Summary of Monitoring and Analysis
Cave Rock Estates General Improvement District Stormwater System

December 2012

Prepared for:
Nevada Division of Environmental Protection
901 South Stewart Street, Suite 4001
Carson City, Nevada 89701–5249

Prepared by:

Meghan Kelly, P.E.
Nevada Tahoe Conservation District
PO Box 915
Zephyr Cove, NV 89448

Nevada Tahoe Conservation District

TABLE OF CONTENTS

Introduction	1
Original Design Report	1
Historical Observations	1
LiDAR	2
Infiltration Testing	2
PLRM	2
Water Quality Monitoring	3
Conclusion	6
References	6
APPENDIX A Cave Rock Estates PLRM Model Development	7
APPENDIX B NOAA Point Precipitation Estimates	9
APPENDIX C Water Quality Monitoring Results	13
APPENDIX D Cave Rock Estates GID Maintenance Plan	15
APPENDIX E TRPA Letter of Support	61

Introduction

This report summarizes the analysis performed by the Nevada Tahoe Conservation District (NTCD) in coordination with the Tahoe Regional Planning Agency (TRPA) on the feasibility of treating stormwater runoff from private properties in the Cave Rock Estates General Improvement District's (CREGID) existing treatment bed filter. In order to assess the feasibility, the following tools were utilized: review of original design report, basin wide LiDAR, infiltration testing, PLRM, and water quality monitoring. Results show that the existing treatment system can accommodate both public and private runoff resulting from the 20 year storm for the region if the system is properly maintained.

Original Design Report

The Cave Rock Estates Erosion Control Project was constructed in 1993 with funding from the USDA Forest Service and the State of Nevada Lake Tahoe Basin Act. The design and associated design report was completed by KB Foster in 1990. The key treatment asset in this project, collecting over 93 percent of the runoff from Cave Rock Estates, was to be a large "dry extended detention basin" or bed filter. The bed filter design was chosen both due to public safety and to provide treatment for full build-out of the CREGID subdivision (KB, 1990). The analysis to size the bed filter was the TR-55 method and modeled using the 25 year storm or 3.4 inches of precipitation in 24 hours over the entire 68.35 acre catchment. The report specifically states:

> *The runoff volumes generated by the TR-55 method are consistent with rule-of-thumb practices in the Lake Tahoe Basin. The California Regional Water Control Board (Lahontan) estimates runoff from impervious surfaces at 1.0 inch in a 20 year storm. Our calculations result in 0.86 inches of runoff from Watershed "A" during a 25-year event. The difference can be explained because of the inclusion of non-developed pervious area within the watershed which would result in an aggregate value of less than 1.0 inch.*

Furthermore, analysis by NTCD revealed that only 16 percent of impervious residential area is directly connected to the roads that feed stormwater to the bed filter while the design report used a figure of 35 percent (Staggs, 2012). While models are only estimates, NTCD can ascertain that the KB Foster Design overestimated the amount of runoff reaching the bed filter in a 25 year event and included both private and public inputs.

Historical Observations

Since the installation of the bed filter in 1994, the emergency overflow from the filter has only been observed to be in use one time by longtime residents and CREGID board members (Swanson, 2011). NTCD staff confirmed that the overflow was not activated during the result rain and snow events from November 28th to December 2nd, 2012 which deposited approximately 5 inches of rain and was estimated to be the 25 year storm.

LiDAR

The LiDAR was imported into AutoCAD Civil 3D and used to construct an accurate catchment area for Cave Rock Estates. The entire catchment entering the bed filter was estimate to be 78 acres by using contour interpolation. This number was field verified and subsequently used in the PLRM model.

Infiltration Testing

At the recommendation of TRPA and in accordance with the BMP RAM, NTCD conducted infiltration testing of the bed filter using constant head permeameters (CHPs) in November 2011 and found extremely variable results.

Table 1. Results from initial infiltration testing at Cave Rock Bed Filter.

Soil Cover	CHP	Initial	Final	Time (min)	Infiltration Rate (in/hour)
Vegetated	1	153	149	5	0.8
	2	78	73	5	1
	3	101	87	5	2.8
Bare Soil	4	90	2	1	88
	5	100	98	5	0.4
	6	142	140	5	0.4

The infiltration testing was found to be inconclusive. In 2012, NTCD received funding to conduct infiltration testing using the Modified Philip Dunne Infiltrometer (MPD) and compare the results to the CHP. The MPD device was designed to measure the saturated hydraulic conductivity (K_{sat})of the surface soil, while the CHP measures the K_{sat} at depth. This round of infiltration testing was more comprehensive and yielded results that averaged 2.7 inches per hour using the MPD and 1.6 inches per hour using the CHP. Results are preliminary and the full report will not be available until Spring 2013.

PLRM

Karin Staggs, Hydrologist with NTCD, conducted the PLRM for this site. The memorandum detailing the model is included in Appendix A. This catchment is considered to be 100% connected to Lake Tahoe, as the outlet from the bed filter discharges to the Lake within a short distance. Results from the PLRM show that if the bed filter functioned at its maximum potential, a reduction of 337 kg/yr of fine sediment particles could be expected. Table 2 summarizes these results.

Table 2. PLRM Results for the baseline condition and the fully functioning condition of the Bed Filter.

Conditions:	Baseline	Expected
Runoff Volume (ac-ft/yr)	7.04	6.48
TSS (lbs/yr)	1600	215.6
FSP (lbs/yr)	959.77	215.6
FSP (kg/yr)	434.77	97.6
# FSP Particles	4.78E+16	1.07E+16
Load Reduction (kg/yr)		337
Difference #FSP Particles (Credits)	Difference (credit)	4

Water Quality Monitoring

Because of the intended function of the bed filter, TRPA and NTCD decided that water quality monitoring could best illustrate the bed filter's level of treatment. Since the bed filter is designed to filter out sediments and nutrients and then discharge clean water, water quality monitoring is the only way to determine if the discharge is meeting the regulations. The design report expected the following level of pollutant reduction (Table 3).

Table 3. Expected Water Quality Results based on Design Report (KB, 1990)

Constituent	Load Before	Load After	Percent Reduction
Sediment	152 tons	< 3 tons	> 98 %
Total Nitrogen	415 lbs	307 lbs	26%
Total Phosphorous	173 lbs	66 lbs	62 %

Cave Rock is known to receive less precipitation than other areas of the Lake Tahoe Basin. In fact, NOAA estimates the 25-year storm as 0.99 inches in one hour, which is less than the 20-year storm of 1 inch per hour used by the TRPA (Appendix B). Due to the low frequency of rain and the long lag time between water entering the inlet and flowing out the outlet of the bed filter, samples were not easy to obtain. Over the course of 2 years, NTCD was able to obtain 5 water quality samples. The averages of these results are displayed in Table 4 with the full results available in Appendix C. Results were sporadic, with the outlet sometimes showing higher pollutant levels than the incoming stormwater. This was especially true for nitrogen, where the expected removal rate was only 26 percent, the bed filter actually seemed to add nitrogen to the stormwater. The mechanism for nitrogen removal is by settling and it is explained in the design report that this will not be very effect. The typical nitrogen treatment processes are biological and since the bed filter seems to have very little biological activity (i.e. vegetation cover), it is not surprising that nitrogen is not removed. A probable reason for the results showing an increase in nitrogen is the time between the stormwater entering the inlet and leaving the outlet. The expected removal rate of 40 percent was based on a 12 hour detention time. Either the sampling is flawed, we should be taking a sample from the outlet 12 hours after the inlet sample is collected, or the detention time is less than the design report calls for. We may be sampling the typically pollutant-laden first flush at the outlet and a more mid storm sample at the inlet. Future monitoring may stager samples 12 hours or use some sort of harmless indicator to determine the detention time. Carbon is another possible removal method for nitrogen and could be investigated for the retrofit in addition to adding more biological activity through plant processes (Lindeburg, 2008).

Phosphorus was removed more often than nitrogen was from the bed filter which was expected. The process for phosphorus removal is also settling and phosphorus tends to be more closely associated with sediment removal (Lindeburg, 2008). For the retrofit, we may investigate media with properties that adsorb dissolved phosphorus for a greater removal rate.

The filter was usually efficient at removing suspended sediment and was more effective at removing particles larger than 16 µm. However, if the percent fine sediment is translated to mg/L, there was usually an overall reduction in fine sediment from the stormwater coming in versus the water leaving. In comparison to the expected water quality results, the water quality monitoring did not show the same efficiency; only sediment was consistently removed, at a rate of nearly 80 percent. On October 19th, 2012, CREGID had a contractor complete maintenance actions as advised by the Maintenance Plan created by NTCD (Appendix D). Monitoring results did not show definitive improvement.

Table 4. Summary of Results from Water Quality Monitoring. All results are averages.

Constituent	TRPA Standard	Cave Rock In (mg/L except FSP)	Cave Rock Out (mg/L except FSP)	% Removal
Dissolved Inorganic Nitrogen as N*	0.5 mg/L	0.18	0.81	-350.0%
Dissolved Phosphorus as P	0.1 mg/L	0.16	0.17	-11.1%
Suspended Sediment	250 mg/L	62.8	13.4	78.7%
Fine Sediment Particles (%<16 µm)	TBD	68.4%	94.0%	-37.3%
Fine Sediment Particles (mg/L)**	TBD	32.9	12.4	62.1%

*0.15 is the reporting limit for Dissolved Inorganic Nitrogen., therefore the actual average may be lower.
**FSP in mg/L is calculated as percent FSP x TSS

Figure 1. Left: The bed filter during the storm. Right: Outlet from bed filter to Lake Tahoe.

Unfortunately, because of the bed filter configuration, the stormwater does go through one sediment trap prior to collection at the inlet to the concrete forebay. The stormwater also receives further treatment after the outlet sample is obtain, but this water is combined with stormwater from Highway 50 before the additional treatment in two large sediment traps. NTCD took one sample at the outlet just above the input to Lake Tahoe and those results are in Table 5. There was a reduction in phosphorus and nitrogen from the outlet to the lake input, but an increase in total suspended sediment and FSP.

Table 5. Summary of Results from Water Quality Monitoring on 11/30/2012.

Constituent	Precipitation (inches)	Cave Rock In (mg/L except FSP)	Cave Rock Out (mg/L except FSP)	Outlet near Lake (mg/L except FSP)
Dissolved Inorganic Nitrogen as N*	1.5	0.15	0.71	0.15
Dissolved Phosphorus as P	1.5	0.19	0.16	0.087
Suspended Sediment	1.5	51	15	60
Fine Sediment Particles (%<16 µm)	1.5	67.6%	94.8%	75.0%
Fine Sediment Particles (mg/L)**	1.5	32.9	12.4	45.0

*0.15 is the reporting limit for Dissolved Inorganic Nitrogen. The actual amount may be lower.
**FSP in mg/L is calculated as percent FSP x TSS

Conclusion

While not statistically conclusive, testing of the bed filter showed marginal function. Meanwhile, the design report and historical observations show that the bed filter has the capacity to accept the current amount of stormwater it receives. The monitoring results combined with a literature review of bed filters have led TRPA and NTCD to agree that the existing bed filter needs a retrofit to increase the treatment level. To achieve maximum benefit, the retrofit treatment should focus on removal of fine sediment. Integrating some vegetation, using a well selected media, and combining a series of proven treatments may improve the water quality of the runoff passing through this system. TRPA has even provided a letter supporting the use of the bed filter as treatment for the entire watershed as designed (Appendix E). The retrofit process would be guided by a Technical Advisory Committee so that the best and most cost effective design is chosen. One-half of the funding has already been secured through the USDA Forest Service. NTCD will seek match funding from the Nevada Division of State Lands and the CREGID. Using a combination of the existing private BMPs, source control techniques, and an improved bed filter, the CREGID should be able to reduce the input of FSP to Lake Tahoe by 337 kg per year.

References

KB Foster, 1990, Project Report for Cave Rock Estates Erosion Control Project.

Lindeburg, Michael, 2008, Civil Engineering Reference Manual for the PE Exam, 11th Edition.

NRCS, 1986, Urban Hydrology for Small Watersheds, Techical Release TR 55, United States Department of Agricultre Natural Resources Conservation Service.

Staggs, Karin, 2012, Memo to Meghan Kelly - Cave Rock Estates PLRM Model Development.

Swanson, North, 2011, Personal Communication.

APPENDIX A

Cave Rock Estates PLRM Model Development

December 19, 2012

Memorandum

To: Meghan Kelly

From: Karin Staggs

Subject: Cave Rock Estates PLRM Model Development

Baseline and Expected Conditions PLRM Model Development

This memorandum details the assumptions in creating the Baseline and Expected Conditions PLRM models for the Cave Rock Estates Urban Catchment (CRE). PLRM Input Templates provided by model developer NHC have been populated for both Baseline and Expected Conditions models for easy input value reference (attached). This outline follows the steps of input in the Catchment Properties Editor in PLRM. Many default baseline conditions (2004) have been established by the Lake Clarity Crediting Program (LCCP) Handbook (Handbook), and these will be discussed herein, as well as the values representative of expected conditions (upon construction of the new treatment bed).

This modeling is being conducted because a grant has been awarded to re-build the treatment, therefore the County will receive a number of TMDL credits for the reduction in pollutant load associated with this basin.

The baseline model will consider the treatment basin in poor operating condition, and the existing conditions model will represent the basin according to its design conditions. The difference will be a reduced pollutant load equating to a number of credits.

Step 1 – Define Physical Attributes

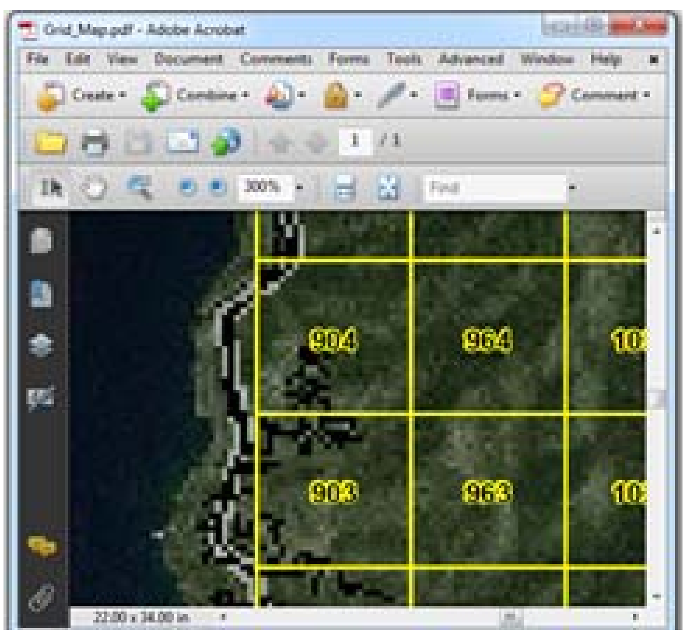
CRE encompasses an area 78 acres in size (Table 1). This catchment is located on the east side of Highway 50, nearly adjacent to Cave Rock, in Douglas County, Nevada. This catchment falls almost exactly in half of PLRM meteorologic grid 903 (lower half) and 904 (upper half) (Figure 1). Because model output of results for Baseline and Expected Conditions is relative, the use of either met grid still gives the same relative results. Therefore, I have used met grid 904 for this catchment. Slope has been determined from the approximate 3,000 foot length of the catchment and a change in elevation of 600 feet, therefore 20% slope.

