

**Appendix B**  
**Annotated Bibliography of Select Water Quality Monitoring Projects from the**  
**Lake Tahoe Basin**

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## References

Alexandria Department of Transportation, Virginia Chesapeake Bay Local Assistance Dept. (monitoring/ supporting agencies). Airpark Sand Filter, Alexandria, Virginia.

### Summary:

Runoff generated from the parking lot of the National Airport in Alexandria, Virginia was diverted to two Delaware Sand Filters located on the parking lot perimeter. Results from this study are presented in the National BMP Database. The sand filters were capable of removing 79% of the TSS, 67% of the total phosphorous, 75% of the dissolved organic phosphorous, 21% of the total Cu, and 94% of the total Zn. Total nitrogen was removed by 65% while nitrate and nitrite was increased by 44%. Problems observed in the filter configuration included slow drainage and anaerobic conditions at the bottom of the filter.

### Source:

National Stormwater Best Management Practices Database

Ann Y, Reddy, K.R., Delfino, J.J. Influence of chemical amendments on phosphorus immobilization in soils from a constructed wetland

### Summary:

Soils previously used for agriculture are currently being converted to wetlands with the goal that they will function as sinks for nutrients. However, residual fertilizer nutrients, especially phosphorus (P) are rapidly released upon flooding. The objective of this study was to evaluate the efficacy of selected chemical amendments in immobilizing the soluble soil P. Soil used in the study was an organic soil, obtained from a 3-month old constructed wetland created on an agricultural land in Lake Apopka Basin, central Florida. Chemical amendments used were: CaCO<sub>3</sub>, (calcite), Ca(OH)<sub>2</sub>, CaMg(CO<sub>3</sub>)<sub>2</sub> (dolomite), Al<sub>2</sub>(SO<sub>4</sub>)<sub>3</sub> (alum), FeCl<sub>3</sub> and mixtures of selected amendments. The effective amounts required for each chemical amendment to minimize P release from soil to overlying floodwater were 7-x, the order of effectiveness in immobilizing soluble P was as follows: FeCl<sub>3</sub> > alum > Ca(OH)<sub>2</sub> > calcite > dolomite. High rates of chemical amendments are needed to reduce P levels, because of complexation of P binding cations (Ca, Fe and Al) with organic matter.

### Source:

Ecological Engineering. 14 (1-2): 157-167

Backstrom, M. Sediment transport in grassed swales during simulated runoff events.

### Summary:

Particle trapping in nine different grassed swales was measured successfully with a standardized runoff event simulation procedure. It was found that sedimentation processes, rather than grass filtration governed the overall particle trapping efficiency. The highest particle trapping efficiency was observed in the field swales with dense, fully developed turf. A high infiltration rate was beneficial for the particle trapping and an increased swale length made it possible for smaller particles to be captured. A densely vegetated, ten meter long swale, receiving a stormwater flow of 1.0 liter per second, may capture a majority of the waterborne particles with settling velocities larger than 0.1 meter per hour. A simple model of particle trapping efficiency in grassed swales was developed and tested. It was found that mean swale residence time could be used as a design parameter for particle removal in grassed swales. The suggested exponential relationship between mean swale residence time and particle settling velocity associated with a certain trapping efficiency is so far only valid for a limited range of swale designs and residence times.

Source:

Water Science and Technology. 45 (7): 41-49

Backstrom, M. and Bergstrom, A. Draining function of porous asphalt during snowmelt and temporary freezing. June, 2000

Summary:

Urban runoff creates problems with flooding and pollution of receiving waters. Furthermore, cold climate conditions have a degenerating effect on stormwater systems and road constructions. Porous asphalt has been used as a wearing course on highways and in porous pavement constructions all around the world. The main focus of this study was to evaluate the function of porous asphalt in cold climates. Measurements of the draining function of porous asphalt were carried out in a climate room with adjustable temperature in the range -10°C to +20°C. At freezing point, the infiltration capacity of porous asphalt was approximately 50% of the infiltration capacity at +20°C. When the porous asphalt was exposed to alternating melting and freezing during 2 days, conditions similar to the snowmelt period, the infiltration capacity was reduced by approximately 90%. Based on the results of this study and previous studies, the infiltration capacity of porous asphalt was estimated to be 1-5 mm/min for snowmelt conditions.

Source:

Canadian Journal of Civil Engineering. 27 (3): 594-598

Backstrom, M. and Viklander, M. Integrated Stormwater Management in Cold Climates. 2000

Summary:

Integrated stormwater management is based on the natural processes in the water cycle and the criteria for sustainable development. The aim of this

paper was to investigate which integrated stormwater system components might be suitable in cold climate regions. The evaluation was based on literature reviews and studies made in Lulea, Northern Sweden. It was found that porous pavement, grassed waterways (swales, ditches), wet pond, and percolation basin were the most suitable integrated stormwater system components in cold regions whereas dry basin, stormwater infiltration surfaces, and stormwater reuse seemed to be the less suitable. Polluted snow may be treated at a central (large-scale) snow deposit; cleaner snow may be placed in many local snow depots.

Source:

Journal of Environmental Science and Health Part A: Toxic/Hazardous Substances & Environmental Engineering. 35 (8): 1237-1249

Beck, Nicole et al., Lake Tahoe BMP Monitoring Evaluation Process. Synthesis of Existing Research – Final Report. Prepared for the USFS Lake Tahoe Basin Management Unit, October, 2006

Summary:

The BMP Monitoring Evaluation Process was funded by the United States Forest Service Lake Tahoe Basin Management Unit (LTBMU) to compile and synthesize the existing research on BMP urban stormwater quality improvement performance. The synthesis consisted of a detailed review and evaluation of the study designs, study communications, available data and general BMP performance. The primary BMPs evaluated were dry detention basins (3), constructed wetlands/wet basin/meadow (3), and mechanical treatment structures (8). One source control study and three controlled experiments were also reviewed and incorporated into the synthesis. Based on the independent nature of Lake Tahoe water quality monitoring studies, the strengths and weaknesses of various studies were used to develop recommendations to standardize pollutant nomenclature, pollutant parameters of concern, monitoring study priorities, study communication structure, necessary BMP design and catchment characteristics to be included in study communications, data reporting structure, etc. The goal is to incorporate these recommendations into the LTIMP Lake Tahoe Monitoring Guidelines.

Preliminary quantitative comparisons of inflow and outflow BMP event mean concentrations (EMCs) and reported study BMP load and EMC reductions were conducted for each final report, where applicable. Evaluations of mechanical treatment structures, such as vaults, sand traps and roadside sediment basins, suggest effective treatment of particulate pollutants as measured by reductions in total suspended solids (TSS), total organic nitrogen (TKN) and particulate phosphorous (PP). The greatest limitation of mechanical treatment structure performance is inconsistent maintenance, which results in elevated effluent dissolved constituents such as nitrate (NO<sub>x</sub>), ammonia (NH<sub>4</sub><sup>+</sup>), dissolved phosphorous (DP), and soluble reactive phosphorous (SRP). Detention basin evaluations suggest consistent and

reliable treatment of particulate pollutants due to physical settling, but variable treatment of dissolved constituents was reported. Preliminary comparisons suggest detention basin characteristics may be unable to further reduce dissolved constituents when inflowing concentrations approximated  $\text{NO}_x < 250 \text{ ug/L}$ ,  $\text{NH}_4^+ < 50 \text{ ug/L}$ ,  $\text{SRP} < 50 \text{ ug/L}$ , and  $\text{DP} < 80 \text{ ug/L}$ . Wetland/wet basin systems may provide the additional treatment capabilities to “polish” stormwater and further reduce dissolved nutrient loads when inflowing dissolved levels are moderate. The seasonal function of these BMPs should be evaluated since eutrophic wet environments that accept elevated levels of dissolved N and P have been observed to provide reliable removal of  $\text{NO}_x$  through de-nitrification, yet variable treatment of the reduced N species,  $\text{NH}_4^+$ , as well as increases in SRP levels as a result of iron hydroxide reductions upon which phosphate will absorb.

These results support a need for preliminary water quality evaluations to identify target pollutants in order to select and design appropriate BMPs, as well as a watershed treatment train approach for complete stormwater quality improvements prior to discharge to Lake Tahoe. While the data collection techniques and sampling protocols do vary across many of the projects, a standardized data reduction and database creation effort of existing water quality and hydrologic data would significantly improve the integration and power of these extensive data sets. A BMP Stormwater Analysis Database would make existing and future water quality data directly accessible for Phase II of the TMDL, the BMP Design Manual and other planning efforts that should be based upon Lake Tahoe-specific water quality observations. The BMP Synthesis recommendations aim to improve the accessibility of existing and future data to focus research, as well as facilitate greater collaboration between science, engineering and policy.

Source:

USFS Lake Tahoe Basin Management Unit, October, 2006.

Bengtsson, L., and Singh, V.P. Model Sophistication in Relation to Scales in Snowmelt Runoff Modeling. 2000.

Summary:

Snowmelt induced runoff from river basins is usually successfully simulated using a simple degree-day approach and conceptual rainfall-runoff models. Fluctuations within the day cannot be described by such crude approaches. In the present paper, it is investigated which degree of sophistication is required in snow models and runoff models to resolve the basin runoff from basins of different character, and also models of different degree of sophistication are tested on basins ranging from 6,000  $\text{km}^2$  down to less than 1  $\text{km}^2$ . It is found that for large basins it is sufficient to use a very simple runoff module and a degree day approach, but that the snow model has to be distributed related to land cover and topography. Also for small, forested basins, where most of the stream flow is of groundwater origin, the degree-day method combined with a conceptual runoff model reproduces the snowmelt induced runoff well. Where

overland flow takes place, a high resolution snow model is required for resolving the runoff fluctuations at the basin outlet.

Source:

Nordic Hydrology. 31 (4-5): 267-286

Bennett, E. R., Linstedt, K. D., Nilsgard, V., Battaglia, G. M., and Pontius, F. W. Urban snowmelt - characteristics and treatment. 1981.

Summary:

The suspended solids and COD loadings for snowmelt runoff compared to rainfall in Denver, Colorado, were ~1:2, total P, total N, and NO<sub>3</sub><sup>-</sup> were 1:4 or less, and Pb was 1:1, respectively. Snowmelt runoff has particulates which are more colloidal and contain more oil and grease that sedimentation in settling ponds is less effective than with rainfall. In 3 coagulation-settling tests of snowmelt runoff, optimum chem. doses were alum 50, FeCl<sub>3</sub> 50, and lime 100 mg/L. Plain filtration through 30-mesh sand was also evaluated. Total solids loadings of snowmelt varied with the amount of deicing chemicals used.

Source:

Water Pollution Control Federation. 53(1), 119-25

Boughton, C.J., Lico, M.S. Volatile Organic Compounds in Lake Tahoe, Nevada and California, July-September 1997. June, 1998

Summary:

In an effort to evaluate the impacts of 2-stroke engines in Lake Tahoe, the USGS in coordination with the Tahoe Regional Planning Agency (TRPA) sampled various locations in the lake to determine VOC levels. Samples were tested for concentrations of methyl tert-butyl ether (MTBE), ethyl tert-butyl ether (ETBE), tert-amyl methyl ether (TAME), benzene, toluene, ethylbenzene, and Xylene. The analysis revealed the MTBE was detected in all samples, ranging from 0.18 to 4.2-ug/L up to depths of 30-m. Higher concentrations of MTBE were observed in samples collected in areas of high water craft activity. TAME, benzene, toluene, ethylbenzene, and xylene ranged from non-detectable levels to 2.2-ug/L. However, no drinking water limits were exceeded in any of the samples.

Source:

USGS Fact Sheet. FS-035-02

Braskerud, B.C. Design Considerations for Increased Sedimentation in Small Wetlands Treating Agricultural Runoff. 2002.

Summary:

Some suggestions to increase the sedimentation of non-point source pollution in small surface flow wetlands are presented. The recommendations are based on results from seven Norwegian constructed wetlands (CWs) after 3-7 years of investigation, and a literature review. The wetlands were located in first and second order streams. Surface areas were 265-900 m<sup>2</sup>,

corresponding to 0.03-0.4% of the watershed. Each CW had a volume proportional composite sampler in the inlet and outlet, in addition to sedimentation plates. The mean annual retention of soil particles, organic particles and phosphorus was 45-75%, 43-67% and 20-44%, respectively. Results showed that erosion and transportation processes in arable watersheds influenced the retention. Sedimentation was the most important retention process, and increased with runoff, because the input of larger aggregates increased. Retention of nitrogen did not follow the same pattern, and was only 3-15%. Making CWs shallow (0-0.5 m) can optimize sedimentation. The hydraulic efficiency can be increased by aquatic vegetation, large stones in the inlet, baffles and water-permeable, low dams. Vegetation makes it possible to utilize the positive effect of a short particle settling distance, by hindering re-suspension of sediments under storm runoff conditions. As a result, the phosphorus retention in shallow CWs was twice that of deeper ponds.

Source:

Water Science and Technology. 45 (9): 77-85

Braskerud, B.C. Factors Affecting Phosphorus Retention in Small Constructed Wetlands Treating Agricultural Non-point Source Pollution, July, 2002

Summary:

Four surface flow constructed wetlands (CWs) have been intensively investigated for phosphorus retention, from 3 to 7 years in the cold temperate climate of Norway. The aim of this study was to identify factors that affect phosphorus retention from non-point sources. The wetlands were located in first order streams, with surface areas of 0.06-0.4% of the watershed (CW-area 350-900 m<sup>2</sup>). Volume proportional composite samples were taken from inlet and outlet, and sedimentation plates were used in selected areas. The average retention of total phosphorus for the individual CWs was 21-44% of input, despite the high hydraulic load (mean load was 0.7-1.8 in per day). This equals a retention of 26-71 g phosphorus m<sup>-2</sup> surface area per year. A first-order model was fitted to the data giving an average removal constant, k, of 214 in per year. However, the constant increased with increasing hydraulic load due to the simultaneous increase in particle settling velocity. Hence, retention increased in spite of increasing hydraulic loads. Moreover, linear multiple regression models showed that retention was influenced by several external variables, e.g. input of phosphorus, season, phosphorus content on suspended solids and phosphorus settling velocity. The results suggest that the first-order model is less suitable to estimate phosphorus retention in similar gravity fed wetlands. The best of the proposed statistical prediction models, reproduced observed data from two independent test-CWs with a deviation of 0.1%. The investigation shows that small wetlands are a useful supplement to best management practice on arable fields. However, the present study focuses on the necessity to investigate how pollutants enter wetlands. Such knowledge can then be used to suggest improvements of wetland layout.

Source:

Ecological Engineering. 19 (1): 41-61

Brezonik, P.L., Stadelmann, T.H. Analysis and Predictive Models of Stormwater Runoff Volumes, Loads, and Pollutant Concentrations from Watersheds in the Twin Cities Metropolitan area, Minnesota, USA. April, 2002

Summary:

Urban non-point source pollution is a significant contributor to water quality degradation. Watershed planners need to be able to estimate non-point source loads to lakes and streams if they are to plan effective management strategies. To meet this need for the twin cities metropolitan area, a large database of urban and suburban runoff data was compiled. Stormwater runoff loads and concentrations and watershed characteristics were examined. The best regression equation to predict runoff volume for rain events was based on rainfall amount, drainage area, and percent impervious area ( $R^2 = 0.78$ ). Median event-mean concentrations (EMCs) tended to be higher in snowmelt runoff than in rainfall runoff, and significant seasonal differences were found in yields (kg/ha) and EMCs for most constituents. Simple correlations between explanatory variables and stormwater loads and EMCs were weak. Rainfall amount and intensity and drainage area were the most important variables in multiple linear regression models to predict event loads, but uncertainty was high in models developed with the pooled data set. The most accurate models for EMCs generally were found when sites were grouped according to common land use and size.

Source:

Water Research. 36 (7): 1743-1757

Byron, E. and Reuter, J. 1988. *El Dorado County Erosion Control Project Water Quality Evaluation, 1987-1988*. Prepared for El Dorado County Department of Transportation by UCD Tahoe Research Group

Objective:

Evaluate water quality conditions at several erosion control projects in the South Lake Tahoe area.

Summary:

This report focuses on Country Club Heights and Pioneer Trail erosion control projects for Water Year 1988. This was a low precipitation year so few samples were collected. Pioneer Trail stations did not respond similarly to the Country Club Heights stations. At Country Club Heights, most concentrations were higher in the ponds than upstream, except for turbidity and particulate phosphorus. At Pioneer Trail, the upstream stations usually had the highest concentrations. TP, PP, Fe, and turbidity were removed by the ponds, while soluble nutrients were the same or higher, related to the concentration of suspended sediments. The rock-lined ditch at Pioneer Trail-5 appeared to work extremely well. The ponds at Country Club Heights trapped sediments but not nutrients, although the wetlands may increase nutrient retention.



