This paper was presented at the 1994 Engineering Foundation Conferece, Crested Butte, Colorad and served as the basis to begin the development funding by EPA of the International BMP Database.

PARAMETERS TO REPORT WITH BMP MONITORING DATA

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ABSTRACT

This paper presents an argument for standardization of the physical, chemical, climatic, geological, biological, and meteorological parameters being reported along with the data acquired by various investigators on the performance of structural stormwater Best Management Practices (BMPs) used to enhance stormwater quality. Also, a standard minimum list of such parameters is suggested. Such a list is needed if we want to have a meaningful exchange of data among the various studies being conducted throughout the world. Transferability of performance results and consistency, or lack of it, in the performance of various BMPs has been an ongoing problem. A mutually agreed upon minimum list of reporting parameters that can be used to relate the performance of BMPs to some, or all, of these parameters could begin to address this problem. Over time such standardization will conserve the resources being expended by various field investigations and may eventually lead to improvements in the selection of and in the design of various BMPs.

INTRODUCTION

Much data have been collected over the past 10 to 20 years on the performance or "efficiency" of many structural stormwater quality BMPs. Most existing data relate to the performance of detention basins (i.e., detention basins that drain out completely after a storm runoff end, sometimes called "dry pond"), retention ponds (i.e., ponds that have a permanent pool of water and retain at least part of one storm's runoff after its runoff period ends, sometimes called "wet pond") and wetlands. Less data are available on field effeciveness of other types of BMPs. Howeve, this data and/or its reporting has lacks consistency. In addition, musch of the reported results do not show clear mathematical relationships between the performance of similar BMPs among various sites in which they were investigated. One of the reasons may be that sufficient parametric information about each site has typically not been reported along

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with the performance data to permit systematic analysis of data collected under a variety of field studies, or to relate these data to a set of physical, climatic, geologic, or hydrologic conditions.

What we have now is a variety of independent interpretations with very little attempt to relate to other investigations that may have occured in the past or may beoccuring concurrently. Some of these interpretations may make a lot of sense while others leave us wondering and questioning what was studied and found and why? At the same time, and more importantly, we cannot answer with any degree of confidence what role various site parameters play in the performance of any particular BMP.

As an example for a retention pond, is it more important to know the *pond size vs. inflow event volume* ratio when designing for the removal of Total Suspended Solids (TSS) or Total Phosphorous (TP), or is it more important to know the *surface area of the pond vs. tributary watershed area* ratio, or is another set of parameters more important? Such questions can only be answered by a systematic and consistent BMP monitoring activities, wherever they may take place. Without these we will never be able to develop reliable, field tested, selection and design guidance for structural BMPs, guidance that we can need to use these BMPs with confidence.

When we examine what occurs at a retention pond, there are two distinctly separate phases of sedimentation. The first takes place during storm runoff when settling occurs under turbulent conditions, the other takes place during the quiescent conditions between storm runoff periods. In addition, in-between runoff events biological and chemical processes can remove or remobilize suspended and dissolved constituents in the water column.

In the TSS removal example discussed above, the settling of solids under quiescent conditions is a function of particle density, particle size and the fluid's viscosity, which in turn is a function of temperature. According to Dobbin (1944) and Camp (1946), particle settling under dynamic inflow conditions is dependent on the unit surface hydraulic loading (i.e., Q/A), the measured distribution of TSS particle settling velocities and critical shear stress, which in turn is a function of flow velocity and depth. There is also evidence (Grizzard et al; 1986) that TSS and other constituent removal efficiencies can be significantly affected by the initial concentration of the constituent. Laboratory and field data using stormwater show that it is easy to remove 80 to 90 percent of TSS from urban runoff when its initial concentration is high (e.g., > 400 mg/l) and difficult to remove even 20% when the initial concentrations are low (e.g., < 20 mg/l).

There are a number of key parameters that need to be obtained and reported whenever BMP performance is monitored. Identifying all such parameters at this time is not posible. We can add to the list as we learn more about the passive treatment mechanisms and the performance of structural BMPs. However, an initial list is suggested for a variety of BMPs that are currently or may be field tested in the future for effectiveness. They need to be reported in all study reports, data transfer reports, and other literature, along with performance data such as the inflow and outflow event mean concentrations (EMCs), the percentages of removal of each constituent, the flow rates and the volumes entering and leaving each structural BMP facility being investigated.

As municipalities and industries in United States of America begin to operate under the federally mandated National Pollutant Elimination Program's separate stormwater discharge permit system, we can expect a profound increase in the amount of stormwater monitoring data being collected and reported. Much of it will be associated with the performance of various BMPs. This data will be collected in a variety of ways, using different monitoring and reporting techniques, manual sampling, automatic sampling, different constituent detection levels, etc. The selection of the techniques used at each site will be determined by local conditions, budgets, expertise of the investigators, and other factors impossible to predict in advance. Some level of consistency in how this data and the type BMP parameters being reported will be needed if we ever hope to make any sense of this data or hope to draw repeatable quantitative conclusions. This will be of particular challenge when trying to draw conclusion in how this data relates to various BMP's and tributary watershed's design parameters.

It is hoped that the consistent use in the professional literature of a minimum set of standard parameters will result in more reliable tools for the selection of structural BMPs and in better design tools than we have today. In developing this list, various potential physical, biologic and chemical processes were considered for several types o BMPs . Although this list is extensive, every attempt was made to kept it as brief as possible. This does not mean, however, that other site specific parameters should not be measured or reported.

It is also recommend at this time that additional parameters be carefully evaluated before adding them to this list. It is not the intent to limit this initial list or to keep out other potential parameters of merit. I is suggested that before adding on to this list consider tha the complexity of finding meaningful empirical relationships expands exponentially with each newly added parameter. Also, we need to be sure that any new parameter is not already within this list, either as part of another parameter or within a grouping of the parameters on the present list. For example, it is not necessary to report the tributary impervious watershed area if the total watershed area and its percent of total imperviousness are reported.

REPORTING CONSTITUENTS AND THEIR REMOVALS

The way that we report data on the constituents in the water column and their removal rates is dictated is we have a detail study report or a summary paper. The former merits much more detail. Also, should data be reported as event mean concentrations for a storm or should it be reported as a set of discrete sample data obtained at different times during a storm? There is a need to have some level of consistency in how we handle this issue.