A stormwater treatment was constructed in the catchment in 1996. Nearly the entire catchment has been designed to drain to this large sand/media filter at the base of the catchment. However, a typical sand filter's life is less than 10 years (with maintenance), so knowing that no maintenance has been conducted allows for the assumption that this is either not-functioning for the 2004 baseline conditions, or functioning at a low rate. The Lake Clarity Crediting Program (LCCP) requires assuming that BMPs in place as of 2004 are operating at a BMP RAM level of "2". This assumption and subsequent representation of the basin operating conditions will be discussed in detail later.

Table 1. Land use area calculations.

Land Use	Land Use Code	Area (acres)	% Land use
Residential_SFP	1	29	37
Residential_MFP	2	1	1
CICU-Pervious	3	0	0
Veg_Unimpacted	502	11	14
Veg_Unimpacted	503	15	20
Veg_Unimpacted	504	4	5
Residential_SFI	1001	10	12
Residential_MFI	1002	1	1
CICU-Impervious	1003	0	0
Roads_Secondary	1013	8	11
TOTAL		78	100

Figure 1. PLRM meteorologic grids over Cave Rock Estates



Step 2 – Define Land Uses

Land uses have been determined from the Lake Tahoe TMDL Land Use GIS layer. In this catchment, land uses are secondary roads, single family residential, CICU, multi residential, and erosion potentials 1, 2 and 3. The areas calculated for each land use have been determined using Douglas County Assessor Parcel Map data. Percentage of impervious values for each land use have also been calculated by Douglas County. The same values have been used in this step for both Baseline and Expected Conditions, since there have been no changes in this time period.

Step 3 – Define Soils

Soil data was obtained from the NRCS Web Soil Survey using the catchment boundary.

Step 4 – Define Land Use Conditions

Baseline Conditions

Road Methodology

Only secondary roads exist in this catchment. The Road Risk Categories have been calculated using the percent area of road within each risk category according to the Road Risk GIS layer; this same methodology applies for road shoulders, and percent directly connected impervious area (%DCIA) for all secondary roads. This area has not been developed since 2004, i.e., no additional building or construction, therefore this is the same for the Expected Conditions model as well.

Parcel Methodology

For the Baseline model, certain values were assigned to be used by all jurisdictions for input of BMP implementation. Although this is not truly representative of the Baseline conditions, it sets a level playing field for all jurisdictions to use. The baseline input values for parcels with BMP certificates are set at single family residential (7%), multi-family residential (19%), and CICU (5%). Percent means the percent of that land use that is BMP certified. There is an assumption that no parcels have received source control certificates.

Expected Conditions

Road Methodology

As stated, the road risk categories have been calculated using the percent area of road within each risk category according to the Road Risk GIS layer, and road shoulder and %DCIA.

Parcel Methodology

The number and acreage of parcels that have received BMP certificates are shown in Table 2. Obtained from the TRPA website and using acreages from the Douglas County Assessor, there are a total of 10.76 acres of single family residential parcels that have received BMP Certificates in this catchment, for about 28% of the SFR area in the catchment. There are no BMP certificates on the multi-family portion of the catchment, and the only commercial parcel has received a BMP certificate, for 100% of the land use BMP certified. One single family residential parcel has received a source control certificate, accounting for 1% of the total land use.

Table 2. List of parcels with BMP certification in Cave Rock Estates.

Number	APN	Address	Area (acres)
1	1418-27-410-001	1300 Cave Rock Dr, Zephyr Cove, 89448	0.46
2	1418-27-410-004	1311 Winding Wy, None, 89413	0.58
3	1418-27-410-006	1317 Winding Wy, None, 89413	0.56
4	1418-27-410-007	1318 Cave Rock Dr, Zephyr Cove, 89448	0.46
5	1418-27-710-004	270 Lark Ci, None, 89413	0.36
6	1418-27-710-007	280 Lark Ci, None, 89413	0.39
7	141827710011	282 Chukkar	0.5
8	141827711001	286 Chukkar	0.41
9	1418-27-711-002	1362 Winding Wy, None, 89413	0.44
10	141827712003	267 Chukkar	1.01
11	1418-27-712-008	1366 Winding Wy, None, 89413	0.46
12	1418-27-712-009	1370 Winding Wy, None, 89413	0.42
13	1418-27-712-010	1374 Winding Wy, None, 89413	0.28
14	1418-27-712-015	1394 Winding Wy, None, 89413	1.16
15	141827810001	287 Chukkar	0.32
16	1418-27-810-004	1356 Winding Wy, None, 89413	0.45
17	141827810009	281 Robin	0.35
18	1418-27-810-012	271 Robin Ci, None, 89413	0.49
19	1418-27-810-016	1322 Winding Wy, None, 89413	0.43
20	141827810020	285 Wren	0.36
21	1418-27-810-025	1346 Winding Wy, None, 89413	0.47
22	1418-27-810-027	1342 Winding Wy, None, 89413	0.58
23	1418-27-810-029	301 Pheasant Ln, None, 89413	0.59
24	141827810036	317 Gull Court	0.47
25	141827810037	315 Gull Court	0.37
26	1418-27-810-040	1345 Winding Wy, None, 89413	0.58
27	1418-27-810-047	1321 Winding Wy, None, 89413	0.43
28	1418-27-810-009	281 Robin Ci, None, 89413	0.35
29	1418-27-810-020	285 Wren Ci, None, 89413	0.36
30	141827810050	1321 Cave Rock	0.44
31	1418-27-811-002	265 Lark Ci, None, 89413	0.52
32	141827811008	285 Chukkar	0.38
33	1418-27-812-001	306 Pheasant Ln, None, 89413	0.44
34	1418-27-812-003	314 Pheasant Ln, None, 89413	0.44

Road Conditions Editor

Baseline Conditions

Road shoulder conditions have been based on field observations, and are assumed to be the same as Expected Conditions again because no changes have been made in this catchment. The road abrasive application strategy and sweeper and sweeping frequency are the default values to be assigned in all catchments per the LCCP, which are considered “minimum” abrasive control strategy (in other words, just apply with no regard for how much and where) and minimal sweeping.

Expected Conditions

Road shoulder conditions have been based on field observations. Minimal control measures are defined here by minimal sand application to high and moderate risk roads. Advanced control measures here indicate no sand application to the low risk roads. The sweeping effectiveness uses the minimum sweeping frequency available; although it does state that there will be 1-2 sweepings in the summer, this is not accurate as long as Douglas County does not use sweeping equipment, but for purposes of this model (baseline conditions use the same value so same relative difference) this is acceptable.
No other values have been changed in this Editor.

Step 5 – Define Drainage Conditions

Road Methodology

%DCIA values were estimated using the data in the Road Conditions GIS layer. This is an approximation of the percent of the flow on impervious roads routed to the outlet. Road by road, this yielded 67% DCIA of the secondary roads.

Parcel Methodology

The percent directly connected impervious area (%DCIA) for parcels is an estimate of the connectivity of the impervious areas of the parcels (roofs, driveways) to the drainage system; basically runoff that gets to the street and is conveyed via the storm water conveyance system to the treatment basin. From multiple sources, the level of imperviousness of the single family residential parcels in CRE is 25% (the house and driveway cover about 25% of the parcel property). We went house by house to determine the percent of each house (roof) and driveway that drains either to the street (DCIA) or to the adjacent land (forest). For example, if we determined that 50% of the impervious area drained to the street, the following calculation was used to determine area of DCIA:

Example:

Individual Parcel acreage =	0.38
25% impervious =	0.1
50% of this is DCIA=	0.05 acres DCIA on this parcel

This was done for each parcel, for a total of 1.52 acres of the overall impervious area considered DCIA. This yielded 16% of the total impervious area is considered DCIA. A similar analysis was made to the multi-family residential area, for an estimated 23% DCIA. This applies to both baseline and existing conditions, since the houses were built prior to the 2004 baseline date.

Treatment Structure

The primary stormwater treatment in this development is the large extended detention pond with an impervious liner. This can be considered a "Bed Filter" according to PLRM. It is expected that as the runoff flows downward through the filter that some sediment is removed, and therefore water with a reduced fine sediment particle load is discharged from the outfall. The original design configuration of this basin consists of an area of 16,500 square feet, a depth of 1.25 feet, for a volume of 20,625 cubic feet. Since this Bed Filter was installed prior to 2004 (baseline PLRM conditions), it must be input into the baseline conditions as if it would receive a BMP RAM score of "2" (LCCP Handbook). However, in PLRM, there is no corresponding input – there is only filtration rate. Therefore, if we assume that if a "5" means it is operating at 100%, then a "2" means it is operating at 40%. Therefore, if originally all of the flow was infiltrating through the filter and exiting treated, then 100% of the incoming flow is being treated. To simulate 40%, I'm going to program the bed filter in PLRM such that 60% of the incoming flow goes directly to the outlet standpipe, and only 40% gets treated (this was discussed with Brent Wolfe). To do this, a sensitivity analysis using volume and footprint and filtration rate was conducted until that amount was achieved. For the Expected conditions PLRM model, the original design numbers were used to assume full treatment. This basin will have to be maintained according to a maintenance plan for Cave Rock Estates to receive their full credit, once a Catchment Credit Schedule has been submitted and approved by NDEP.

Although there is also a very small retention basin on Chukkar Drive, this receives only a small amount of flow; from our assessment (from one home). The other parcels in the area are either Forest Service, or were determined to be not connected to the stormwater system (i.e., flow to the forest anyway), so the effect of this basin is really already considered in the drainage conditions in the model.

Catchment Credit Schedule

The values in the following table are the results achieved using the aforementioned input parameters. This catchment is considered to be 100% connected to Lake Tahoe, as the outlet from the sand filter discharges to the Lake within a short distance.

Results:

Conditions:	Baseline	Expected
Runoff Volume (ac-ft/yr)	7.04	6.48
TSS (lbs/yr)	1600	215.6
FSP (lbs/yr)	959.77	215.6
FSP (kg/yr)	434.77	97.6
# FSP Particles	4.78E+16	1.07E+16
Load Reduction (kg/yr)		337
Difference #FSP Particles (Credits)	Difference (credit)	4

APPENDIX B

NOAA Point Precipitation Estimates

NOAA Atlas 14, Volume 1, Version 5
Location name: Nevada, US*
Coordinates: 39.0409, -119.9441
Elevation: 6502ft*
* source: Google Maps

POINT PRECIPITATION FREQUENCY ESTIMATES

Sanja Perica, Sarah Dietz, Sarah Heim, Lillian Hiner, Kazungu Maitaria, Deborah Martin, Sandra Pavlovic, Ishani Roy, Carl Trypaluk, Dale Unruh, Fenglin Yan, Michael Yekta, Tan Zhao, Geoffrey Bonnin, Daniel Brewer, Li-Chuan Chen, Tye Parzybok, John Yarchoan

NOAA, National Weather Service, Silver Spring, Maryland

PF_tabular | PF_graphical | Maps_&_aerials

PF tabular

PDS-based point precipitation frequency estimates with 90% confidence intervals (in inches)[1]

Duration	Average recurrence interval (years)									
	1	2	5	10	25	50	100	200	500	1000
5-min	0.124 (0.109–0.144)	0.154 (0.136–0.181)	0.201 (0.175–0.235)	0.245 (0.212–0.286)	0.316 (0.265–0.369)	0.380 (0.310–0.446)	0.458 (0.361–0.542)	0.550 (0.417–0.663)	0.699 (0.499–0.861)	0.838 (0.569–1.05)
10-min	0.189 (0.165–0.220)	0.235 (0.207–0.275)	0.306 (0.266–0.357)	0.373 (0.322–0.435)	0.481 (0.404–0.562)	0.579 (0.472–0.679)	0.696 (0.550–0.825)	0.838 (0.635–1.01)	1.06 (0.760–1.31)	1.28 (0.866–1.60)
15-min	0.234 (0.205–0.272)	0.291 (0.256–0.341)	0.379 (0.330–0.443)	0.463 (0.399–0.539)	0.596 (0.500–0.697)	0.717 (0.585–0.842)	0.863 (0.681–1.02)	1.04 (0.787–1.25)	1.32 (0.942–1.62)	1.58 (1.07–1.99)
30-min	0.316 (0.276–0.366)	0.392 (0.345–0.459)	0.510 (0.444–0.596)	0.623 (0.538–0.726)	0.803 (0.674–0.938)	0.966 (0.788–1.13)	1.16 (0.917–1.38)	1.40 (1.06–1.69)	1.78 (1.27–2.19)	2.13 (1.45–2.68)
60-min	0.391 (0.342–0.454)	0.485 (0.427–0.568)	0.631 (0.550–0.738)	0.771 (0.666–0.898)	0.994 (0.834–1.16)	1.20 (0.975–1.40)	1.44 (1.14–1.71)	1.73 (1.31–2.09)	2.20 (1.57–2.71)	2.64 (1.79–3.32)
2-hr	0.545 (0.494–0.611)	0.672 (0.607–0.753)	0.834 (0.750–0.933)	0.981 (0.875–1.10)	1.20 (1.04–1.35)	1.39 (1.18–1.58)	1.60 (1.34–1.84)	1.86 (1.50–2.17)	2.31 (1.79–2.76)	2.75 (2.06–3.35)
3-hr	0.679 (0.621–0.745)	0.838 (0.771–0.926)	1.02 (0.933–1.13)	1.18 (1.07–1.30)	1.39 (1.25–1.54)	1.57 (1.38–1.76)	1.77 (1.53–2.00)	2.02 (1.71–2.32)	2.43 (2.00–2.84)	2.84 (2.29–3.38)
6-hr	1.04 (0.953–1.14)	1.29 (1.18–1.42)	1.56 (1.42–1.71)	1.77 (1.60–1.94)	2.05 (1.84–2.26)	2.26 (2.01–2.51)	2.46 (2.16–2.77)	2.71 (2.33–3.07)	3.03 (2.56–3.49)	3.30 (2.74–3.87)
12-hr	1.52 (1.38–1.69)	1.90 (1.71–2.11)	2.34 (2.10–2.60)	2.69 (2.40–2.99)	3.16 (2.79–3.53)	3.52 (3.08–3.96)	3.88 (3.35–4.41)	4.25 (3.61–4.89)	4.73 (3.92–5.54)	5.09 (4.14–6.04)
24-hr	1.99 (1.77–2.24)	2.49 (2.22–2.80)	3.11 (2.78–3.50)	3.63 (3.22–4.07)	4.33 (3.83–4.86)	4.89 (4.30–5.49)	5.48 (4.79–6.16)	6.09 (5.28–6.86)	6.92 (5.94–7.84)	7.58 (6.44–8.63)
2-day	2.55 (2.26–2.89)	3.21 (2.85–3.64)	4.12 (3.64–4.66)	4.88 (4.30–5.52)	5.96 (5.22–6.74)	6.84 (5.95–7.75)	7.79 (6.72–8.86)	8.80 (7.51–10.1)	10.2 (8.61–11.8)	11.4 (9.48–13.3)
3-day	2.89 (2.53–3.30)	3.66 (3.21–4.18)	4.77 (4.17–5.44)	5.69 (4.96–6.48)	7.00 (6.06–7.99)	8.08 (6.95–9.23)	9.25 (7.88–10.6)	10.5 (8.85–12.1)	12.3 (10.2–14.2)	13.8 (11.3–16.1)
4-day	3.22 (2.81–3.71)	4.11 (3.58–4.73)	5.41 (4.70–6.22)	6.49 (5.62–7.45)	8.05 (6.91–9.24)	9.33 (7.96–10.7)	10.7 (9.04–12.3)	12.2 (10.2–14.1)	14.3 (11.8–16.7)	16.1 (13.0–18.9)
7-day	3.89 (3.39–4.49)	4.99 (4.35–5.76)	6.64 (5.77–7.65)	7.97 (6.91–9.18)	9.86 (8.49–11.4)	11.4 (9.75–13.1)	13.0 (11.0–15.1)	14.8 (12.4–17.2)	17.2 (14.3–20.2)	19.3 (15.7–22.7)
10-day	4.50 (3.92–5.15)	5.79 (5.04–6.61)	7.68 (6.67–8.77)	9.17 (7.95–10.5)	11.3 (9.70–12.8)	12.9 (11.1–14.8)	14.7 (12.5–16.8)	16.5 (13.9–19.0)	19.1 (15.9–22.1)	21.1 (17.4–24.6)
20-day	6.09 (5.32–6.93)	7.81 (6.84–8.90)	10.3 (8.97–11.7)	12.1 (10.6–13.8)	14.7 (12.7–16.7)	16.6 (14.4–19.0)	18.7 (16.0–21.4)	20.8 (17.7–23.8)	23.6 (19.8–27.3)	25.8 (21.5–30.1)
30-day	7.27 (6.36–8.27)	9.34 (8.17–10.6)	12.3 (10.7–14.0)	14.5 (12.7–16.5)	17.6 (15.2–20.0)	19.9 (17.2–22.7)	22.3 (19.1–25.5)	24.8 (21.1–28.4)	28.1 (23.6–32.5)	30.7 (25.6–35.7)
45-day	8.91 (7.83–10.1)	11.5 (10.1–13.0)	15.1 (13.2–17.0)	17.7 (15.5–20.0)	21.3 (18.5–24.1)	24.0 (20.8–27.2)	26.8 (23.0–30.5)	29.5 (25.3–33.8)	33.2 (28.1–38.2)	36.1 (30.3–41.8)
60-day	10.3 (8.97–11.7)	13.3 (11.6–15.1)	17.5 (15.2–19.9)	20.5 (17.8–23.3)	24.3 (21.0–27.7)	27.1 (23.4–31.0)	29.9 (25.7–34.3)	32.6 (27.9–37.5)	36.1 (30.7–41.7)	38.7 (32.7–45.0)