Caltrans: Tahoe Highway Runoff Characterization and Sand Trap Effectiveness  
Studies 2001-2002 Monitoring Session. 2002

Summary:

This report presents results and data evaluations of the Tahoe Basin Stormwater Runoff and Sand Trap Monitoring Program conducted by the California Department of Transportation (Caltrans). This report presents data from the second period of Monitoring in the Lake Tahoe Basin performed from August 2001 to April 2002. Results include runoff water quality and particle and sediment characterization and sand trap treatment and removal effectiveness. Runoff water quality evaluation results indicated the levels of TDS and metals were significantly higher and conversely the levels of nutrient concentrations lower after the start of snow management activities. Land use type (urban Vs rural) and elevation (low Vs high) have indirect impact on runoff water quality. Low elevation and urban sites were observed to have higher constituent concentrations than high elevation and rural sites.

Sand Trap Effectiveness: Data analysis indicated that sand traps reduced effluent concentrations for 19 out of 34 parameters evaluated. However, sand traps were observed to be the source of contamination for 9 out of 34 water quality parameters. For nutrients the sand traps provided the most treatment for orthophosphate, dissolved phosphorus and TKN. Overall, runoff constituent concentrations exceeded the stormwater discharge limits established for Lake Tahoe Basin.

Source:

California Department of Transportation, Sacramento, CA. CTSW-RT-02-044

Caltrans: Monitoring and Operations Plan, Caltrans Tahoe Basin Full-Scale Activated Alumina Filter Media BMP Pilot Study Monitoring Season 2004-2005

Summary:

Monitoring and Operations Plan for Full-Scale BMP Pilot Study of two BMPs using activated alumina filter media.

Source:

California Department of Transportation, Sacramento, CA. CTSW-PL-05-129.02.1

Caltrans: Monitoring and Operations Plan. Caltrans Tahoe Basin Highway 267 Full-Scale BMP Pilot Study Monitoring Season 2004-2005

Summary:

Two sand trap BMPs installed to manage runoff from Hwy 267 in Placer County. Provide enhanced treatment through settling and filtration through fabric filter media. Evaluate treatment effectiveness, characterize operations and maintenance requirements. CTSW-PL-05-129.03.2

Source:

California Department of Transportation, Sacramento, CA CTSW-PL-05-129.03.2

Caltrans: Caltrans Lake Tahoe Storm Water Small-Scale Pilot Treatment Project Phase VI Monitoring and Operations Plan

Summary:

Descriptions of scheduled project activities for the sixth year of stormwater pilot testing (Phase VI, to be conducted during 2006/2007 rainy season. (Comment and responses included.)

Source:

California Department of Transportation, Sacramento, CA CTSW-PL-06-157.04.02

Caltrans: Tahoe Basin Storm Water Monitoring Program, Sampling & Analysis Plan

Summary:

Presents standard procedures specified by Caltrans guidance manual and other specifications to conduct storm water runoff, snowmelt runoff, summer storms, and precipitation monitoring and characterization from three highway sites in District 3, Tahoe Basin

Source:

California Department of Transportation, Sacramento, CA CTSW-RT-00-039

Caltrans: Final Report Caltrans Tahoe Basin Storm Water Monitoring Program, Monitoring Season 2000-2001

Summary:

Presents summary results of the storm water runoff, snowmelt runoff, thunder- storm, and precipitation characterizations from three highway sites in Districts 3 (Tahoe Basin) during the 2000/01 monitoring season.

Source:

California Department of Transportation, Sacramento, CA CTSW-RT-01-038

Caltrans: Lake Tahoe Storm Water Treatment Pilot Project, Monitoring and Operations Plan

Summary:

Presents the monitoring and operations plan for 17 small-scale pilot studies to be performed at the small-scale facility located at Myers Maintenance Station (Caltrans, District 3).

Source:

California Department of Transportation, Sacramento, CA CTSW-RT-01-054

Caltrans: Sampling and Analysis Plan, Caltrans Tahoe Basin Water Quality Characterization and Sediment Trap Effectiveness Studies

Summary:

Presents the Sampling and Analysis Plan for six monitoring sites in the Lake Tahoe Basin. All of the sites are at double-barreled sand traps, two of the sites monitor influent as well as effluent. The purpose of the study is to characterize highway runoff.

Source:

California Department of Transportation, Sacramento, CA CTSW-RT-01-072

Caltrans: Tahoe Basin Storm Drain System Inventory

Summary:

Discharge point inventory, site description, and aerial photo of MS-4 area.

Source:

California Department of Transportation, Sacramento, CA CTSW-RT-02-049

Caltrans: Sampling and Analysis Plan Caltrans Tahoe Basin Water Quality Characterization and Sediment Trap Effectiveness Studies Monitoring Season 2002-2003

Summary:

Presents the Sampling and Analysis Plan for six monitoring sites in the Lake Tahoe Basin. All of the sites are located at double-barreled sand traps, two of the sites monitor influent as well as effluent.

Source:

California Department of Transportation, Sacramento, CA CTSW-RT-02-061

Caltrans: Caltrans Lake Tahoe Storm Water Small-Scale Pilot Treatment Project - First Year Report

Summary:

Pilot project to identify and evaluate storm water treatment technologies that may be capable of meeting the Tahoe Basin numeric surface water discharge limits.

Source:

California Department of Transportation, Sacramento, CA CTSW-RT-03-042

Caltrans: Caltrans Lake Tahoe Storm Water Small-Scale Pilot Treatment Project- Phase II Monitoring and Operations Plan

Summary:

Presents the operation, maintenance, and monitoring plan for the Year Two (2002/2003 wet season) Tahoe Small-Scale Facility stormwater treatment technology testing activities.

Source:

California Department of Transportation, Sacramento, CA CTSW-RT-03-053.33.41

Caltrans Tahoe Highway Runoff Characterization and Sand Trap Effectiveness Studies, 2000-2003 Monitoring Report

Summary:

Presents the results of highway runoff characterization in the Tahoe Basin and the effectiveness of sand traps.

Source:

California Department of Transportation, Sacramento, CA CTSW-RT-03-054.36.02

Caltrans: Monitoring and Operations Plan- Caltrans Tahoe Basin Highway 50 Full-Scale BMP Pilot Study, Monitoring Season 2003-2004

Summary:

Source:

California Department of Transportation, Sacramento, CA CTSW-RT-03-061.31.37

Caltrans: Caltrans Lake Tahoe Storm Water Treatment Pilot Project Jar Test Results and Summary Report, Vols. 1,2,3

Summary:

Presents the results of jar tests performed on up to 13 coagulants in an effort to identify a promising coagulant for the Tahoe Small-Scale Facility treatment technology tests.

Source:

California Department of Transportation, Sacramento, CA CTSW-RT-03-063.33.41

Caltrans: Caltrans Lake Tahoe Stormwater Small-Scale Pilot Treatment Project, Phase II Report

Summary:

Identify and evaluate storm water treatment technologies to meet the Tahoe Basin numeric surface water discharge limits for turbidity, total phosphorus, total nitrogen, total iron, and oil/grease. Results and analyses from Phase II of the pilot.

Source:

California Department of Transportation, Sacramento, CA CTSW-RT-03-079.31.37

Caltrans: Caltrans Lake Tahoe Chemical Dosing System Development - Final Work Plan

Summary:

Lake Tahoe pilot studies - Chemically enhanced sedimentation. Work plan in the development of a feasible chemical dosing system that can be implemented in roadside operations.

Source:

California Department of Transportation, Sacramento, CA CTSW-RT-04-069.04.03

Caltrans: Caltrans Lake Tahoe Storm Water Small-Scale Pilot Treatment Project Phase III Monitoring and Operations Plan

Summary:

Source:

California Department of Transportation, Sacramento, CA CTSW-RT-04-069.04.04

Caltrans: Caltrans Lake Tahoe Storm Water Small-Scale Pilot Treatment Project - Phase III Final Report

Summary:

Pilot project to identify and evaluate storm water treatment technologies to

meet Lake Tahoe numeric surface water discharge limits for turbidity, total phosphorus, nitrogen, iron, and oil/grease. Results and analysis from pilot testing program year three,

Source:

California Department of Transportation, Sacramento, CA CTSW-RT-05-069.04.07

Caltrans: Caltrans Lake Tahoe Storm Water Small-Scale Pilot Treatment Project - Phase IV Monitoring and Operations Plan

Summary:

Multi-year project. Phase IV continues use of 4-inch diameter filter columns to investigate long-term performance of granular media filters. Continues and expands jar testing and sedimentation testing of chemical coagulants.

Source:

California Department of Transportation, Sacramento, CA CTSW-RT-05-069.04.08

Caltrans: Lake Tahoe Chemical Dosing System Development Test Report

Summary:

Design a chemical dosing system that can reliably deliver flow proportional chemical coagulants to stormwater runoff, and can be feasibly implemented in the field.

Source:

California Department of Transportation, Sacramento, CA CTSW-RT-05-069.04.09

Caltrans: Operational Monitoring Report No. 1--Caltrans Tahoe Basin Highway 267 Full-Scale BMP Pilot Study Sand Traps No. 1 and No. 2, December 7 through 22, 2004 Monitoring Event

Summary:

Reports the results of the first operational monitoring inspection, which was performed during the period from December 7 through 22, 2004.

Source:

California Department of Transportation, Sacramento, CA CTSW-RT-05-129.03.3

Caltrans: Operational Monitoring Report No. 2--Caltrans Tahoe Basin Highway 267 Full-Scale BMP Pilot Study Sand Traps No. 1 and No. 2, December 23, 2004 through March 9, 2005, Monitoring Event

Summary:

Reports the results of the second operational monitoring inspection, which was performed during the period from December 23, 2004 through March 9, 2005.

Source:

California Department of Transportation, Sacramento, CA CTSW-RT-05-129.03.4

Caltrans: Operational Monitoring Report No. 3--Caltrans Tahoe Basin Highway

267 Full-Scale BMP Pilot Study Sand Traps No. 1 and No. 2, March 10 through April 6, 2005, Monitoring Event

Summary:

Reports the results of the third operational monitoring inspection, which was performed during the period from March 10 through April 5, 2005.

Source:

California Department of Transportation, Sacramento, CA CTSW-RT-05-129.03.5

Caltrans: Caltrans Tahoe Basin Highway 267 Sand Trap With Filter Fabric Pilot Study Monitoring Season 2005-2006, Monitoring and Operations Plan

Summary:

Study to evaluate treatment effectiveness and operations and maintenance requirements at two pilot treatment BMPs in Tahoe Basin. Comments and responses received.

Source:

California Department of Transportation, Sacramento, CA CTSW-RT-05-157.01.1

Caltrans: Caltrans Lake Tahoe Storm Water Small-Scale Pilot Treatment Project

Summary:

Presents the results from the fourth year (Phase IV) of the pilot testing program.

Source:

California Department of Transportation, Sacramento, CA CTSW-RT-05-157.04.02

Caltrans: Caltrans Tahoe Basin Highway 267 Filter Fabric Sand Trap Pilot Study Basis of Design Report

Summary:

Documents the design parameters associated with the design of two filter fabric pilot sand traps. Comments and responses received.

Source:

California Department of Transportation, Sacramento, CA CTSW-RT-06-157.01.1

Caltrans: Caltrans Tahoe Basin Highway 267 Sand Trap With Filter Fabric 2-Year Pilot Study 2004-2005 Monitoring Report

Summary:

Presents results of 2 years of monitoring during the 2004-2005 and 2005-2006 wet seasons. The purpose was to determine the effectiveness of the filter fabric sand traps in meeting Lake Tahoe numeric discharge limits and their overall feasibility.

Source:

California Department of Transportation, Sacramento, CA CTSW-RT-06-157.01.2

Caltrans: Caltrans Tahoe Basin Highway 50 Activated Alumina Media Filter Pilot

Study 2003-2006 Final Monitoring Report

Summary:

Results of project to evaluate performance and overall feasibility of new technology stormwater treatment controls.

Source:

California Department of Transportation, Sacramento, CA CTSW-RT-06-157.02.1

Caltrans: Caltrans Tahoe Basin SR267 Media Filter Pilot Study Monitoring Season 2005-2006

Summary:

Presents results of the first year of monitoring that was conducted from October 2005 through May 2006.

Source:

California Department of Transportation, Sacramento, CA CTSW-RT-06-157.03.1

Caltrans: Caltrans Lake Tahoe Storm Water Small-Scale pilot Treatment Project Phase V Final Report

Summary:

Presents results of the fifth year (Phase V) of the pilot-testing program. (Comments and Responses submitted).

Source:

California Department of Transportation, Sacramento, CA CTSW-RT-06-157.04.01

Caltrans: Tahoe Roadside Treatment Study-Literature Review and Site Selection

Summary:

Results of the initial phase of the Tahoe RTS, covers literature review and identification of potential monitoring locations.

Source:

California Department of Transportation, Sacramento, CA CTSW-RT-07-157.20.1

Center for Watershed Protection. Stormwater BMP Design Supplement for Cold Climates. December, 2001.

Summary:

This manual addresses some of the unique challenges in cold climates and makes design recommendations for BMPs to make them more effective in cold regions. Chapter 1 is the background of the report, and gives general guidance. First, it describes the telephone and write-in surveys that provided much of the background information for the manual. It also includes maps that can be used to identify cold and snowy climate regions. Next, it outlines the specific challenges of cold climates, and how they can affect BMP performance. This manual addresses some of the unique challenges in cold climates and makes design recommendations for BMPs to make them more effective in cold regions. Chapter 1 is the background of the report, and gives

general guidance. First, it describes the telephone and write-in surveys that provided much of the background information for the manual. It also includes maps that can be used to identify cold and snowy climate regions. Next, it outlines the specific challenges of cold climates, and how they can affect BMP performance. Finally, a matrix of the applicability of BMPs to cold climates is presented, and the reader is referred to other chapters for specific design recommendations. Chapter 2 presents modified sizing criteria for cold climates. These criteria address both water quality and water quantity sizing. The physical basis behind these modifications is the changes in the hydrologic cycle and pollutant loadings that occur in cold climates. Specifically, much of the annual runoff occurs during a short period when the snow pack melts and rain-on-snow events can produce large runoff volumes. Chapters 3 through 7 provide specific cold climate design criteria five basic BMP groups. These include ponds, wetlands, infiltration systems, filtering systems and open channel systems. For each BMP group, specific types of BMPs within the group are described. Base criteria, which apply to both moderate and cold climates are presented. The cold climate modifications for each BMP follow. BMPs can be modified in up to six categories, including: feasibility, conveyance, pretreatment, treatment, maintenance and landscaping. Chapter 8 explores alternatives for Pollution Prevention in cold climates. This chapter primarily focuses on ways to reduce pollutant loading from deicers. These include sand application, road deicers and airport deicers. This discussion is relatively brief, as the manual's primary focus is the modification of BMPs.

Source:

Center for Watershed Protection, Maryland

Coats, R., Liu, F.J., and Goldman, C.R. A Monte Carlo Test of Load Calculation Methods, Lake Tahoe Basin, California-Nevada. June 2002.

Summary:

The sampling of streams and estimation of total loads of nitrogen, phosphorus, and suspended sediment play an important role in efforts to control the eutrophication of Lake Tahoe. We used a Monte Carlo procedure to test the precision and bias of four methods of calculating total constituent loads for nitrate-nitrogen, soluble reactive phosphorus, particulate phosphorus, total phosphorus, and suspended sediment in one major tributary of the lake. The methods tested were two forms of the Beale's Ratio Estimator, the Period Weighted Sample, and the Rating Curve. Intensive sampling in 1985 (a dry year) and 1986 (a wet year) provided a basis for estimating loads by the "worked record" density that characterizes the present monitoring program. The results show that: (1) the Period Weighted Sample method was superior to the other methods for all constituents for 1985; and (2) for total phosphorus, particulate phosphorus, and suspended sediment, the Rating Curve gave the best results in 1986. Modification of the present sampling program and load calculation methods may be necessary to improve the precision and reduce the bias of estimates of total phosphorus



loads in basin streams.

Source:

Journal of the American Water Resource Association. 38 (3): 719-730

Cristina, C., Tramonte, J., and Sansalone, J.J. A Granulometry-Based Selection methodology For Separation of Traffic-Generated Particles in Urban Highway Snow melt Runoff. March 2001

Summary:

This study characterized the granulometric indices of snow samples collected at ten metropolitan sites in Cincinnati. The targeted event produced 46-cm of snowfall over a 48-hr period. The samples were exposed to traffic and winter maintenance activities for a 102-hr period before analysis. The study also discusses a methodology for using a process selection diagram to determine appropriate mechanisms of particle separation. According to the process selection diagram presented in the study, sedimentation could remove approximately 90% of the particle mass within two hours. Applications of this methodology could be used to size roadway drainage systems capable of allowing adequate settling times.

Source:

Water, Air and Soil Pollution. 136 (1-4): 33-53

Crompton, J.E., Glen, W.H., and Williams, R.P. Estimated Flood Flows in the Lake Tahoe Basin, California and Nevada. July 2002

Summary:

As part of the Lake Tahoe Interagency Monitoring Program, the USGS estimated flood frequencies of contributing streams to Lake Tahoe. Flood estimates were calculated for 46 sites in 21 watersheds. The USGS estimates the peak flow magnitude for a 50-yr and 100-yr recurrence interval event. In the Lake Tahoe basin, observed precipitation varies from 40-in/yr on the east side to 90-in/yr on the west side. The paper presents a table of estimated peak discharges for a 50-yr and 100-yr event as well as the largest observed flood peak. According to the table, peak flows at 31 monitoring sites were observed in January of 1997. This was the effect of an extensive rain-on-snow event.