Data and Study Reports

Typically, literature reports the constituents being monitored, their removal efficiencies and associated flows. Sometimes the constituents are reported as EMCs entering and leaving the BMP facility, while at other times data are reported for individual discrete samples taken throughout the runoff event even though discrete samples are often composited into a single EMC. To provide consistency, it is recommended that stormwater BMP data be reported in literature as paired inflow and outflow EMCs for all the events sampled, along with the event's volume of runoff (inflow and outflow if different) and percent constituent removal rates during each event.

The collection and the reporting of discrete sample data taken at various times during runoff events is not discouraged by the above recommendation. It is, however, very expensive to test each discrete sample for a number of constituents and many stormwater data collection efforts elect to test only the flow weighted composite sample to find the storm's EMC. If budgets permit, however, much understanding can be gained through the collection and analysis of discrete water quality samples throughout the runoff hydrograph. The reporting of storm composite EMCs in published literature is suggested for the sake of reporting constancy, while any available discrete sample data can be made available to investigators upon request as ASCII or data base files, along with the organization and format of these files.

Inconsistencies also occur in literature in reporting removal efficiencies. To cope with this, it is recommended that the percent removal (*PR*) for any constituent be calculated and reported for each monitored event using the inflow and outflow loads. If the facility records less surface outflow than inflow, as can be the case when infiltration/percolation occurs, the outflow loads should be reported for the surface outflow component based on the measured outflows and for the subsurface component based on the estimates of the water infiltrated/percolated, into the ground. This should prevent the impression that infiltration/percolation actually eliminates constituents, instead of, as sometimes happens, transferring them to the groundwater flow regime. Equation 1 is suggested as the basic equation for calculating the percent removal rate of any sampled constituent.

$$PR = \frac{V_{in} \cdot EMC_{in} - V_{out} \cdot EMC_{out}}{V_{in} \cdot EMC_{in}} \cdot 100 \tag{1}$$

in which, PR = percent constituent load removed,
V_{in} = storm runoff volume inflow into the BMP facility,
EMC_{in} = event mean concentration of inflow volume,
V_{out} = storm runoff volume outflow from a into the BMP,
EMC_{out} = event mean concentration of outflow volume,

Reporting of constituent concentrations in dry weather inflows and outflows, if any, can reveal much about the true performance of a BMP. Many on-site BMPs do not experience dry weather flows and the reporting of the percent constituent removal efficiencies for storm events is sufficient. However, if dry weather flows are present, they sometimes can have a very significant effect on the actual constituent removal rates that take place over an extended period of time (Urbonas et al, 1994). To help us understand how any BMP being studied is affected by dry weather flows, it is recommended that constituent concentrations in dry weather flows be obtained and reported in sufficient numbers to provide averages and their coefficient of variation.

Report Summaries and Published Summary Papers

Summaries of monitoring studies and published papers often cannot include all the data that were collected. As a result, the information has to be reduced to fit the available space. Again there is no consistency in how this is done and it is suggested that, as a minimum, summary reports and published summary papers report the constituent EMC data as monitoring period (or season) averages for both the inflow and outflow, along with the inflow (and outflow if different) volume averages and numbers of EMC data points (i.e., storm events sampled) for each parameter, along with each average's coefficient of variation (*CV*). These data need to be accompanied by the lon-term average percent removal rates for each constituent reported as the arithmetic mean of individual removal rates. Calculated these using Equation 2.

$$PR_{av} = \frac{\sum_1^n PR_i}{n} \tag{2}$$

in which,
PR_{av} = Average % removed, all monitored events, single constituent,
n = number of events for which percent removals were calculated,
PR_i = % removed for the i_{th} event sampled.

BASIC SEDIMENTATION EQUATIONS

Much of the performance effectiveness attributed to BMPs currently focusws on the removal of TSS from runoff. This is definitely not always the case. Local concerns, such as those in watersheds tributary to Chesapeake Bay and the watersheds in State of Florida suffering from groundwater depletio, may dictate that the removal of nutrients is of greatest concern, or, as is the case for the watershed draining to San Francisco Bay, the removal of copper, soluble and total, may be of most interest. Never the less, the selection of the parameters being suggested are based on the principles for the removal of TSS and on the removal of other constituents. The reduction in the toxicity of some of the constituents was also considered in developing the recommended list.

The TSS removal process is much more complex than can be explained using simple sedimentation equations. Nevertheless, these equations provide some of the mathematical basis for identifying many of the physical parameters that should be looked at, especially when considering the design of facilities to remove particulates and the constituents that adhere to them.

Newton's Sedimentation Law For Spherical Particles:

Newton proposed the following equation to describe the settling velocity of a particle in a fluid:

$$V_S = \sqrt{\frac{4}{3} \cdot \frac{d_p \cdot g \cdot \left(r_p - r_v\right)}{C_D \cdot r_v}} \tag{3}$$

in which, V_S = settling velocity of a given particle size in m/s
d_p = diameter of the particle in m
r_p = specific gravity of the particle,
r_v = specific gravity of the fluid,
g = gravitational acceleration in m/s^2
C_D = drag coefficient, a function of Reynolds Number R_n , which in turn is a function of the fluid's temperature.

Basic Suspended Solid Settling in Turbulent Flow :

Geyer (1954) suggested a relationship to describe the sediment fraction that can be removed in a pool of water under the dynamic conditions that can occur as water enters the pool at one end and overflows an outlet at the other end. This relationship, Equation 4, relies on the pool's hydraulic surface loading rate, namely the flow-through rate divided by the pool's surface area.

$$R_d = 1.0 - \left[1.0 + \frac{1}{n} \cdot \frac{V_S}{Q/A} \right]^{-n} \tag{4}$$

in which, R_d = fraction of the inflow solids removed under dynamic conditions,
V_S = settling velocity of a given particle size in m/s (ft/sec),
Q = flow through rate in cubic m/s (ft/sec),
A = surface area of the permanent water pool in m^2 (ft^2),
n = turbulence, or short-circuiting, constant,
= 1.0 for poor performance, high sort-circuiting potential,
= 5.0 for very good performance, low short-circuiting potential,
= $\propto$ for ideal performance.