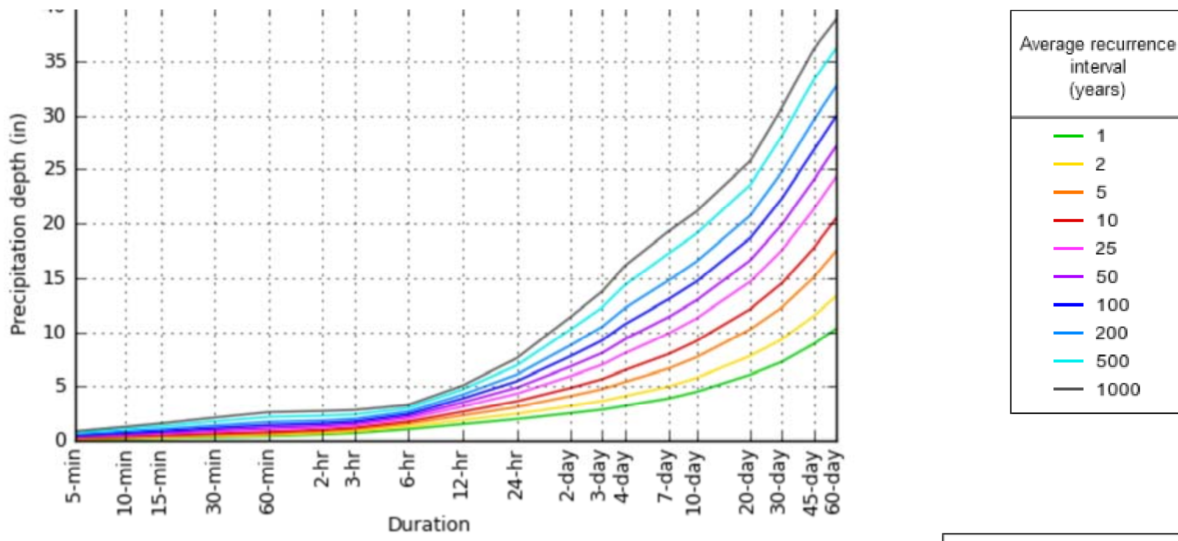
[1] Precipitation frequency (PF) estimates in this table are based on frequency analysis of partial duration series (PDS).

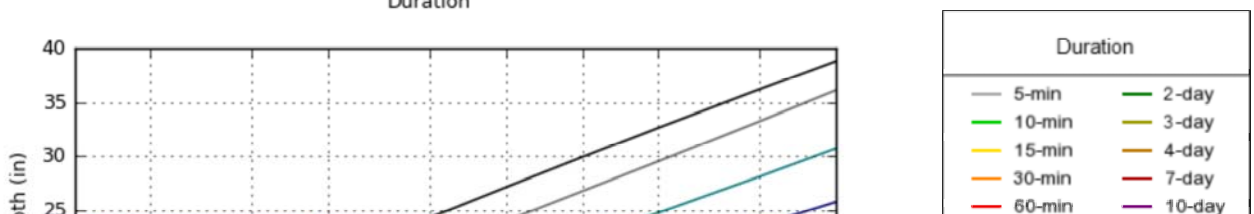
Numbers in parenthesis are PF estimates at lower and upper bounds of the 90% confidence interval. The probability that precipitation frequency estimates (for a given duration and average recurrence interval) will be greater than the upper bound (or less than the lower bound) is 5%. Estimates at upper bounds are not checked against probable maximum precipitation (PMP) estimates and may be higher than currently valid PMP values.

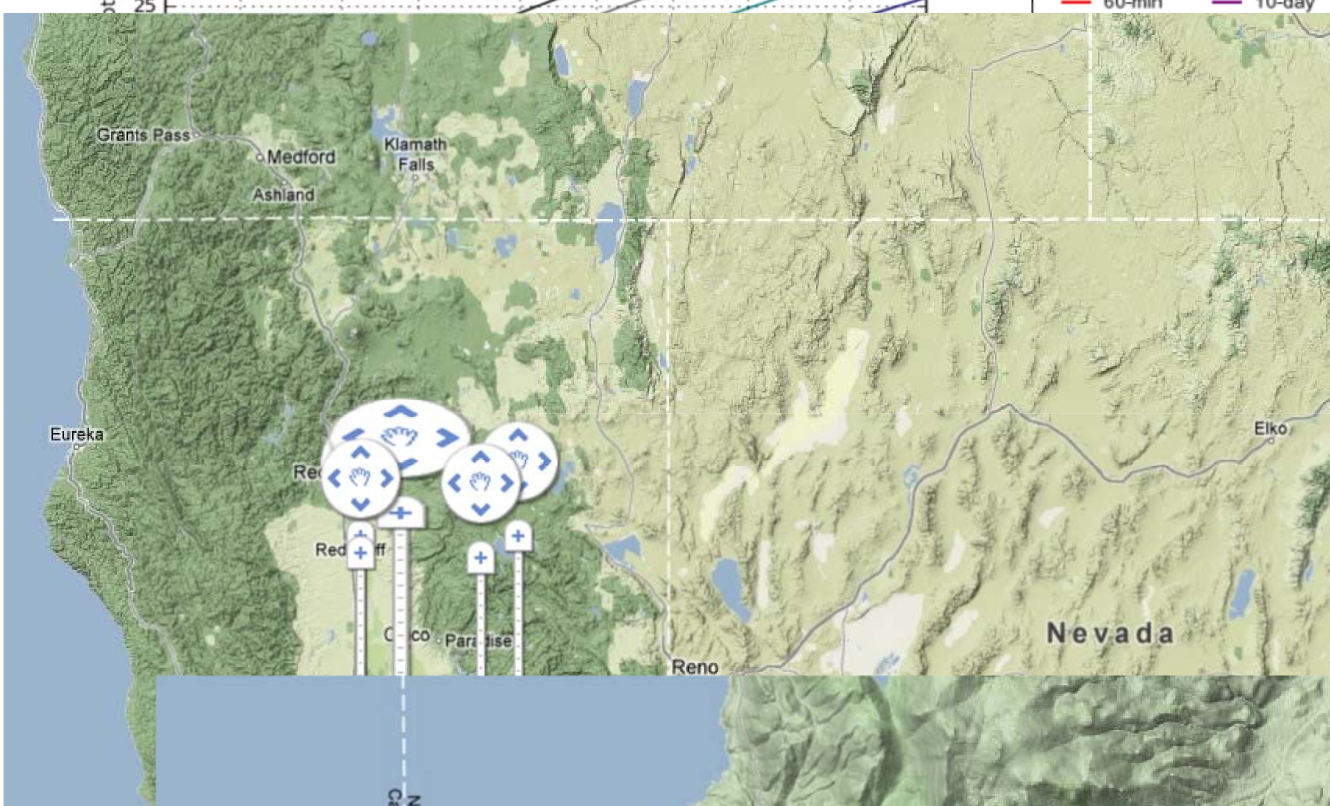
Please refer to NOAA Atlas 14 document for more information.

Back to Top

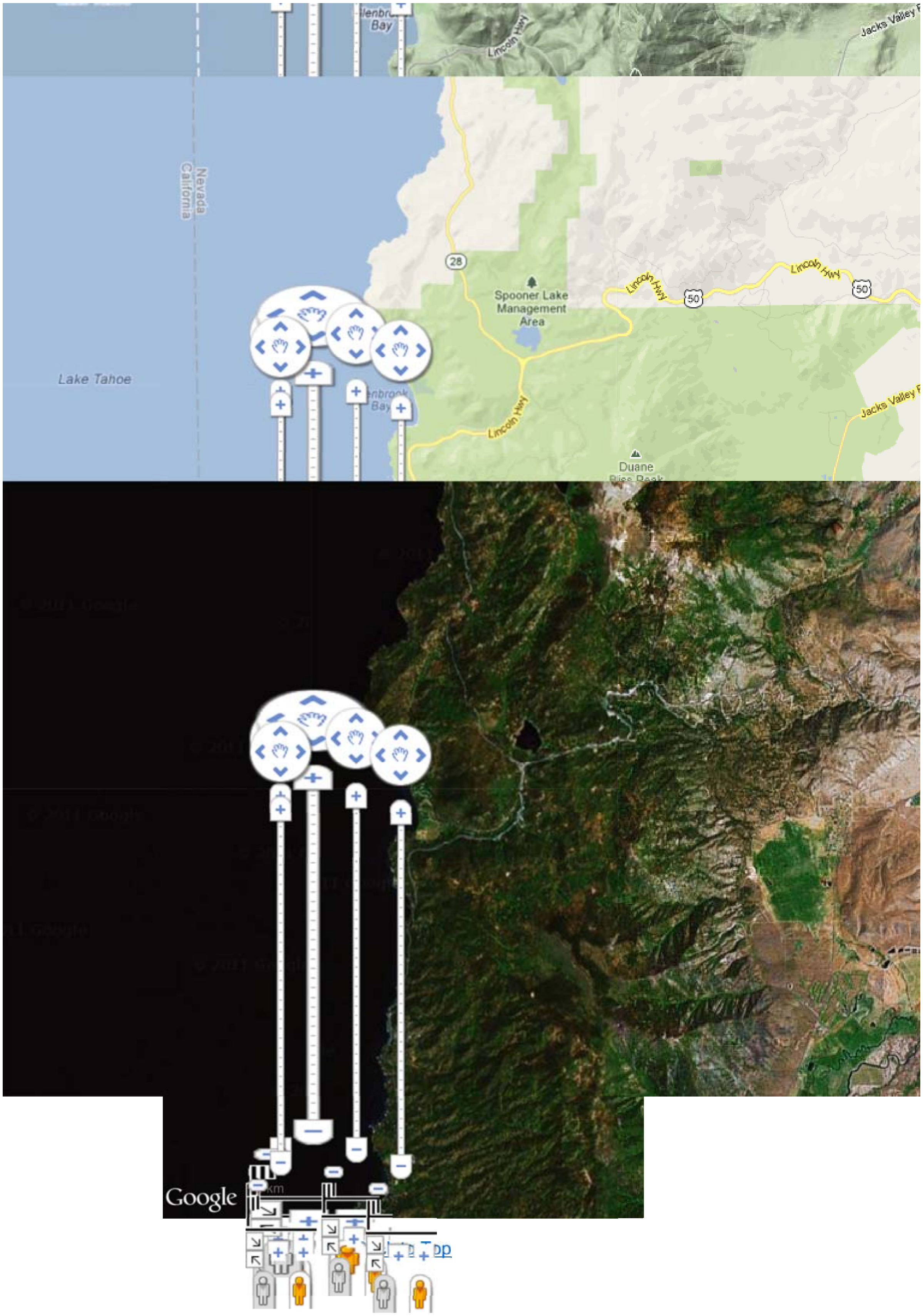
PF graphical


Precipitation depth (in)
35
30
25
20
15
10
5
0
5-min
10-min
15-min
30-min
60-min
2-hr
3-hr
6-hr
12-hr
24-hr
2-day
3-day
4-day
7-day
10-day
20-day
30-day
45-day
60-day
Duration
Average recurrence interval (years)
1
2
5
10
25
50
100
200
500
1000


40
35
30
25
Duration
5-min
10-min
15-min
30-min
60-min
2-day
3-day
4-day
7-day
10-day


Grants Pass
Medford
Ashland
Klamath Falls
Eureka
Elko
Nevada
Reno
Paradise


Nevada
California
28
Spooner Lake Management Area
Lincoln Hwy
50
Lake Tahoe


Lake Tahoe
Nevada
California
Lincoln Hwy
Jacks Valley
Spooner Lake Management Area
28
50
Duane
Google

APPENDIX C

Water Quality Monitoring Results

Results from Water Quality Monitoring at the Inlet and Outlet of the Cave Rock Bed Filter.

Constituent	TRPA Standard	Date	Estimated Precipitation (inch)	Cave Rock In (mg/L except FSP)	Cave Rock Out (mg/L except FSP)	% Removal
Dissolved Inorganic Nitrogen as N*	0.5 mg/L	10/5/2011	0.5	0.3	**0.85**	-183.3%
		1/20/2012	0.4	0.15	**0.97**	-546.7%
		3/22/2012	N/A	0.15	0.22	-46.7%
		11/17/2012	0.4	0.15	**1.3**	-766.7%
		11/30/2012	1.5	0.15	**0.71**	-373.3%
Dissolved Phosphorus as P	0.1 mg/L	10/5/2011	0.5	0.19	**0.43**	-126.3%
		1/20/2012	0.4	0.19	0.057	70.0%
		3/22/2012	N/A	0.055	0.055	0.0%
		11/17/2012	0.4	0.16	0.17	-6.3%
		11/30/2012	1.5	0.19	0.16	15.8%
Suspended Sediment	250 mg/L	10/5/2011	0.5	5	9	-80.0%
		1/20/2012	0.4	190	27	85.8%
		3/22/2012	N/A	16	4	75.0%
		11/17/2012	0.4	52	12	76.9%
		11/30/2012	1.5	51	15	70.6%
Fine Sediment Particles (%<16 µm)	TBD	10/5/2011	0.5	74.91%	95.92%	-28.0%
		1/20/2012	0.4	38.38%	92.42%	-140.8%
		3/22/2012	N/A	85.19%	100.00%	-17.38%
		11/17/2012	0.4	75.96%	86.69%	-14.1%
		11/30/2012	1.5	67.64%	94.77%	-40.11%
Fine Sediment Particles (mg/L)**	TBD	10/5/2011	0.5	3.75	8.63	-130.5%
		1/20/2012	0.4	72.92	24.95	65.8%
		3/22/2012	N/A	13.63	4.00	70.65%
		11/17/2012	0.4	39.50	10.40	73.66%
		11/30/2012	1.5	34.50	14.22	58.79%

Bold indicates a level above the TRPA Water Quality Standard.