Source:

USGS Fact Sheet. FS-035-02

Dennett, Keith and Ridenoure, Brian. Evaluation and Enhancement of the Effectiveness of Sediment Trapping and Retention Devices Installed on the Nevada Side of the Lake Tahoe.

Summary:

Source:

University of Nevada, Reno, December 2007

Dogrul, E.C., Kavas, M., Levent, Aksoy, and Hafzullah. Effects of Urbanization on the Suspended Sediments from an Intervening Zone of Lake Tahoe. October 2001

Summary:

Identification of the sources of sediment and nutrients that eventually affect the clarity of Lake Tahoe has recently been an important issue. Until now, most studies have concentrated on the identification of such sources in watersheds of Tahoe basin and the zones that intervene the watersheds have been ignored. The goal of this study is to analyze the effect of urbanization on sediment and nutrient loads in an intervening zone located between Carnelian Bay and Kings Beach. 49.9% of this intervening zone is urbanized and the rest of it is rural. The U. S. Environmental Protection Agency (EPA) Storm Water Management Model (SWMM) is used to simulate the quantity and quality of urban storm water runoff. The UC Davis Hydrologic Research Laboratory rural watershed hydrology and erosion model is coupled with SWMM in order to model the runoff in the rural part of the intervening zone. The coupled model can simulate runoff quantity and quality due to snowmelt as well as rainfall events. For this study, the storm drain network was mapped and the major outlets were identified. Then the areas draining into these outlets were obtained by the analysis of digital elevation maps (DEM) using GIS (Figure 1). GIS was also used in order to obtain other parameter values regarding soil characteristics, topography, road and storm drain network. At this point in time, the model is being calibrated for several snowmelt and rainfall events that were observed in the year 1999. After the calibration is completed, the percentage of urbanization in the intervening zone will be modified and the runoff quantity and quality will be simulated. It is expected that the analysis of the results obtained for different percentages of urbanization will lead to the understanding of the effect of urbanization on the sediment and nutrient loads transported to Lake Tahoe.

Source:

Hydrologic Research Laboratory Report Series, University of California, Davis. Report No. 2

Driscoll and Schecher. 1990. Chemistry of Aluminum in the Environment. Environmental Geochemistry and Health. 12 (1-2): 28-49.

Summary:

Source:

Feng, X.H., Taylor, S., Renshaw, C.E., and Kirchner, J.W. Isotopic Evolution of Snow melt - 1. A Physically Based One-Dimensional Model. October 2002

Summary:

The O-18/O-16 ratio of snowmelt from a seasonal snow pack typically

increases with time as the melting process progresses. This temporal evolution is caused by isotopic exchange between liquid and ice as melt water percolates down the snow column. Consequently, hydrograph separations of spring runoff using the bulk snow composition as the new water end-member will be erroneous. Accurate determinations of the new water input should take into account the temporal variation of the snowmelt. Here we present a one-dimensional (1-D) physically based model for the isotopic evolution of snowmelt. Two parameters, the effective rate of isotopic exchange between water and ice and the ice to liquid ratio of the exchange system, are important for controlling the range and temporal pattern of the isotopic variation in snowmelt. For all plausible values of these parameters the modeled isotopic signature of snowmelt changes by 1-4 parts per thousand as snowmelt progresses. These isotopic shifts will affect the results of hydrograph.

Source:

Water Resources Research

Ferguson, Gignac, Stoffan, Imbrahim, and Aldrich, Rouge River National Wet Weather Demonstration Project, Cost Estimating Guidelines, Best Management Practices and Engineering Controls, July 1997.

Objective:

The intent of this manual is to provide an introduction to and cost information for common methods used to control storm water runoff.

Summary:

This manual was prepared to help community planning and public works managers develop storm water runoff control programs in an effective manner. The information listings include: BMPs, their descriptions, and how to engineer, construct and implement them. The cost information provided is relevant to southeast Michigan in 1996.

Source:

<http://www.rougeiver.com/pdfs/stormwater/sr10.pdf>

Garcia, K.T. 1988. *Effect of erosion-control structures on sediment and nutrient transport, Edgewood Creek drainage, Lake Tahoe Basin, Nevada, 1991-1983.*

Objective:

Determine the effectiveness of erosion-control structures in reducing sediment and nutrient transport.

Summary:

The study site is in the upper Edgewood Creek drainage along Nevada State Highway 207 (also known as Kingsbury Grade). Erosion control structures, consisting of rock gabions, wooden retaining walls, rock-lined roadside ditches, curbs and gutters, and vegetation, were established in 1982.

Water quality parameters, including precipitation, stream flow, temperature, specific conductance, dissolved nitrate nitrogen, dissolved nitrite nitrogen, total nitrite nitrogen, total nitrite and nitrate nitrogen, dissolved nitrite and nitrate nitrogen, total ammonia, dissolved ammonia, total organic nitrogen, dissolved organic nitrogen, total phosphorus, dissolved phosphorus, dissolved ortho-phosphorus, total recoverable iron, dissolved iron, and total sediment concentrations, and sediment load, were monitored at three stations. The two upper stations (1 and 2) were on separate tributaries that converged before reaching the downstream station (3). Flow into station 1 is from a mostly undeveloped area and unaffected by erosion-control structures, while flow into station 2 runs through some developed area and erosion-control structures.

Total sediment concentrations were reduced by at least 90% from station 2 to station 3, although station 3 also received flow from station 1. Mean concentrations and loads of total iron also were significantly by erosion-control structures between stations 2 and 3, but mean concentrations of nitrogen and phosphorus did not change significantly.

Source:

Prepared by USGS. Report # 87-4072.

Geosyntec Consultants (2003). Lake Tahoe Feasibility Study Water Quality Information, initial review, A Technical Memorandum Submitted to Lahontan Regional Water Quality Control Board and Tahoe research group for the Lake Tahoe Sediment and Nutrients TMDL Study.

Objective:

Determine how useful urban runoff data is in assessing treatment of storm water controls, and if BMP monitoring data is adequate to assess BMP effectiveness.

Summary:

Geosyntec was tasked with performing a literature review, as well as modeling available information related to storm water, surface water, and BMPs. The focus of the review was to evaluate treatment performance by comparing effluent concentrations to TRPA and Lahontan's discharge standards. The primary exceedances for storm water effluent were TP, followed by TSS. When comparing data to the ASCE/EPA database, the Tahoe Basin appears to have higher TSS values than what is typically presented; TP and TN are relatively lower. In addition to evaluating BMP performance, a financial analysis was performed, and a comprehensive Annotated Bibliography is presented. Tahoe Basin appears to have higher TSS values than what is typically presented; TP and TN are relatively lower. In addition to evaluating BMP performance, a financial analysis was performed, and a comprehensive Annotated Bibliography is presented.

GeoSyntec Consultants; Urban Drainage and Flood Control District, April 2002. Urban Stormwater BMP Performance Monitoring: A Guidance Manual for Meeting the National Stormwater BMP Database Requirements. Prepared for

the USEPA.

Summary:

Glenn, G.W. III, and Sansalone, J.J. Accretion and Partitioning of Heavy Metals Associated with Snow Exposed to Urban Traffic and Winter Storm Maintenance Activities- Part II. July 2001

Summary:

Accretion and partitioning of heavy metals was analyzed at four highway sites in Cincinnati. Metals analyzed included dissolved and particulate phases of Pb, Cu, Cd, Zn, Al, Ca, Na, Mg and Fe. Results indicated that Pb, Cu, Cd, Zn, Al, Mg and Fe were primarily particulate bound while Na and Ca were highly dissolved. The analysis revealed that concentrations of Pb, Cu, Cd, Zn and cyanide were one to two orders of magnitude higher than typical stormwater concentrations. The study also found that specific surface area increased with decreasing particle size while the predominance of the surface area remained in the coarser sized particles

Source:

ASCE- Journal of Environmental Engineering. 128 (2): 167-185

Glenn III, Donald W. and Sansalone, John J. Accretion and Partitioning of Heavy Metals Associated with Snow Exposed to Urban Traffic and Winter Storm Maintenance Activities. II. February 2002.

Summary:

Compared to storm water runoff, urban roadway snow exposed to traffic and winter maintenance practices has a much greater capacity to accumulate and retrain heavy metals and other anthropogenic constituents. Heavy metals once released in the environment are not degraded and partition between the dissolved and particulate-bound fractions. Residence time, solid loadings, alkalinity, hardness, and pH influence partitioning. Accretion and partitioning of Pb, Cu, Cd, Zn, Al, Ca, Na, Mg, and Fe from a series of urban highway sites in Cincinnati, Ohio, are compared to temporal accretion trends at a control site removed from the highway environment. Results from partitioning analysis indicate that Pb, Cu, Cd, Zn, Al, Mg, and Fe were all highly particulate bound, while Na and Ca were mainly dissolved for all highway sites. Partition coefficients for most heavy metals in snowmelt ranged from 103 to 106 L/kg. Concentrations for Pb, Cu, Cd, Zn, and cyanide were orders of magnitude higher than at the control site and exceeded storm water runoff concentrations by one to two orders of magnitude. For residuals analyses, the specific surface area generally increased with decreasing particle size while the predominance of total surface area (SA) was associated with the medium to coarser size fractions. Heavy metal mass trends followed similar general trends to that of the SA. Characterization of accretion and partitioning of these metals is a necessary first step toward development of management and treatment strategies designed to address urban snow pollution.

Source:

Journal of Environmental Engineering. Volume 128, Issue 2, pp. 167-185

Goran, Westerstrom and Singh, Vijay P. An Investigation of Snow Melt Runoff on Experimental Plots in Lulea, Sweden. 2000

Summary:

Empirical characteristics of snow melt runoff are derived from observations made during snowmelt in a six-year period from 1980 to 1985 on three experimental plots and three plates located on the campus of the Lulea University of Technology in Lulea, Sweden. The plots had asphalt, gravel and grass surfaces. The plates were of different designs with one having the bottom cut out so that it was more like a frame. With the assumption that the asphalt surface of the plots was impervious, infiltration of melt water into gravel and grass surfaces was deduced. Unlike rainfall infiltration, the graph of snowmelt infiltration rate resembled a flow hydrograph, with a distinct rise, a peak and a distinct recession. A strong linear relationship between the snowmelt runoff hydrograph peak and the snowmelt amount was found, which explained more than 90% of the variability in the snowmelt peak. This is in contrast with rainfall runoff where the relationship between runoff peak and volume is decidedly non-linear. Hourly snowmelt runoff peak and daily snowmelt amount were found to exhibit nearly constant skew and follow approximately a Gumbel frequency distribution.

Source:

Hydrological Processes. Publication No. 14

Han, J.S., Miyashita, E.S, Lin, Y., and Roa, A. Stormwater Filtration of a Municipal Detention Pond. December 1999.

Summary:

In Madison, WI, the USDAFS Forest Products Laboratory tested the effectiveness of wood and non-wood based fibers for removing pollutants from stormwater runoff. Due to the fibers sorption capacity, the media has a high adsorptive capacity for ionized copper. Kenaf bast and core fibers were chosen as the materials for the media. A series of filters were placed at the effluent end of a Monroe Street stormwater detention pond to enhance the effectiveness of the BMP. Results from the study indicate that on average, Cu was reduced by 19%, Ni was reduced by 32%, COD was reduced by 11%, P was reduced by 11%, and TSS was reduced by 4%.

Source:

Kenaf Properties, Processing & Products. Chapter 39.

Harper, Harvey H., Herr, Jeffrey L. and Livingston, Eric H. Alum Treatment of Stormwater Runoff- An innovative BMP for Urban Runoff Problems. 1996

Summary:

This article describes about a system that provides treatment of stormwater runoff entering the Lake Ella, Florida by injecting liquid alum into major storm sewer lines on a flow-weighted basis during rain events. When added to runoff, alum forms non-toxic precipitates of  $\text{Al}(\text{OH})_3$  and  $\text{AlPO}_4$  which combine with phosphorus, suspended solids and heavy metals causing them to be rapidly moved from the treated water. Alum treatment has consistently achieved a 90% reduction in heavy metals, and >99% reduction fecal coliforms. Percent removal efficiency has been related to the percentage of total inputs treated by the system. A pertinent point to note here is that the comparison of pre- and post-modification water quality characteristics for typical alum treatment systems indicated an effluent quality for Total P was around 25 ug/L irrespective of the influent quality of the incoming stormwater. This article also gives estimate of anticipated sludge production from alum treatment of storm water at various doses, cost estimates for the construction and O&M of alum treatment systems.

Source:

Environmental Research and Design, Orlando, FL

Hatch, L.K., Reuter, J.E., and Goldman, C.R. Daily phosphorus variation in a mountain stream. December 1999

Summary:

Monthly diel monitoring studies for phosphorus content were conducted (1995-1996 period) for multiple stations on Incline Creek, a mountain stream in the Lake Tahoe basin (California-Nevada). Large discharge and particulate P (PP) concentration fluctuations occurred during June in the early evening as snowmelt from higher elevations arrived at the lower stream reaches. June diel dissolved organic P (DOP) reactive P (SRP) concentrations remained constant. June diel PP concentrations associated with sand-sized particles (PPsand:  $>63 \mu\text{m}$ ) exhibited a clockwise hysteresis, indicating possible sediment source depletion on a daily timescale. June diel PP associated with silt- and clay-sized particles (PPsc:  $>0.45 \mu\text{m}$  and  $<63 \mu\text{m}$ ) exhibited counterclockwise hysteresis behavior, suggesting a potential groundwater contribution to PPsc. PPsc comprised the majority of PP concentration, except during high-discharge events when PPsand, concentration was dominant. Areal PP loading, specifically PPsand, appears to originate primarily from the lower eastern branch of Incline Creek during the spring snowmelt season. Possible sources include a ski resort/parking lot and a golf course. DOP and SRP areal loads were greatest from the undeveloped upper sub-watershed, suggesting that natural factors such as slope are influencing loading of small-sized P fractions.

Source:

Water Resources Research. 35 (12): 3783-3791

Hatch, L.K., Reuter, J.E., and Goldman, C.R. Stream phosphorus transport in the

Lake Tahoe basin, 1989-1996. June 2001

Summary:

Lake Tahoe is undergoing the initial stages of cultural eutrophication due to human alteration of the airshed and watershed. The lake's switch from nitrogen (N) to phosphorus (P) limitation has been attributed primarily to atmospheric N loading. This places an increased importance on controlling watershed movement of P to the lake. A stream water quality monitoring data set consisting of nine streams in the Lake Tahoe basin has been analyzed to characterize the spatiotemporal variation of P delivery to the lake. This data is from the Lake Tahoe Interagency Monitoring Program (LTIMP), which provides scientific data for planning and regulatory agencies to address environmental problems in the Lake Tahoe basin. Results indicate that P delivery (concentrations, loads) varies greatly at inter-annual concentrations can vary up to three orders of magnitude in a given stream and are strongly associated with suspended sediment. Particulate P is the major form of P transported by Tahoe streams and was strongly correlated with percent surficial geologic deposits, which are primarily located near streams. Tahoe streams with the highest annual P concentrations often had the lowest annual P loads, and visa versa. P loading is greatest during the spring snowmelt (75% of annual average). Potential watershed parameters influencing P delivery to Lake Tahoe have been identified as precipitation, basin area, basin steepness, and road and human development coverage. Results also suggest that human development impacts on stream P loads are most prevalent during high precipitation years. Identification and quantification of stream sediment and P sources such as stream banks and impervious surface is necessary to aid in watershed restoration efforts.

Source:

Environmental Monitoring and Assessment. 69 (1): 63-83

Heyvaert, A.C., Reuter, J.E., and Hackley, S. 2001. *Progress report and preliminary results from monitoring and evaluation of selected California Tahoe Conservancy stormwater treatment projects.*

Objective:

Determine project effectiveness and evaluate various operational and maintenance strategies for optimization or improvement of storm water treatment effectiveness in the Lake Tahoe Basin.

Summary:

This study describes two constructed wetland treatment systems and compares the water quality data to the Pioneer Trail site and five additional sites in four intervening zones, each with different land uses and degrees of urbanization. Storm events from March 1998 to August 1999 were sampled and analyzed for NO<sub>3</sub>, NH<sub>4</sub>, SRP, DP, TP, SS, and TOC (as LOI).

An autosampler was also installed at Pioneer Trail and preliminary data was available as well as flow information. A first flush was diluted and associated with particle scouring and transport during peak discharge.



The Tahoe City Water Quality Improvement Project wetland was constructed in 1997 and was operational by 1998. It consists of an upper detention basin and a lower wetland pond. Sampling between March 2000 and April 2001 showed an overall 80% reduction in concentrations in all constituents, with 40% reduction in each treatment. Autosamplers are being installed along with a flow meter.

The second wetland system, at Ski Run Boulevard in South Lake Tahoe, had autosamplers and flow instruments installed, although no analyses had yet been conducted. Overall, results from the wetland treatment appear favorable.

Source:

Prepared for California Tahoe Conservancy by UCD Tahoe Research Group.