As n approaches infinity, Equation 4 reduces to:

$$R_d = 1.0 - e^{-kt} \tag{5}$$

in which,
k = V_S/h, sedimentation rate coefficient in /s units,
h = average depth of the pond in m (ft),
t = V/Q, resident time in the pool in seconds
V = volume of the pool in m^3

GENERAL PARAMETERS TO CONSIDER FOR ALL BMPS

There are a number of general parameters that should be recorded and reported, regardless of the type of BMP being tested. Some of these can be used to assess the aquatic environment and the toxicology of the constituents being monitored. Others, such as temperature, give the investigator an idea of the fluid's density and viscosity, both of which influence the settleability of solids. Table 1 lists a number of such general parameters. All of them can be measured in the field and, except for V_{SD}, are relatively inexpensive to obtain.

RUNOFF PARAMETERS

Since storm runoff is a function of the tributary watershed area and its imperviousness, always report the *Tributary Watershed* (A_T), its *Total Percent Imperviousness* (I_{IT}) and the *Percent of the Total Imperviousness that is Hydraulically Connected* (I_{IC}) to the storm conveyance system. Often not reported in published literature is information about storm runoff peaks, runoff volumes or storms and of base flows associated with BMP facilities. Figure 1 illustrates storm runoff events as a time series of hydrographs, which information can be summarized using a probability distribution graph shown in Figure 2. To help us find relationships between runoff distribution data at a variety of sites being monitored and the performance of these BMPs, it is recommended that, as a minimum, runoff data (and outflow data if different) be summarized as suggested below for *Runoff Volume, Storm Runoff Duration* and *Storm Runoff Inter-Event Time* parameters as follows:

TABLE 1. GENERAL PARAMETERS TO REPORT FOR ALL BMPs

Inlet and Outlet	Plan, profile and details, including dimensions and elevations of the inlet and outlet works. Include inflow baffles and outlet trash racks, if any.
Temp *	Water temperature of influent, effluent and possibly the pond itself. Summarize this data as monitoring seasonal average, along with its coefficient of variation.
V_{SD}	Settling velocity distribution of the sediments in stormwater determined from a number of settling column tests.
Alkalinity & Hardness	Affect the solubility and the toxicity of metals and of other constituents. To be measured and reported as the Event Mean Concentration (EMC) of the influent and the effluent of the facility.
Conductivity *	Provides a surrogate indicator of ionic activity in the water column, which may indicate the availability of metals to aquatic life in toxic state. Reporting *dissolved* metals along with *total* metals data provides an indicator of potentially available toxic forms.
pH *	Affects the solubility and toxicity of metals and other constituents.
*	Indicates that these parameters are to be measured in the field and reported as the mean of the measured values.
Solar Radiation	Measured daily, only at retention ponds, wetlands and other biologically active treatment water quality facilities. Summarize this data as the mean of daily averages for the monitoring season and their Coefficient of Variation.
Maintenance	Provide type and frequency of maintenance such as dredging of sediments, harvesting, mowing, removing and replacing filter media, etc.
Facility Description	Full description of the BMP, including layout, typical cross-section and profile, inlet and outlet details, vegetative cover, etc.

Runoff Volume Parameters During Monitoring Season:

V_R = Volume of the average **r**unoff event in watershed mm (in),

V_{R50} = Volume of the **50th** percentile **r**unoff event in watershed mm (in),

CV_{VR}= **C**oefficient of **V**ariation in the **v**olumes of **r**unoff events (V_{SD-R}/V_R),

in which $V_{SD\text{-}R}$ = **S**tandard **d**eviation of **R**unoff volumes,

V_B = Volume of the seasonal dry weather **b**ase **f**low in watershed mm (in),

Q_P = Average runoff peak rate in m^3/s (ft^3/sec),

CV_{QP}= **C**oefficient of **V**ariation of **f**low **p**eaks.

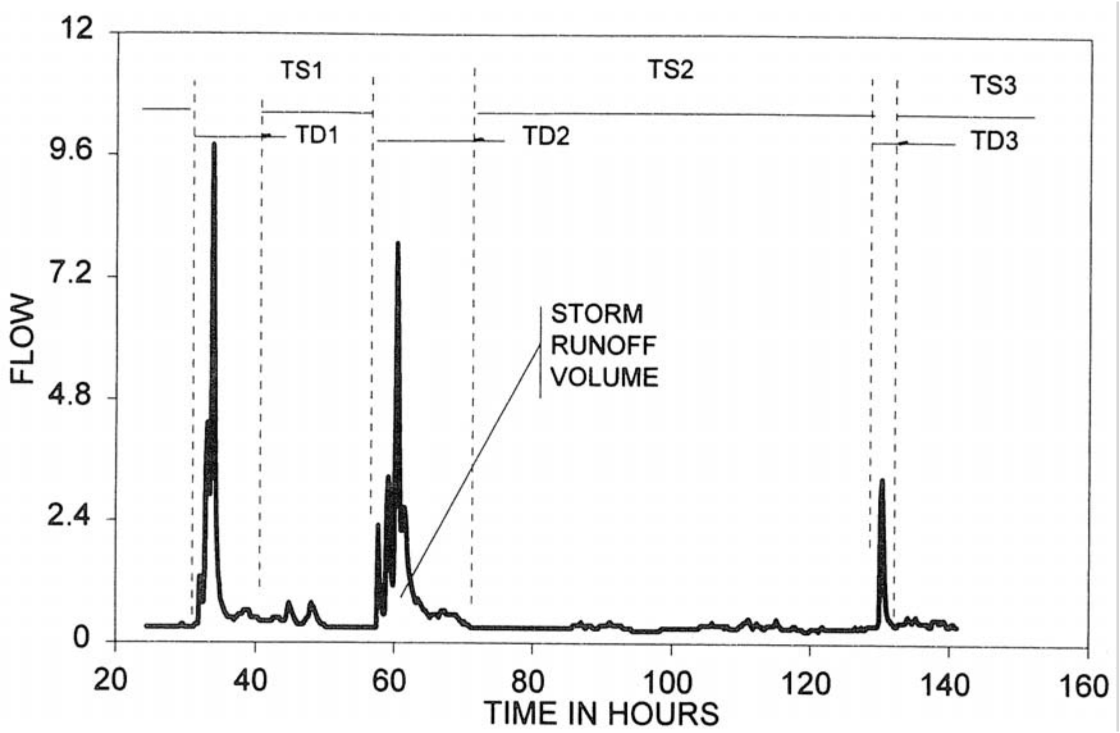

Figure 1. Time series of storm hydrographs, their duration and inter-event times.