3/22/12 was a snowmelt sample

*0.15 is the reporting limit for Dissolved Inorganic Nitrogen. The actual amount may be lower.

** Fine sediment particles are calculated by multiplying the percent sub-16 micron x the TSS concentration

APPENDIX D

Cave Rock Estates GID Maintenance Plan

Cave Rock Estates Stormwater System Maintenance Plan

May 2012

Prepared for:
Cave Rock Estates General Improvement District
PO Box 10426
Zephyr Cove, NV 89448

Prepared by:

Meghan Kelly, P.E.
Nevada Tahoe Conservation District
PO Box 915
Zephyr Cove, NV 89448

Nevada Tahoe Conservation District

Introduction

Completion of the Cave Rock Estates Erosion Control Project in 1990 resulted in the installation of: retaining walls, revegetation, drainage inlets, sediment traps, curb and gutter, conveyance piping, rock lined channel, trench drain, an infiltration basin, and a bed filter to control stormwater runoff in Cave Rock, Nevada. Cave Rock Estates General Improvement District (CREGID) is responsible for the inspection and maintenance of the stormwater Best Management Practices (BMP) in order to ensure continued performance.

Lake Tahoe Total Maximum Daily Load Program

The stormwater assets installed as part of the Cave Rock Estates Erosion Control Project have been factored into the Lake Tahoe Total Maximum Daily Load (TMDL) baseline pollutant load estimate. Stormwater runoff from Cave Rock Estates is considered to be directly connected to Lake Tahoe – meaning that the discharge from the stormwater assets reaches the lake before significantly infiltrating into the ground on a regular basis. The following inspection and maintenance plan will assist CREGID in complying with the Lake Tahoe TMDL by documenting regular inspection and maintenance of the existing assets. The BMP Rapid Assessment Methodology (BMP RAM) specifies inspection and maintenance protocols on stormwater treatment BMPs. In order to streamline data collection and entry, this plan is consistent with the inspection and maintenance protocols described in the BMP RAM User Manual V.1, where applicable. Inspection and maintenance protocols for source control BMPs such as retaining walls and revegetation, though important, are not discussed in BMP RAM, but are discussed within this maintenance plan.

Lake Tahoe Clarity Crediting Program

The Lake Clarity Crediting Program (LCCP) Handbook classifies BMPs into one of three categories (Essential, Key and Supporting) according to their importance to water quality (expected load reduction). The catchment registration has not been performed yet for the Cave Rock watershed to determine the water quality importance of the installed BMPs, however, the existing BMPs are discussed below in order of their ***expected*** classification according to the LCCP Handbook. NTCD is currently performing a mapping and inventory of the existing stormwater BMPs in Douglas County. This inventory will support the LCCP. The Cave Rock catchment delineation and registration is expected to occur by the end of 2014. Documentation and tracking of inspection and maintenance activities will be required as part of the LCCP. This inspection and maintenance plan is consistent with the requirements of the TMDL, BMP RAM and the LCCP.

Inspection and Maintenance

Inspecting and maintaining BMPs is a long-term commitment requiring time and resources. Thus, each jurisdiction must create a budget that properly addresses the resources needed to perform inspections and maintenance. Maintenance of BMPs is a balance between the cost of time and materials and the potential that a BMP would perform unacceptably before the next inspection. All inspection and maintenance activities should be documented with log books, photos, and receipts from any purchases or contractors. Data should be entered into the BMP RAM database.

Actively implementing the Cave Rock Estates Inspection and Maintenance Plan (Plan) can help monitor and reduce the amount of stormwater pollutants discharged to Lake Tahoe. The Inspection and Maintenance Plan complements the TMDL program and references BMP function targets set forth in the BMP RAM manual. By following an inspection and maintenance plan, CREGID will know if BMPs are functioning at optimal, acceptable, or below acceptable performance levels. Thus, changes, repairs or replacement of BMPs can be made in a timely manner. Jurisdictions can gain or lose TMDL credits based on the performance condition of each BMP, so actively inspecting and maintaining BMPs is an effective way to earn or maintain TMDL credits.

Basic inspection equipment

This Plan includes a BMP description, lists basic inspection and maintenance equipment, suggests frequency and timing of inspections, references applicable BMP RAM protocols, provides maintenance triggers consistent with BMP RAM, and suggests corrective maintenance actions. To adequately inspect a BMP, an inspector must be familiar with its intended function, physical layout, connectivity, and past maintenance issues. Inspectors must also be equipped with the proper inspection equipment. Equipment should at the minimum consist of: a clipboard or rite in the rain field book with pen or pencils, appropriate inspection forms, tape measure, and a camera to photo-document conditions and changes over time. Inspection of some BMPs requires additional specialized equipment. Refer to the Inspection and Maintenance Protocols in Appendix A for additional equipment required for inspection of specific BMPs.

Photo-documentation of a BMP is an important tool in establishing how the condition evolves over time. Vegetation density, extent of corrosion, and erosion progression are some examples of when photo-documentation is vital in tracking condition changes. Photo-documentation also provides visual proof to convince managers of the need for capital improvements. To be effective, the photographs must be taken from the same location, with the same field of view, and ideally at the same time of day and season. A common strategy is to mark the photo location with a capped section of rebar to facilitate easy relocation.

The BMP Inspection and Maintenance Protocols offer an inspection frequency schedule for each individual BMP. Update and refine this schedule based on observations, experiences, inspection findings, and the changing conditions of your site.

Appendix A contains the Inspection and Maintenance protocols for various BMPs. These protocols guide the inspection and maintenance crews in critically observing BMP condition and function, suggest inspection frequency, list maintenance triggers, and offer methods to perform triggered maintenance. These protocols reference the BMP RAM inspections where applicable and set forth BMP function targets, including maintenance triggers at the lowest acceptable level of BMP function and conditions for optimum performance.

Appendix B contains the BMP RAM Field Observation Sheets. These forms should be filled out in the field by inspection personnel according to the Inspection and Maintenance protocols for the specific BMP

Appendix C contains the applicable BMP RAM Field Inspection Protocols.

Stormwater BMPs of Cave Rock

Bed Filter

The Cave Rock bed filter has several components: two inlets, a sediment forebay, maintenance access, rock lined channel, outlet protection, impervious liner, filter media, underdrain, outlet standpipes, emergency overflow, and retention berm. The inspection and maintenance crew should be familiar with the design of the bed filter in order to informatively assess its condition and function.

The bed filter is a shallow basin designed to treat stormwater runoff by removing sediment and pollutants through filtration. The bed filter utilizes the filtering ability of the soil and gravel to remove sediment and pollutants from stormwater runoff. The bed filter is designed to filter runoff through the bed media, collect filtered runoff in the underdrain, and discharge treated stormwater to a standpipe outlet. The bed filter has an impermeable liner beneath the filter media to prevent infiltration of runoff, thus no reduction in stormwater volume is achieved. The bed filter should function as long as the design infiltration rate is maintained and conveyance (inlets and outlets) is functional, however, subsurface isues may reduce the treatment level of stormwater. The regular maintenance of the sediment forebay and other pretreatment and source control BMPs (i.e. sediment traps and retaining walls) will significantly minimize maintenance requirements for the bed filter.

<u>What to look for during an inspection</u>

- Flow obstruction at inlet or outlet
- Infiltration capacity of filter media
- Sediment accumulation
- Vegetation encroachment
- Aesthetics
- Safety hazards & spills

Inspection/Maintenance Considerations

Inspect and observe the system during and after heavy precipitation events, to ensure proper function. Be sure the inlet and outlet are open and the emergency overflow is structurally sound. If the inlet or outlet is clogged, remove the material and dispose of it properly. Record all observations, including how long standing water remains in the bed filter following storm/snowmelt events. Stormwater runoff should completely infiltrate into the filter media within 96 hours to prevent creating mosquito habitat and within 24 hours to meet the design parameter. Rehabilitation or replacement is in order when standing water persists for more than 96 hours.

Inspection should include monitoring infiltration capability of the filter media and functionality of the conveyance feature (inlets and outlets) per BMP RAM protocols. Inspectors should document the infiltration rate using a Constant Head Permeameter (CHP) to a depth of 6" minimum and 12" maximum following BMP RAM infiltration testing protocols. Inlet and outlet feature functionality should be assessed by following the BMP RAM conveyance protocols.

The primary maintenance tasks associated with bed filters are:

- Removing accumulated sediment and debris from sediment traps and conveyance features
- Maintaining infiltration capacity of the filter media
- Controlling vegetation encroachment

Maintenance crews should be prepared to remove accumulated sediment and debris from the linear, concrete sediment forebay at least twice a year. Removal of trash and debris to maintain conveyance functionality is another common maintenance practice. When infiltration measurements indicate surface clogging or loss of infiltration, capacity of the bed filter media can be maintained by removing the top two (2) inches of media. Dispose of removed sediment outside of the Tahoe Basin. Restore media depth to 18 inches when overall media depth drops to 12 inches – determining this depth can be done through maintenance logs. Avoid using heavy equipment, vehicles and heavy foot traffic within the bed filter, and **never** when the soil is wet or moist. Spill response procedures and controls should be implemented to prevent spills from reaching the filter media.

Specialized Inspection Equipment

- Constant Head Permeameter Kit (CHP) (to measure infiltration rates)
- Staff plate/stadia rod (to probe sediment depth in pretreatment BMPs)

The inspection crew may want to install a staff plate or reference point to help monitor sediment accumulation in pretreatment sediment traps. The CREGID may want to strongly consider retrofitting a sediment trap to the slotted drain inlet, as this inlet is observed to contribute sediment to the bed filter.

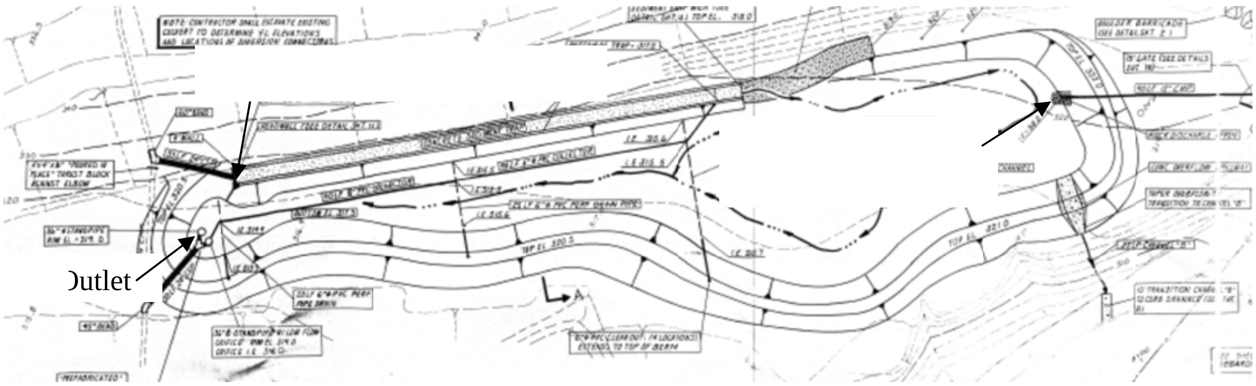


Figure 1. Existing Bed Filter and Components at Cave Rock Estates GID.

Sediment Forebay

The sediment forebay in the bed filter is a pre-treatment BMP designed to allow sediment to settle out of stormwater runoff before entering the bed filter. The sediment forebay helps isolate sediment deposition to the linear, concrete channel that is easily accessed and cleaned with a bobcat. The sediment forebay is divided into multiple sections via 2x10 boards fitted into wall slots, which act as weirs to further slow runoff velocities and enable additional settling. The boards must be removed prior to maintenance and then replaced. Currently, some of the boards are damaged and need replacement. The inspection and maintenance crew should be familiar with the design and function of the sediment forebay in order to informatively assess its condition and restore function.

<u>What to look for during an inspection</u>

- Sediment accumulation
- Flow obstruction
- Structural integrity
- Safety hazards & spills

<u>Inspection/Maintenance Considerations</u>

Inspect and observe the system during and after heavy precipitation events, to ensure runoff access to the sediment forebay. Inspection should include documenting the accumulated sediment from the sediment forebay with a staff gauge or stadia rod measurement. The measurements should be taken in the same location to ensure data comparability between inspections. The inspection crew may want to permanently install a staff plate or ruler to monitor sediment accumulation. Inspectors should also ensure that the site is accessible to maintenance vehicles and personnel.

Inspection should include monitoring material accumulation and functionality of the conveyance feature (inlets and outlets) per BMP RAM protocols for 'settling basin'. Inspectors should document the sediment deposition following BMP RAM material accumulation protocols. Inlet and outlet feature functionality should be assessed by following the BMP RAM conveyance protocols.

The most crucial maintenance needs of sediment forebays are removing the captured sediment and debris. Maintenance crews should be prepared to remove accumulated sediment and debris from the sediment forebay at least twice a year. Maintenance crews should keep a log of the amount of sediment collected, date of removal and site of disposal to help shape future maintenance scheduling. Removed sediment should not be left on site unless it is contained.

Specialized Inspection Equipment

- Staff gauge/Stadia rod (to probe sediment depth in pretreatment BMP)

Sediment Traps and Drainage Inlets

There are numerous sediment traps and drainage inlets installed in Cave Rock Estates. The inspection and maintenance of sediment traps and drainage inlets with sumps are the same. The inspection and maintenance crew should be familiar with the design and function of sediment traps and drainage inlets in order to informatively assess its condition and restore function.

Sediment traps and drainage inlets are designed to collect stormwater and retain sediment and debris. They have a sump which detains incoming water, allowing particles to settle out. The sump may or may not allow infiltration into the surrounding soils depending on the application. The sediment traps and drainage inlets in Cave Rock are constructed out of concrete. Their effectiveness in removing sediment and debris is dependent on their sump size and maintenance regularity.

What to look for during an inspection

- Sediment accumulation
- Flow obstruction
- Structural integrity
- Safety hazards & spills

Inspection/Maintenance Considerations

Inspection should include documenting the accumulated sediment in the sump of the sediment traps and drainage inlets. Before heavy precipitation events, inspection crews should also ensure runoff access to the sediment trap or drain inlet by looking for debris (pine needles) on the grates and in flow path.

Inspection should include monitoring sediment trap capacity and functionality of the inlets and outlets per BMP RAM protocols for ‘sediment trap.’

The BMP RAM maintenance trigger should be replaced with the following protocol: *Storm drains and sediment traps can capture sediments up to approximately 60 percent of the sump volume. When sediment fills greater than 60 percent of their volume, stormwater flows re-suspend captured sediments, and runoff will bypass treatment*[1]. *Therefore, cleaning sediment traps and storm drains is recommended* ***before*** *the sump volume reaches 60 percent full.*

The most crucial maintenance need of sediment traps and drainage inlets is removing the captured sediment and debris. Removing trash and debris captured by the trash rack or grate is also an important maintenance practice. Maintenance crews should be prepared to remove accumulated sediment and debris with Vactor trucks when sumps are half full. Maintenance crews should keep a log of the amount of sediment collected, date of removal and site of disposal to help shape future maintenance scheduling. The inspection crew may want to install a staff plate or ruler to monitor sediment accumulation in the sumps. Consider retrofitting double sediment traps in locations that capture sediment more quickly.