Heyvaert, Alan C. and Wigart, Russ. Analysis of Water Quality Monitoring Data from the Glorene and Eighth Erosion Control Project. Water Year 2002 (DRAFT). April 30, 2003

Summary:

This report summarizes the findings of the first year of baseline monitoring prior to commencement of construction activities in the Glorene and Eighth Project area. Two monitoring stations were set up to collect water quality samples and measure flow. A total of eight events were monitored that included rainfall, rain on snow, and rain plus snow. One large summer thunderstorm event (1.43 inches over 5-hours) dominated the hydraulic and pollutants loads estimated over the study period. The results section of the report provides EMCs for NO<sub>3</sub>-N, NO<sub>2</sub>-N, NH<sub>4</sub>-N, TKN, OP, TDP, TSS, and runoff volume. Measured concentrations were higher for most parameters during larger events at the most downstream station, though not directly proportional. The upstream station showed a similar trend for TSS and all Nitrogen species and Total Phosphorus however concentrations of DP and OP seemed to be independent of storm size. High suspended solids concentrations during and November storm event were speculated to have been related to de-icing activities that occurred during the storm period. The runoff rate during the large storm event peaked rapidly and declined soon after precipitation ended. The rainfall/runoff response appears closely related to the amount of roadway surface in the drainage. Pre-construction monitoring is to continue through the 2003 water year. It is interesting to note that by far the majority of the nitrogen loading was in the form of TKN while quite often NO<sub>3</sub>-N was below detect. TKN is generally not considered bio-available. If this trend is consistent throughout the basin, Total Nitrogen may not be a good estimator for evaluating potential impacts to the lake.

Source:

Unpublished report Prepared for the California Tahoe Conservancy

Heyvaert, Alan, C., Mihevc, Todd, and Jacobson, Roger. Efficiency Assessment of Stormwater Treatment Vaults in the Round Hill General Improvement District. April, 2005.

Summary:

Source:

April 2005, DHS Publication No. 41216, Prepared by Division of Hydrologic Sciences, Desert Research Institute, University and Community College System of Nevada and the Tahoe Environmental Research Center, University of California, Davis. Prepared for: Nevada Tahoe Conservation District and Nevada Division of State Lands.

Heyvaert, A.C., J.E. Reuter, and C.R. Goldman. 2006. Sub-alpine, Cold Climate, Stormwater Treatment with a Constructed Surface Flow Wetland. *Journal of American Water Resources*. 42(1): 45-54.

Summary:

Hinckley, Jr., John A. Object-GAWSER Object-Oriented Guelph All-Weather Storm-Event Runoff Model Phase I: Training Manual Application of Object-Oriented Simulation to Hydrologic Modeling. February, 1996

Summary:

Hydrologic models are currently used to understand the economic and ecological impacts of hydrologic processes. A new hydrologic model entitled Object-GAWSER was designed using an object-oriented platform to provide new insights into watershed hydrology. Object-GAWSER is a temperature index model that simulates upland watershed hydrology. Object-GAWSER is different from other hydrologic models in that each one of its components can be easily studied to understand its sensitivity to various inputs. First, this report will show how Object-GAWSER can be used to simulate the hydrologic behavior of forested, agricultural, and suburban watersheds. Second, this report will describe how Object-GAWSER was designed.

Source:

Us Army Corps of Engineers Special Report 96-4

Hoffman, K. 1990. *Water Quality Report of the Watershed Staff, 1989 Water Year, Lake Tahoe Basin Management Unit*, prepared by USFS

Objective:

Assess the effects on water quality of various land disturbance activities, as well as to help define the baseline water quality of several creeks.

Summary:

This report summarized water quality at 15 sites for the 1989 Water Year: 3 baseline stations (Trout Creek at Fountain Place, Meeks Creek, and Meiss Country - Big Meadow and Grass Lake Creeks); 4 Santini Burton erosion control projects (Griff Creek, Snow Creek, Tahoe Mountain Road Drainage Project, and Santa Fe Road Closure and Meadow Enhancement); 2 Forest Service permittee stations (South Zephyr Creek and Heavenly Valley Creek); 6 Forest Service projects (Wildwood/Keller, Marlette Creek, Blackwood

Creek, Sawmill Pond Restoration Site, Burke Creek [former Jennings' Casino Site], and Saxon Creek)

Some sites involved monitoring of BMPs, and most of those sites involved above/below sampling schemes. WY 1989 data for each parameter was summarized by mean, minimum, and maximum. Raw data (from STORET) for WY 1989 was also reported. Annual means were reported from 1982 to 1989, where available, and linear regression analyses were conducted to analyze for trends of constituents over time. 1987 through, and including 1989, were considered drought years, so caution was raised about the ability of the data to represent normal conditions. California State water quality objectives were exceeded on eight creeks for total phosphorus and three creeks for total nitrate-nitrite. Baseline sites occasionally had total phosphorus values over the objectives, although not in 1989. However, this suggests that total phosphorus values may be unrealistic. Three streams had trends of decreasing pH. This may have been due to air pollution and deposition or increased bacterial decomposition resulting from the drought conditions over the period of study.

Hydro-Science. Bio-available Nutrient Loading into Lake Tahoe and Control Opportunities with an Emphasis on Utilizing SEZs to Treat Urban Runoff, November 1999.

Objective:

Review the status of knowledge of the relationship between water quality and wetlands associated with stream environment zones (SEZs) at Lake Tahoe.

Summary:

The vast majority of surface runoff enters as stream flow from snowmelt originating on non-urbanized areas of the basin. However, urbanization has an effect on nutrient loads; loading rates of bio-available nutrients are 17 to 18 times higher in urban areas. The effectiveness of stream and floodplain restoration increases as the percent of the watershed is urbanized, and restoration of floodplain-associated wetlands will not significantly reduce bio-available nutrient loading to Lake Tahoe in large watersheds where the peak snowmelt runoff originates from un-urbanized areas. Nutrient removal efficiency of wetlands decreases with decreasing nutrient concentrations. Absolute limits on removal efficiency at low concentrations are a serious concern. A more accurate method of assessing the importance of urban runoff would be to perform the analysis based on loads. SEZs are more effective than water quality basins, and pre-treatment of urban runoff prior to discharge to natural or restored SEZs should be required. Any design which provides for capture and extended detention of first flush runoff would be expected to greatly enhance basin performance, and lining basins has a negative effect on phosphorus removal. It does not appear that properly designed water quality basins have removal efficiency limitations due to excessively high nutrient loads. Natural wetlands are limited in their ability to reduce bio-available nutrient export rates; nutrient removal is also hampered by the seasonal differences in runoff vs. vegetative growth. Treatment wetlands have average export concentrations far in excess of nitrogen

concentrations in the lake. Higher removal efficiencies may be attained by increasing the volume of the basin over 20-year, 1-hour storm sizing. Current policies and BMPs are insufficient to halt the decline in water clarity.

Lake Tahoe Basin Urban Runoff BMP and SEZ Restoration Project Pollutant Removal Efficiencies: NO<sub>3</sub> = -10%, NH<sub>4</sub> = 10%, TKN = 9%, TN = 24%, Ortho-P = 16%, TP = 32%, TSS = 50%. These figures are suspect because of the lack of first flush monitoring and the water quality basins and other BMPs were recently constructed. Expected Pollutant Removal Efficiencies in mature systems with first flush monitoring are NO<sub>3</sub> = <0 to 35, NH<sub>4</sub> = 35%, and Ortho-P = 25%. At least 80% sediment removal efficiency is required to treat fine sediment, which account for 20% of total sediment load.

Some of the recommendations from this study include:

1. All water quality policies should focus on control of bio-available nutrients instead of sediment.
2. BMPs should focus on removal of dissolved nutrients and fine particulates.
3. Control efforts should be redirected from erosion control toward control of urban run-off and atmospheric deposition.

Source:

Hydro Science prepared for Tahoe Regional Planning Agency

Johannessen, M. and Henriksen, A. Chemistry of snow melt water: changes in concentration during melting. 1978

Summary:

Over much of Norway a large portion of the yearly precipitation falls as snow, and the pollutants contained in precipitation accumulate in the snow pack to be released during a short period in the spring. Atmospheric fallout of S compounds has been estimated to be about 30% of the total deposition in Norway, but fallout on the snow cover is probably considerably smaller. During winters with little or no snowmelt before spring, most of the pollutant load is retained in the snow pack. Laboratory and field lysimeter experiments indicate that 50-80% of the pollutant load is released with the 1st 30% of the melt water. The average concentration of pollutants in this fraction is 2-2.5 times the concentration in the snow pack itself. The very 1st fractions may contain >5 times the snow pack concentrations. These high concentrations are due to a freeze-concentration process during snow re-crystallization and melting in which contaminants accumulate preferentially at the surfaces of ice particles. The resulting increase in the acid concentration of low-buffered water courses lead to severe physiological stress to fish and other aquatic organisms and even to massive fish kills. This process occurs at a time which is critical to the hatching stage of salmonid fish species.

Source:

Water Resource Research. 14(4), 615-19

Jurries, D. Flocculation of Construction Site Runoff in Oregon.

Summary:

After failed attempts to reduce turbidity to State Water Quality Standards, the West Linn Corporate Park construction sites located in Oregon decided to utilize flocculation as a means of construction runoff treatment. Runoff generated from the 24.0-acre site drained into a series of stormwater channels where it was then pumped to a 17000-gallon flocculation chamber where Sumalchlor 50, an inorganic flocculant, was added. The conditioned water was then pumped to a settling basin. Results from the study indicate that turbidity was reduced by at least 72.3% in each event analyzed. Effluent NTUs were comparable to background receiving stream conditions. Results from pH analyses indicate that pH was slightly reduced and that temperature was unaffected between influent and effluent conditions. Effluent turbidity of less than 25 NTU was consistently achieved (influent range 130-470 NTU). For this study, the authors estimate the treatment costs at \$0.08 per gallon of storm water treated. Chemical costs were about \$0.30 per 1000 gallons.

Source:

State of Oregon Department of Environmental Quality, NWR

Jones, T., Thomas, J., Mihevc, T., and Gunter, M. Evaluation of Effectiveness of Three Types of Highway Alignment Best Management Practices for Sediment And Nutrient Control, December, 2004, Publication No. 41209

Summary:

Source:

Prepared by Nevada Department of Transportation and Division of Hydrologic Sciences, Desert Research Institute, University and Community College System of Nevada. U.S. Forest Service, Lake Tahoe Basin Management Unit, Nevada Division of State Lands, and the Nevada Department of Transportation.

Kadlec, R.H. Chemical, Physical and Biological Cycles in Treatment Wetlands. 1999

Summary:

Treatment wetlands are solar powered ecosystems. Solar radiation varies diurnally, as well as on an annual basis. Wetland processes are therefore driven to respond on these same two cyclic periods. The first and most obvious effect is on the temperature of the water and soils in the wetland. Intense summer radiation results in warmer conditions and higher evapotranspiration. Winter radiation is smaller, and results in cooler temperatures and less evapotranspiration. Other meteorological variables, such as air temperature, humidity and precipitation, also have annual cycles, but with considerable stochastic variability. The water and soil temperature variations cause changes in microbial activity, which in turn creates changes in microbially mediated water quality improvement. The cyclic changes in rain and evapotranspiration may create significant effects on the water budget for

the wetland, and thus influence treatment efficiency. In addition, there are seasonal cycles in the vegetation and litter in the system, which occur in response to solar inputs and meteorological factors. This causes seasonal changes in nutrient and chemical uptake and release. This combination of cyclic influences is reflected in the treatment performance of the constructed wetland. It is shown that wetland water temperature alone is not a sufficient descriptor of wetland biogeochemical cycles. Mass balances demonstrate cyclic interactions in treatment wetlands. The effects of vegetative cycles are quantified for an example system.

Source:

Water Science and Technology. 40 (3): 37-44

Kang, L.S. and Cleasby, J.L. Temperature Effects on Flocculation Kinetics Using Fe(III) Coagulant. December, 1995.

Summary:

The effect of low water temperature on flocculation kinetics was examined using ferric nitrate to coagulate kaolin clay in water under tightly controlled treatment conditions. Both the particle size distribution data obtained from an automatic image analysis system and the on-line measurement of the degree of turbidity fluctuation in a flowing suspension by a photometric dispersion analyzer were used to measure flocculation kinetics. Results show that cold water temperature had a pronounced detrimental effect on flocculation kinetics. To improve flocculation kinetics at low water temperature, maintaining constant pOH to adjust water chemistry for temperature changes was found to be partially effective, but only in the more acidic pH range studied (pH 6.8). However, the improved performance did not reach the performance at room temperature.

Source:

Journal of Environmental Engineering. Vol. 121, No. 12, pp. 893-901

Koob, T., Barber, M.E., and Hathhorn, W.E. Hydrologic design considerations of constructed wetlands for urban stormwater runoff. April 1999

Summary:

The successful design of constructed wetlands requires a continuous supply of water or vegetation that can withstand drought conditions. Having a constant water source is the best alternative to insure species diversity throughout the season. Consequently, detention structure designs should be based on times between events as well as on hydrologic return periods, since between events is when most evaporation and infiltration losses are likely to occur. In arid or semi-arid environments, this is a difficult process because of long inter-event times and seasonal changes in precipitation patterns. This discussion is predicated on the assumption that phytoplankton, epiphytic algae, and emergent vegetation require moist conditions to be effective at removing nutrients, metals and other pollutants. There are drought tolerant species of vegetation that can be used in constructed wetlands but it may take several days to re-establish the attached bacteria communities

necessary for optimum pollutant removal. This paper examines a stochastic framework to examine the probability of extended dry periods based on historic rainfall data. The number of consecutive dry days is selected for a specified level of assurance. By multiplying this value by the sum of daily system losses, an overall pond volume can be determined that ensures a minimum depth of water. To illustrate the utility of the approach, the method is applied to a site in Spokane, Washington.

Source:

Journal of the American Water Resource Association. 35 (2): 323-331

La Camera, R.J. and Browning, S.B. 1988. *Data on surface-water quality and quantity, Lower Edgewood Creek Basin, Douglas County, Nevada, 1984-1985.*

Summary:

Thirty-nine water samples were taken at 3 sites in lower Edgewood Creek and at a newly constructed sediment-catchment basin. Analyses include total and dissolved NH<sub>4</sub>, organic N, NO<sub>2</sub>, NO<sub>3</sub>, P, ortho-P, SS, T Fe, Mn, Zn, and dissolved solids. Flow, temperature, conductivity, pH, and DO were also measured. Precipitation during this study was lower than normal.

Source:

Prepared by USGS

Landphair, Harlow, McFalls, Jett, Thompson, and David: Design Methods, election, and Cost-effectiveness of Stormwater Quality Structures, Texas Transportation Institute, November 2000.

Objective:

To examine a variety of options for meeting stormwater quality requirements, and to develop a cost comparison index.

Summary:

The Texas Department of Transportation (TxDOT) has developed a variety of permanent BMPs designed to improve stormwater quality. Many of these structures are considered costly to maintain. For that reason TxDOT performed a literature review on pollutant removal efficiencies, as well as removal comparisons between "High-end" and "Low-end" BMPs. A cost effectiveness index is also presented. The bulk of this report contains performance and cost effectiveness information on stormwater BMPs including a variety of infiltration systems, retention structures, detention structures and filtration methods. This report also contains TxDOT's recommendations for using a simplified approach for estimating runoff and pollutant loads, adapted from T.S. Schueler. The procedure by which TXDOT sizes their water quality BMPs is also presented.

Lee Ing Ho, Carrie. Urban Snow Hydrology and Modeling. December, 2002.

Summary:

Urban winter hydrology has garnered very little attention due to the general notion that high intensity rainfalls are the major flood-generating events in urban areas. As a result, few efforts have been made to research urban snow

and its melt characteristics. This study investigated the characteristics of urban snow that differentiates it from rural snow, and the impact of incorporating these characteristics in an urban snowmelt model. A field study was conducted from fall of 2001 to spring of 2002 at the University of Calgary campus. Data collected includes snow depth and density, soil moisture, soil temperature, snow albedo, net radiation, snow evaporation, and surface temperature. Snow cover was classified into several types; snow piles, snow on road shoulders, snow on sidewalk edges, and snow in open areas. This resulted in the development of four separate functions for the changing snow albedo values. Shortwave radiation was found to be the main source of energy for urban snow, and as a consequence, the albedo of urban snow is a very important factor in urban snowmelt modeling. In addition, urban elements such as vehicle traffic and buildings can influence the energy balance of the snow pack. A study of the frozen ground conditions reveals that antecedent soil moisture conditions had very little impact on frozen ground, and thus frozen ground acts as a near impervious area. In the modeling component of this study, urban snowmelt was modeled using the energy balance method with hourly time steps and the incorporation of snow redistribution, and hence the simulation of snow piles. Three simulated tests of varying conditions revealed that peak volume, time to peak and runoff period differs for areas with snow piles versus a uniform urban snow cover. Simulation of rain-on-snow events revealed a sharp increase in runoff peak volume. Hence, under the adverse condition of intense snowmelt, frozen ground, and rainfall, flooding in urban areas can easily occur. Improved flood forecasting for urban catchments in cold regions can only be achieved with accurate modeling of urban winter runoff that involves the energy balance method, incorporating snow redistribution and urban snow cover characteristics, and using small time steps.

