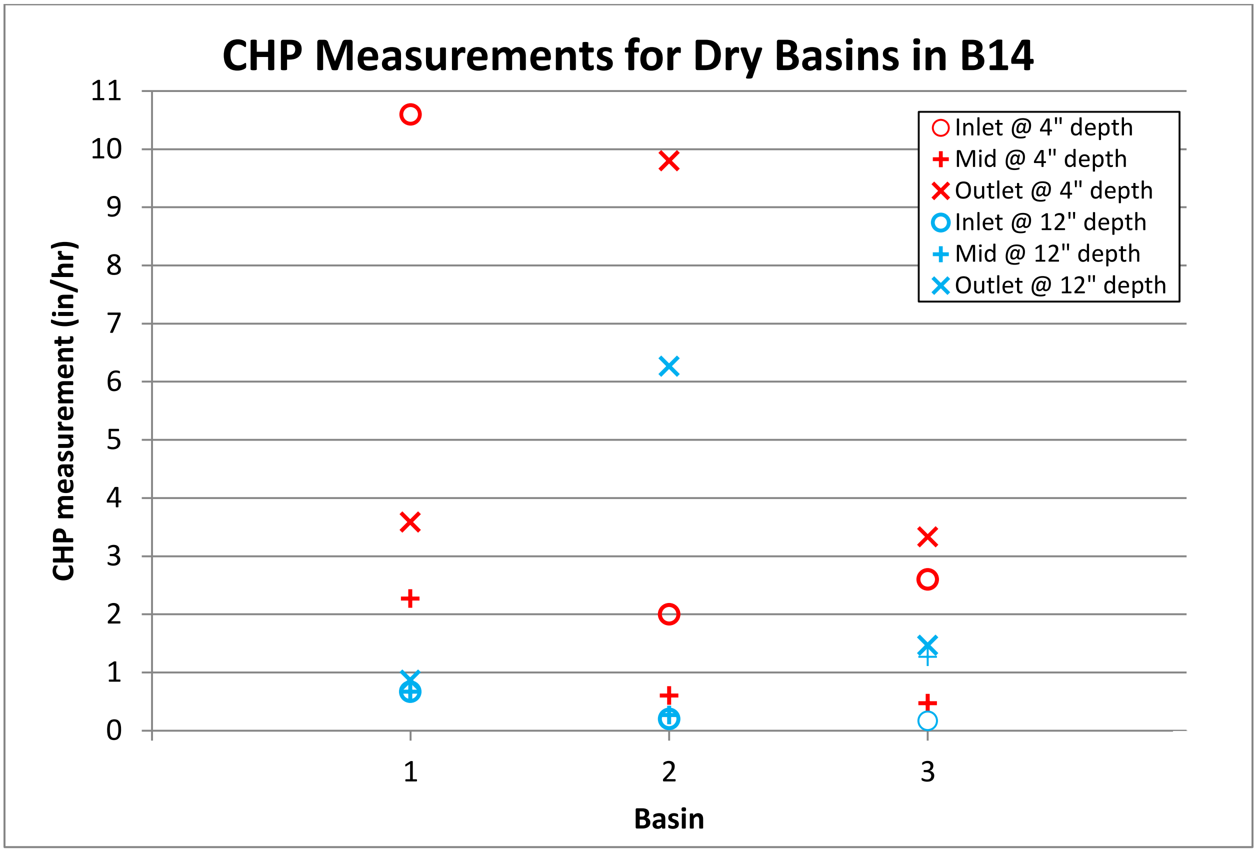

Figure 2 CHP measurements for the three dry basins in the B14 catchment; measurements were taken at both a 4" and a 12" depth at the inlet, middle, and outlet of each dry basin.

CHP measures the saturated hydraulic conductivity of the soil, which will be equal to the rate at which water moves through soil at saturation when there is no ponding. However, the measurement is taken in the subsurface and therefore fails to measure the rate at which water infiltrates at the soil surface. Without maintenance, fine sediment particles can build up in dry basins, causing an almost impermeable surface layer to form (William Loftis, NRCS, personal communication, October 2014). CHP measurements punch through this layer, giving potentially false results of BMP performance. CHP may therefore be a poor choice of measurement for dry basins that are designed to infiltrate water at the soil surface. Additionally, several factors confound measurements conducted with a CHP. First, soil is not a homogenous medium, but rather is subject to a large degree of spatial heterogeneity. It is therefore nearly impossible to get repeatable measurements from the same location, and CHP measurements within the same basin may therefore show a wide range of saturated hydraulic conductivities (as was observed with the measurements in the three dry basins in B14 UPC). Additionally, CHP measurements will change with different soil temperatures, and although equations exist to account for this discrepancy, soil and air temperature are not often recorded with CHP measurements. Finally, **it is not possible to conduct CHP in all locations such as areas with very rocky soils, very sandy soils, or very steep slopes**.

2.1.2 SINGLE-RING INFILTROMETER

Single-ring infiltrometers are used to measure the rate at which water infiltrates into the soil at the soil surface. The measurement is subject to the antecedent soil moisture and the number of “presoaks” conducted prior to measurement. Dryer soil will tend to have a *much* greater infiltration rate than soil that is completely saturated due to the matric potential of the soil which causes water to be absorbed by dry soil at a much faster rate. In CSLT UPC B14, infiltrometer measurements were taken at three locations within each basin, similar to CHP: near the inlet, in the middle, and near the outlet. At each location three measurements were taken in succession to measure how the infiltration rate changed with increased soil wetness.

Each single-ring infiltrometer measurement took 10 to 20 minutes, so if three measurements per basin were conducted with one soak each, **each basin would take 30 - 60 minutes at a minimum to RAM with 1 staff member.** Like CHP, infiltrometer measurements require water to conduct the measurement; each measurement takes about half a gallon of water, or **one and a half gallons per basin**.