Specialized Inspection Equipment

- Tape measure/Stadia rod/8' long rebar (to probe sediment depth in pretreatment BMPs)

Infiltration Basin

There is one infiltration basin located in Cave Rock Estates off of Chukkar Drive. The infiltration basin has several components: inlet, sediment trap, maintenance access ramp, outlet protection, slope stabilization, outlet standpipe, emergency overflow, rock lined channel and retention berm. The infiltration basin is a shallow, vegetated depression designed to capture and infiltrate stormwater runoff. It is designed with a sediment trap to capture large sediment prior to the runoff entering the basin. The most crucial maintenance needs are emptying the sediment trap and periodically removing accumulated sediment from the basin, which over time, reduces infiltration capability.

What to look for during an inspection

- Infiltration capacity
- Flow obstruction
- Sediment accumulation
- Standing water
- Safety hazards & spills

Inspection/Maintenance Considerations

Inspect and observe the system during and after heavy precipitation events, to ensure proper function. Pay particular attention to the inlet and outlets to be sure they are not clogged and

[1] U.S. EPA National Pollution Discharge Elimination System (NPDES) website, Catch Basin Inserts fact sheet http://cfpub2.epa.gov/npdes/stormwater/menuofbmps/index.cfm?action=factsheet_results&view=specific&bmp=77

functioning properly. Stormwater runoff should completely infiltrate into the soil within 96 hours to prevent creating mosquito habitat. Rehabilitation or replacement is in order for a basin that supports standing water for more than 96 hours.

Inspectors must conduct a wetland and riparian species vegetation cover survey, a Constant Head Permeameter (CHP) infiltration test and a conveyance functionality assessment per BMP RAM. Vegetation cover should be 20% or less of the surface area; excess vegetation is an indication of reduced infiltration capacity. If the CHP infiltration test shows the infiltration rate has been reduced by 20% or more from the benchmark rate, maintenance is required. Inlet and outlet feature functionality should be assessed by following the BMP RAM conveyance protocols.

Avoid using heavy equipment, vehicles and heavy foot traffic within the basin, and **never** when the soil is wet or moist. Spill response procedures and controls should be implemented to prevent spills from reaching the infiltration system.

Specialized Inspection Equipment

- CHP Kit

Slotted Channel Drain

There are two slotted channel drains or trench drains installed in Cave Rock Estates. One has the primary function of capturing runoff from Winding Way and conveying it to the bed filter. The other captures runoff from Chukkar Dr. and Lark Cir. and conveying it to the infiltration basin on Chukkar. Both are older style channel drains made of corrugated metal pipe with a fixed entry grate. The fixed grate makes maintenance a challenge. The channel drain conveys runoff directly into the bed filter and infiltration basin. Because of the low traffic and small contributing area for the infiltration basin, the existing slotted drain is adequate and functions well. For the slotted drain at the bed filter, maintenance is an issue and adding a sediment trap between the drain and the bed filter would reduce the need for more costly bed filter maintenance. CREGID may consider installing a sediment trap at the channel drain outlet and upgrading the channel drain to a newer style with removable grates to facilitate easier maintenance. For the slope (15-20%) and contributing area (23,000 ft^2) above the slotted drain, there are a variety of drains available to replace the existing drain and the manufacturer can help size the drain. Appendix D contains the list of NDOT approved trench drains.

What to look for during an inspection

- Flow obstruction
- Sediment accumulation
- Structural integrity
- Safety hazards & spills

Inspection/Maintenance Considerations

Inspect and observe the system during and after heavy precipitation events, to ensure proper function. Alternatively, the inspection crew may pour water via a hose or large water container on the road above the channel drain to verify proper function.

The inspection crew should look for accumulated sediment and debris in the channel drain. The crew should also inspect the structural integrity of the channel drain to ensure that corrosion has not compromised its function. A long piece of rebar to poke the bottom and test for rusted spots is an easy way to verify structural integrity. A corroded or compromised drain should be replaced as soon as possible to avoid undermining and damaging the road bed.

The most crucial maintenance need of slotted channel drains is removing the sediment and debris to ensure proper capture and conveyance of runoff. Sediment should be removed when the channel is half full. Remove accumulated sediment with a high pressure hose. Start at the far end and loosen and spray sediment to the outlet. Vactor sediment and water from the outlet. Care should be taken not to wash accumulated sediment and debris directly into the bed filter.

Specialized Inspection Equipment

- 3-4' section of rebar

Rock Lined Channel

There are several rock lined channels installed in Cave Rock Estates. Rock lined channels are designed to convey runoff down a slope without erosion. Rock lined channels slow flow and allow for some infiltration. Often, sediment settles out and buries the original channel, requiring periodic sediment removal to ensure proper function.

What to look for during an inspection

- Flow obstruction
- Sediment accumulation
- Slope stability
- Excess vegetation
- Safety hazards & spills

Inspection/Maintenance Considerations

Inspectors should compare existing site conditions with original design plans and photo documentation (if these records are available). Inspection should include monitoring sediment and debris accumulation, identifying contributing sediment sources, and documenting erosion in the channel. Installation of a staff plate in areas which accumulate sediment will allow consistent quantification of sediment accumulation.

Maintenance of rock lined channels typically involves the removal of accumulated sediment and debris as well as excess vegetation. Rocks may need to be replaced due to relocation by plow trucks, snow or other disturbance.

Inspection Equipment

- See Appendix A for additional inspection equipment needed

Outlet Protection

Outlet protection is designed to dissipate the energy of the concentrated flow, reducing the velocity of the flow and preventing scour and erosion. The outlet protection used in Cave Rock Estates consists of rip rap. There are three locations where outlet protection was installed: the inlet outfall of the infiltration basin, the slotted channel drain outlet of the bed filter and the end of the rock lined channel on the west side of HWY 50 near the beach.

What to look for during an inspection

- Erosion protection
- Flow obstruction
- Sediment accumulation
- Safety hazards & spills

Inspection/Maintenance Considerations

Inspection should include identifying erosion problems, documenting excessive sediment accumulation, and identifying blocked or obstructed stormwater flow. Chronic sediment accumulation indicates a significant sediment source upslope in need of stabilization.

Maintenance crews should be prepared to replace or extend riprap to provide erosion protection if necessary and remove accumulated sediment and debris to ensure unobstructed flow. Removal of trash and debris is another common maintenance practice.

Inspection Equipment

- See Appendix A for additional inspection equipment needed

Retaining Walls, Revegetation, and Slope Stabilization

Retaining walls, revegetation, and slope stabilization are located along most roadways throughout the steep Cave Rock Estates neighborhood. Each of these are considered a source control BMP, meaning that they prevent sediment from being eroded.

What to look for during an inspection

- Damage to retaining wall timber or concrete
- Soil or sediment spilling over the top or through a retaining wall
- Bare soil accumulating on road from a slope

Inspection/Maintenance Considerations

Inspection should include identifying erosion problems and damaged walls. Maintenance crews should be prepared to replace damaged structures and remove accumulated sediment from behind walls. Revegetation on steep slopes can be difficult and a professional should be consulted.

Conveyance

In addition to rock lined channels, structures dedicated to conveying runoff to treatment BMPs include curb and gutter and pipes.

What to look for during an inspection

- Damage to curbs or gutter from snow plows
- Obstructions in gutters
- Damage to pipes (Collapsing, leaking)

Inspection/Maintenance Considerations

Inspection and maintenance should include identifying damaged structures and replacing them as necessary.

Current Maintenance Needs

NTCD staff conducted a visual inspection of Cave Rock Estates GID Stormwater Assets on May 2, 2012 and found the following current maintenance needs.

Bed Filter

- Remove trash and debris
- Clean inlet (Inlet 2 in Figure 1, Photo in Figure 2) from slotted channel drain and dispose of material outside of the basin.

Sediment Forebay

- Repair or replace damaged wood partitioning
- Remove sediment and dispose of outside of the basin

Figure 2. Inlet 2 in Bed Filter filling up with sediment. Adding a sediment can between this point and the slotted drain will help reduce further maintenance.

Sediment Traps and Drainage Inlets

- There are 3 drainage inlets (DI) that are blocked by debris. 2 are on Cave Rock Drive and 1 is located on Wren Circle. NTCD recommends using weighted coir logs to contain the traction control material above the DI pictured in Figure 3.

Figure 3. Drainage inlet is clogging due to runoff from stockpiled traction control material.

Figure 4. Pine needles and cones can be removed by hand or mechanical sweeping.

<u>Slotted Channel Drain</u>

- The slotted channel drain at the bottom of Cave Rock Dr. should be replaced with a trench drain with removable grates for easier maintenance. NTCD recommends using an NDOT approved trench drain found in Appendix D.

Appendix A

Inspection and Maintenance Protocols

BED FILTER

General Description

A bed filter is a shallow basin that is designed to treat stormwater. Bed filters utilize the filtering ability of the soil (or other filter media) to remove sediment and pollutants in stormwater runoff. A bed filter is hydraulically similar to infiltration basins except the runoff is filtered through the bed media (soil), collected into an underdrain, and discharged to an outlet rather than being infiltrated to the underlying soil. Bed filters have a liner beneath the filter media to prevent infiltration of runoff, thus no reduction in stormwater volume is achieved. Bed filters function as long as infiltration capacity of the filter media is maintained and vegetation encroachment is controlled. The use and regular maintenance of pretreatment BMPs will significantly minimize maintenance requirements for the bed filter.

The Cave Rock bed filter has several components: inlet, sediment trap, maintenance access, impervious liner, filter media, underdrain, and outlet. The inspection and maintenance crew should be familiar with the design of the bed filter in order to informatively assess its condition and function.

What to look for during an inspection

- Flow obstruction
- Infiltration capacity of filter media
- Sediment accumulation
- Vegetation encroachment
- Aesthetics
- Safety hazards & spills

Inspection/Maintenance Considerations

Inspect and observe the system during and after heavy precipitation events, to ensure proper function. Be sure the inlet and outlet are not clogged and the emergency overflow is structurally sound. Record all observations, including how long standing water remains in the bed filter following storm/snowmelt events. Stormwater runoff should completely infiltrate into the filter media within 96 hours to prevent creating mosquito habitat. Rehabilitation or replacement is in order for a bed filter that supports standing water for more than 96 hours.

Inspection should include monitoring infiltration capability of the filter media and functionality of the conveyance feature (inlets and outlets). Inspectors must document the infiltration rate using a Constant Head Permeameter (CHP) following BMP RAM infiltration testing protocols. Inlet and outlet feature functionality should be assessed by following the BMP RAM conveyance protocols.

The primary maintenance tasks associated with bed filters are:

- Maintaining infiltration capacity of the filter media
- Removing accumulated sediment and debris from sediment traps and conveyance features
- Controlling vegetation encroachment

Maintenance crews should be prepared to remove accumulated sediment and debris from pre-treatment sediment traps at least twice a year. Removal of trash and debris to maintain conveyance functionality is another common maintenance practice. Infiltration capacity of the bed filter can be maintained by removing the top two (2) inches of media, when infiltration measurements indicate surface clogging or loss of infiltration. Dispose of removed sediment outside of the Tahoe Basin. Restore media depth to 18 inches when overall media depth drops to 12 inches. Avoid using heavy equipment, vehicles and heavy foot traffic within the bed filter, and **never** when the soil is wet or moist. Spill response procedures and controls should be implemented to prevent spills from reaching the filter media.

Inspection Equipment

- Inspection and Maintenance Log (preferably on write in the rain paper)
- Pen/Pencil
- Camera
- Constant Head Permeameter Kit (CHP) (to measure infiltration rates)
- Staff plate (to measure sediment accumulation in pretreatment BMPs)

The inspection crew may want to install a staff plate to help monitor sediment accumulation in pretreatment sediment traps if not already installed.

Inspection and Maintenance Activities	Suggested Frequency	Inspection Equipment	Maintenance Equipment
■ Inspect for signs that stormwater runoff is properly accessing inlets and outlets. Look for any blockages or diversions. Emergency overflow spillways should be structurally sound and accessible. ❖ Repair any blocked or diverted conveyances, inlets and outlets and ensure that emergency spillways are structurally sound and functioning.	Before and During Major Storms		Trash Bag Shovel
■ Inspect for standing water 96 hours after a storm event. ❖ If water is present, then contact your local vector abatement office for specific instructions on controlling mosquitoes until rehabilitation can be performed	96 hours after major storms		Tools suggested per qualified individual
■ Inspect for erosion and undercutting, especially along the adjacent slopes, and at the inflow and outflow areas. ❖ Stabilize eroded slopes and undercut and eroded areas at inflow and outflow structures.	Monthly (April—Oct)		Erosion Control Blanket, Coir Logs
■ Inspect for trash and debris. ❖ Remove trash and debris from bed filter.	Monthly (April—Oct)		Trash Bag
■ Inspect for invasive weeds[1]. ❖ Remove invasive weeds monthly during the first two growing seasons. Thereafter, weed annually, or as needed.	Monthly During First Growing Season and Annually Thereafter	Invasive Weeds Inspector	Tools as needed to control infestation
■ Inspect sediment traps and measure depth of sediment to determine accumulated depth. ❖ If accumulated material has decreased sediment trap capacity by 50%, removal of accumulated material is needed. If frequently full of sediment, consider retrofitting with a larger sediment trap. Investigate higher in the drainage area for possible contributing sediment sources. 1. Remove check dams. 2. Remove sediment and debris from sediment trap with a bobcat. 3. Dispose of sediment and debris out of the Tahoe Basin.	Semi-annually (spring and fall) and after major storms	Stadia Rod Or Ruler	Grate removal tools Vactor Truck Shovel or Scoop Trash Bag
■ Perform Constant Head Permeameter (CHP) infiltration tests according to BMP RAM protocols[2] to determine current infiltration rates. Only perform when bed filter is dry. ❖ Compare infiltration test results to initial infiltration rates of the bed filter. If the rate has decreased by 20%, rehabilitation of the bed filter is needed. ❖ Rehabilitate bed filter to restore infiltration capability of the filter media. To prevent compaction, perform only when bed filter is dry. Rehab includes: 1. Scrape bottom (shovel, backhoe, or bobcat) to remove top two inches of filter media and restore original cross-section and infiltration rate. 2. Dispose of sediment out of the Tahoe Basin. 3. Restore filter media depth to 18 inches when overall media depth drops to 12 inches.	Annually in Summer	CHP Kit and Instructions	Shovel, Backhoe, or Vactor Truck Pickup or Dump Truck Aerator for basin bottom

[1] Lake Tahoe Basin Weed Coordinating Group. http://www.tahoeinvasiveweeds.org/.
[2] BMP RAM Users Manual V.1. The Lake Tahoe Stormwater Community and Environmental Improvement Program. Final – September 2009. Step 4. Field Observation Protocol Constant Head Permeameter (CHP). pg 49-52

Inspection and Maintenance Activities (continued)	Suggested Frequency	Inspection Equipment	Maintenance Equipment
■ Inspect site for unusual or unsafe conditions (snow plow damage, structural damage, dumping, vandalism, etc.). ❖ Repair structural components as necessary.	Annually in Spring		Tools as needed
■ Inspect for animal burrows, holes and mounds. ❖ If burrows are causing erosion or compromising structural integrity, backfill firmly.	Annually in Fall		Tools as needed to repair
■ Monitor ongoing effectiveness and determine whether another BMP type or additional BMPs could improve long-term effectiveness and improve benefits to costs versus the existing dry basin. ❖ Analyze Inspection and Maintenance Log for trends and recurring issues. ❖ Prepare a plan that more effectively addresses stormwater runoff, reduces long term maintenance costs and improves overall effectiveness and safety of the BMP.	Every 5 years	Qualified Inspector or Consultant	Qualified Inspector or Consultant

Notes:

SEDIMENT TRAPS & STORM DRAINS

General Description

Sediment traps and storm drains are designed to collect stormwater and retain sediment and debris. They have a sump which stills incoming water, allowing particles to settle out. The sump may or may not allow infiltration into the surrounding soils depending on the application. Sediment traps and storm drains are typically constructed out of concrete, but may be metal, plastic, fiberglass, or other material. Their effectiveness in removing sediment and debris depends on their sump size and maintenance regularity.