Source:

UCGE Reports. Number 20169

Lowry, M. and Norman, S. 1995. *Griff Creek Erosion Control Project, Water Quality Monitoring Report, Water Years 1985-1993*. Prepared by USFS.

Summary:

The Griff Creek erosion control project, constructed in 1984, was designed to reduce erosion and nutrient and sediment transport in lower Griff Creek. The project restored the original lower Griff Creek channel, constructed a sediment retention basin within the channel, and re-vegetated streamside creeks. Historic and current land use in the Griff Creek watershed includes timber management, recreation, and urban development. Three stations were monitored in Griff Creek for water quality since 1985, and analyzed for alkalinity, SS, THP, DP,  $\text{NO}_3+\text{NO}_2$ , turbidity, conductivity, and pH. Ten to fifteen samples were taken annually, most during spring runoff; summer and fall were sampled monthly, and weekly during spring. Flow weighted means were calculated for alkalinity, SS,  $\text{NO}_3+\text{NO}_2$ , TP, and DP.

There was no significant effect of the treatment between upstream and



downstream samples. The sediment retention basin is of limited use in long-term retention of sediment. Non-statistically significant decrease in nutrients below the basin. Restored streamside vegetation is adequate to insure bank and channel stability. THP above and below the sediment basin consistently violated California state water quality standard for TP.

Lowry, M., Meeker, D. and Norman, S. 1993. *South Zephyr Creek Water Quality Monitoring Report, Water Years 1984-1991*. Prepared by USFS.

Objective:

Determine water quality impacts from horse stables and determine effectiveness of BMPs completed in 1989 to control erosion from parking lot.

Summary:

In 1988, the parking lot was redesigned and paved, and curb and gutter drainage was installed to reduce erosion. In 1989, a one acre meadow was restored and 1200 feet of infiltration trench was installed. Four sampling locations were monitored. Fecal coliform was analyzed at all sites, and SS, NO<sub>3</sub>+NO<sub>2</sub>, TP, DP, and turbidity at one station. Sampling period represented drought conditions and most monitoring showed no trends. Fecal coliform is suspected to be from the stables.

Maehlum, T. and Stalnacke, P. Removal Efficiency of Three Cold-climate Constructed Wetlands Treating Domestic Wastewater: Effects of Temperature, Seasons, Loading Rates and Input Concentrations. 1999

Summary:

This paper outlines the influence of temperature, flow rate and input concentrations on the treatment efficiency of organic matter and nutrients in constructed wetlands (CWs). Three integrated 10 PE systems with horizontal subsurface flow (HSF) treating domestic wastewater are described. Particular attention is devoted to: (1) aerobic pre-treatment in vertical-flow filters, (2) filter media with high phosphorus (P) sorption capacity, and (3) the treatment efficiency during winters. Aerobic pre-treatment followed by CW units including P sorption media removed most organic matter (BOD > 75%), P (> 90%) and total and ammonia N (40-80%). P retention was relatively stable in wetland filters, both with lightweight aggregates and ferruginous sand during 3-6 years of monitoring. Iron-rich sand from B-sh and B-s horizons of ferromorphic podzols was efficient for P sorption, but removal efficiencies of GOD, TOC and SS were negative. The differences in efficiency between cold and warm periods were less than 10 percentage points for all parameters. It is anticipated that temperature effects are partially compensated by the large hydraulic retention time. The findings suggest that HSF systems do not require vegetation.

Source:

Water Science and Technology. 40 (3): 273-281

Maehlum, T., Jenssen, P.D. and Warner, W.S. Cold-Climate Constructed Wetlands. 1995

Summary:

This paper outlines design considerations for constructed wetlands with horizontal subsurface flow treating domestic wastewater in cold climates of northern latitudes. Particular attention is devoted to the use of a filter medium with high phosphorus adsorption capacity. Experience from two Norwegian multistage systems consisting of an aerobic pretreatment step followed by constructed wetland units indicates purification processes are nearly the same during winter and summer seasons, with quite high removal of organic matter (COD, BOD), phosphorus and nitrogen.

Source:

Water Science and Technology. 32 (3): 95-101

*Maidment, D.R.* Handbook of Hydrology, McGraw Hill Inc., New York, N.Y., 1992.

Objective:

To provide a compendium of essential hydrologic theory and practice.

Summary:

More than 50 experts from around the world have provided vital information and guidance for practicing hydrologists in this comprehensive reference. The information contained in this book provides solutions to perplexing on-the-job problems such as: ways to mitigate the impact of floods through better urban drainage; how to assess water supplies; effective ways to prevent and remove pollution from waterways; how to halt erosion; and techniques used to preserve wetlands and associated wildlife.

Marsalek, P.M., Watt, W.E., Marsalek, J., and Anderson, B.C. Winter Flow Dynamics of an On-stream Stormwater Management Pond. 2000

Summary:

The winter operation of an on-stream stormwater management pond, located in Kingston, Ontario, Canada, was studied with respect to ice cover formation and breakup, density stratification, velocity field under the ice cover, and the risk of sediment washout. The pond freezes over in late November, with the ice thickness reaching up to 0.5 m. During the first half of the winter period, the ice thickness was well described by Stefan's formula with empirical coefficients appropriate for shallow water bodies. The pond was chemically stratified, with total dissolved solids concentrations up to 1200 mg . L<sup>-1</sup> observed close to the bottom. The meromictic stability of this stratification was calculated as 882 g . cm . cm<sup>(-2)</sup>. Measurements of the velocity field under the ice cover indicated a flow pattern comprising a fast flow region, a small dead zone and a large recirculation zone to the north and south of the fast flow trajectory, respectively. Such a pattern agreed well with that simulated by a CFD model (PHOENICS(TM)). During a snowmelt event, the near-bottom velocities reached up to 0.05 m/s(-1), but were not sufficient to scour the bottom sediment.

Source:

Water Resource Journal of Canada. 35 (3): 505-523

Medalie, L. Monitoring the Effectiveness of Urban Best Management Practices in Improving Water Quality of Englesby Brook, Burlington Vermont. September 2000.

Summary:

In 1999, the USGS, the State of Vermont, and the City of Burlington teamed up with the Lake Champlain Basin Program to perform a study that tested the effectiveness of a BMP designed to reduce loads of total phosphorous, total nitrogen, total suspended solids, specific conductance, temperature, pH, dissolved oxygen and turbidity being discharged into Englesby Brook. Approximately 24% of the contributing watershed is impervious. Current water quality monitoring revealed that snowmelt and stormwater runoff significantly increased the loads of pollutants into the stream. Peak concentrations of 1.1-mg/L for total phosphorous, 750-mg/L for total suspended sediment, 1.5-mg/L for total nitrogen, and 14.5-mg/L for total dissolved oxygen were observed during the series of sampled runoff events. Results from the BMP effectiveness study are ongoing.

Source:

USGS Fact Sheet. FS-114-00

Merli, M.J., Carlson, R.F., and Behr-Andes, C. Water Quality Effects of Snow Storage Areas. April 1996

Summary:

Snow and melt water samples were collected and analyzed from a series of snow storage facilities in Fairbanks and Anchorage, Alaska. Samples were analyzed for metal concentrations, ion content, oil and grease, TKN, total phosphate and chemical oxygen demand. Results from the study indicate that concentrations of Chloride, Cu, Fe, Cd, and Pb exceeded maximum contamination levels identified by Alaska's Water Quality Criteria for Toxic Substances in Freshwater. Analysis of oil and grease content yielded concentrations of 236-ppm and 95-ppm for samples collected in Anchorage and Fairbanks, respectfully. Data gathered from the study could be used to redesign storage facilities or develop new BMPs.

Source:

Transportation Research Center, Institute of Northern Engineering, University of Alaska. Report # INE/TRC 95.06 SPR-UAF-94-14

Merriam-Webster OnLine. 2006. Webster.com

Metropolitan Council Environmental Services, Minnesota. Minnesota Urban Small Sites Best Management Practice Manual- Stormwater Best Management Practices for Cold Climates. July 2001

Summary:

The Urban Small Sites Best Management Practice (BMP) Manual provides

information on tools and techniques to assist Twin Cities municipalities and WMOs in guiding development and redevelopment. The manual includes detailed information on 40 BMPs that are aimed at managing stormwater pollution for small urban sites in a cold-climate setting. The goal of the manual is to support the principles of accommodating growth while preserving the environment.

Source:

Metropolitan Council Environmental Services, Minnesota.

Ministry of the Environment, Canada. Stormwater Management Planning and Design Manual, Draft Final Report. November 1999

Summary:

The key components of this manual include providing an overview as to the impacts of urbanization; addressing the evolution of the sub-watershed planning process and how this impacts the design process; incorporating water quantity, erosion control and water balance principles into the selection and design of Stormwater Management Practices (SWMPs); documenting the performance of SWMPs that have recently been monitored; incorporating design considerations for SWMPs for cold climate conditions; providing information on new SWMPs such as sand filters, bio-retention filters, wet swales and hybrid wet ponds/wetlands; writing a chapter on infill projects; operating and maintenance chapters; providing design examples for SWMPs; updating material relating to planting strategies and the function of plant material in the design of SWMPs; providing an appendix on assessment methodology for retrofitting SWMPs together with an example; and providing an appendix which deals with integrated planning for stormwater management.

Source:

Ministry of the Environment, Canada

Moser, Rick. Efficiency of Sediment Basins, Analysis of the Sediment Basin Constructed at Part of the Straight Creek Erosion Control Project. January 1999

Summary:

The Straight Creek Erosion Control Project, constructed by the Colorado Department of Transportation (CDOT) in 1994, was developed to reduce erosion, sedimentation, and water quality impacts caused by highway runoff from snowmelt and rainfall events. Eleven sedimentation basins were constructed along the toe of the I-70 cut slope to reduce potential sediment and pollutant loads into Straight Creek, a stream immediately down grade of the interstate. The CDOT performed studies to determine the effectiveness of the basins and found that approximately 985-tons of sand was removed each year. The study also revealed that the basins reduced TSS loads by 95%. According to sieve analysis of the runoff and basin sediments, the basins captured all material larger than 0.25-mm.

Source:

Moustafa, M.Z. Analysis of phosphorus retention in free-water surface treatment wetlands. 1999

Summary:

Wetlands have become the focus of numerous research and restoration efforts due to their ability to assimilate phosphorus and nitrogen from urban wastewater and stormwater runoff. Long-term data collected at Boney Marsh, Florida, USA, and the USEPA wetland database were analyzed to develop a simple tool that can be used to predict and optimize phosphorus retention in wetland treatment systems. Wetland properties such as water loading rate, water depth, P-loading rate, and water retention time were examined for their influence on phosphorus retention. The relationship between wetland properties and phosphorus removal efficiency was reduced to a simple quantitative diagram provides a simple management tool that predicts expected treatment range using controllable hydrologic conditions.

Source:

Hydrobiologia. 392 (1): 41-53

Mukesh, Sharma and McBean, Edward A. Atmospheric PAH Deposition: Deposition Velocities and Washout Ratios. February 2002

Summary:

The urban snow pack effectively acts as a collection device for atmospheric-deposited PAHs. When these PAHs are flushed out in a short time interval along with springtime snowmelt, these cause shock loading to receiving waters. The assessment of PAH deposition, accumulation, and possibly remediation of PAHs in urban snow packs requires an understanding of source-receptor linkages. In this research, a mechanistic model based on atmospheric dispersion and the physics of wet and dry deposition is described for the transport of PAHs and time-dependent accumulation of PAHs in the snow pack. Two independent data sets of long-term PAH deposition levels from the study area of Sault Ste. Marie, Ontario, Canada have been utilized in this study. The first data set is used to estimate the model parameters (dry deposition velocities and washout ratios) for three PAH species (phenanthrene, fluoranthene, and pyrene) and the second data set for the validation of the model. The dry deposition velocity for all three PAH species is statistically significant, although the washout ratio is not significant in a statistical sense. The statistical conclusions indicate that dry deposition is a dominant deposition process in the urban environment. The point estimates of deposition velocities and washout ratios compare favorably with previous investigations into deposition parameters.

Source:

Journal of Environmental Engineering. Volume 128, Issue 2, pp. 186-195

Nissen, J. Basin Specific Feasibility Studies- Everglades Stormwater Program

Basins- Final Report. October 2002

Summary:

In an effort to reduce nutrient discharge into the Everglades Protection Area, the Everglades Forever Act (EFA) is anticipated to establish a total phosphorous criterion of 10-ppb. This stringent criterion would require the use of advanced treatment technologies (ATT) such as chemical treatment/ solid separation, low-intensity chemical dosing in wetlands, managed wetland treatment systems, submerged aquatic vegetation/ lime rock, and periphyton-based storm water treatment areas. The goal of the ATTs would be to treat surface waters released from Lake Okeechobee and runoff generated from the Everglades Agricultural Area (EAA). The purpose of this study was to model (bench scale) certain treatment alternatives to develop the best management strategy for six basins draining into the everglades. Of the chemical alternatives evaluated, chemical treatment/ solids separation (CTSS) proved to be one of the most effective strategies in reducing total phosphorus. Ferric chloride and alum were used as coagulants. The results revealed that orthophosphate was easier to remove than polyphosphate and organic phosphorous and that CTSS was capable of reducing total phosphorous concentrations to 10-ppb.

Source:

South Florida Water Management District. Contract C-E024

Norman, Susan. Hell Hole Road Water Quality Improvement Project, Monitoring Report (1991-1995). April 1996

Summary:

This report presents monitoring data performed to evaluate the impacts of this road on the water quality of the adjacent Trout Creek Tributary before and after implementation of a road improvement project in 1992. Results show that the values for TP exceeded the current state standard (0.015 mg/L) every year at both the upper and lower sites with annual average means ranging from 0.021 to 0.029 mg/L. The TSS standard for a tributary stream to Lake Tahoe is 60 mg/L and this value was not exceeded at either site with average annual means of 1.5 and 6.8 mg/L. Turbidity showed no significant increase over natural level with its value ranging from 0.5 and 1.0 NTUs. The road restoration project implemented on Hell Hole Road, overall indicated effective erosion control.

Source:

USDA Forest Service, Lake Tahoe Basin Management Unit

Norman, Susan. Pope Marsh Burn, Monitoring Report Update (1995-1998). December 1998

Summary:

The Pope Marsh Burn was a controlled 11-acre broadcast that was conducted in September of 1995. Water quality, soil, and re-vegetation monitoring was implemented between 1995 and 1997 to determine the

impacts of the burn. Results indicated that standards for TP and TN were consistently exceeded at all monitoring sites. Annual concentrations at the outlet exceeded the state standards by a magnitude of two ten times. Monitoring also indicated sediment levels at the outlet were lower than at Highway 89, nutrient levels increased between the Highway 89 in-let to the outlet of the marsh. Comparisons of spring run-off data collected in 1995 and 1996 did not indicate any noticeable corresponding change in water quality nutrient concentrations corresponding to the burn. Results also suggested that the capacity of the Pope Marsh to filter the nutrients has been exceeded. The report recommends more analyses to determine if and how the filtering capabilities of the marsh can be improved.

Source:

USDA Forest Service, Lake Tahoe Basin Management Unit

Norman, Susan. Cave Rock Erosion Control Projects, Water Quality Monitoring Report, Water Years 1991-1995. June 1996

Summary:

This report presents the results of the water quality monitoring of Cave Rock Erosion Control Projects performed for the water years 1991-1995. The project improvements consisted of retaining walls, re-vegetation, curb and gutter, rock-lined ditches, and other drainage conveyance structures. Monitoring results indicated exceedance of TRPA standards for P and TSS for both lined sediment basin and rock lined ditch. Nutrient levels did not show significant difference between inlet and outlet of sediment basin and was attributed to limited infiltration capacity and residence time in the basin. Overall, treatment projects showed most efficiency in trapping coarse particles and provided limited treatment for suspended and dissolved constituents.

Source:

USDA Forest Service, Lake Tahoe Basin Management Unit

Norman, Susan. Watson Creek Salvage Timber Sale Project, Water Quality Monitoring Report, Water Years 1990-1994. June 1996

Summary:

This report presents the results of water quality monitoring conducted between 1990 and 1994 on Watson Creek and Carnelian Canyon Creek. The purpose of this monitoring was to evaluate if the water quality of Watson Creek above and below the salvage timber sale and Carnelian Creek below the sale meets the California state standards. Monitoring results indicated state standards for total P was exceeded at all three sites, however the magnitude of this increase over the state standard was within the measured variability of the data. No other applicable standards were exceeded. Overall, no significant impact due to timber sale activity was observed.

Source:

USDA Forest Service, Lake Tahoe Basin Management Unit

Norman, Susan. Wasiu I and Wasiu II Timber Sale, Water Quality Monitoring Report, 1980-1995. April 1997

Summary:

This report presents data from monitoring work performed to determine if water quality of Meeks Creek above and below the timber sale meets applicable California State Standards. Results indicated that the state standard for total P was exceeded 7 out of 16 years at the upper site and 11 out of 12 times at the lower site. The results also indicated turbidity, nitrite and nitrate showing higher levels at downstream station during timber sale activity although the magnitude of the impact was relatively small. A significant increase in TSS was observed below the sale in spring of 1992 that was related to failed stream crossing attempt. This event appears to have caused stream bank erosion during peak runoff at the crossing location.