<u>Time Variable Parameters of Storms During Monitoring Season:</u>

Storm Runoff Inter-Event (Separation) Time:

T_S = Average **s**eparation period between the end of a storm runoff hydrograph and the beginning of the next one in hours,

T_{S50} = The **50th** percentile of storm runoff event **s**eparation periods in hours,

CV_{TS} = **C**oefficient of **V**ariation in storm runoff event **s**eparation periods (T_{SD-S}/T_S), in which $T_{SD\text{-}S}$ = **S**tandard **d**eviation of storm runoff event **s**eparation periods.

Storm Runoff Duration:

T_D = Average **d**uration of storm runoff in hours,

T_{D50} = The **50th** percentile value of storm runoff duration in hours,

CV_{TD}= **C**oefficient of **V**ariation in storm runoff **d**uration (T_{SD-D}/T_D), in which $T_{SD\text{-}D}$ = **S**tandard **d**eviation of storm runoff **d**uration.

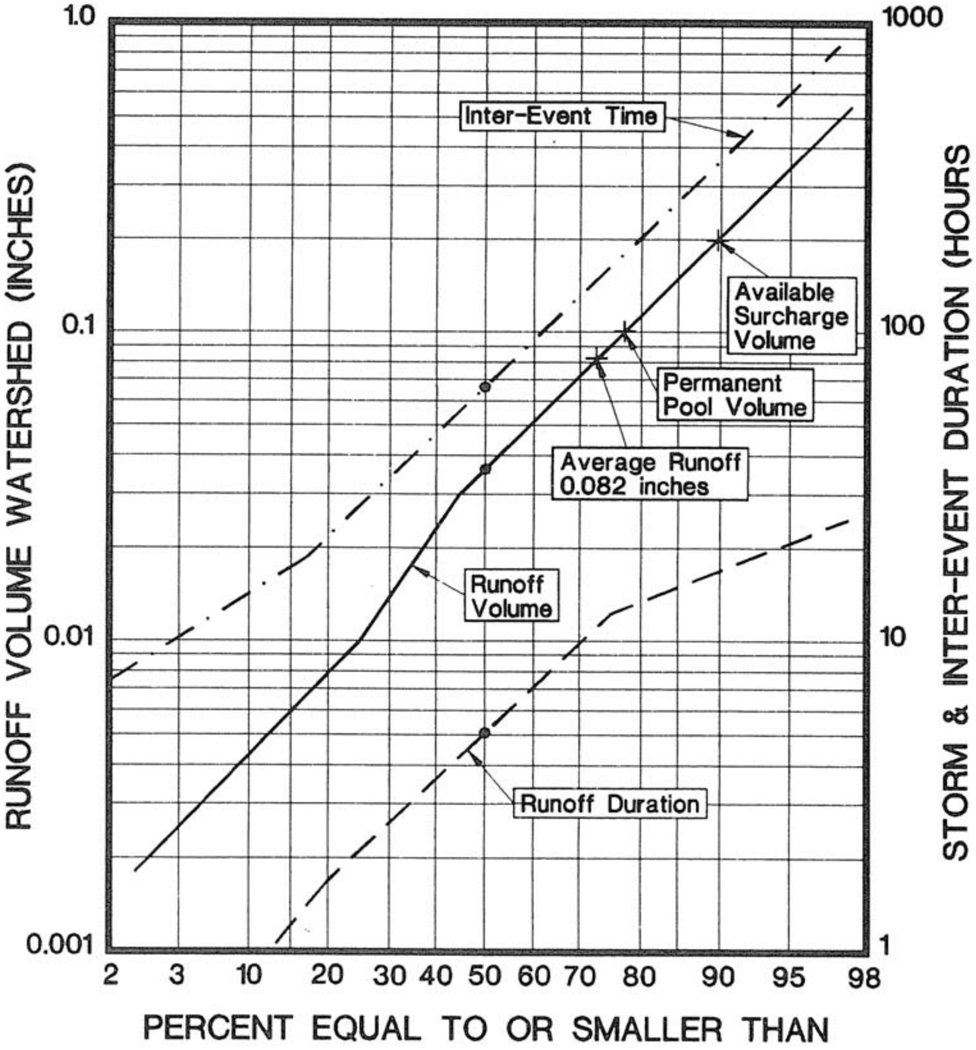

Figure 2. Example of cumulative probability distribution of Surface Runoff, Storm Separation and Inter-Event Time for one BMP site (After Urbonas et al, 1994).

PARAMETERS FOR RETENTION PONDS

Figure 3 illustrates a plan view of an idealized stormwater retention pond used as a structural BMP. Retention ponds such as this always have some surcharge detention storage above the permanent pool water surface.

There are several pollutant removal mechanisms at work within a retention pond. These include sedimentation during runoff events and in between runoff events, other physical processes, chemical processes and biological processes. As a result, more information needs to be reported for these types of facilities than for facilities that remove pollutants primarily though physical processes. Also, keeping these points and Equations 3 through 5 in mind, the following set of parameters emerge as needing to be reported with removal efficiency data of retention ponds.