What to look for during an inspection

- Sediment accumulation
- Flow obstruction
- Structural integrity
- Safety hazards
- Contaminant spills

Inspection/Maintenance Considerations

Inspection should include documenting and removing accumulated sediment from the sump of sediment trap or storm drain inlet. Before heavy precipitation events, inspection crews should also ensure runoff access to the sediment trap or drain inlet by looking for debris (pine needles) on the grates and in flow path.

Storm drains and sediment traps can capture sediments up to approximately 60 percent of the sump volume. When sediment fills greater than 60 percent of their volume, stormwater flows re-suspend captured sediments, and runoff will bypass treatment[1]. Therefore, cleaning sediment traps and storm drains is recommended ***before*** the sump volume reaches 60 percent full.

Vactor trucks are commonly used for sediment removal in sediment traps and storm drains, but hand-tools, such as shovels or scoops, can be used on smaller sites. If a proprietary treatment device has been installed to filter sediment and pollutants, maintain it according to the manufacturer's specifications.

Maintenance crews should keep a log of the amount of sediment collected, date of removal and site of disposal to help shape future maintenance scheduling.

The most crucial maintenance needs are removing the captured sediment and debris. Removing trash and debris captured by the trash rack or grate is also an important maintenance practice.

The inspection crew may want to install a staff plate or ruler to monitor sediment accumulation in the sump.

Inspection Equipment

- Inspection and Maintenance Log (preferably on write in the rain paper)
- Pen/Pencil
- Camera
- See below for additional inspection equipment needed

[1] U.S. EPA National Pollution Discharge Elimination System (NPDES) website, Catch Basin Inserts fact sheet http://cfpub2.epa.gov/npdes/stormwater/menuofbmps/index.cfm?action=factsheet_results&view=specific&bmp=77

Sediment Trap and Storm Drains Inspection and Maintenance Protocols	Suggested Frequency	Inspection Equipment	Maintenance Equipment
■ Inspect for trash and debris on the trash rack and/or grate and in the flow path. ❖ Remove trash and debris.	Monthly (April—Oct) and before and after major storms		Trash Bag
■ Inspect that the sediment trap or storm drain is properly capturing runoff from the impervious surface and conveying it to the treatment system. The inspection crews may want to pour water on the surface to verify connectivity. ❖ Repair any blocked or diverted conveyances.	Annually in Spring and during major storms	Water Source	Tools as needed to repair
■ Inspect sediment traps and storm drains and measure depth of sediment to determine accumulated depth. ❖ If accumulated material has decreased sediment trap or storm drain capacity by 50%, removal of accumulated material is needed. If frequently full of sediment, consider retrofitting with a larger sump. Investigate higher in the drainage area for possible contributing sediment sources. 1. Remove grate. 2. Remove sediment and debris from sediment trap or storm drain with a vactor truck or by hand. 3. Dispose of sediment and debris at a stable on-site location or out of the Tahoe Basin.	Semi-annually (spring and fall) and after major storms	Stadia Rod Or Ruler	Grate removal tools Vactor Truck Shovel or Scoop Trash Bag
■ Inspect for contributing sediment sources to reduce the accumulation of sediment in the sediment traps and storm drains. ❖ Stabilize contributing eroding slopes and bare soil areas to prevent sediment entry. ❖ Routinely sweep the street/driveway to remove sediment before it enters the sediment traps and storm drains.	Annually in Spring and after major storms		Soil Amendment, Seeds/Plants, Irrigation, Mulch, Erosion Control Blanket, Riprap, Coir Logs Streetsweeper
■ Inspect for standing water 96 hours after a storm event. ❖ If sump is designed to retain runoff and water is present, then contact your local vector abatement office for specific instructions on controlling mosquitoes. ❖ If sump is designed to drain and water is present, then contact your local vector abatement office for specific instructions on controlling mosquitoes and remove accumulated sediment.	96 hours after major storms		Tools suggested per qualified individual
■ Inspect for sediment traps and storm drains structural integrity. This is best performed after sediment and debris removal. ❖ Repair or replace structurally suspect or deteriorated sediment traps or storm drains.	Annually	Qualified Individual (safety/structural condition)	Tools as needed to repair or replace
■ Inspect site for unusual or unsafe conditions (snow plow damage, structural damage, dumping, vandalism, etc.). ❖ Repair structural components as necessary.	Annually in Spring		Tools as needed
■ Monitor ongoing effectiveness and determine whether another BMP type or additional BMPs could improve long-term effectiveness and improve benefits to costs versus the existing sediment traps and storm drains. ❖ Analyze Inspection and Maintenance Log for trends and recurring issues. ❖ Prepare a plan that more effectively addresses concentrated water runoff, reduces long term maintenance costs and improves overall effectiveness and safety of the BMP.	Every 5 years	Qualified inspector or consultant	Qualified inspector or consultant

Notes:

INFILTRATION BASIN

General Description

An infiltration basin is a constructed shallow, vegetated or rock-lined depression designed to capture and infiltrate stormwater runoff. Well designed infiltration basins convey runoff into a sediment trap or other pretreatment BMP prior to the runoff entering the basin. The most crucial maintenance needs are removing accumulated sediment, which over time, reduces infiltration capability. There may also be a need for stabilization of the side slopes and removal of invasive weeds and excess vegetation depending on the site.

What to look for during an inspection

- Infiltration capacity
- Flow obstruction
- Sediment accumulation
- Standing water
- Slope stability
- Safety hazards & spills

Inspection/Maintenance Considerations

Inspect and observe the system during and after heavy precipitation events, to ensure proper function. Pay particular attention to the inlet and outlets to be sure they are not clogged and functioning properly. Stormwater runoff should completely infiltrate into the soil within 96 hours to prevent creating mosquito habitat. Rehabilitation or replacement is in order for a basin that supports standing water for more than 96 hours.

Inspectors should identify the targeted infiltration capability, expected annual sediment capture, and identify rainfall/runoff conditions when the basin capacity will be exceeded and overflow expected. Avoid using heavy equipment, vehicles and heavy foot traffic within the basin, and **never** when the soil is wet or moist. Spill response procedures and controls should be implemented to prevent spills from reaching the infiltration system.

Inspectors must conduct a wetland and riparian species vegetation cover survey[1] and a Constant Head Permeameter (CHP) infiltration test[2]. Vegetation cover should be 20% or less; excess vegetation is an indication of reduced infiltration capacity. If the CHP infiltration test shows the infiltration rate has been reduced by 20% or more from the benchmark rate, maintenance is required.

The inspection crew may want to install a staff plate in the basin bottom to monitor sediment accumulation and erosion pins[3] on the side slopes to monitor erosion if not already installed.

Inspection Equipment

- Inspection and Maintenance Log (preferably on write in the rain paper)
- Pen/Pencil
- Camera
- See below for additional inspection equipment needed

---

[1] BMP RAM Users Manual V.1. The Lake Tahoe Stormwater Community and Environmental Improvement Program. Final – September 2009. Step 4. Field Observation Protocol. Vegetation Cover. pg 63-64.
[2] BMP RAM Users Manual V.1. The Lake Tahoe Stormwater Community and Environmental Improvement Program. Final – September 2009. Step 4. Field Observation Protocol Constant Head Permeameter (CHP). pg 49-52
[3] Erosion pins are markers, often steel rods of certain length and diameter, driven into the soil at a certain depth. The initial length of the erosion pin exposed is recorded. Continue to record the length of pin exposed on a bi-annually schedule, spring and fall, and after large precipitation events. The change in the length of pin exposed is interpreted as erosion.
Field Measurement of Soil Erosion and Runoff. Norman Hudson, 1993 pg13.

Inspection and Maintenance Activities	Suggested Frequency	Inspection Equipment	Maintenance Equipment
■ Inspect for signs that stormwater runoff is properly accessing any inlets and outlets. Look for any blockages or diversions. Emergency overflow spillways should be structurally sound and accessible. ❖ Repair any blocked or diverted conveyances, inlets and outlets and ensure that emergency spillways are structurally sound and functioning.	Before and During Major Storms		Trash Bag Shovel
■ Inspect the basin for standing water 96 hours after a storm event. If water has not fully infiltrated and outlets are functioning, then rehabilitate the basin. ❖ Contact your local vector abatement office for specific instructions on controlling mosquitoes until basin can be rehabilitated. ❖ Drain and rehabilitate basin (described below).	96 hours after major storms		Tools suggested per qualified individual
■ Inspect for trash and debris especially at the inlet and outlet structures. ❖ Remove trash and debris from basin.	Monthly (April—Oct)		Trash Bag
■ Inspect for erosion and undercutting, especially along the adjacent slopes, and at the inflow and outflow areas. ❖ Stabilize eroded slopes and undercut and eroded areas at inflow and outflow structures.	Monthly (April—Oct)		Erosion Control Blanket, Coir Logs
■ Inspect for successful vegetation establishment and initial die off to determine if remedial actions are needed, such as reseeding and irrigation the first few years. ❖ Amend soils, reseed/replant, mulch and irrigate as necessary to achieve desired vegetative establishment. See Chapter 6 for vegetation information.	Monthly During First Growing Season	Vegetation Inspector	Soil Amendment Seeds/Plants Mulch Irrigation
■ Inspect for invasive weeds[4]. ❖ Remove invasive weeds monthly during the first two growing seasons. Thereafter, weed annually, or as needed.	Monthly During First Growing Season and Annually Thereafter	Invasive Weeds Inspector	Tools as needed to control infestation
■ Inspect in-channel vegetation for percent cover according to BMP RAM protocols[5]. ❖ If riparian and wetland species percent cover is greater than 20%, vegetation removal is needed. Presence of riparian or wetland vegetation likely indicates a decline in infiltration rate. (reference CHP protocols described below) ❖ Prune and remove woody vegetation (leaving the roots) in the fall. ❖ If vegetation exceeds 12", mow to 6" height, use care (such as not mowing while ground is moist) to avoid excess compaction[6]. ❖ Remove and compost or otherwise dispose of vegetative cuttings and debris.	Spring and Fall	Vegetation Inspector	Loppers Mower Trash Bag

Notes:

[4] Lake Tahoe Basin Weed Coordinating Group. http://www.tahoeinvasiveweeds.org/.
[5] BMP RAM Users Manual V.1. The Lake Tahoe Stormwater Community and Environmental Improvement Program. Final – September 2009. Step 4. Field Observation Protocol. Vegetation Cover. pg 63-64.
[6] Caltrans BMP Retrofit Pilot Program Maintenance Indicator Document. Pg. 11

Inspection and Maintenance Activities (continued)	Suggested Frequency	Inspection Equipment	Maintenance Equipment
■ Inspect site for unusual or unsafe conditions (snow plow damage, structural damage, dumping, vandalism, etc.). ❖ Repair structural components as necessary.	Annually in Spring		Tools as needed
■ Measure depth of sediment to determine accumulated depth. ❖ If accumulated material has decreased basin capacity by 50%[7], characterize and remove accumulated material. To prevent compaction, perform only when basin is dry. ❖ Scrape bottom (shovel, backhoe, or vactor) to remove sediment and restore original cross-section. ❖ Aerate the bottom of basin to restore infiltration rate and reseed/replant if necessary.	Annually in Summer	Staff Plate or Stadia Rod	Shovel, Backhoe, or Vactor Truck Pickup or Dump Truck Aerator for Basin Bottom
■ Perform Constant Head Permeameter (CHP) infiltration tests according to BMP RAM protocols[8] to determine current infiltration rates. Only perform when basin is dry. ❖ Compare infiltration test results to initial infiltration rates of the basin. If the rate has decreased by 20%, rehabilitate the basin. ❖ Rehabilitate basin to restore infiltration capability. To prevent compaction, perform only when basin is dry. Rehab options include: 1. Scrape bottom (shovel, backhoe, or vactor) to remove sediment and restore original cross-section and infiltration rate. 2. Dispose of sediment at a TRPA approved stable on-site location or out of the Tahoe basin. 3. Remove riparian vegetation species with accumulated sediment. 4. Aerate the bottom of basin to restore infiltration rate and reseed/replant if necessary.	Annually in Summer	CHP Kit and Instructions	Shovel, Backhoe, or Vactor Truck Pickup or Dump Truck Aerator for basin bottom
■ Inspect for animal burrows, holes and mounds. ❖ If burrows are causing erosion or compromising structural integrity, backfill firmly.	Annually in Fall after vegetation trimming		Tools as needed to repair
■ Monitor ongoing effectiveness and determine whether another BMP type or additional BMPs could improve long-term effectiveness and improve benefits to costs versus the existing infiltration basin. ❖ Analyze Inspection and Maintenance Log for trends and recurring issues. ❖ Prepare a plan that more effectively addresses stormwater runoff, reduces long term maintenance costs and improves overall effectiveness and safety of the BMP.	Every 5 years	Qualified Inspector or Consultant	Qualified Inspector or Consultant

Notes:

[7] BMP Inspection and Maintenance. EPA. http://cfpub.epa.gov/npdes/stormwater/menuofbmps/index.cfm?action=factsheet_results&view=specific&bmp=91
[8] BMP RAM Users Manual V.1. The Lake Tahoe Stormwater Community and Environmental Improvement Program. Final – September 2009. Step 4. Field Observation Protocol Constant Head Permeameter (CHP). pg 49-52

SLOTTED CHANNEL DRAIN

General Description

The primary function of slotted channel drains is to capture runoff from paved surfaces and convey it to a treatment or infiltration system. Well designed slotted channel drains convey runoff into a sediment trap or other pretreatment BMP before entering a treatment/infiltration system. Newer style slotted channel drains have removable grates to facilitate cleaning.

What to look for during an inspection

- Flow obstruction
- Sediment accumulation
- Safety hazards & spills
- Standing water

Inspection/Maintenance Considerations

The inspection crew should pour water via a hose or large water container on the impervious surface above the slotted channel drain to verify the drain is capturing runoff from the impervious surface along the entire length of the drain and conveying the runoff to the infiltration/treatment system.

Be sure to inspect the structural integrity of the channel drain to ensure that corrosion has not compromised its function. If corrosion has damaged the drain, a crack or leak will be visible and water will undermine the drain and threaten the structural integrity of the slotted channel drain and area as a whole.

The inspection crew should look for any accumulated sediment and debris in the channel drain and on the protective grates. Methods of removing sediment vary depending upon the style and size of grate.

For drains with removable grates; removal of sediment, debris and trash can be accomplished by hand. For older style channel drains with non-removable grates; a pressure washer or vactor truck should be used to wash sediment and debris out the pipe end. Care should be taken not to wash accumulated sediment and debris directly into a treatment or infiltration system.