Source:

USDA Forest Service, Lake Tahoe Basin Management Unit

Norman, Susan. 1999. *Burke Creek Stream Channel Restoration, Monitoring Report 1990-1998*. Prepared by USFS.

Objective:

1) Determine if state water quality standards are being met, 2) determine if reconstructed channel significantly improves nutrient and sediment concentrations, and 3) evaluate channel stability and fish habitat characteristics.

Summary:

The USFS reconstructed 2000 meters of Burke Creek stream channel and Douglas County implemented the Kahle Drive erosion control project. Water quality was monitored between 1990 and 1998 at three stations, two on Burke Creek above and below the reconstructed channel, the third is at the outlet of the erosion control project sediment basin which discharges into Burke Creek above the reconstructed channel. Monitoring includes channel cross-sections, stream condition inventories, and photo-points. Samples were analyzed for flow, turbidity, SS, conductivity,  $\text{NO}_3+\text{NO}_2$ , TP, and DP.

Water quality improvements are not statistically significant at 90% confidence interval for nutrients and sediment. Channels with low gradient have the most potential for significant reduction in sediment and nutrients. The trend is of reduction in variability for sediment, turbidity, and DP.

Norman, Susan. 1996. *Cave Rock Erosion Control Project, Water Quality Monitoring Report, Water Years 1991-1995*. Prepared by USFS.

Objective:

1) Determine if discharge meets TRPA urban runoff water quality standards for sediment and nutrients, 2) evaluate effectiveness of a lined sediment basin and a double-barreled sediment trap in improving water quality, and 3)



determine if erosion control measures were successful in stabilizing previously eroding areas.

Summary:

Cave Rock Erosion Control Project was monitored from 1990 to 1995 to determine the effects of erosion control and water quality treatment structures in reducing sediment and nutrient transport to Lake Tahoe. Project improvements consisted of retaining walls, re-vegetation, curb and gutter, rock-lined ditches, and other drainage conveyance structures. In addition, several water quality treatment facilities were constructed.

Outflow does not meet TRPA standards for DP and SS. Conductivity and turbidity are significantly higher below the lined basin than above (may be related to inputs from Highway 50). No significant difference in dissolved nutrient concentrations above and below the lined basin, probably due to the limited infiltration capacity and residence time in the lined basin. Nutrient uptake may increase during low flow storm events. No significant difference in dissolved nutrients or SS was found above and below the sediment trap. The treatment facilities are more effective in trapping coarse particles, but are limited for suspended or dissolved particles.

NRCS, Natural Resources Conservation Service. "Urban Hydrology for Small Watersheds." Technical release 55, United States Department of Agriculture, 1986.

Objective:

To estimate stormwater runoff volume and peak rates of discharge from urban or rural watersheds, as well as to produce hydrographs, and calculate stormwater volumes for detention basins.

Summary:

Long-term stationary stream flow records are needed to construct reliable runoff and peak discharge events. Because data in smaller watersheds and drainage areas are seldom to rare, it is typical to estimate peak discharges by using hydrologic models that incorporate information on land use, and impervious cover. This report presents a simplified method for estimating runoff and peak discharges in small watersheds. Methods for determining flow routing for retention and detention facilities are also provided.

Oberts, G.L., Marsalek, J., and Viklander, M. Review of Water Quality Impacts of Winter Operation of Urban Drainage. 2000

Summary:

Urban snow packs accumulate large quantities of solids and contaminants, which originate from such sources as airborne fallout, vehicular deposition, and applied grit and salt. Both contaminants and solids may be quickly released during the periods of snowmelt and, consequently, melting contaminated snow in urban areas in cold climates has the potential to substantially impact the water quality of receiving water bodies. Although data on the water quality impacts of melt water are relatively scarce, instances of toxicity of the highly concentrated first flush and deterioration of the receiving

water quality by winter discharges of solids and chemicals have been well documented. Common rainfall-runoff management techniques do not usually address snowmelt impacts because of the cold weather effects on biological systems and physical processes. Further research on adaptation of conventional stormwater management techniques to cold climate conditions is needed.

Source:

Water Quality Research Journal of Canada. 35 (4): 781-808

Oberts, G. L. The search for effective cold climate BMPs. 2000

Summary:

The control of non-point source runoff in cold climates during snowmelt events has usually been ignored as a lost cause. Frozen conduits, ponds, soils and wetlands, biological dormancy, and the addition of chemicals and grit to roadways all confound our best efforts to treat highly pollutant-laden snowmelt runoff. Because of these factors working against us, a substantial portion of annual pollution load remains untreated prior to reaching receiving waters. A brief summary of snowmelt behavior and associated pollutant loading precedes a discussion of management approaches that hold promise for pollutant load reduction. Adaptation of commonly used "best management practices" (BMPs) can be undertaken to accomplish some level of treatment. Modified outlet structures on detention ponds and use of new subsurface "vault" treatment systems are two areas where improvements in melt treatment can be achieved. Seasonally variable detention structures can be lowered to provide some level of detention during large volume melt events. Subsurface treatment trains operate below the frost line and treat most of the pollutants of concern. An active, hands-on management program must be considered an essential element in any successful attempt to control cold climate runoff.

Source:

Proceedings; AWRA's spring specialty conference; Water resources in extreme environments AWRA - American Water Resources Association, Bethesda, MD, United States. TPS 00-1 (2000): 147-153

P'ng, J., Simovic, Henry, D.L., and Thornley, S. Stormwater Management Planning and Design Manual. Ontario. March 2003

Summary:

This manual, developed by the Ontario Ministry of the Environment, serves as a guidance document for planning, designing, and evaluating possible strategies for stormwater management in Ontario, Canada and the surrounding areas. Due to the colder climate of Ontario, this manual serves as an appropriate source for cold weather BMP design. The manual provides guidance on a range of topics including environmental planning, developing design criteria, developing storm water management plans (including BMP designs) and operation, maintenance and monitoring of a site.

Source:

Ontario Ministry of the Environment

Praul, C. and Gavigan, T. 2005. Water Quality Project Inventory (WQPI). Prepared by Nevada Tahoe Conservation District. Final Report. July 2005.

Summary:

Prudic, D., Sager, J., Wood, J., Henkelman, K. and Caskey, R. 2005. Chemistry of Runoff and Shallow Ground Water at the Cattleman's Detention Basin Site, South Lake Tahoe, California, August 2000 – November 2001.

Summary:

Regenmorter, L.C., Kayhanian, M., and Tsay, K. Stormwater Runoff Water Quality Characteristics From Highways in Lake Tahoe, California. August 2002.

Summary:

This paper discusses the quality of highway runoff from the representative roadway conditions (elevations above lake level, geographic distribution within the basin, traffic volume, adjacent land use and stormwater treatment facilities). Highway runoff water quality is compared with stormwater discharge limits established for the Tahoe Basin and the implications of the results as they pertain to stormwater management and treatment options. This article provides a table summarizing the water quality data from FY 2000-2001 and FY 2001-2002 Tahoe Basin Highway Runoff Monitoring Programs. A comparison of untreated runoff data to the stormwater discharge limits indicate that the concentrations often exceeded the limits for majority of the parameters. Also, preliminary results of double barrel sand traps after one season monitoring are provided. Results indicate that although current best management practices do provide treatment, additional treatment may be necessary to meet stormwater discharge limits depending on where the discharge is located in regards to Lake Tahoe.

Source:

Stormwater Program, Office of Water Programs, California State University, Sacramento, CA

Reuter, J.E., Marzolf, E.R. and Goldman, C.R. 1990. *Evaluation of water quality monitoring data associated with erosion control projects in El Dorado County, California: Water year 1989: Elks Club and Pioneer Trail Projects*. Prepared for El Dorado County Department of Transportation by UCD Tahoe Research Group.

Summary:

A total of 147 individual flow and water quality samples were taken at El Dorado erosion control projects in the Lake Tahoe basin. 1150 separate analyses were performed including flow, TSS, NH<sub>4</sub>-N, NO<sub>3</sub>-N, TKN, SRP, TP,

and TR Fe. Sampling focused on two sites: Elks Club (two large detention basins) and Pioneer Trail (naturally existing wet meadow). Most samples were collected in March 1989, when rainfall and snowmelt produced consistent and high flows.

Overall, at Elks Club, average concentrations of  $\text{NH}_4$ ,  $\text{NO}_3$ , SRP, and TP did not change as water flowed through the detention basins, while TKN and TR Fe increased. When analyzed as load, the results were similar except  $\text{NO}_3$  and TP increased through the detention basins. Two types of first flush were observed: 1) short-term over 1-2 days, and 2) seasonal first flush over a 5-6 week period of maximum annual runoff. Reasons for the observed lack of sediment and nutrient removal were possibly due to the early stage of development and is expected to increase as vegetation and bottom and bank become stabilized.

At Pioneer Trail, as upstream-downstream comparison of water flow showed that this treatment facility was very effective in reducing the volume of runoff within the meadow. Little downstream reduction of measured water quality constituents are observed. Only TSS was reduced,  $\text{NH}_4$ , SRP, and TP showed no change. TR Fe declined slightly, and  $\text{NO}_3$  and TKN increased. On the basis of load, the meadow is a very effective treatment facility. Mean loads for TSS, TKN, SRP, TP, and TR Fe were reduced by 37-55%,  $\text{NH}_4$  by 18%, and  $\text{NO}_3$  increased. Reduction in load was related to reduction in flow. Outflow water quality was quite good. Erosion control structures which increase the spreading and overall reduction of downstream flow are very effective for water treatment.

Reuter, John E. and Miller, Wally W. Chapter 4. Aquatic Resources, Water Quality, and Limnology of Lake Tahoe and its Upland Watershed. 2000

Summary:

Provides good documentation of current sources and sinks of nutrients to Lake Tahoe. Calculation of nutrient loading from runoff from a limited database indicates that urban runoff contributed more nutrients compared to the non-urban sources. According to this study, using the field concentrations measured in the summer of 1998 the average TSS:TP ratio was estimated at 0.0007. Concentration of total-P per unit of wet sediment in single sample ranged from 0.0013 to 0.00003 g TP per g sediment. The mean values of TP per g of wet weight sediment at the sampling sites ranged from 0.00041 to 0.00098. This chapter provides another useful information regarding variability of nutrient content in sediments from same as well as different sources. On the order of one to six percent of TP was determined to be biologically available P as determined by chemical testing. A summary information of nutrient input is provided. While major source for nitrogen loading is atmospheric deposition, surface runoff (direct runoff 34% and stream loading 29%) is the major source for total P loads. This study clearly suggests the importance of direct runoff. Another study reported in this chapter relates movement of water, nutrients and sediments.

Source:

The Lake Tahoe Watershed Assessment (Murphy and Knopp eds.)

Reuter, J.E. and Goldman, C.R. 1992. *Evaluation of water quality monitoring data associated with erosion control projects in El Dorado County, California: Water years 1990-1991: North Upper Truckee Road, Pioneer Trail, Elks Club.* Prepared for El Dorado County Department of Transportation by UCD Tahoe Research Group.

Summary:

Report on monitoring of water quality constituents associated with surface erosion control project sites within the Lake Tahoe basin. Primary project areas sampled include: North Upper Truckee Road, Pioneer Trail, Elks Club, and Apache-Mandan.  $\text{NH}_4$ ,  $\text{NO}_3$ , DIN, TKN, SRP, THP, BA Fe, TSS, and flow were measured. Fewer samples were collected due to low precipitation, reduced snow pack, and decreased surface runoff, therefore sampling was not representative.

Reuter, J.E. Lake Tahoe Basin Stormwater Runoff Monitoring to Assess Nutrient and Sediment Loading by Source and Land Use, Hydrologic Modeling, and Best Management Practices Effectiveness and Feasibility, 2nd Progress Report (January 1, 2003-April 31, 2003)

Summary:

This study provides list of TMDL implemented autosampler sites and drainage characteristics, runoff event characteristics and samples collected by site and sample TRG datasheet for analyses of samples collected through first quarter. This is an ongoing study.

Source:

Tahoe Research Group, University of California, Davis. Agreement No. 01-176-160-0

Reuter, J.E., Heyvaert, A.C., and Hackley, S.H. Preliminary Analysis of Sediments and Phosphorus in the Surface Runoff from Selected Intervening Zones in the Tahoe Basin: 1998-1999 Monitoring. December 15, 2000

Summary:

Sediment and phosphorus runoff were collected from selected intervening zones in Lake Tahoe Basin. Water quality data including TSS, Dissolved Phosphorus, Total Phosphorus and Particulate Phosphorus was analyzed. Data was analyzed from seasonal variations, natural versus urban loading, influence of hydrological events (rain vs. snowmelt vs. rain on snow). Seasonality was observed in the concentration of particulate phosphorus as its concentration reached zero during spring snowmelt period of May-June. However concentration of DP remained uniform throughout the year with no significant change.

TSS concentration was found to be at least 100-fold greater in the urbanized zone than the undisturbed zone. Hydrological events had some effect on the transport of PP but no effect on the TSS.

Source:

Tahoe Research Group, UC Davis, December 2000

Reuter, J.E., Heyvaert, A.C., Luck, M. and Hackley, S.H. Investigations of Stormwater Monitoring, Modeling, and Effectiveness in the Lake Tahoe Basin. November 30, 2001

Summary:

This document includes three separate study reports re-grading the effect of urbanization (Dogrul et al., October 2001), land use based runoff monitoring (Reuter et al., November 2001) and analysis of sediment and phosphorus in intervening zone runoff (Reuter et al., December 15, 2000). In Appendix B, a listing of about 20 BMPs implemented in Lake Tahoe Basin and a comparison of their influent and effluent water quality are given. Good source of information for Lake Tahoe urban runoff characteristics and related BMP performance.

Source:

Tahoe Research Group, University of California, Davis

Reuter, J.E., Heyvaert, A.C., Luck, M., and Hackley, S.H. Land Use Based Stormwater Runoff Monitoring Evaluation of BMP Effectiveness in the Tahoe Basin. November 2001

Summary:

This study provides nutrient and sediment concentration in the stormwater runoff monitored at 17 site/studies in the lake Tahoe Basin. Useful information on land use type relationship with runoff quality aggregated from the 17 sites is presented. Effectiveness of 19 individual projects included in this report provides %removal efficiencies. Performance of BMPs, grouped by classification, were then compared with the National Database. Overall, removal efficiencies seen in the National Database were better than values measured for BMPs in Lake Tahoe.

Source:

Tahoe Research Group, UC Davis, December 2000

Robinson, C. 1999. *Angora Creek Erosion Control Project*. Prepared for El Dorado County Department of Transportation by CLR Hydrographics.

Objective:

Evaluate the functioning of the meadow as a treatment area for urban runoff.

Summary:

System consists of two small meadows. The upper meadow is surrounded by improved curb and gutter installation, sediment traps, rock-lined channel, a sediment basin, and drop inlets and culverts. The lower meadow has relatively few constructed improvements. Some water from the upper meadow is directed to the lower meadow. A preliminary analysis of water quality data collected during 1998. Construction of Phase II was completed in summer 1997, and water quality monitoring began in September 1998. 5

monitoring stations were established with autosamplers and flow meters. Storm event water sampling occurs when there is sufficient flow depth. Attempt to collect initial first flush samples and sub samples every 50 cubic feet during storm events. 4 entire storm periods in fall 1998 were collected. The first storm captured was the largest, and all 4 storms are typical small to moderate size for the area. Concentrations of TSS, TP, NO<sub>3</sub>+NO<sub>2</sub>, NH<sub>4</sub>, TKN, BA Fe, and HP were also analyzed for loading.

Robinson, C. 1996. *Apache Erosion Control Project: Final Water Quality Monitoring Project WY 1991-WY 1996*. Prepared for El Dorado County Department of Transportation by CLR Hydrographics.

Objective:

1) Comparison of different sediment traps with respect to their ability to infiltrate runoff, remove sediment, and remove nutrients, 2) develop recommendations for optimization of erosion control monitoring programs, and 3) demonstrate the overall effectiveness of the installed project at the Apache erosion control site in the Lake Tahoe basin.

Summary:

Data was collected in each of the five years between 1992 and 1996. This report includes experimental and monitoring data. Monitoring included pre-(1992-1993) and post-construction (1993-1996). Analytes included NH<sub>4</sub>, NO<sub>3</sub>+NO<sub>2</sub>, TKN, SRP, THP, BA Fe, TSS, and turbidity. A detailed sediment size analysis was also conducted.

Three different types of sediment traps were compared. One (type CI) showed the best reduction of sediment. This may be due to their higher holding capacities and higher infiltration rates. Pre- and post-construction data were not feasible, with many nutrients increasing post-construction. However, sample sizes were small and concentrations were quite low. BMP effectiveness changed during the initial years of operation; vegetation became established and infiltration characteristics changed.

Robinson, C. 1993. *Erosion Control Project Water Quality Monitoring Data: North Upper Truckee, Apache, and Meyers Bike Trail Erosion Control Projects*. Prepared for El Dorado County Department of Transportation by CLR Hydrographics.