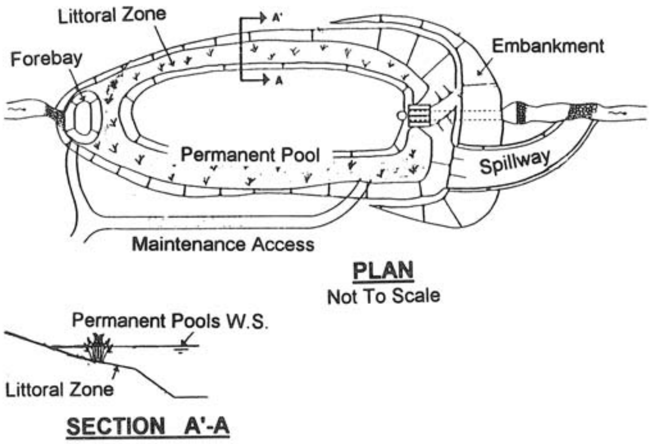

Figure 3. Plan of an Idealized Retention Pond. (After UDFCD, 1992)

Surface Area and Pond Layout Parameters:

A_P = Surface **a**rea of the **p**ermanent pool in m^2 (ft^2),

A_L = Surface **a**rea of the **l**ittoral zone (zone $\leq$ 0.5 m (1.5 ft) deep) in m^2 (ft^2),

A_D = Surface **a**rea of the top of the surcharge **d**etention basin in m^2 (ft^2),

L_P = **L**ength of the **p**ermanent pool or flow path in m (ft),

L_D = **L**ength of the surcharge **d**etention basin in m (ft),

A_F = Surface **a**rea of the **f**orebay in m^2 (ft^2),

L_F = **L**ength of the **f**orebay in m (ft).

Basin Volume Parameters:

V_P = **V**olume of the permanent **p**ool in m^3 (ft^3),

V_D = Design volume of the surcharge **d**etention basin above the permanent pool's water surface in m^3 (ft^3),

V_F = **V**olume of the **f**orebay in m^3 (ft^3).

Emptying Time Parameters:

T_E = Time needed to **e**mpty 99% of V_D assuming no inflow takes place while the surcharge pool is emptying, in hours, and

$T_{0.5E}$ = Time needed to **e**mpty the upper one-half of V_D assuming no inflow takes place while the surcharge pool is emptying, in hours.

PARAMETERS FOR EXTENDED DETENTION BASINS

Fugue 4 shows the plan vies of an idealized extended detention basin. Such basins employ sedimentation as their primary pollutant removal mechanism. As a result, Equations 3, 4 and 5 also apply to extended detention basins, but have to be viewed somewhat differently than for a retention pond. In a retention pond, sediments that settle below the overflow outlet level are essentially trapped within the permanent pool and are less likely to be discharged through the outlet. The trapped sediment continues to settle to the bottom of the pond even after the surcharge volume is drained off. In an extended detention basin stormwater empties thorough an outlet located on the bottom. As the sediments settle to the bottom they concentrate within the lower levels of the ever shrinking pool and discharge through the outlet. Unless they are scoured out, only the sediments that deposit on the bottom can be trapped within the basin.

The design for extended detention basins thus requires much longer drain times to permit the sediments to settle onto the bottom of the basin. Current state-of-practice suggests that the emptying time be set at 24 to 48 hours for a volume equal to the average runoff event expected to occur at the design site. Current practice also suggests that extended detention basins be designed to have two levels. The lower level basin is filled frequently by the predominant numbers of small runoff events, while the upper basin is inundated only few times a year. This two layer design significantly improves the upper basin's usability for other community uses.

The list that follows reflects most of the parameters of importance for an extended detention basin. Many of the same parameters that were recommended for retention ponds are repeated for an extended detention basin.

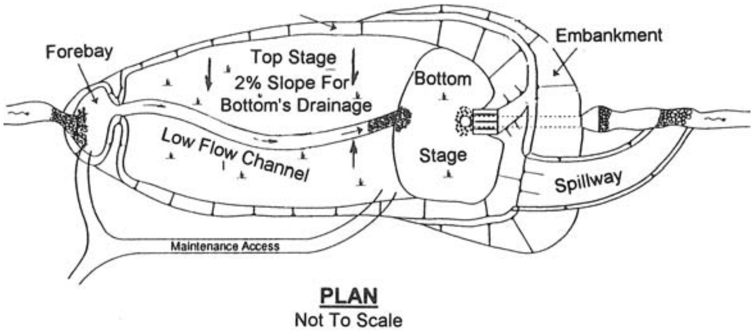

Figure 4. Plan of an Idealized Extended Detention Basin. (After UDFCD, 1992)

Surface Area and Plan Layout Parameters:

A_D = Surface **a**rea of the **e**xtended **d**etention basin in m^2 (ft^2),

L_D = **L**ength of the extended **d**etention basin in m (ft),

A_B = Surface **a**rea of the **b**ottom stage (i.e., lower basin) in m^2 (ft^2),

L_F = **L**ength of the **f**orebay in m (ft).

Basin Volume Parameters:

V_D = Total **V**olume of the **e**xtended **d**etention **b**asin in m^3 (ft^3)

V_B = **V**olume of the **B**ottom stage only of the basin in m^3 (ft^3)

V_F = **V**olume of the **F**orebay in m^3 (ft^3)

Time Variables:

Use the same *Emptying Time* parameters as defined for the retention pond.

PARAMETERS FOR WETLAND BASINS

Figure 5 depicts an idealized wetland basin. Some wetland basins are similar in their operation to retention ponds while others resemble extended detention basins, the distinction between the two being whether or not the wetland basin has standing water or a wetland meadow as its bottom. The pollutant removal mechanisms are probably similar to those found in retention ponds and in detention basins, except that stormwater comes in contact with wetland flora and fauna. This contact and the physical structure of the wetland provide pollutant removals through adsorption and biochemical processes and possibly through reoxygenation of the sediments and detoxification of the water column, processes that may or may not be available in retention ponds and are not available in detention basins.

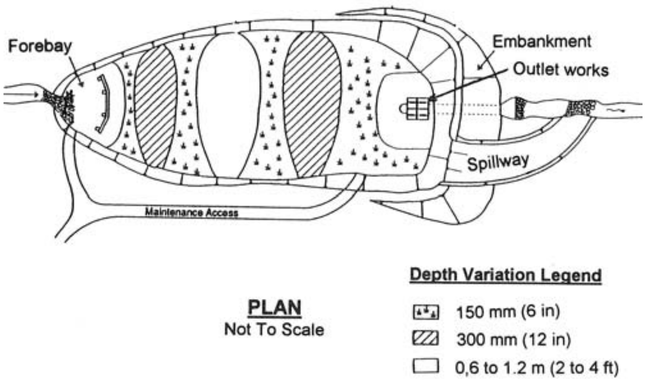

Figure 5. Plan of an Idealized Wetland Basin. (After UDFCD, 1992)

In addition to the parameters of Equations 3, 4 and 5, each performance monitoring program should report parameters that are peculiar to the wetland being studied. Most currently available wetland monitoring data rarely contain such information, often not even reporting many of the parameters commonly being reported for other BMPs. Because the quantification of wetland performance as a BMP is relatively new, very little information can be found in current literature and it is difficult to suggest parameters to report when reporting the performance data of wetland basins. Table 2 and the list that follows it suggest the parameters that appear to be most important, many of which are identical to those recommenced for retention ponds.