Inspection Equipment

- Inspection and Maintenance Log (preferably on write in the rain paper)
- Pen/Pencil
- Camera
- See below for additional inspection equipment needed

Inspection and Maintenance Activities	Suggested Frequency	Inspection Equipment	Maintenance Equipment
■ Inspect site for the presence of standing water 96 hours after precipitation events. ❖ Contact your local vector abatement office for specific instructions if standing water is present.	96 hours after major storms		Tools suggested per qualified individual
■ Inspect that the channel drain is properly capturing runoff from the impervious surface and conveying it to the infiltration/treatment system. The inspection crews should pour water using a hose or large water container on the surface to verify performance. Be sure to check the entire length of the drain. ❖ Repair any blocked or diverted conveyances.	Annually in Spring	Water Source	Tools as needed to repair
■ Inspect for accumulated sediment, debris and litter. ❖ Remove accumulated material as described below. ❖ For drains with removable grates, 1. Remove grates and mark grates so they can be properly reinstalled. 2. Remove sediment and debris from channel drain by hand or using a vactor truck. 3. Dispose of sediment and debris in a TRPA approved stable on-site location or out of the Tahoe basin. ❖ For drains with non-removable grates, 1. Obtain access to an end of the channel drain. 2. Wash sediment and debris out of channel drain end by using pressure washer or suck sediment and debris out of drain with a vactor truck. Use care **not** to wash sediment into a treatment or infiltration system. 3. Dispose of sediment and debris in a TRPA approved stable on-site location or out of the Tahoe basin.	Annually in Spring and after major storms	Stadia Rod Or Ruler	Grate removal tools, Pressure washer or Vactor truck, Trash bag
■ Inspect for channel drain structural integrity. This is best performed after cleaning the drain of debris. For metal channel drains with non-removable grates, poke the drain bottom with a piece of rebar to determine corrosion extent. ❖ Repair or replace structurally suspect or deteriorated channel drains.	Annually	3' Long Rebar	Tools as needed to repair or replace
■ Inspect the concrete or asphalt apron of the channel drain for chipping, cracking or other damage. ❖ Repair or replace structurally suspect or deteriorated aprons.	Annually		Tools as needed to repair or replace
■ Inspect for up slope contributing sediment sources to reduce the accumulation of sediment in the channel drain. ❖ Stabilize contributing eroding slopes and bare soil areas to prevent sediment entry into drain. ❖ Routinely sweep the street/driveway to remove sediment before it enters the channel drain.	Annually in Spring and before major storms		Soil Amendment, Seeds/Plants, Irrigation, Mulch, Erosion Control Blanket, Broom, Streetsweeper

Inspection and Maintenance Activities (continued)	Suggested Frequency	Inspection Equipment	Maintenance Equipment
■ Inspect site for unusual or unsafe conditions (snow plow damage, structural damage, dumping, etc.). ❖ Repair structural components as necessary.	Annually in Spring		Tools as needed
■ Monitor ongoing effectiveness and determine whether another BMP type, or additional BMPs could improve long-term effectiveness and improve benefits to costs versus the existing channel drain. ❖ Analyze Inspection and Maintenance Log for trends or recurring issues. ❖ Prepare a plan that more effectively addresses conveyance needs, reduces long term maintenance costs and improves overall effectiveness and safety of the BMP.	Every 5 years	Qualified Inspector or Consultant	Qualified Inspector or Consultant

Notes:

ROCK LINED CHANNEL

General Description

Rock lined channels are designed to convey runoff down a slope in a manner that minimizes the potential for erosion. Vegetation is often incorporated with rock lined channels to help slow flows. Rock lined channels do allow for stormwater infiltration and some are built with step-pool combinations or check dams, thus allowing stormwater to slow and particles to settle. Often, these pools are so full of sediment that the rock of the original channel is buried, so periodic maintenance and controlling upstream sediment sources to the channel will minimize maintenance and ensure proper functioning.

What to look for during an inspection

- Flow obstruction
- Sediment accumulation
- Slope stability
- Excess vegetation
- Safety hazards & spills

Inspection/Maintenance Considerations

Inspectors should compare existing site conditions with original design plans and photo documentation (if these records are available). Inspection should include monitoring sediment and debris accumulation, identifying contributing sediment sources, and documenting erosion in the channel. Installation of a staff plate in areas which accumulate sediment will allow consistent quantification of sediment accumulation.

Inspectors must conduct a vegetation cover survey[1]; excess vegetation is an indication of reduced infiltration capacity. If vegetation cover exceeds 10%, vegetation should be removed to 10% cover or below to restore the benchmark infiltration capacity.

Maintenance of rock lined channels typically involves the removal of accumulated sediment and debris as well as excess vegetation. Accumulated material must be disposed of properly: hazardous material must be disposed of at a hazardous waste facility and non-hazardous material may be disposed of at a TRPA approved stable on-site location or out of the Tahoe basin.

Rocks may need to be replaced due to relocation by plow trucks, snow or other disturbance.

Inspection Equipment

- Inspection and Maintenance Log (preferably on write in the rain paper)
- Pen/Pencil
- Camera
- See below for additional inspection equipment needed

[1] BMP RAM Users Manual V.1. The Lake Tahoe Stormwater Community and Environmental Improvement Program. Final – September 2009. pg 63.

Inspection and Maintenance Activities	Suggested Frequency	Inspection Equipment	Maintenance Equipment
■ Inspect for signs that runoff is properly accessing and being conveyed by the channel. ❖ Repair any blocked or diverted conveyances. ❖ If standing water remains 96 hours after a storm, vector control for mosquitoes and rehabilitation of the channel is needed. ❖ Contact your local vector abatement office for specific instructions.	Before and During Major Storms		Trash Bag Shovel
■ Inspect for trash and debris. ❖ Remove trash and debris from the channel.	Monthly (April—Oct)		Trash Bag
■ Inspect for dislodged or unstable rock and any erosion, especially along the channel bottom and adjacent slopes. ❖ Repair dislodged or unstable rock. ❖ Stabilize eroded and undercut areas	Monthly (April—Oct)		Tools as needed to replace rock and address erosion
■ If applicable, inspect for successful vegetation establishment and initial die off to determine if any remedial actions are needed, such as reseeding and irrigation the first year. ❖ Amend soils, reseed/replant, mulch and irrigate as necessary to achieve desired vegetative establishment. ❖ Flows may have to be redirected if major work to the channel exposes bare soil for an extended time period.	Monthly During First Growing Season and Annually Thereafter	Vegetation Inspector	Soil Amendment Seeds/Plants Mulch Irrigation
■ Inspect for invasive weeds[2]. ❖ Remove invasive weeds monthly during the first two growing seasons. Thereafter, weed annually, or as needed.	Monthly During First Growing Season and Annually Thereafter	Invasive Weeds Inspector	Tools as needed to control infestation
■ Inspect in-channel vegetation growth. ❖ Prune and remove any woody vegetation (leaving the roots) in the fall. ❖ If vegetation exceeds 12”, cut to 6” height[3]. Remove and compost cut vegetation from the site to avoid release of sequestered nutrients.	Spring and Fall	Vegetation Inspector	Weed whacker Loppers Trash Bag
■ Measure depth of sediment to determine accumulated depth. ❖ If accumulated material has buried any portion of the rock lined channel, remove accumulated material. ❖ Scrape bottom (shovel, backhoe, or vactor) to remove sediment and restore original cross-section. ❖ Dispose of sediment at a stable on-site location or outside of the Tahoe basin.	Semi-annually (spring and fall) and after major storms	Staff Gauge or Ruler	Shovel, Backhoe, or Vactor Truck Pickup or Dump Truck Aerator for basin bottom
■ Inspect site for unusual or unsafe conditions (snow plow damage, structural damage, dumping, vandalism, etc.). ❖ Repair structural components as necessary.	Annually in Spring		Tools as needed

[2] Lake Tahoe Basin Weed Coordinating Group. http://www.tahoeinvasiveweeds.org/.
[3] Caltrans Stormwater Quality Handbook Maintenance Staff Guide. Revised October 2009. pg C-109.

Inspection and Maintenance Activities (continued)	Suggested Frequency	Inspection Equipment	Maintenance Equipment
■ Inspect for animal burrows, holes and mounds. ❖ If burrows are causing erosion or compromising structural integrity, backfill firmly. It may be necessary to chink void spaces with smaller rock.	Annually in Fall after vegetation trimming		Tools as needed to repair
■ Monitor ongoing effectiveness and determine whether another BMP type or additional BMPs could improve long-term effectiveness and improve benefits to costs versus the existing rock lined channel. ❖ Analyze Inspection and Maintenance Log for trends and recurring issues. ❖ Prepare a plan that more effectively addresses stormwater runoff, reduces long term maintenance costs and improves overall effectiveness and safety of the BMP.	Every 5 years	Qualified Inspector or Consultant	Qualified Inspector or Consultant

Notes:

<u>OUTLET PROTECTION</u>

General Description

Outlet protection is designed to prevent erosion (in the form of scour and channel degradation) at drainage outlets where stormwater exits at high velocities and the concentrated flow has considerable erosion potential. Outlet protection dissipates the energy of the concentrated flow, reducing the speed of the flow to a non-erosive velocity. Riprap is the most common outlet protection, but there are numerous proprietary products also available on the market.

What to look for during an inspection

- Erosion protection
- Flow obstruction
- Sediment accumulation
- Safety hazards
- Contaminant spills

Inspection/Maintenance Considerations

Inspection should include identifying erosion problems, documenting sediment accumulation, and identifying blocked or obstructed stormwater flow. The inspection crew may want to install a staff plate or ruler to monitor sediment accumulation if not already installed. Chronic sediment accumulation indicates a significant sediment source up stream in need of stabilization.

Maintenance crews should be prepared to replace riprap to provide erosion protection and remove accumulated sediment and debris to ensure unobstructed flow. Removal of trash and debris is another common maintenance practice.

Inspection Equipment

- Inspection and Maintenance Log (preferably on write in the rain paper)
- Pen/Pencil
- Camera
- See below for additional inspection equipment needed

Inspection and Maintenance Activities	Suggested Frequency	Inspection Equipment	Maintenance Equipment
■ Inspect that conveyance is unobstructed and able to access the outlet protection. ❖ Repair any blocked or diverted conveyances.	Monthly (April—Oct) and before major storms		Trash Bag Shovel
■ Inspect for trash and debris. ❖ Remove trash and debris from the area.	Monthly (April—Oct)		Trash Bag
■ Inspect for erosion, scour and undercutting, especially at the drainage outlet and along the edges of the outlet protection. ❖ Stabilize eroded and undercut areas. ❖ Improve outlet protection to dissipate energy and prevent future erosion.	Monthly (April—Oct)		Additional Armor Rocks and Tools as needed
■ Inspect for invasive weeds[1]. ❖ Remove invasive weeds monthly during the first two growing seasons. Thereafter, weed annually, or as needed.	Monthly During First Growing Season and Annually Thereafter	Invasive Weeds Inspector	Tools as needed to control infestation
■ Inspect for accumulated sediment and debris. Measure depth of sediment and mark where measurement was taken. ❖ If accumulated material has covered outlet protection by more than 2 inches, removal of material is needed. ❖ Remove accumulated sediment with vactor truck or shovel and dispose of sediment at a TRPA approved stable on-site location or out of the Tahoe basin. ❖ If chronic sediment accumulation is a problem consider retrofitting a sediment trap upstream to ease sediment removal. ❖ Stabilize eroding slopes and bare soil areas to prevent sediment entry into conveyance system. ❖ Routinely sweep the street/driveway to remove sediment before it enters the conveyance system.	Semi-annually (spring and fall) and after major storms	Staff Plate, Stadia Rod or Ruler	Shovel, Backhoe, or Vactor Truck Pickup or Dump Truck
■ Inspect site for unusual or unsafe conditions and structural damage especially displaced rocks. ❖ Repair components as necessary to restore proper function.	Annually in Spring	Qualified Individual (safety/structural condition)	Tools as needed
■ Monitor ongoing effectiveness and determine whether another BMP type or additional BMPs could improve long-term effectiveness and improve benefits to costs versus the existing outlet protection. ❖ Analyze Inspection and Maintenance Log for trends and recurring issues. ❖ Prepare a plan that more effectively addresses stormwater capture, reduces long term maintenance costs and improves overall effectiveness and safety of the BMP.	Every 5 years	Qualified Inspector or Consultant	Qualified Inspector or Consultant

Notes:

[1] Lake Tahoe Basin Weed Coordinating Group. http://www.tahoeinvasiveweeds.org/.

Appendix B

BMP RAM Field Observation Sheets

Inspection and Maintenance Log

Name of Area: ____ Date of Last Precipitation: __________

System/Structure Type: ____ Type: ____________________

Inspectors: ____ Amount: _____________ Inches

Maintenance Personnel: ____ Current Weather: _____________

INSPECTION					MAINTENANCE		
Structure ID Location	Date	Comments and Observations	Maint. Needed	Initial	Date	Work Performed	Initial

Notes:

BMP RAM Field Observation Datasheet
BED FILTER

BMP ID	
Observation Date & Time	
Observer Name	

Constant Head Permeameter (Infiltration)

BMP Area (ft2)		# of measurements necessary		Benchmark Reading?	Yes No

Measurement Location ID

	t*	r*	t*	r*	t*	r*	t*	r*	t*	r*	t*	r*	t*	r*
1														
2														
3														
4														
5														

*Where t is **Time** in minutes and r is **Reading** in inches

Conveyance

Conveyance Feature ID	Functioning as intended? (Y/N)	If **NOT** functioning as intended: Debris removal required? (Y/N)	Advanced maintenance required? (Y/N)

Notes:

BMP RAM Field Observation Datasheet DRAINAGE INLET	
BMP ID	
Observation Date & Time	
Observer Name	

Sediment Trap Capacity (Depth)	
Depth ID (same as BMP ID)	
Depth (ft)	
Benchmark Reading? (Y/N)	

Conveyance			
Conveyance Feature ID	Functioning as intended? (Y/N)	If **NOT** functioning as intended	
		Debris removal required? (Y/N)	Advanced maintenance required? (Y/N)

Notes:

BMP RAM Field Observation Datasheet **INFILTRATION BASIN**	
BMP ID	
Observation Date & Time	
Observer Name	

Vegetation Cover					
Wetland Species **Wet %**	Riparian Species **Riparian %**	Terrestrial Trees **Tree %**	Grass Species **Grass %**	NO Vegetation **No Veg %**	Total = 100%

Constant Head Permeameter (Infiltration)					
BMP Area (ft2)		# of measurements necessary		Benchmark Reading?	Yes No

Measurement Location ID														
	t*	r*	t*	r*	t*	r*	t*	r*	t*	r*	t*	r*	t*	r*
1														
2														
3														
4														
5														

*Where t is **Time** in minutes and r is **Reading** in inches

Conveyance			
Conveyance Feature ID	Functioning as intended? (Y/N)	If **NOT** functioning as intended Debris removal required? (Y/N)	Advanced maintenance required? (Y/N)

Notes:

BMP RAM Field Observation Datasheet ROCK LINED CHANNEL	
BMP ID	
Observation Date & Time	
Observer Name	

Vegetation Cover					
Wetland Species **Wet %**	Riparian Species **Riparian %**	Terrestrial Trees **Tree %**	Grass Species **Grass %**	NO Vegetation **No Veg %**	Total = 100%

Runoff	
Measurement ID	Is pool of water present after 20 seconds? (Y/N)
IF any measurements above = yes THEN result = yes ELSE no	

Runoff	
Measurement ID	Is pool of water present after 20 seconds? (Y/N)

Conveyance			
Conveyance Feature ID	Functioning as intended? (Y/N)	If **NOT** functioning as intended	
		Debris removal required? (Y/N)	Advanced maintenance required? (Y/N)

Notes:

Appendix C

BMP RAM Field Inspection Protocols

STEP 4. Field Observation Protocol

CONSTANT HEAD PERMEAMETER (CHP)

The BMP RAM utilizes the accepted Constant Head Permeameter developed by the NRCS within the Lake Tahoe Basin.

Treatment BMP Type(s): Dry Basin, Infiltration Basin (non-enclosed), Bed Filter (non-enclosed).

Objective: Measure saturated hydraulic conductivity (Ksat) of the base of a Treatment BMP.