In hydrology, it is well-established that infiltration rates in unsaturated soils tend to be very rapid initially and then quickly decline as the soil approaches saturation (Dingman 2002). As anticipated, the infiltration rates measured with the single-ring infiltrometer tended to decrease with the second and third measurements at the same location. This can be seen clearly in Figure 3, which shows pressure head of the water above the soil surface in inches versus time. The infiltration rate is equal to the slope (tangent) of the curve, with steeper slopes indicating higher infiltration rates. During the first soak, the infiltration rate is at its highest (steepest), but by the third soak the infiltration rate is approaching the flow rate at saturation. The infiltration rate for each soak was estimated from these data and is displayed in Table 1. The data clearly show the decrease in infiltration rate as the soil becomes more saturated, with a very high initial infiltration rate of 30 inches per hour, dropping to less than a third of that rate (9 inches per hour) by the final soak. A comparison of first soak infiltrometer measurements is shown in Figure 4. The range of observed infiltrometer measurements for each basin was quite large – ranging from 13.5 to 30in/hr in Basin 1; 1.25 to 15in/hr in Basin 2; and 7.5 to 20in/hr in Basin 3.

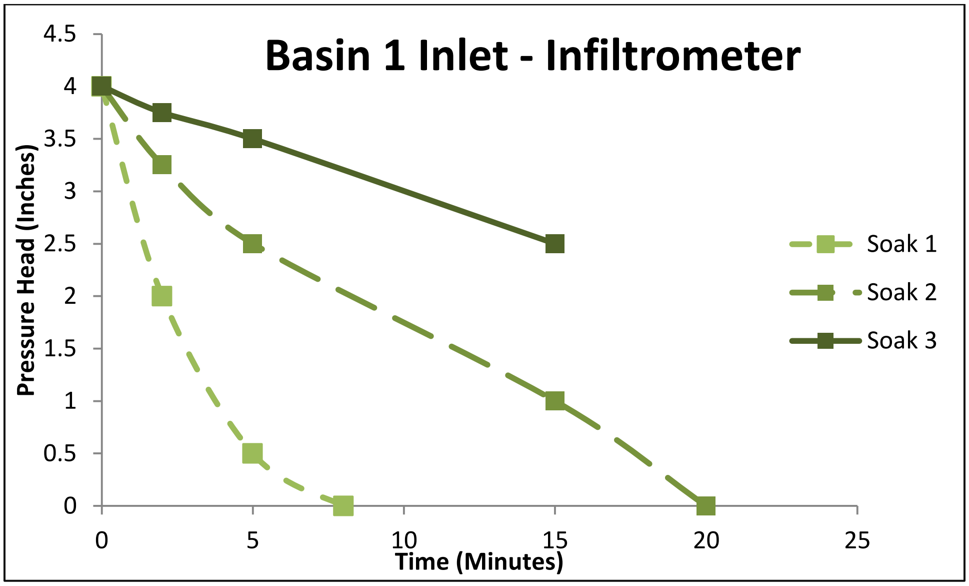

Figure 3 Infiltrometer measurements taken at the inlet of Basin 1 in the CSLT UPC B14 catchment. Infiltration rate decreases with the second and third soak. These measurements were taken on 10/30/2014.

Table 1 Estimated infiltration rate at Basin 1 Inlet for soaks 1, 2, and 3 in CSLT UPC B14 in inches per hour (in/hr).

Infiltration Rate at Basin D Inlet (in/hr)		
Soak 1	Soak 2	Soak 3
30	12	9

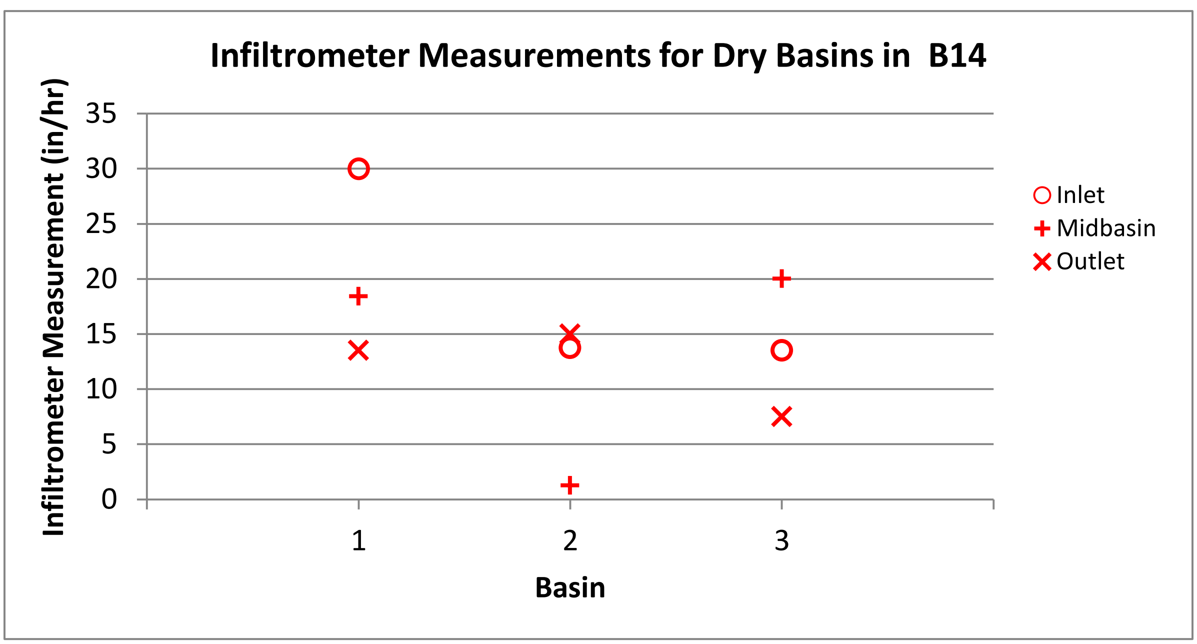

Figure 4 First soak infiltrometer measurements for the three dry basins in B14.

For evaluating infiltration in a dry basin, using an infiltrometer may be a better option than using CHP because it measures infiltration at the surface rather than the subsurface. However, like the CHP, it is very time consuming, and different results will be obtained based on the antecedent moisture level and the number of presoaks conducted prior to measurement. Similar to the CHP measurement, single-ring infiltrometer measurements are complicated by several issues. Spatial heterogeneity of the soil makes it nearly impossible to duplicate infiltrometer measurements. Single-ring infiltrometer measurements also require water to be ponded above the soil surface, causing higher infiltration rates due to additional pressure head. However, measuring infiltration rates with ponding may be desirable because during runoff events the dry basins will naturally have ponding that will change the infiltration rate with increased pressure head. Further complicating the infiltration rate measured by single-ring infiltrometers is that flow occurs horizontally as well as vertically, rather than the one dimensional vertical flow that is assumed by the user, so the infiltration rate may be skewed towards higher infiltration rates. However, this difference may be negligible because the single ring infiltrometer still measures the desired parameter of infiltration at the surface (William Loftis, NRCS, personal communication, January 2015).