TABLE 2. ADDITIONAL GENERAL PARAMETERS TO REPORT FOR WETLANDS

Type of Wetland	Cattail marsh, northern peat land, meadow, palustrine, southern marshland, hardwood swampland, brackish marsh, high altitude riverine, freshwater riverine, mixed (include types), constructed or natural, etc.
Rock Filter?	Is there a rock filter media present in the wetland bottom?
Dominant Plant Species	Lists the dominant plant species in the wetland and the age of these plants, namely, time since their original planting or replanting.

Surface Area and Layout Plan Parameters:

A_P = Surface **a**rea of permanent wetland **p**ool, if any, in m^2 (ft^2),

A_M = Surface **a**rea of the **m**eadow wetland, if any, in m^2 (ft^2),

$P_{0.30}$ = Percent of permanent pool less than 0.30 m (<12 in) in depth,

$P_{0.60}$ = Percent of the permanent pool more than 0.60 m (>24 in) in depth,

A_S = Surface area of the surcharge detention basin's top in m^2 (ft^2),

L_S = Length of the wetland surcharge/detention pool or flow path in m (ft),

A_F = Surface **a**rea of the **f**orebay in m^2 (ft^2),

L_F = **L**ength of the **f**orebay in m (ft).

Basin Volume Parameters:

V_P = Volume of the permanent **p**ool, if any, in m^3 (ft^3),

V_D = Design volume of the surcharge/**d**etention basin in m^3 (ft^3),

V_F = Volume of the forebay in m^3 (ft^3).

Time Variables:

Use the same *Emptying Time* parameters as defined for the retention pond.

PARAMETERS FOR WETLAND CHANNELS

Channels can be designed to have a wetland bottom which are designed to flow very slowly. Figure 6 show a profile for such a channel. When properly designed, the channel's bottom is covered by wetlands, with only the sideslopes having terrestrial vegetation. The flow velocity is controlled by transverse berms, by check dams or by an outlet at the downstream end of a given channel's reach. In the last case, the channel is essentially a long and narrow wetland basin.

The pollutant removal mechanisms in wetland bottom channels are similar to those found in wetland basins, except that contact time of stormwater with the wetland vegetation is likely to be less. Because of the flowing channel nature of this BMP, the following parameters, in addition to those in Tables 1 and 2, should provide the information needed to compare the performance of different installations:

$V_{2\text{-}yr}$ = Average channel velocity during a 2-year runoff event in m/s (ft/sec),

A_D = Surface **a**rea of the wetland bottom in square m^2 (ft^2),

L_D = **L**ength of the wetland channel in m (ft).

Prt = Describe any pretreatment provided ahead of the channel (e.g. detention).

Time Variables.

There are no *Emptying Time* parameters to report for wetland channels.

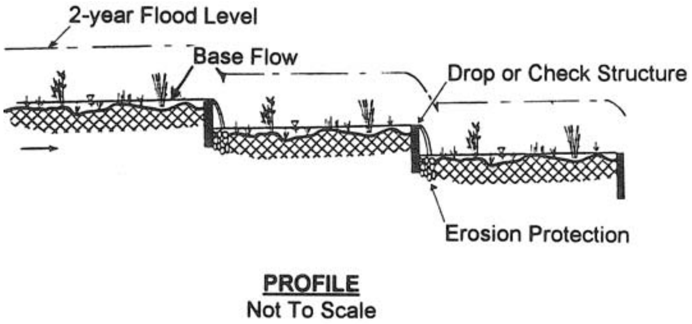

Figure 6. Profile of an Idealized Wetland Bottom Channel. (After UDFCD, 1992)

PARAMETERS FOR SAND FILTERS

Sand filters can be installed as basins or as sand filter inlets. Figure 7 illustrates an idealized filter basin and Figure 8 does the same for a filter inlet. Typically, these installations will have a detention basin or a retention pond (or tank) upstream of the filter to remove the heavier sediment and, if properly designed, some of the oil and grease found in stormwater. However, such a pretreatment basin is not always present. All of the parameters called for a *Retention Pond* or for an *Extended Detention Basin* should also be reported along with the information about the sand filter whenever the filter is preceded by a pre-treatment basin. For example, a filter inlet is often equipped with an underground tank which helps to remove some of the sediment, oil and grease before stormwater is applied onto the filter. Such a tank is similar to a retention pond and all of the parameters associated with a retention pond, such as volume, surface area, length, surcharge volume, etc. should be reported.

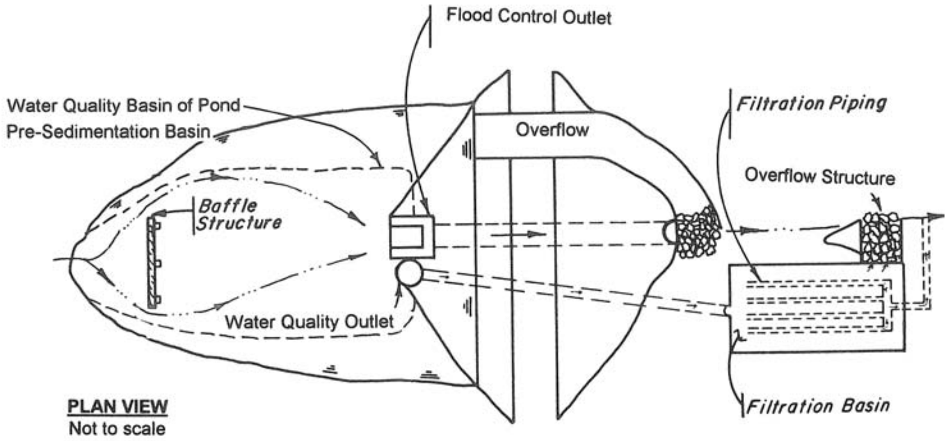

Figure 7. Plan of an Idealized Sand Filter Basin. (After UDFCD, 1986)

In addition to the parameters of the pond or basin associated with the filter, provide the following:

- Dimensions of the installation.
- Depth of various filter material layers.
- Type of filter media, its median particle size (i.e., D_{50}) and its Coefficient of Uniformity.
- Maintenance frequency.
- All associated drainage and flooding problems attributed to the installation because of its configuration size, maintenance practices, etc.