Summary:

This report covers two primary erosion control projects, North Upper Truckee Erosion Control Project and Apache Erosion Control Project, and a preliminary report from Meyers Bike Trail Erosion Control Project. Runoff storm events were monitored since October 1987. Samples were analyzed for NH<sub>4</sub>, NO<sub>3</sub>, TKN, SRP, THP, BA Fe, TSS, turbidity, and flow.

The North Upper Truckee site, phase I, was completed in 1991, and phase II was constructed in 1993. Data from stations NU-3, NU-4, and NU-5 are all pre-construction. NU-6 and NU-7 are located above and below a constructed sediment basin. NU-3A and NU-3B are above and below two constructed sediment basins. Data is summarized by storm type, station, and date, and

pre- and post-construction.

Rowe, T.G., Saleh, D.K., Watkins, S.A., and Kratzer, C.R. Streamflow and Water-Quality Data for Selected Watersheds in the Lake Tahoe Basin, California and Nevada, Through September 1998. 2002.

Summary:

In an effort to determine the cause behind the diminishing clarity in Lake Tahoe, the USGS teamed up with the Tahoe Regional Planning Agency and the University of California, Davis- Tahoe Research Group to characterize the stream flow and water quality for selected watersheds contributing flows to the lake. Monitoring results revealed that the Upper Truckee River at South Lake Tahoe yielded the highest median monthly runoff as well as nutrient and suspend sediment loads while Logon House Creek had the lowest flows and median nutrient and sediment loads. Water temperature ranged from 0 to 23o C, specific conductance ranged from 13 to 900-uS/cm, pH ranged from 6.7 to 10.6 and dissolved-oxygen ranged from 5.2 to 12.6-mg/L. Higher concentrations were usually observed during summer thunderstorms and during rain-on-snow events.

Source:

USGS Water-Resources Investigation. Report # 02-4030

RS Means, Site Work and Landscape cost data, 21<sup>st</sup> Edition, RS Means Construction Publishers, 2001.

Objective:

To provide a comprehensive cost manual, and a valuable estimating tool for projects.

Summary:

The RS Means 2007 Site Work and Landscape Cost book includes 2007 unit and assemblies cost tables for earthwork, sewerage, piped utilities, site improvements, handicapped access ramps, drainage, paving, street openings/repairs, trees and shrubs, underground tanks, railroad and marine work, walls - site work and landscape construction of all types.

Sample, D.J., Heaney, J.P., Wright, L.T., and Chi-Yuan Fan, F.L.; Costs of best management Practices and associated Land Costs for Stormwater Control, journal of Water resources Planning and Management, Jan/Feb, 2003.

Objective:

The purpose of this work was to provide a process-oriented approach to evaluate costs for stormwater infrastructure.

Summary:

Although source control may be the most cost effective approach in dealing with stormwater runoff, the authors have expressed many existing data gaps. This work provides new methods for determining cost estimates for stormwater BMPs by assigning costs at the parcel level. This analysis



assumes a dual-purpose water collection system, containing both a sewer and stormwater system. Availability of a transportation utility was also assumed. Estimation methods for costs associated with land, transportation, and construction materials are presented. However, the authors feel this work benefit from including costs for on-site controls such as infiltration. It was also suggested that better quantification of urban storm water systems will help determine the true cost effectiveness of these projects.

Sansalone, J.J., and Glenn, D.W. III. Accretion of Pollution in Roadway Snow Exposed to Urban Traffic and Winter Storm Maintenance Activities- Part I. July 2001

Summary:

Snowmelt from four highway sites in urban Cincinnati, were analyzed for water quality parameters as a function of residence time. Results indicate that chloride levels were correlated to the application of de-icing salts. Total chemical oxygen demand and TSS concentrations increased as the snow residence time increased, indicating that deposited snow accumulated pollutants. Accretion of total dissolved solids occurred rapidly and even decreased late in the snowfall events.

Source:

ASCE- Journal of Environmental Engineering. 128 (2): 151-166

Sansalone, John J. and Glenn III, Donald W. Accretion of Pollutants in Snow Exposed to Urban Traffic and Winter Storm Maintenance Activities. I. February 2002.

Summary:

Urban snow is impacted by traffic activities and winter maintenance practices that result in significant accretion of dissolved, colloidal, and suspended solids in a complex heterogeneous snow matrix that includes heavy metals, inorganic, and organic compounds. Extended residence times of snow as a roadway snow bank exposed to these pollutant-generating activities lead to significant pollutant accretion and partitioning in the snow matrix. This study analyzed four highway sites in urban Cincinnati with respect to specific water quality indices for the residence time of roadway snow. Chloride levels in roadway snow illustrate a direct correlation to application of de-icing salts. While accretion of total dissolved solids (TDS) was initially rapid with a decrease late in the event, total suspended solids (TSS) accretion demonstrated a more gradually increasing trend for the duration of roadway snow, approaching 105 mg/L. Temporal trends towards increasing total chemical oxygen demand (COD<sub>t</sub>) exerted by roadway snow are similar to TSS, with COD<sub>t</sub> values approaching 105 mg/L. Applications of 2.2×10<sup>5</sup> kg of de-icing salt containing cyanide as an anti-caking agent, along a 27-km section of interstate, resulted in approximately 6 kg of cyanide discharged along this major north-south interstate in the study area. Results indicate that traffic activities and winter storm management practices can have a

significant impact on pollutant accretion in urban snow.

Source:

Journal of Environmental Engineering. Volume 128, Issue 2, pp. 151-166

Sansalone, J.J., Glen III, Donald W., Tribouillard, T. Physical and Chemical Characteristics of Urban Snow Residuals Generated from Traffic Activities. July 2002

Summary:

Snow samples collected at ten metropolitan sites in Cincinnati were analyzed for their physical characteristics and metal content. Particles associated with the snow ranged from 5000-um to less than 25-um and had a d50 of 1222-um. Specific gravities ranged from 2.5 to 3.2 and tended to be lower for particles less than 100-um. Metal analysis of the snow residuals indicate that about 50% of the heavy metal mass of Pb, Cu, Cd, and Zn was bound to particles greater than 250-um.

Source:

Water, Air and Soil Pollution

Schanz, R.W., Coats, R., Reuter, J. and Ziegler, J. 1994. *Evaluation and Monitoring of the Ski Run Water Quality Improvement Project*. Prepared for City of South Lake Tahoe by Philip, Williams and Associates. Report # 919.

Summary:

The Ski Run project was designed to reduce loading of pollutants, including nitrogen, phosphorus, and iron, from 175 acres of residential land. This study summarizes the results of hydrologic and water quality sampling for March 1993 to May 1994. The majority of samples were analyzed for NH<sub>4</sub>, NO<sub>3</sub>+NO<sub>2</sub>, TKN, SRP, TP, TBA Fe, DBA Fe, Turbidity, and TSS. TKN, SRP, TP, and BA Fe appeared to exhibit a significant first flush, and nitrogen, phosphorus, and iron showed a seasonal pattern increasing in early summer (primarily from evapotranspiration and leaching from soils). Concentrations of nitrogen, phosphorus, iron, turbidity, and suspended sediment in stormwater typically exceeded water quality standards.

Schuler, T. and Clayton, R. 2000 Maryland Stormwater Design Manual Volumes I & 2. 2000

Summary:

The Center for Watershed Protection and the Maryland Department of the Environment prepared this document to provide developers and existing landowners with guidance for development, evaluating, and improving stormwater management strategies. The purpose of the document is to protect the waters of Maryland from potential hazardous impacts of stormwater runoff and to increase the effectiveness of BMPs through increased longevity, ease of operation and maintenance and community education.

Source:

Center for Watershed Protection and the Maryland Department of the Environment

Schuler, T.R. Performance of a Gravel-Based Wetland in a Cold, High Altitude Climate. 2000

Summary:

A study by John Reuter and his colleagues implemented a gravel-based wetland to achieve improved pollutant removal capability in the cold climate of Lake Tahoe Basin. Results indicated high pollutant removal efficiency by wetland basin.

Source:

The Practice for Watershed Protection. Article 95.

Semadeni-Davies, A. Modeling Snow Melt Induced Waste Water Inflows. 1998

Summary:

Impacts of urbanization on hydrological processes are different for snowmelt and rainfall events. Furthermore, snowmelt and runoff generation differ between rural and urban areas. Within an urban area, melt intensities are increased at some sites; hence, the volume of water early in thaw can be greater than in rural areas. However, shading can reduce melt in other areas so that the melt period is extended. Many surfaces are at least seasonally impervious and generate overland flow - there is an apparent increase in the area contributing to quick-flow as normally permeable surfaces become saturated or frozen or both. Water infiltrating permeable soil causes saturation and groundwater recharge so that water can seep into sewers. Regardless of whether water enters via inlets or sewer infiltration, drainage networks ensure swift delivery of melt-water to outlets.

Snowmelt induced runoff reaching the Uddebo Waste Water Treatment Plant in Lulea, Sweden, is investigated and a model of urban snowmelt and melt-water routing is proposed. The role of surface type (permeable and impervious) and snow cover characteristics (snow-free, undisturbed, compacted and piled) upon model output is studied. Results are encouraging and provide a good platform for further research.

Source:

Nordic Hydrology. 29 (4-5): 285-302

Smith, D.W., Facey, R.M., Novotny, V., and Kuemmel, D.A. Management of Winter Diffuse Pollution from Urban Areas: Effect of Drainage and Deicing Operations. 2000

Summary:

Snowmelt from streets and highways in snow belt areas of North America is polluted by traffic emissions, atmospheric deposition, and deicing chemicals. Contamination due to de-icing chemicals include cyanides, increased toxicity

from metals, direct effects of elevated salt concentrations, and the acidic leaching of chemicals from snow and soils. The pollution impact of snowmelt discharges on water body integrity is drainage specific. For BMPs to be successful they must be designed to match the drainage type and the deicer used. Suggested BMP measures include application of alternative deicing compounds such as calcium chloride, reduction of deicer application rate, use of modern technologies including RWIS and thermal mapping, and designation of salt-free areas on roads next to streams, wetlands and resource areas.

Structural BMP strategies include operating stormwater detention ponds for storage of the most polluted first flush snowmelt from which snowmelt is slowly directed to treatment either by discharging the effluent into a sanitary or to an infiltration area. Ponds are least effective for winter conditions as they may stratify due salt loads. Residual snowmelt should be cleared as soon as practical to avoid additional impacts following first flush. Drainage by combined sewers and drainage by roadside swales are the other two BMPs discussed in this article.

Source:

Cold Regions Impact on Civil Works

Strecker, Eric W., Quigley, Marcus M., Urbanos, Ben, and Jones, Jonathon. Analyses of the expanded EPA/ASCE International BMP Database and Potential Implications for BMP Design: Proceedings of the World Water and Environmental Congress 2004, edited by Gerald Sehlke, Donald F. Hayes, and David K. Stevens.

Objective:

The intent of this database is to critically examine previous goals and practices, and to offer innovative concepts and models to assist professionals in enhancing past efforts.

Summary:

This CD-ROM includes 493 papers presented at the World Water & Environmental Resources Congress held in Salt Lake City, UT, 2004. The papers in the proceedings address avoidance and / or mitigation of past water resources and environmental mistakes. The following areas of interest are discussed in depth: arid lands; best management practices (BMP) technology; groundwater issues; international water resources issues; river restoration and urban streams; and the 6<sup>th</sup> Annual Symposium on Water Distribution Systems Analysis.

Source:

ISBN 0-7844-0737-1, ASCE, Reston, VA, 2004

Strecker, E.W., Quigley, M.M., Urbonas, B.R., Jones, J.E., and Clary, J.K. Determining Urban Stormwater BMP Effectiveness. June 2001

Summary:

The goal of this U.S. EPA-funded cooperative research program with the ASCE is to develop a more useful set of data on the effectiveness of storm water best management practices (BMPs) used to reduce pollutant discharges from urban development. BMP monitoring data gathered at a particular site should not only be useful for that site, but also need to be useful for comparing the effectiveness of similar and different types of BMPs at other locations. Most BMP effectiveness studies in the past have provided data that is difficult, if not impossible, to use in comparing BMP design effectiveness and in the selection among individual BMP types to meet desired goals. This paper describes some of the comparability problems encountered between different BMP effectiveness studies. Also discussed are considerations that affect data transferability, such as methods used for determining efficiency and statistical significance. It outlines the efforts used to establish and analyze the currently available data and proposes protocols for future analyses, when more studies that have data are available. Finally, it recommends that effluent quality appears to be a much more robust measure of BMP efficiency than the currently used "percent removal" metrics.

Source:

Journal of Water Resources Planning and Management – ASCE. 127 (3): 144-149

Strumm and Morgan, 1996. Aquatic Chemistry, Chemical Equilibria and Rates in Natural Waters, John Wiley and Sons Ed.

Summary:

Source:

Swanson Hydrology and Geomorphology. Assessment of Seasonal Pollutant Loading and Removal Efficiency of Detention Basins. February 2003

Summary:

This report compares the annual and seasonal pollutant (nutrient and fine sediment) loading from three different land use cover types including industrial, residential and turf grass sites into three stormwater detention basins. Precipitation, runoff, and pollutant loading by event are given. Rare data such as pollutant loading segregated by winter rain, rain on snow and snowmelt events is provided. Average ratio of biologically available nutrients to totals for each site and by event type is also provided (Table 4). Summary of event data are provided in Table 3, 5, and 6. In p-36 detention basin efficiency summary is provided.

Source:

Unpublished report prepared for the Tahoe Regional Planning Agency, USEPA, and Nevada State of Lands

Swift, T.J., Perez-Losada, J., Schladow, S.G., Reuter, J.E., Jassby, A.D., and Goldman, C.R., 2006. Water clarity modeling in Lake Tahoe: Linking

suspended matter characteristics to Secchi depth.

Summary:

Source:

Aquatic Science, 68: 1-15.

Tahoe Interagency Roadway Runoff Subcommittee. Guidance Manual for Implementing Permanent Stormwater Best Management Practices in the Lake Tahoe Basin. January 2001.

Summary:

The guidance manual provided by Tahoe Interagency Roadway Subcommittee (2001) is a good source of information about various BMPs (structural, non-structural, and vendor supplied pretreatment devices) implemented in Lake Tahoe Basin. However, field experience information associated with each BMP provides scarcely any information about performance monitoring data.

Source:

Tahoe Interagency Roadway Runoff Subcommittee

Tahoe Regional Planning Agency. Water Quality Management Plan for the Lake Tahoe Region, Volume II: Handbook of Best Management Practices. November 30, 1988

Summary:

This handbook contains five chapters of BMPs, which are grouped by primary application. Chapter 4 deals with temporary BMPs that basically control measures used to prevent erosion and sedimentation before and during construction, or until permanent BMPs are installed. Temporary BMPs include construction site practices, sediment barriers, non-vegetative soil stabilization practices, runoff control diversions on slopes, and grade stabilization and sediment retention structures. Permanent best management practices discussed in Chapter 5 include slope stabilization, infiltration systems, and permanent runoff collection and conveyance practices. Chapter VI and Chapter VII describe vegetative practices and practice to protect the shoreline and backshore respectively. Overall the focus of this manual is erosion and sedimentation control BMPs both temporary and permanent.

Source:

Tahoe Regional Planning Agency

Tanner, C.C., Sukias, J.P.S., and Upsdell, M.P. Relationships Between Loading Rates and Pollutant Removal During Maturation of Gravel-Bed Constructed Wetlands. March - April, 1998.

Summary:

Relationships between pollutant mass loading and removal are reported for a

series of five pilot-scale constructed wetlands in their 4th and 5th years of operation. The wetlands received different hydraulic loadings ranging between similar to 15 and 70 mm d<sup>-1</sup> (9.5-2 d theoretical retention, respectively), Effluent concentrations of 5-d carbonaceous biochemical oxygen demand (CBOD), total nitrogen (TN), ammonium N (NH<sub>4</sub>N), and fecal coliforms (FC) broadly followed seasonal patterns in influent wastewater strength, Mean annual mass removals of 58 to 78% suspended solids (SS), 73 to 91% CBOD, 48 to 65% TN, 34 to 60% NH<sub>4</sub>-N, 15 to 38% total phosphorus (TP), and 93 to 99.6% of FC were recorded, with removal efficiencies inversely related to loadings, Mass removal rates were monotonically related to loading rates, and could be modeled using a simple plug-flow, first-order approach accounting for removal down to nonzero background concentrations, Comparisons with treatment performance recorded for the wetlands soon after commissioning showed relatively constant relationships between mass loading and removal of CBOD, TN, and FC, In contrast, SS and TP removal declined significantly over the same period, Reduced SS removal efficiency appeared to result from clogging of the gravel substratum by refractory organic solids, and reduced TP removal from saturation of substratum sorption capacity and filling of plant storage pools. To improve N removal predictions for wetlands treating ammonium-rich wastewaters, the use of a combined carbonaceous and nitrogenous BOD term is proposed, which addresses the oxygen dependence of microbial nitrification, the principal rate-controlling process.