2.1.3 CASQA 48-HOUR BASIN DRAW DOWN TIME

The California Stormwater Quality Association (CASQA) provides nationally recognized BMP standards. The CASQA Stormwater Best Management Practice Handbook's recommendations on infiltration basins (i.e. dry basins) design guidelines suggest using a draw down time of 48 to 72 hours in most areas of California (See Appendix C for CASQA's guidance on dry basin). Times longer than this are typically not suggested due to vector breeding, and times shorter than this are only suggested for areas with very rapidly draining soils. In 2007, the California Department of Public Health relaxed this detention time to up to 96 hours, with no time limit for elevations >5000 from October 1 – April 15th (See Appendix D - California Department of Public Health Vector Control).

The CASQA method entails inspecting the facility 48 hours after the first large storm to determine whether the desired residence time for stormwater treatment has been achieved (CASQA 2003). Some advantages of the CASQA method over the CHP and infiltrometer methods are that it is less time and water intensive and that it clearly demonstrates whether or not the basin is working (either the basin has infiltrated water or it hasn't). Similar to the infiltrometer method (and CHP if the measurement begins before steady state is achieved), antecedent moisture conditions may influence results. The main difference with this method is that it is weather dependent and must be scheduled within 48 hours of a large precipitation event. Another difference with the CASQA method compared to the other two methods is that it doesn't give you an exact number for infiltration rate; the basin infiltrates water in either greater than or less than 48 hours. **For basins where CHP/infiltrometer is not possible (i.e. rock lined basins), the 48-hour CASQA drawdown time may be the only viable option.**

Tahoe RCD staff conducted full BMP RAM assessments using the CASQA method on all basins within CSLT UPC B14 and EDC UPC04 in one and a half hours on November 24th; each measurement took approximately 6 minutes per basin.

3 RECOMMENDATIONS

Under the NPDES permit issued by the Lahontan Regional Water Quality Control Board to ensure compliance with the Lake Tahoe TMDL, all California jurisdictions located in the Tahoe basin are required to inspect all "key and essential" BMPs using BMP RAM to ensure they are functioning properly. Tahoe RCD staff compared three methods of estimating infiltration capacity that could be used for conducting BMP RAM on dry basins. The methods compared were CHP (the current BMP RAM standard for dry basins), single-ring infiltrometer, and the CASQA 48-hour basin draw down time in catchments located within the City of South Lake Tahoe's UPC B14 and El Dorado County's UPC04. The CHP method measures saturated hydraulic conductivity at the subsurface rather than the soil surface; the soil surface is the area that is prone to sediment buildup and subsequent decrease in infiltration rate and where infiltration would naturally occur in a dry basin. In contrast, the single-ring infiltrometer and the CASQA 48-hour basin draw down time methods observe infiltration at the surface and are therefore may be more appropriate methods to assess infiltration in dry basins.

There are many advantages to using the CASQA 48-hour basin draw down time method over CHP and infiltrometer. First and foremost, **CASQA provides BMP information sheets that are nationally recognized and considered the industry standard**. In addition, both CHP and infiltrometer measurements were very time consuming, while the **CASQA 48-hour basin draw down time took roughly 10% of the time that the CHP or infiltrometer methods took**. Using the CASQA 48-hour basin draw down time, all eleven basins in both CSLT UPC B14 and EDC UPC04 could be evaluated in less than 2 hours. If CHP or infiltrometer methods were used, this same task would take one to two field days. Furthermore, the CASQA method is the most representative observation by which to determine if the basins are in functioning condition and the method only requires staff to check basins after a runoff event to see whether or not water has infiltrated within a 48-hour time period. The main disadvantage of the CASQA method is that scheduling measurements is weather dependent. In a drought year, it may not be possible to conduct measurements if large enough precipitation events do not occur, which could leave jurisdictions out of compliance with regulatory requirements. **However, in basins where CHP/infiltrometer is not possible (i.e. rock lined basins), the 48-hour CASQA drawdown time may be the only viable option.**

Despite potential scheduling difficulties, the Tahoe RCD recommends the CASQA 48-hour basin draw down time as the infiltration observation for BMP RAM in dry basins. The CASQA 48-hour basin draw down time is faster, cheaper, and requires fewer resources than both the CHP and the single-ring infiltrometer measurements.

4 REFERENCES

2NDNATURE LLC et al. September 2009. BMP RAM User's Manual. Prepared for the U.S. Army Corps of Engineers, Sacramento District.

California Stormwater Quality Association (CASQA) 2003. California Stormwater Quality Association Stormwater Best Management Practice Handbook – New Development and Redevelopment. "Infiltration Basin" Section 5.7 TC-11

Dingman, S. L. 2002. Physical hydrology. Upper Saddle River, N.J: Prentice Hall.

Lahontan Water Quality Control Board and Nevada Division of Environmental Protection. 2011. Lake Clarity Crediting Program Handbook: for Lake Tahoe TMDL Implementation v1.0. Prepared by Environmental Incentives, LLC. South Lake Tahoe, CA.