Time Variables:

Use same parameters for *Emptying Time* as defined for the retention pond.

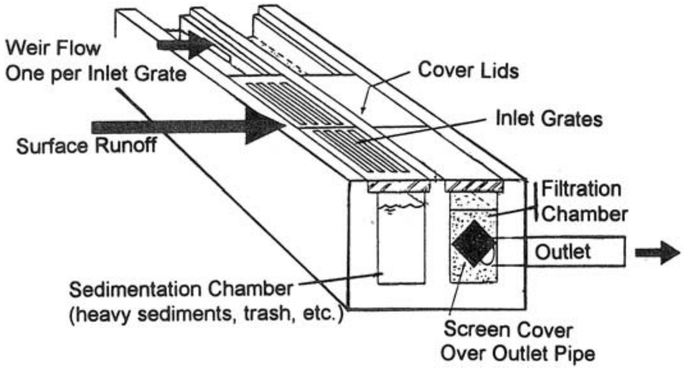

Figure 8. An Idealized Sand Filter Inlet. (After Shaver, 1993)

PARAMETERS FOR OIL, GREASE AND SAND TRAPS

An oil, grease and sand trap is an underground tank, similar to the one illustrated in Figure 9. It is nothing more then a special configuration of a retention pond. As a result, report all of parameters listed for a *Retention Pond* should also be reported for these installations. Typically these installations have a forebay and an outlet basin. In addition to reporting the parameters for a pond, provide the *dimensions of the installation, details of its design (including skimmers, sorbent pillows, lamella plates, baffles, etc.) and the maintenance provided during the testing period.* Because these type of traps are much smaller than a surface pond, the flow-through velocity is of concern because it can cause trapped oil, grease and sediment to be remobilized and flushed out of the trap. As a result, provide the *average flow velocity that can be expected to occur in this device during a 2-year storm*, which velocity can be used as an index for comparing the performance a variety of installations.

Time Variables:

Use the same *Emptying Time* parameters as defined for a retention pond.

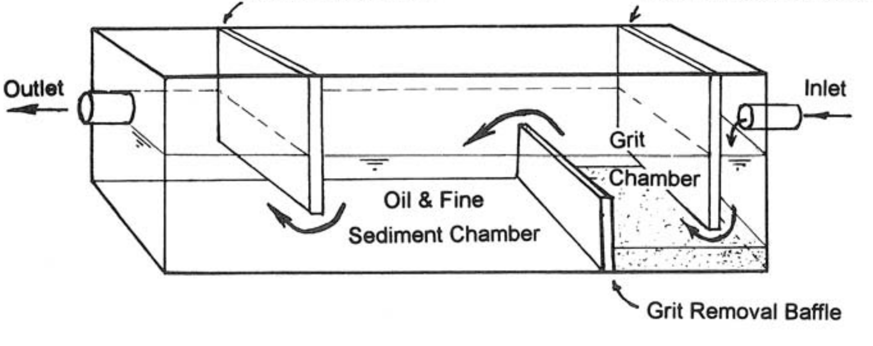

Figure 9. An Idealized Oil, Grease and Sand Trap (After Neufeld, 1994).

PARAMETERS FOR INFILTRATION AND PERCOLATION FACILITIES

An idealized percolation trench is illustrated in Figure 10. For percolation trenches and for infiltration basins report all of the parameters suggested for the *Extended Detention Basin.* In addition, report the following:

- Depth to high groundwater and to impermeable layers below the infiltrating surface of the basin, or below the bottom of the percolation trench.
- The hydraulic conductivity of soils adjacent to percolation trenches and the saturated surface infiltration rates of soils underlying infiltration basins.
- Dimensions of the installation.
- Maintenance needs and associated drainage and flooding problems attributed to the installation.
- Failures to empty out the captured water completely within the design emptying time.

Time Variables:

Use the same *Emptying Time* parameters as defined for a retention pond.

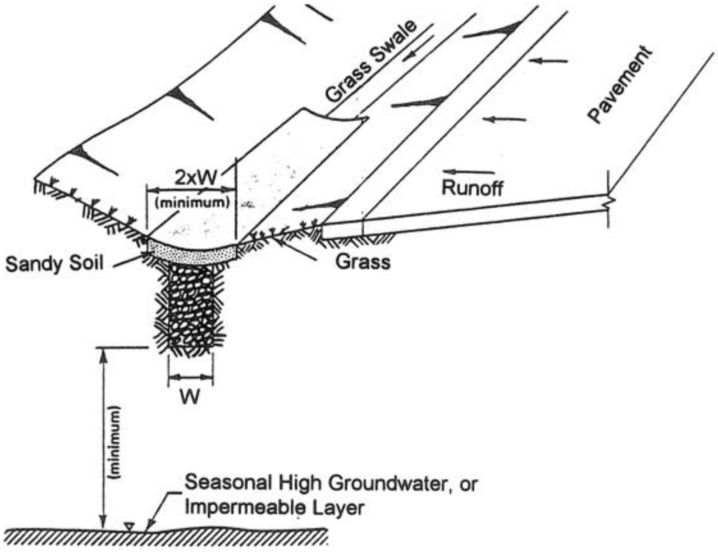

Figure 10. An Idealized Percolation Trench. (After Urbonas & Stahre, 1993)

SUMMARY AND RECOMMENDATIONS

In summary, there is a great need for consistent reporting of various BMP parameters along with field testing data on their performance. Table 3 these parameters. It is recommended that all agencies and organizations that undertake field studies of BMP performance be encouraged to include in their reports and report summaries the information suggested in this paper. Only through a concerted effort by stormwater professionals to report the suggested minimum list of parameters about each installation, or some other list that the research community deems more appropriate, will all of the field research activities yield parametric relationships that refine and optimize structural BMP designs.