Personnel Required: 1 field worker will require 20 minutes to make one measurement. Each Treatment BMP will require a minimum of 3 measurements depending upon size and the complexity of topography of the Treatment BMP footprint.

Equipment Required (Figure 11):

- Constant Head Permeameter
- Spacer and spacer base
- Bore hole tool (1” diameter pipe sharpened internally on one end)
- Wood dowel or rebar cleaner rod
- Hammer
- 1 gallon of water per measurement
- Stop watch
- BMP RAM Field Observation Datasheet for the respective Treatment BMP
- BMP RAM Inventory and Map (RAM STEP 2 product)

Optimal time to perform: May 1- June 30th

A. Preparation

- Avoid making observations within 24hrs of most recent runoff event.
- Determine Treatment BMP footprint area from Inventory (ft^2) and enter into datasheet. Prior to making CHP measurement field observations should be conducted to determine the distribution of the Treatment BMP footprint that will experience different inundation frequencies. The surfaces at lower elevations will be inundated more frequently and have a greater rate of sediment and material accumulation. This characteristic will result in different infiltration rates in areas with different elevations. The goal of the CHP measurements is to complete 3 distinct measurements in each surface type as determined by the relative inundation frequency. Table 8 summarizes the number of required measurements based on the number of observed surface types as defined by inundation frequency. Three measurements within each surface type allows verification of the Ksat expected by visual observation and relative inundation frequency. There is no need to define more than 4 different surface types within one Treatment BMP.

- The most reliable CHP observations over time will be repeated in the same locations within each specific Treatment BMP. It is recommended that users create and maintain Treatment BMP specific maps on larger more centralized Treatment BMPs that require CHP BMP RAM observations to ensure that CHP measurement locations are repeated.

- Use Table 8 to determine the number of required measurements and enter in datasheet.

Table 8. Number of CHP measurements required based on the distribution of different surface types within the Treatment BMP footprint. Each surface type, based on visual observations, is expected to have similar substrate types and thus similar Ksat values.

Number of distinct surface types	1	2	3	4
Number of Measurements Required	3	6	9	12

- If the observation is being conducted to establish the benchmark value, indicate Y on the field datasheet.

B. Select measurement locations

- Visually determine the area of each distinct surface type within the footprint of the Treatment BMP. Within each surface type distribute the 3 required measurements equally throughout the Treatment BMP. Do this for each surface type that exists. The distinct surface types will collectively represent a range of the footprint characteristics of the Treatment BMP (i.e., some locations that are inundated during all smaller events and some locations that are only inundated during larger events). The three measurements per surface type will allow verification that the Ksat estimates are relatively similar for each surface type.
- All measurement locations must be close to level.
- Measurement ID is for the user to keep track of CHP measurements if desired. A simple map of the locations of each measurement may be useful, though the map is for internal use only. The measurement location can either be:
    - a simple text description of location (*ex. near outlet*), or
    - consecutive numbers 1-*n*, where *n* is the number of CHP measurement conducted at the respective Treatment BMP.

C. Instrument setup

- Select location for measurement. The ground surface should be flat and free of debris.
- Record measurement location ID on field datasheet.
- Vertically hammer the bore hole tool into the ground to a depth of 4 inches.
- Gently remove the bore hole tool from the ground.
- Remove the soil from the bore hole tool with the dowel/rebar or by tapping the back of the tool on the ground or the hammer.
- *Note: In very sandy, dry, or uncompacted soils, material may fall out of the bore hole tool and back into the measurement hole when the tool is extracted. If this happens, slowly apply ~½ liter of water to the measurement hole and allow it to infiltrate; this will make the sediment more cohesive. Use the bore hole tool to clean out the hole to a depth of 4 inches.*
- Clean the soil debris away from the rim of the hole and place spacer base over the hole.
- Fill the CHP with water to the 175 mark. Do not over fill the CHP.
- Gently place the CHP tip through the hole in the spacer base, and slide in the spacer.

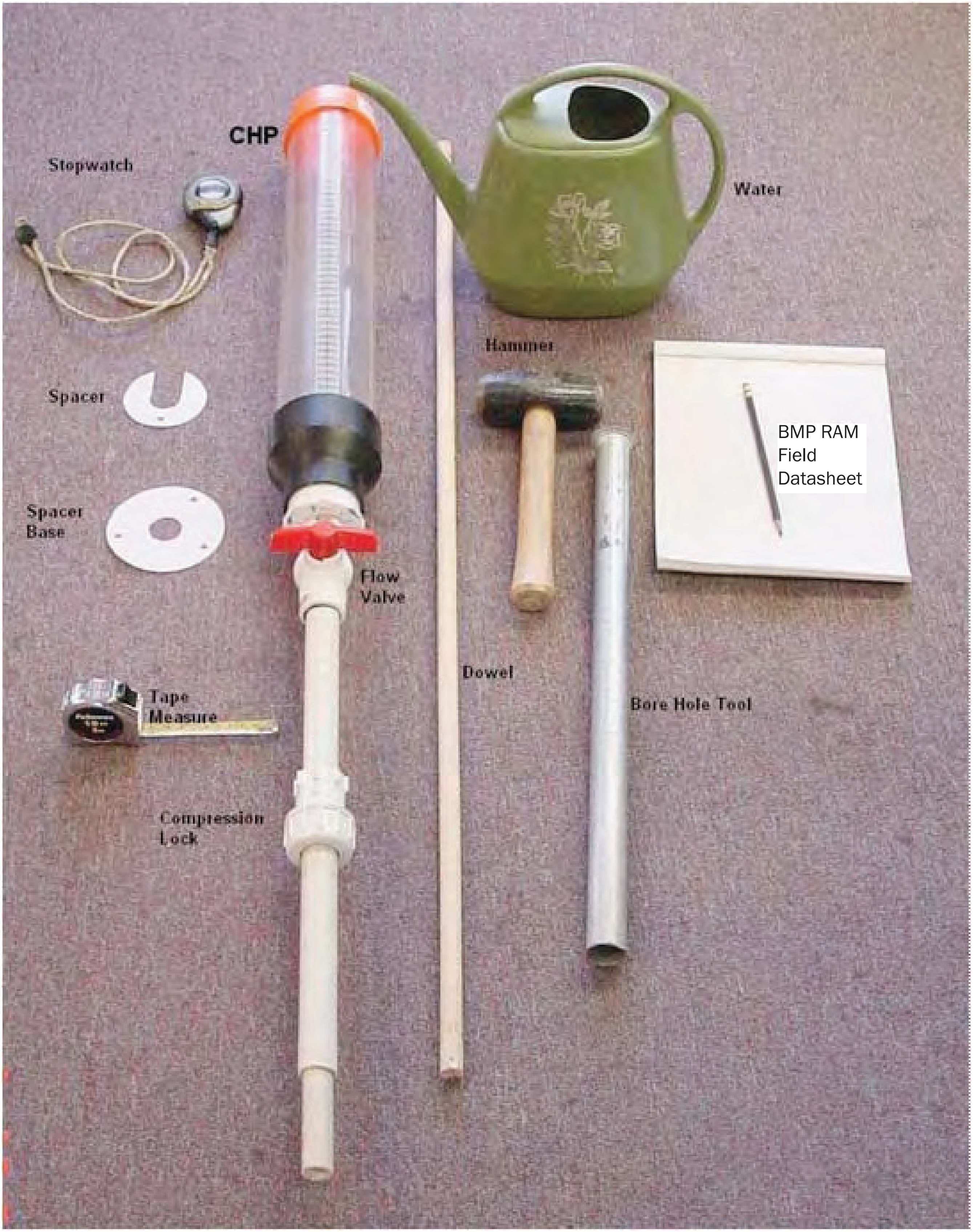
D. Observation

- Slowly open the flow valve. Bubbles will enter the water storage chamber as water flows down through the insertion probe and displaces air. The water level within the storage chamber should stabilize within 30 seconds.
- Begin the stop watch after opening valve.
- Take the first reading at 2 minutes. This allows the surrounding soils to saturate during the first 2 minutes.
- On the field datasheet record time (exact minute) in the t column and reading (inches) in the r column.
- Take a second reading in the middle of the infiltration process within 8 minutes.
- Take a third reading at 15 minutes.
- If it appears that the entire volume of water may drain during 15min, record the reading and time on an even minute prior to the water level reaching 0. It is not necessary to refill the tank to complete the 15 minute period.

Constant Head Permeameter (Infiltration)														
Number of surface types			2		# of measurements necessary			6		Benchmark Reading (Y/N) **Benchmark?**			N	
Measurement ID **Location**														
	1		2		3		4		5		6			
	t*	r*	t	r	t	r	t	r	t	r	t	r	t	r
1	2	99	2	105	2	84	2	109	2	162	2	110		
2	8	93	8	70	8	41	8	67	8	141	8	50		
3	15	89	15	27	13	0	15	31	15	110	14	0		
4														
5														
*Where t is **Time** in minutes and r is **Reading** in inches														

Troubleshooting

- If the CHP is losing water but no bubbles are observed in the chamber, air is coming in from the top. Reseal the cap.
- If small bubbles are observed, they may be leaking in through the joints above or below the valve. This is common with new valves. If the small bubbles are accompanied by regular larger bubbles coming from the bore hole, the CHP is operating properly. This is because the Ksat of the soil is exceeding the minor air leak. To stop these small leaks try applying some silicone grease to both sides of the ball in the ball valve and reapply plumbers tape to the threads in the joints and tighten until snug.
- No water flow is observed when the CHP valve is open. Likely the CHP chamber has been overfilled. Empty all water and refill to 175.



DESIGNED BY
2NDNATURE LLC
TEL: 831.426.9119 FAX: 831.421.9023
www.2ndnaturellc.com

CONSTANT HEAD PERMEAMETER (CHP)

FIGURE 11

Appendix D
NDOT Approved Trench Drains

609.02.01c TRENCH DRAINS

Vendor Name / Address		Product Name	Remarks	
ABT Incorporated Brad Short 259 Murdock Road/PO Box 837 Troutman NC 28166 bshort@abtdrains.com	Phone: (800) 438-6057 Cell: (949) 633-6111 Fax: (704) 528-5478 www.abtdrains.com	A-67 Interceptor Polydrain XHD	this is a general QPL ONLY; the unit will be selected based on the specific project requirements.	ID#: 0394, 0395, 0767 approved 1 /17/2003
ABT Incorporated Brad Short 259 Murdock Road/PO Box 837 Troutman NC 28166 bshort@abtdrains.com	Phone: (800) 438-6057 Cell: (949) 633-6111 Fax: (704) 528-5478 www.abtdrains.com	MHD 200 8" MHD 300	(8"/12" Trench Drain System) This is a general QPL ONLY. The unit will be selected based on the specific project requirements.	ID#: 0561, 0765 approved 7 /5 /2006
ACO Polymer Products Inc Justin White 825 Beechcraft Casa Grande AZ 85222 jwhite@aco-online.com	Phone: (888) 490-9552 Cell: (209) 204-0988 Fax: (209) 574-1014 www.acousa.com	FF300 Concrete FG200 Concrete TraffikDrain	this is a general QPL ONLY; the unit will be selected based on the specific project requirements.	ID#: 0726, 0663, 0380 approved 1 /28/2003
ACO Polymer Products Inc Justin White 825 Beechcraft Casa Grande AZ 85222 jwhite@aco-online.com	Phone: (888) 490-9552 Cell: (209) 204-0988 Fax: (209) 574-1014 www.acousa.com	S100K Concrete S300K Concrete	this is a general QPL ONLY; the unit will be selected based on the specific project requirements.	ID#: 0396, 0397 approved 1 /28/2003
Hubbell Thomas Beattie 273 Willow Green Way Vacaville CA 95687 tbeattie@hubbell.com	Phone: (800) 346-3061 Cell: (707) 291-6991 Fax: (865) 986-0585 www.polycastdrain.com	Polycast 700 Polycast 900R Polycast 3000	this is a general QPL ONLY; the unit will be selected based on the specific project requirements. R =Removeable	ID#: 0512, 0513, 0514 approved 3 /2 /2005
Multidrain Systems Incorporated Steve Born PO Box 88 Barium Springs NC 28010 steve.born@multidrainsystems.com	Phone: (800) 433-1119 Cell: (704) 881-4064 Fax: (704) 508-1011 www.multidrainsystems.com	EconoDrain MultiDrain	this is a general QPL ONLY; the unit will be selected based on the specific project requirements.	ID#: 0492, 0493 approved 4 /6 /2004
Zurn Industries Incorporated Jim Delre 1801 Pittsburgh Avenue Erie PA 16502 jim.e3l43@zurn.com	Phone: (814) 455-0921 Cell: (919) 332-5653 Fax: (814) 875-1402 www.zurn.com	Z-882 (9.25" Wide) Z-886 (4" Wide)	this is a general QPL ONLY; the unit will be selected based on the specific project requirements.	ID#: 0441, 0442 approved 3 /28/2003

610.02.01 CELLULAR EROSION CONTROL MATS

Vendor Name / Address		Product Name	Remarks	
Basalite Concrete Products LLC Damian Swain 335 Greg Street Sparks NV 89431 damian.swain@paccoast.com	Phone: (775) 745-1286 Cell: (775) 358-1200 Fax: (775) 359-5997 www.submar.com	UltraFlexTM	this is a general QPL ONLY; the unit will be selected based on the specific project requirements.	ID#: 0685 approved 11/18/2009
Hanes Geo Components Ben Brough 5927 Balfour Court Suite 108 Carlsbad CA 92008 ben.brough@hanesindustries.com	Phone: (702) 341-0354 Cell: Fax: (702) 341-0355 www.hanesgeo.com	Armorflex	this is a general QPL ONLY; the unit will be selected based on the specific project requirements.	ID#: 0326 approved 1 /21/1998

APPENDIX E

TRPA Letter of Support

TAHOE REGIONAL PLANNING AGENCY

Mail
PO Box 5310
Stateline, NV 89449-5310

Location
128 Market Street
Stateline, NV 89449

Contact
Phone: 775-588-4547
Fax: 775-588-4527
www.trpa.org

LAKE TAHOE EIP
CONSERVATION. CLEARLY.

November 5, 2012

Meghan Kelly, P.E.
Nevada Tahoe Conservation District
PO Box 915
Zephyr Cove, NV 89448

CAVE ROCK ESTATES GENERAL IMPROVEMENT DISTRICT PUBLIC/PRIVATE AREA-WIDE STORMWATER BEST MANAGEMENT PRACTICE (BMP) PILOT PROJECT FEASIBILITY ANALYSIS

Dear Meghan:

I have reviewed the monitoring results from the Cave Rock Estates extended detention basin (Basin) and the pollutant load reduction model report that NTCD ran for the project in order to analyze the existing condition and feasibility of public/private treatment in the Basin. The results indicate that the Basin may handle private property runoff in addition to the roads and other public areas if it is retrofitted to increase pollutant removal capacity and maintained on a regular basis.

TRPA supports the NTCD to move forward with the retrofit design for the Basin. It is expected that the design will be developed by NTCD with input from a technical advisory committee (TAC) to determine the appropriate level of retrofit required in order for the Basin to meet TRPA discharge standards and help Douglas County implement the Total Maximum Daily Load requirements for their jurisdiction. Once the retrofit improvements have been implemented the private parcels will be eligible to receive a BMP certificate of completion. Private parcels will be required to implement source control BMPs to receive the certificate. Douglas County may be eligible to receive 4 pollutant load reduction credits upon project completion.

Please contact me if you have questions regarding this letter or the Cave Rock Estates project in general at (775) 589-5205 or at sfriedman@trpa.org.

Sincerely,

Shannon Friedman

Shannon Friedman
Associate Environmental Specialist II
Implementation Branch