5 APPENDIX A – CHP/INFILTROMETER MEASUREMENTS

Basin D - 10/30/2014 11:30 AM - 40 F							Benchmark?
Depth:	Staff Plate Height: N/A						
Vegetation: 10% Tree, 85% Grass, 5% No veg.							**Yes**
CHP:	# of surfaces: 1		# of measurements: 3 @ 4", 3 @ 12"				**Yes**
Location	1_Near Inlet 4" @ 11:50		2_Near Inlet 12" @ 12:25		3_Mid Basin 4" @ 12:45		
	time	reading	time	reading	time	reading	
1	0	165	0	155	0	128	
2	2	117	2	154	2	123	
3	8	56	8	150	8	109	
4	15	6	15	145	15	94	
Location	4_Mid Basin 12" @ 13:00		5_Near Outlet 4" @ 13:15		6_Near Outlet 12" @ 13:20		
	time	reading	time	reading	time	reading	
1	0	132	0	95	0	33	
2	2	130	2	86	2	29	
3	8	123	8	4	8	25	
4	15	122	12	52	15	20	
Conveyance:					Yes / No		
Comments:							

Infiltrometer:	BMP Area: 600sf						**Comments**
Location:	Near Inlet @ 11:30						
Trial:	One		Two		Three		
	time	reading	time	reading	time	reading	
1	0	4	0	4	0	4	
2	2	2	2	3.25	2	3.75	
3	5	0.5	5	2.5	5	3.5	
4	8	0	15	1	15	2.5	
5			20	0			
Location:	Mid Basin @ 12:45						
Trial:	One		Two		Three		
	time	reading	time	reading	time	reading	
1	0	4	0	4	0	4	
2	2	3.125	2.5	3.25	2	3.625	
3	5	2.125	5	2.5	5	3	
4	11	0.625	10	1.5			
5			15	0			

Location:	Near Outlet @ 13:35						
Trial:	One		Two		Three		
	time	reading	time	reading	time	reading	
1	0	4	0	4			
2	2	3.375	2	3.75			
3	5	2.125	5	3.25			
4	10	1.75	10.5	2.5			
5	14	1					
Date:	11/24/2014	**Time:**	16:30				
CASQA	**Standing Water?**	**Vegetation**					
48-hour	No	80% grass, 20% tree					
Notes:	Standing water in stand pipe						

Basin A, Upper - 11/5/2014 13:30 PM - 56 F							**Benchmark?**
Depth:	Staff Plate Height: N/A						
Vegetation: 10% Wetland species, 85% Grass, 5% No veg							**Yes**
CHP:	# of surfaces:		# of measurements:				**Yes**
Location	1_Near Inlet 4" @ 13:50		2_Near Inlet 12" @ 14:10		3_Mid Basin 4" @ 14:45		
	time	reading	time	reading	time	reading	
1	0	150	0	108	0	52	
2	2	144	2	107	2	51	
3	8	132	8	106	8	48	
4	15	120	15	105	15	43	
Location	4_Mid Basin 12" @ 15:05		5_Near Outlet 4" @ 14:05 on 11/10/14		6_Near Outlet 12" @ 14:25 on 11/10/14		
	time	reading	time	reading	time	reading	
1	0	174	0	115	0	137	
2	2	174	2	94	2	135	
3	8	172	8	40	8	88	
4	15	170	10	17	15	43	
Conveyance:					Yes / No		
Comments:							

Infiltrometer:	BMP Area: 800sf						**Comments**
Location:	Near Inlet @ 13:45						
Trial:	One		Two		Three		
	time	reading	time	reading	time	reading	
1	0	4	0	4	0	4	
2	2	3.375	2	3.875	3	3.675	
3	6	2.125	6	3.625	6	3.5	
4	10	1.625	10	3	10	3.25	
5	12	1.25	12	2.875	12	3.125	
Location:	Mid Basin @ 14:40						
Trial:	One		Two		Three		
	time	reading	time	reading	time	reading	
1	0	4	0	4	0	4	
2	2	3.9	2	3.925	4	3.95	
3	6	3.8	6	3.8	8	3.875	
4	10	3.75	10	3.75	12	3.825	
5	12	3.75	12	3.675	16	3.75	
Location:	Near Outlet @ 14:05 on 11/10/14						
Trial:	One		Two		Three		
	time	reading	time	reading	time	reading	
1	0	4	0	4	0	4	
2	2	3.25	2	3.5	2	3.75	
3	6	2.725	6	3.25	6	3.375	
4	10	1.5	10	2.875	10	3.125	
5							
Date:	11/24/2014		**Time:**	16:30			
CASQA 48-hour	**Standing Water?**		**Vegetation**				
	Yes		80% grass, 20% tree				
Notes:	Standing water is frozen						

Basin A, Lower - 11/10/2014 15:00 PM - 55 F							**Benchmark?**
Depth:	Staff Plate Height: N/A						
Vegetation: 100% Grass							**Yes**
CHP:	# of surfaces:		# of measurements:				**Yes**
Location	1_Near Inlet 4" @ 15:15		2_Near Inlet 12" @ 15:30		3_Mid Basin 4" @ 15:50		
	time	reading	time	reading	time	reading	
1	0	143	0	166	0	148	
2	2	135	2	165	2	146	
3	8	120	8	164.5	8	143	
4	15	104	15	163.5	15	141	
Location	4_Mid Basin 12" @ 16:15		5_Near Outlet 4" @ 12:40 on 11.12.14		6_Near Outlet 12" @ 13:00 on 11.12.14		
	time	reading	time	reading	time	reading	
1	0	129	0	175	0	179	
2	2	122	2	167	2	171	
3	8	115	8	147	8	165	
4	15	110	15	125	15	157	
Conveyance:					Yes / No		
Comments:							
Infiltrometer:		BMP Area: 400sf					**Comments**
Location:	Near Inlet @ 15:00						
Trial:	One		Two		Three		
	time	reading	time	reading	time	reading	
1	0	4	0	4	0	4	
2	2	3.25	2	3.375	2	3.375	
3	6	2.5	6	2.5	6	2.5	
4	10	1.75	10	1.25	10	1.5	
5							
Location:	Mid Basin @ 15:50						
Trial:	One		Two		Three		
	time	reading	time	reading	time	reading	
1	0	3.5	0	3.5	0	3.5	
2	2	2.5	2	2.75	2	2.75	
3	6	1.5	6	1.5	6	1.75	
4			10	0.875	10	0.75	
5							

Location:	Near Outlet @ 12:40 on 11/12/14					
Trial:	One		Two		Three	
	time	reading	time	reading	time	reading
1	0	4	0	4	0	4
2	2	3.625	2	3.625	2	3.625
3	6	3.4	6	3.25	6	3.125
4	10	2.75	15	2.625	10	2.5
5						
Date:	11/24/2014		**Time:**	16:30		
CASQA	**Standing Water?**		**Vegetation**			
48-hour	No		95% grass, 5% tree			
Notes:						