Source:

Journal of Environmental Quality. 27 (2): 448-458

Taylor, S., Feng, X.H., Renshaw, C.E., and Kirchner, J.W. Isotopic evolution of snowmelt - 2. Verification and parameterization of a one-dimensional model using laboratory experiments. October 2001

Summary:

Three, controlled cold room experiments were conducted to verify and parameterize a one-dimensional (1-D) model that simulates the isotopic composition of melt water exiting the base of a snow pack. In the model, snow melts at the surface at a constant rate, and water percolates down the column while exchanging isotopically with ice. The effective rate of isotopic exchange and hence the isotopic composition of the melt at a given time is determined by the exchange rate constant  $k_r$ , the height of the original snow pack, the percolation velocity  $u^*$ , and the liquid to ice ratio in the exchange system. The experiments were designed to have different effective rates of exchange by varying the height of the snow column and the melt rate. Fitting the model to each of the experiments yielded  $k_r$  values that fall in a narrow range, 0.14 to 0.17 hr<sup>-1</sup>, confirming that  $k_r$  is an intrinsic rate constant for isotopic exchange. Knowing this value is important for developing future models, in which more complicated hydrological conditions.

Source:

Water Resources Research. 38 (10): art. No. 1218

Thorolfsson, S.T. New Strategies in Stormwater - Meltwater Management in the City of Bergen, Norway. 1999

Summary:

In the City of Bergen, Norway, extensive measures against point pollution sources are now to be implemented and to be finished before the end of year 2000, improving the receiving water conditions. Local politicians and public opinion support high standards of receiving water, even higher than the national level. Future improvements in the receiving water quality is planned through different measures aimed at reducing stormwater-meltwater runoff which causes surface pollution wash-off and combined sewer overflows. The city is now presenting a master plan for the water environment and urban runoff management. One of the main issues of the plan is to measure for stormwater-meltwater quantity and quality problems. This paper describes the background for the plan and the reasons for introducing new strategies in integrated stormwater-meltwater management. The non-polluted stormwater-meltwater is to be handled near the source by percolation and/or detention. The polluted stormwater-meltwater is to be collected and conveyed to an appropriate site for treatment and discharge. The alternative drainage system named the Sandsli-system is described.

Source:

Water Science and Technology. Vol. 39, No. 2, pp 169-176

Tobiason, S.A., Login, L.R.J., and Nickerson, C. Stormwater Filtration Media Testing for Metals Removal and Toxicity Reduction.

Summary:

In a bench scale experiment, the Port of Seattle tested four types of filtration media including leaf compost (CSF®) media, a zeolite/perlite mix, a polyamine sponge and a citric acid modified soybean hull media to determine their effectiveness in reducing metals and toxicity of a synthetic stormwater. Results indicated that the CSF reduced Zn by 75% as well as significantly reduced the toxicity. While the soybean hull reduced zinc by 80% to 90%, pH was reduced to toxic levels. The remaining media had little or no effect in reducing metals and toxicity. In some cases, the media actually generated toxicity.

Source:

Public document prepared by the Port of Seattle, Parametrix, Inc., and Taylor Associates: Seattle, WA

URS. El Dorado County Department of Transportation Angora Monitoring Project, Post Sampling Summary Report. May 2003

Summary:

This report summarizes water quality monitoring data collected from fall of 1999 to the spring of 2003 in the Angora Meadows area of South Lake Tahoe. Angora Meadows is a natural system around which development has occurred over the last 30 years. While the land uses have changed, the historic drainage patterns have been preserved in the 400-acre watershed.



The primary focus of the study is to evaluate the effectiveness of a naturally occurring meadow at reducing concentrations of pollutants of concern. For this project, the nutrients Total Phosphorus, Total Nitrogen, and Total Kjeldhal Nitrogen (TKN) were studied. Five surface-water monitoring stations and eight ground-water monitoring stations were established. It is unclear from the document what the monitoring protocols were, however, from the data it appears that multiple samples were taken over the period of each event. No attempt was made to monitor flows. A total of 27 events were monitored which included: rain, snowmelt, thunderstorms, and seasonal first flush. The authors of the report were critical of the inconsistent procedures followed for the sampling, which led to their conclusion that the data was inconclusive. The data does provide information about pollutant concentrations under different types of events. As with some of the other studies, it appears that the large, intense, thunderstorms generate higher pollutant concentrations and loads than do the other types of events.

Source:

Unpublished report

U.S. Environmental Protection Agency Website. 2006. Terms of Environment: Glossary, Abbreviations, and Acronyms.

Summary:

Source:

[www.usepa.gov/ocepat/terms/tterms.html](http://www.usepa.gov/ocepat/terms/tterms.html)

USEPA, SYNOP Model: Analysis of Storm Event Characteristics for Selected Rainfall Gages Throughout the United States, Washington, D.C., 1989.

Objective:

The performance of any control device that treats urban runoff should be characterized in such a way that the variability and intermittent nature of storm runoff is recognized and accounted for. Important factors include performance over all storms for an area in contrast to those monitored in a test program and performance in areas where storm patterns are different. The methodology presented in this report is based on a probabilistic technique that accounts for the inherent variability of the situation it addresses.

Summary:

Chapter 2.2, p.4, states that hourly precipitation data available from the U.S. Weather Service may be separated into a sequence of discrete storm events, for which volume, duration, average intensity and interval since preceding event can be determined. These parameters can be statistically analyzed to determine mean and standard deviation, as well as the probability distribution of the set of all values. A National Urban Runoff Program publication documents the SYNOP program that computes these statistics from a USWS hourly precipitation record. Appendix 2 provides a tabulated summary of storm statistics for gages around the country, based on SYNOP output. Appendix 3 presents information for estimating runoff coefficients. This

information is provided to assist users to estimate appropriate values for local analyses. Analysis of a number of rainfall records indicates that the storm parameters used in this report are well represented by a gamma distribution.

Source:

USEPA, Methodology for Analysis of Detention Basins in Control of Urban Runoff Quality, EPA 440/5-87-001, September 1986, see: <http://www.epa.gov/ednrmrl/publications/reports/epa440587001/epa-440-5-87-001.pdf>

USEPA, Guidance for Specifying Management Measures for Sources of Non-point Pollution in Coastal Waters

Objective:

Provide guidance to States on the types of management measures that should be included in State Coastal Non-point Pollution Control Programs.

Summary:

This manual provides definitions and descriptions of management measures for agriculture, forestry, urban areas, marinas and recreational boating, channel modification and erosion control, wetlands and vegetated treatment systems. It also provides techniques to monitor water quality. A follow-up document entitled: TECHNIQUES FOR TRACKING, EVALUATING, AND REPORTING THE IMPLEMENTATION OF NON-POINT SOURCE CONTROL MEASURES: URBAN (EPA 841-00-007, January 2001) provides information on tracking the implementation of best management practices (BMPs) used to control urban non-point source pollution. Information is provided on methods for inventorying BMPs, the design and execution of sampling programs, and the evaluation and presentation of results.

Source:

United States Environmental Protection Agency, Office of Water, Doc # EPA\_840-B-92-002, January 1993 see: <http://yosemite.epa.gov/water/owrccatalog.nsf/0.f209c36c2153c0ec85256d83004fd9e9?OpenDocument>

USEPA (Contact: Brian Lovett, Wyoming Department of Environmental Quality). Jackson Hole Rodeo Grounds Snow Storage Site.

Summary:

Due to the diminishing fish habitat quality of the Flat Creek in Jackson Hole, Wyoming, the Wyoming Department of Environmental Quality and Jorgensen Engineering completed a water quality study of the creek. The results from the study indicated that a significant portion of the pollutants were being discharged from a snow storage facility at the Jackson Hole Rodeo Grounds. To reduce pollutant loading into the creek, the Town of Jackson installed a filtration device composed of 2-inch washed rock with a non-woven geotextile fabric. The filter was capable of removing particles greater than 0.0059 inches. The filter was paired with a sediment basin for further removal of sediments.

Source:

USEPA, Preliminary Data Summary of Urban Stormwater BMPs,

Objective:

Summarize existing information and data regarding the effectiveness of BMPs to control and reduce pollutants in urban storm water. EPA's Engineering and Analysis Division conducted a study on storm water best management practices during 1997 and 1998 as part of its series of preliminary studies in the effluent guidelines program. Chapter 6 of the report provides a synopsis of what is currently known about the expected costs and environmental benefits of BMPs and identifies information gaps as well.

Summary:

For various reasons (such as cost, suitability to site, etc.) some urban storm water BMP types are widely used, some infrequently; some are relatively new designs that are not widely in use. Many BMPs are used primarily for water quantity control (i.e. to prevent flooding), although they may provide ancillary water quality benefits. Some BMP types have been analyzed for performance in terms of site-specific pollutant removal, although not extensively enough to allow for generalizations. The pollutant removal performance of some BMP types are essentially undocumented. Some BMP types, particularly non-structural and those that do not have discrete inflow or outflow points are difficult to monitor. There is no widely accepted definition of "efficiency" or "pollutant removal" for storm water BMPs. The role of chemical pollutant monitoring vs. receiving stream biological monitoring in evaluating BMP performance is not well documented.

Only a few cost studies have been conducted for storm water BMPs. Due to the limited cost data, a lack of clear definitions of performance, and limited "performance" data, it is difficult at the time to develop cost-effectiveness comparisons for various BMP types. The benefits of individual BMPs are site-specific and depend on a number of factors including:

- The number, intensity and duration of wet weather events;
- The pollutant removal efficiency of the BMP;
- The water quality and physical conditions of the receiving waters;
- The current and potential use of the receiving waters;
- The existence of nearby "substitute" sites of un-impaired waters.

Because these factors will vary substantially from site to site, data are not available with which to develop estimates of benefits for individual BMP types.

Source:

United States Environmental Protection Agency, Office of Water, Doc # EPA\_821-R-99-012, August 1999, see:

[http://www.epa.gov/waterscience/guide/stormwater/files/usw\\_a.pdf](http://www.epa.gov/waterscience/guide/stormwater/files/usw_a.pdf)

USGS (monitoring/ supporting agency). Barton Creek Square Detention Ponds- Austin, Texas.

Summary:

Between 1982 and 1984, a detention and filtering pond near Barton Creek Square Shopping Center was monitored to determine the BMP's effectiveness in pollutant removal. Results from this study are presented in the National BMP Database. The detention and filtering pond has a capacity of 3.5-acre-ft. The bed of the pond consisted of three stratified layers of media: fine sand, coarse sand and gravel. The results indicate that the basin was capable of removing TSS by 15%, total phosphorous by 36%, total Fe by 38%, dissolved Pb by 46%, and dissolved Zn by 27%. However, total nitrate and nitrite was increased by 137%.

Source:

National Stormwater Best Management Practices Database

Viklander, M. Particle size distribution and metal content in street sediments. August 1998.

Summary:

Sediments that had accumulated during the winter season, and which were left at the surface when the snow had melted, were studied with regard to physical and chemical characteristics. The investigation was carried out in the city of Lulea, which is located in northern Sweden. Sediment samples were collected in the city center and in a housing area at streets with different traffic loads. The results showed that the amount of the sediments at a street surface was evidently affected by the presence of a sidewalk. The street with a sidewalk accumulated much more sediment than the street without a sidewalk did. Both of these streets had approximately the same traffic load. The sidewalk also affected the particle size distribution. The content of heavy metals in the sediments varied with the traffic load and the area type. The highest concentration of cadmium, lead, and zinc was found in the street with the highest traffic load.

Source:

Journal of Environmental Engineering- ASCE. 124 (8): 761-766

Waschbusch, R.J. Evaluation of the Effectiveness of an Urban Stormwater Treatment Unit in Madison, Wisconsin, 1996-97. 1999

Summary:

Between August of 1996 and April of 1997, an urban stormwater treatment unit located in Madison WI, was tested to determine the unit's treatment efficiency. The unit consisted of a sedimentation tank with an overflow bypass weir. Approximately 90% of the runoff generated from the 4.3-acre site was routed through the unit, while flows exceeding 500-gpm were bypassed without treatment. Both rain and snowfall events were sampled throughout

the study. The study revealed that the treatment unit removed approximately 33% of the suspended sediments, 19% of the total phosphorous, 39% of the total PAH, and 20% of the total metals.

Source:

USGS Water-Resources Investigation. Report # 99-4195

Werker, A.G., Dougherty, J.M., McHenry, J.L., and Van Loon, W.A. Treatment Variability for Wetland Wastewater Treatment Design in Cold Climates. July 2002

Summary:

The purpose of this article is to highlight the growing need for small-scale, passive, natural systems that can serve our needs in water pollution control both in small communities and larger urban developments. Engineered wetlands represent one potential wastewater management option that exhibits promise in satisfying community requirements for contaminant and pathogen removal. However, the Canadian climate presents special challenges for constructed wetland treatment systems whose functional reliability is not nearly as well developed as currently available, more conventional, but less sustainable treatment options. The goal of this article is to present some of the key issues that require more fundamental understanding if engineered wetlands are to become a predictable, mainstream approach for decentralized wastewater treatment. Two critical factors limiting the advancement of treatment wetland technologies are a standardized approach to elucidate exact process mechanisms and a basis with which to make more meaningful comparisons within and between systems that naturally evolve and mature with time.

Source:

Ecological Engineering. 19 (1): 1-11

West, Yost & Associates. 1996. *BMP Effectiveness Study*. Prepared for Tahoe Regional Planning Agency. Report # 045-93-01.

Summary:

This report includes data on the effectiveness of residential BMPs for stormwater pollutant load reduction in the Homewood area. Ten sites were sampled, including 5 control, 5 treatment, and one paired set. BMPs include infiltration tests, runoff quality sampling, runoff quantity measurements, and soil water quality sampling. Samples were analyzed for NH<sub>4</sub>-N, NO<sub>3</sub>-N, TKN, SRP, DP, TP, TSS, pH, and EC.

Infiltration rates of drip-line and driveway infiltration trenches were over three times as high as non-BMP drip-lines. The highest pollutant concentrations were generally in fall runoff, except SRP which was higher in spring. Drip-line and driveway infiltration trench BMPs appear to be cost-effective for soils with lower permeability and for sloping ground, and where there is a large tributary area for the trenches. They may not be as cost-effective for level areas with high permeability soils.

Runoff was measured from September 1994 to July 1995, including rainfall, storm, and snowmelt runoff events. TKN was higher in sites with more vegetation in the watersheds. Most P was not from atmospheric sources. EC was higher in driveway samples and TSS was higher in drip-line samples.

Westerstrom, G. and Singh, V.P. An Investigation of Snowmelt Run-off on Experimental Plots in Lula, Sweden. 2000

Summary:

In a study done in Lula, Sweden, snowmelt runoff hydrology was characterized over a six-year period between 1980 and 1985. The study measured snowmelt hydrology for two experimental setups: a series of three plots having an asphalt surface, a gravel surface and a grass surface and a series of three plates having an iron surface, an aluminum surface and the final having just a frame with no surface. Conclusion drawn from the study reveal that snowmelt infiltration is governed by the weather, snow pack and soil type. Snowmelt runoff can be reasonably predicted with an average hydrograph, irrespective of the surface type. However, daily runoff volumes vary from one surface to the other as well as from one year to another.

Source:

Hydrological Process. 14:1869-1885

William, James and James, Robert C. Water Systems Models Hydrology: A guide to the Rain, Temperature and Runoff Modules of the USEPA SWMM4. June 2000

Summary:

This publication is a User's Guide to SWMM4 RUNOFF and supporting modules (Rain, Temperature, Combine and Statistics) Pg-63 to Pg 64 Discusses snow melt. The author explains some of the equations and computational logic the SWMM uses to analyze snow and snowmelt.

Source:

None provided.

Wittgren, H.B. and Maehlum, T. Wastewater Treatment Wetlands in Cold Climates. 1997

Summary:

The best prospects for successful wetland treatment should be in the warmer regions of the world, but studies in North America and Scandinavia show that wetland treatment may be feasible also in cooler regions. A review shows that the number of wetlands of different types (free water surface, FWS; horizontal and vertical subsurface flow, SSF), treating different kinds of wastewater, is steadily increasing in most parts of the cold temperate regions of the world. The major wetland engineering concerns in cold climates, which are discussed in this paper, are related to: (1) ice formation, and its implications

for hydraulic performance; (2) hydrology and hydraulic issues besides ice formation; and (3) the thermal consequences for biologically or microbiologically mediated treatment processes. Energy- and water-balance calculations, as well as thermal modeling, are useful tools for successful design and operation of treatment wetlands, but the shortage of data makes it necessary to adopt a conservative approach. The treatment processes often appear less temperature sensitive in full-scale wetlands as compared to laboratory incubations. Several possible explanations are discussed in the paper: (1) sedimentation playing a significant role, (2) over dimensioning in relation to some constituents, (3) seasonal adsorption (cation exchange) of ammonium, and (4) temperature adaptation of the microbial community. Experience shows that cold climate wetlands can meet effluent criteria for the most important treatment parameters. To gain wide acceptance, however, we need to become more specific about design and construction, and also about operation, maintenance and cost-effectiveness. These goals require detailed knowledge about processes in full-scale wetlands, including long-term changes and response to maintenance.

Source:

Water Science and Technology. 35(5): 45-53.