6 APPENDIX B – CASQA 48-HOUR DRAW DOWN TIME MEASUREMENTS

Date:	11/24/2014	Time:	16:30
Black Bart	**Standing Water?**	**Vegetation**	**Staff Plate**
	No	95% grass, 5% tree	2.99'
Notes:			
Alice Lake	**Standing Water?**	**Vegetation**	**Staff Plate**
	No	100% grass	2.95'
Notes:			
Humboldt	**Standing Water?**	**Vegetation**	**Staff Plate**
	No	100% grass	3'
Notes:			
Copper	**Standing Water?**	**Vegetation**	**Staff Plate**
	No	100% grass	2.52'
Notes:			
Fortune	**Standing Water?**	**Vegetation**	**Staff Plate**
	No	100% grass	3.85'
Notes:			
Del Norte, West	**Standing Water?**	**Vegetation**	**Staff Plate**
	No	100% grass	2.82'
Notes:			
Del Norte, East	**Standing Water?**	**Vegetation**	**Staff Plate**
	No	100% grass	2.81'
Notes:			
Cold Creek, West	**Standing Water?**	**Vegetation**	**Staff Plate**
	No	50% grass, 50% bare	2.22'
Notes:			

7 APPENDIX C- CASQA DRY BASIN FACT SHEET (TC-11)

Infiltration Basin TC-11

Design Considerations

- Soil for Infiltration
- Slope
- Aesthetics

Targeted Constituents

☑	Sediment	■
☑	Nutrients	■
☑	Trash	■
☑	Metals	■
☑	Bacteria	■
☑	Oil and Grease	■
☑	Organics	■

Legend *(Removal Effectiveness)*

● Low ■ High

▲ Medium

Description

An infiltration basin is a shallow impoundment that is designed to infiltrate stormwater. Infiltration basins use the natural filtering ability of the soil to remove pollutants in stormwater runoff. Infiltration facilities store runoff until it gradually exfiltrates through the soil and eventually into the water table. This practice has high pollutant removal efficiency and can also help recharge groundwater, thus helping to maintain low flows in stream systems. Infiltration basins can be challenging to apply on many sites, however, because of soils requirements. In addition, some studies have shown relatively high failure rates compared with other management practices.

California Experience

Infiltration basins have a long history of use in California, especially in the Central Valley. Basins located in Fresno were among those initially evaluated in the National Urban Runoff Program and were found to be effective at reducing the volume of runoff, while posing little long-term threat to groundwater quality (EPA, 1983; Schroeder, 1995). Proper siting of these devices is crucial as underscored by the experience of Caltrans in siting two basins in Southern California. The basin with marginal separation from groundwater and soil permeability failed immediately and could never be rehabilitated.

Advantages

- Provides 100% reduction in the load discharged to surface waters.
- The principal benefit of infiltration basins is the approximation of pre-development hydrology during which a

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CALIFORNIA STORMWATER QUALITY ASSOCIATION

significant portion of the average annual rainfall runoff is infiltrated and evaporated rather than flushed directly to creeks.

- If the water quality volume is adequately sized, infiltration basins can be useful for providing control of channel forming (erosion) and high frequency (generally less than the 2-year) flood events.

Limitations

- May not be appropriate for industrial sites or locations where spills may occur.
- Infiltration basins require a minimum soil infiltration rate of 0.5 inches/hour, not appropriate at sites with Hydrologic Soil Types C and D.
- If infiltration rates exceed 2.4 inches/hour, then the runoff should be fully treated prior to infiltration to protect groundwater quality.
- Not suitable on fill sites or steep slopes.
- Risk of groundwater contamination in very coarse soils.
- Upstream drainage area must be completely stabilized before construction.
- Difficult to restore functioning of infiltration basins once clogged.

Design and Sizing Guidelines

- Water quality volume determined by local requirements or sized so that 85% of the annual runoff volume is captured.
- Basin sized so that the entire water quality volume is infiltrated within 48 hours.
- Vegetation establishment on the basin floor may help reduce the clogging rate.

Construction/Inspection Considerations

- Before construction begins, stabilize the entire area draining to the facility. If impossible, place a diversion berm around the perimeter of the infiltration site to prevent sediment entrance during construction or remove the top 2 inches of soil after the site is stabililized. Stabilize the entire contributing drainage area, including the side slopes, before allowing any runoff to enter once construction is complete.
- Place excavated material such that it can not be washed back into the basin if a storm occurs during construction of the facility.
- Build the basin without driving heavy equipment over the infiltration surface. Any equipment driven on the surface should have extra-wide ("low pressure") tires. Prior to any construction, rope off the infiltration area to stop entrance by unwanted equipment.
- After final grading, till the infiltration surface deeply.
- Use appropriate erosion control seed mix for the specific project and location.

Infiltration Basin TC-11

Performance

As water migrates through porous soil and rock, pollutant attenuation mechanisms include precipitation, sorption, physical filtration, and bacterial degradation. If functioning properly, this approach is presumed to have high removal efficiencies for particulate pollutants and moderate removal of soluble pollutants. Actual pollutant removal in the subsurface would be expected to vary depending upon site-specific soil types. This technology eliminates discharge to surface waters except for the very largest storms; consequently, complete removal of all stormwater constituents can be assumed.

There remain some concerns about the potential for groundwater contamination despite the findings of the NURP and Nightingale (1975; 1987a,b,c; 1989). For instance, a report by Pitt et al. (1994) highlighted the potential for groundwater contamination from intentional and unintentional stormwater infiltration. That report recommends that infiltration facilities not be sited in areas where high concentrations are present or where there is a potential for spills of toxic material. Conversely, Schroeder (1995) reported that there was no evidence of groundwater impacts from an infiltration basin serving a large industrial catchment in Fresno, CA.

Siting Criteria

The key element in siting infiltration basins is identifying sites with appropriate soil and hydrogeologic properties, which is critical for long term performance. In one study conducted in Prince George's County, Maryland (Galli, 1992), all of the infiltration basins investigated clogged within 2 years. It is believed that these failures were for the most part due to allowing infiltration at sites with rates of less than 0.5 in/hr, basing siting on soil type rather than field infiltration tests, and poor construction practices that resulted in soil compaction of the basin invert.

A study of 23 infiltration basins in the Pacific Northwest showed better long-term performance in an area with highly permeable soils (Hilding, 1996). In this study, few of the infiltration basins had failed after 10 years. Consequently, the following guidelines for identifying appropriate soil and subsurface conditions should be rigorously adhered to.

- Determine soil type (consider RCS soil type 'A, B or C' only) from mapping and consult USDA soil survey tables to review other parameters such as the amount of silt and clay, presence of a restrictive layer or seasonal high water table, and estimated permeability. The soil should not have more than 30% clay or more than 40% of clay and silt combined. Eliminate sites that are clearly unsuitable for infiltration.

- Groundwater separation should be at least 3 m from the basin invert to the measured ground water elevation. There is concern at the state and regional levels of the impact on groundwater quality from infiltrated runoff, especially when the separation between groundwater and the surface is small.

- Location away from buildings, slopes and highway pavement (greater than 6 m) and wells and bridge structures (greater than 30 m). Sites constructed of fill, having a base flow or with a slope greater than 15% should not be considered.

- Ensure that adequate head is available to operate flow splitter structures (to allow the basin to be offline) without ponding in the splitter structure or creating backwater upstream of the splitter.

- Base flow should not be present in the tributary watershed.

Secondary Screening Based on Site Geotechnical Investigation

- At least three in-hole conductivity tests shall be performed using USBR 7300-89 or Bouwer-Rice procedures (the latter if groundwater is encountered within the boring), two tests at different locations within the proposed basin and the third down gradient by no more than approximately 10 m. The tests shall measure permeability in the side slopes and the bed within a depth of 3 m of the invert.

- The minimum acceptable hydraulic conductivity as measured in any of the three required test holes is 13 mm/hr. If any test hole shows less than the minimum value, the site should be disqualified from further consideration.

- Exclude from consideration sites constructed in fill or partially in fill unless no silts or clays are present in the soil boring. Fill tends to be compacted, with clays in a dispersed rather than flocculated state, greatly reducing permeability.

- The geotechnical investigation should be such that a good understanding is gained as to how the stormwater runoff will move in the soil (horizontally or vertically) and if there are any geological conditions that could inhibit the movement of water.

Additional Design Guidelines

(1) Basin Sizing - The required water quality volume is determined by local regulations or sufficient to capture 85% of the annual runoff.

(2) Provide pretreatment if sediment loading is a maintenance concern for the basin.

(3) Include energy dissipation in the inlet design for the basins. Avoid designs that include a permanent pool to reduce opportunity for standing water and associated vector problems.

(4) Basin invert area should be determined by the equation:

$$A = \frac{WQV}{kt}$$

where A = Basin invert area (m^2)

WQV = water quality volume (m^3)

k = 0.5 times the lowest field-measured hydraulic conductivity (m/hr)

t = drawdown time (48 hr)

(5) The use of vertical piping, either for distribution or infiltration enhancement shall not be allowed to avoid device classification as a Class V injection well per 40 CFR146.5(e)(4).

Maintenance

Regular maintenance is critical to the successful operation of infiltration basins. Recommended operation and maintenance guidelines include:

- Inspections and maintenance to ensure that water infiltrates into the subsurface completely (recommended infiltration rate of 72 hours or less) and that vegetation is carefully managed to prevent creating mosquito and other vector habitats.
- Observe drain time for the design storm after completion or modification of the facility to confirm that the desired drain time has been obtained.
- Schedule semiannual inspections for beginning and end of the wet season to identify potential problems such as erosion of the basin side slopes and invert, standing water, trash and debris, and sediment accumulation.
- Remove accumulated trash and debris in the basin at the start and end of the wet season.
- Inspect for standing water at the end of the wet season.
- Trim vegetation at the beginning and end of the wet season to prevent establishment of woody vegetation and for aesthetic and vector reasons.
- Remove accumulated sediment and regrade when the accumulated sediment volume exceeds 10% of the basin.
- If erosion is occurring within the basin, revegetate immediately and stabilize with an erosion control mulch or mat until vegetation cover is established.
- To avoid reversing soil development, scarification or other disturbance should only be performed when there are actual signs of clogging, rather than on a routine basis. Always remove deposited sediments before scarification, and use a hand-guided rotary tiller, if possible, or a disc harrow pulled by a very light tractor.

Cost

Infiltration basins are relatively cost-effective practices because little infrastructure is needed when constructing them. One study estimated the total construction cost at about $2 per ft (adjusted for inflation) of storage for a 0.25-acre basin (SWRPC, 1991). As with other BMPs, these published cost estimates may deviate greatly from what might be incurred at a specific site. For instance, Caltrans spent about $18/ft^3 for the two infiltration basins constructed in southern California, each of which had a water quality volume of about 0.34 ac.-ft. Much of the higher cost can be attributed to changes in the storm drain system necessary to route the runoff to the basin locations.

Infiltration basins typically consume about 2 to 3% of the site draining to them, which is relatively small. Additional space may be required for buffer, landscaping, access road, and fencing. Maintenance costs are estimated at 5 to 10% of construction costs.

One cost concern associated with infiltration practices is the maintenance burden and longevity. If improperly maintained, infiltration basins have a high failure rate. Thus, it may be necessary to replace the basin with a different technology after a relatively short period of time.

References and Sources of Additional Information

Caltrans, 2002, BMP Retrofit Pilot Program Proposed Final Report, Rpt. CTSW-RT-01-050, California Dept. of Transportation, Sacramento, CA.

Galli, J. 1992. *Analysis of Urban BMP Performance and Longevity in Prince George's County, Maryland.* Metropolitan Washington Council of Governments, Washington, DC.

Hilding, K. 1996. Longevity of infiltration basins assessed in Puget Sound. *Watershed Protection Techniques* 1(3):124–125.

Maryland Department of the Environment (MDE). 2000. *Maryland Stormwater Design Manual.* http://www.mde.state.md.us/environment/wma/stormwatermanual. Accessed May 22, 2002.

Metzger, M. E., D. F. Messer, C. L. Beitia, C. M. Myers, and V. L. Kramer. 2002. The Dark Side Of Stormwater Runoff Management: Disease Vectors Associated With Structural BMPs. Stormwater 3(2): 24-39.

Nightingale, H.I., 1975, "Lead, Zinc, and Copper in Soils of Urban Storm-Runoff Retention Basins," American Water Works Assoc. Journal. Vol. 67, p. 443-446.

Nightingale, H.I., 1987a, "Water Quality beneath Urban Runoff Water Management Basins," Water Resources Bulletin, Vol. 23, p. 197-205.

Nightingale, H.I., 1987b, "Accumulation of As, Ni, Cu, and Pb in Retention and Recharge Basin Soils from Urban Runoff," Water Resources Bulletin, Vol. 23, p. 663-672.

Nightingale, H.I., 1987c, "Organic Pollutants in Soils of Retention/Recharge Basins Receiving Urban Runoff Water," Soil Science Vol. 148, pp. 39-45.

Nightingale, H.I., Harrison, D., and Salo, J.E., 1985, "An Evaluation Technique for Ground-water Quality Beneath Urban Runoff Retention and Percolation Basins," Ground Water Monitoring Review, Vol. 5, No. 1, pp. 43-50.

Oberts, G. 1994. Performance of Stormwater Ponds and Wetlands in Winter. *Watershed Protection Techniques* 1(2): 64–68.

Pitt, R., et al. 1994, *Potential Groundwater Contamination from Intentional and Nonintentional Stormwater Infiltration*, EPA/600/R-94/051, Risk Reduction Engineering Laboratory, U.S. EPA, Cincinnati, OH.

Schueler, T. 1987. *Controlling Urban Runoff: A Practical Manual for Planning and Designing Urban BMPs.* Metropolitan Washington Council of Governments, Washington, DC.

Schroeder, R.A., 1995, *Potential For Chemical Transport Beneath a Storm-Runoff Recharge (Retention) Basin for an Industrial Catchment in Fresno, CA*, USGS Water-Resource Investigations Report 93-4140.

Southeastern Wisconsin Regional Planning Commission (SWRPC). 1991. *Costs of Urban Nonpoint Source Water Pollution Control Measures*. Southeastern Wisconsin Regional Planning Commission, Waukesha, WI.

U.S. EPA, 1983, *Results of the Nationwide Urban Runoff Program: Volume 1 – Final Report*, WH-554, Water Planning Division, Washington, DC.

Watershed Management Institute (WMI). 1997. *Operation, Maintenance, and Management of Stormwater Management Systems*. Prepared for U.S. Environmental Protection Agency Office of Water, Washington, DC.

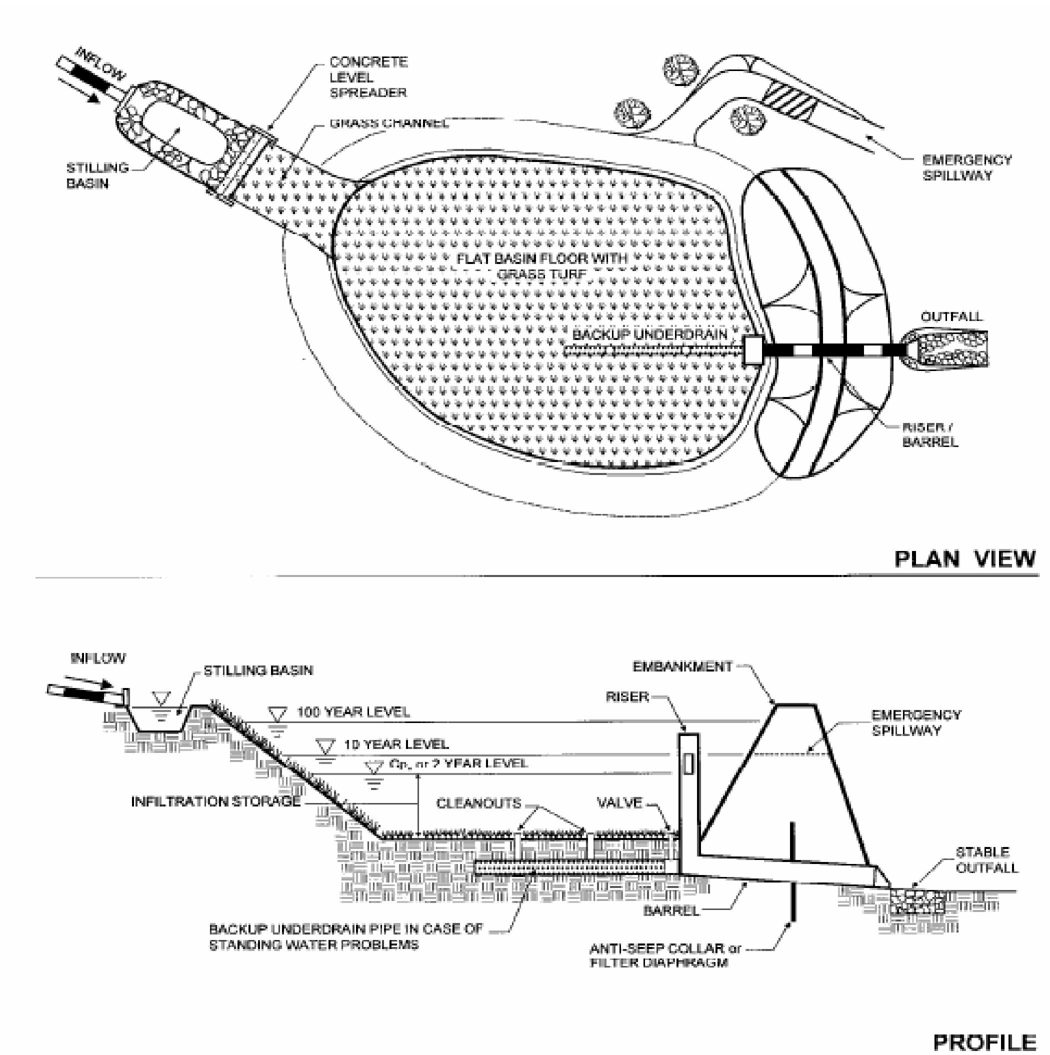
Information Resources

Center for Watershed Protection (CWP). 1997. *Stormwater BMP Design Supplement for Cold Climates*. Prepared for U.S. Environmental Protection Agency Office of Wetlands, Oceans and Watersheds. Washington, DC.

Ferguson, B.K., 1994. *Stormwater Infiltration*. CRC Press, Ann Arbor, MI.

USEPA. 1993. *Guidance to Specify Management Measures for Sources of Nonpoint Pollution in Coastal Waters*. EPA-840-B-92-002. U.S. Environmental Protection Agency, Office of Water, Washington, DC.

TC-11 Infiltration Basin



8 APPENDIX D - CALIFORNIA DEPARTMENT OF PUBLIC HEALTH VECTOR CONTROL

State of California—Health and Human Services Agency
California Department of Public Health

MARK B HORTON, MD, MSPH
Director

ARNOLD SCHWARZENEGGER
Governor

September 18, 2008

Mr. Robert Erlich
Storm Water Coordinator - Public Works Department
City of South Lake Tahoe
1052 Tata Lane
South Lake Tahoe, CA 96150

Dear Mr. Erlich,

As you are aware, the California Department of Public Health (CDPH) recently published and distributed a 64-page guidance manual for minimizing mosquito production on state-owned lands entitled *Best Management Practices for Mosquito Control on California State Properties* (available for download at www.cdph.ca.gov). The manual was developed specifically for state property managers and covers the general principles for mosquito control on typical state lands; however, some local agencies and organizations have adopted this document as well to guide their own mosquito management policies and recommendations. It should be noted that the manual does not address all local considerations such as the following exemption made for your region by CDPH in 2007 regarding stormwater and urban runoff detention:

"In the Lake Tahoe Basin and in other high-elevation regions of the Sierra Nevada >5000 feet with similar alpine climates, water may be retained in structural BMPs as long as necessary between October 1st and April 15th without increasing the potential for production of Cx. tarsalis mosquitoes".

The new CDPH manual should not be interpreted as superseding guidance for your region, thus stormwater managers responsible for BMP design, operation, and maintenance can continue to adhere to the 2007 recommendations (enclosure). If you require additional information, please contact Marco Metzger at Marco.Metzger@cdph.ca.gov or (909) 937-3448.

Sincerely,

Vicki Kramer, Ph.D.
Chief, Vector-Borne Disease Section

Enclosure

Vector-Borne Disease Section, 1616 Capitol Ave., MS 7307, P.O. Box 997377, Sacramento, CA 95899-7377
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State of California—Health and Human Services Agency
California Department of Public Health

MARK B HORTON, MD, MSPH
Director

ARNOLD SCHWARZENEGGER
Governor

Date: July 17, 2007

To: Scott McGowen, P.E., Chief Environmental Engineer
Division of Environmental Analysis - Stormwater
California Department of Transportation
1120 N Street, MS-27
Sacramento, CA 95814

From: Vicki Kramer, Ph.D., Chief
Vector-Borne Disease Section

Re: Statewide Relaxation of 72-Hour Water Detention Policy for Mosquito Prevention in Structural Best Management Practices (BMPs)

Recent studies conducted by the California Department of Public Health, Vector-Borne Disease Section (VBDS), have led to the following revised recommendations:

- **Throughout California**, water may be retained in urban structural BMPs for **up to 96 hours** without increasing the potential for production of *Culex tarsalis, Cx. pipiens*, and *Cx. quinquefasciatus* mosquitoes.
- In the **Lake Tahoe Basin** and in other high-elevation regions of the Sierra Nevada >5000 feet with similar alpine climates, water may be retained in structural BMPs **as long as necessary between October 1st and April 15th** without increasing the potential for production of *Cx. tarsalis* mosquitoes.

Since 1999, VBDS has recommended that structural stormwater Best Management Practices (BMPs) designed to drain completely should hold captured water for no more than 72 hours to prevent mosquito production. This time limit is widely accepted throughout the United States and corresponds to the minimum time required for certain species to complete their life cycle under optimal conditions. Because most urban mosquito species require at least 120 hours to develop from egg to adult, this recommendation provides a margin of safety under most conditions that may influence production potential, regardless of season, species, or other factors. However, detention periods of 72 hours or less may significantly impede or prevent BMPs in environmentally sensitive areas (e.g., Lake Tahoe Basin) from fulfilling more stringent water quality standards.

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In 2006, VBDS evaluated the development time, from egg to adult, of three important vectors of encephalitis viruses including West Nile virus: *Culex tarsalis* in the Tahoe Basin, and *Cx. tarsalis*, *Cx. pipiens*, and *Cx. quinquefasciatus* in the Sacramento Valley and Los Angeles Basin. Statistical models generated from the data predict that development of any of these species requires at least 96 hours under optimal environmental conditions. These results led VBDS to conclude that water may be retained in urban structural BMPs for up to 96 hours without increasing the potential for production of the aforementioned *Culex* compromising the public's health.

Studies conducted by VBDS in the Lake Tahoe Basin in 2002-2006 provided scientific evidence that, given the extended season of cold air and water temperatures, water retention times in BMPs in this region can be extended between October 1st and April 15th to whatever period is necessary to meet water quality goals with minimal risk of *Cx. tarsalis* production. This guidance can be applied to other high-elevation regions of the Sierra Nevada >5000 feet with similar alpine climates where the use of abrasives and deicers on roadways may require specific treatment BMPs to mitigate water quality concerns.

These two revised policies provide effective prevention of *Cx. tarsalis*, *Cx. pipiens*, and *Cx. quinquefasciatus* development with a built-in margin of safety and will allow Caltrans greater flexibility in meeting water quality requirements statewide without unintentionally producing mosquitoes of public health importance. This guidance is based on knowledge of mosquitoes and mosquito-borne diseases currently present in California and is subject to change if new information, new mosquito species, and/or new diseases of public health significance emerge in the future.

If you require additional information, please contact Marco Metzger at Marco.Metzger@cdph.ca.gov or (909) 937-3448.

cc: Karl Dreher, P.E.
Keith Jones, P.E.
Tim Sobelman, P.E.
Bala Nanjundaiah, M.S.
California Department of Transportation
Division of Environmental Analysis – Stormwater