FURTHER REVIEW COMMENTS TO ASCE

A paper that presented the concepts and recommendations made in this paper is also being published by the American Society of Civil Engineer, Water Resource Planning and Management Division's Journal. Anyone wishing to comment on this topic and these recommendations is invited to write to the ASCE Journal's services. All comments are welcome as this topic deserves wide debate and discussion.

ACKNOWLEDGMENTS

The author acknowledges the many professionals that contributed to the development of this paper. The initial and pre-final drafts were distributed to approximately 40 individuals, many of who have contributed significantly to the field of stormwater management over the last 25 to 30 years. A special thanks goes to all those that responded with their comments and suggestions. As a result, the recommendations being made in this paper reflect the suggestions, opinions and the experience of many individuals and not only those of the author. Special acknowledgment goes to the following for their specific and extensive review comments and suggestions offered on this topic to the author: Eric Strecker, John Warwick, Betty Rushton and Jim Wulliman.

Table 3. Summary of Site Parameters to Report For BMP Investigations.

Parameter	Ret. Pnd	Ext. Det. Bsin	Wet-land Bsin	Wet-land Chn'l	Sand Filetr	Oil/ Sand Trap	Infilt. & Perc.
Tributary Watershed Area - A_T	Y	Y	Y	Y	Y	Y	Y
Total % Trib. Watershed is Impervious - I_{IT}	Y	Y	Y	Y	Y	Y	Y
% of Impervious Area Hyd. Connected - I_{IC}	Y	Y	Y	Y	Y	Y	Y
Gutter/Sewer/Swale/Ditches in Watershed?	Y	Y	Y	Y	Y	Y	Y
Avarage Storm Runoff Volume - V_R	Y	Y	Y	Y	Y	Y	Y
50th Percentile Runoff Volume - V_{R50}	Y	Y	Y	Y	Y	Y	Y
Coeff. Var. of Runoff Volumes- CV_{VR}	Y	Y	Y	Y	Y	Y	Y
Av. Daily Base Flow Volume - V_B	Y	Y	Y	Y	Y	Y	Y
Average Runoff Inter-Event Time - T_S	Y	Y	Y	Y	Y	Y	Y
50th Percentile Inter-Event Time - T_{S50}	Y	Y	Y	Y	Y	Y	Y
Coeff. Var. of Inter-Event Times - CV_{TS}	Y	Y	Y	Y	Y	Y	Y
Average Storm Duration - T_D	Y	Y	Y	Y	Y	Y	Y
50th Percentile Storm Duration - T_{D50}	Y	Y	Y	Y	Y	Y	Y
Coeff. Var. of Storm Durations- CV_{TD}	Y	Y	Y	Y	Y	Y	Y
Water Temperature - *Temp*	Y	Y	Y	Y	Y	Y	Y
Alkalinity, Hardness & pH	Y	Y	Y	Y	Y	Y	Y
Sediment Settling Velocity Dist. - V_{SD}	Y	Y	Y	Y	Y	Y	Y
Type & frequency of maintenance	Y	Y	Y	Y	Y	Y	Y
Inlet & Outlet dimensions & details	Y	Y	Y	Y	Y	Y	Y
Solar Radiation	Y	N	Y	Y	N	N	N
Volume of Permanent Pool - V_P	Y	N	Y	N	Y	Y	N
Perm. Pool Surface Area - A_P	Y	N	Y	N	Y	Y	N
Littoral Zone Surface Area - A_L	Y	N	N	N	N	N	N
Length of Permanent Pool - L_P	Y	N	Y	N	Y	Y	N
Detention (or Surcharge) Vol. - V_D	Y	Y	Y	N	Y	Y	Y
Detention Basin's Surface Area - A_D	Y	Y	Y	N	Y	Y	Y
Length of Detention Basin - L_D	Y	Y	Y	N	Y	Y	Y
Brim-full Emptying. Time - T_E	Y	Y	Y	N	Y	Y	Y
½ Brim-full Emptying Time - $T_{0.5E}$	Y	Y	Y	N	Y	Y	Y
Bottom Stage Volume - V_B	N	Y	N	N	N	N	N
Bottom Stage Surface Area - A_B	N	Y	N	N	N	N	N
Forebay Volume - V_F	Y	Y	Y	N	Y	Y	Y
Forebay Length - L_F	Y	Y	Y	N	Y	Y	Y
Wetland Type, Rock Filter Present?	N	N	Y	Y	N	N	N
% of Wetland Surface at $P_{0.3}$ & $P_{0.6}$ Depths	N	N	Y	Y	N	N	N
Meadow Wetland Surface Area - A_M	N	N	Y	Y	N	N	N
Plant Species and Age of Facility	Y	Y	Y	Y	N	N	N
2-year Flood Peak Velocity	N	N	N	Y	N	Y	N
Depth togroundwater or impermeable layer	N	Y	Y	N	N	N	Y

REFERENCES

Camp, T.R., "Sedimentation and Design of Settling Tanks," *Trans. of the Am. Soc. of Civil Engrs.* Paper No. 2285, pp. 895-958, ASCE, New York, NY, 1946.

Dobbin, E., "Effectiveness of Turbulence on Sedimentation," *Trans. of the Am. Soc. of Civil Engrs.* Paper No. 2218, pp. 629-678, ASCE, New York, NY, 1944.

Grizzard, T.L., Randall, C.W., Weand, B.L., and Ellis, K.L., "Effectiveness of Extended Detention Ponds," *Urban Runoff Quality*, ASCE, New York, NY, 1986.

Neufeld, Curtis, "Design Concepts for a Sediment & Oil Trap Vault," preliminary design details of BMP evaluation effort, Internal Technical Note of the Urban Drainage and Flood Control District, Denver, CO, 1994.

Shaver, E., "Beach Community Adds Sand Filters to Storm Drains," *Water Environment and Technology*, Water Environment Federation, Alexandria, VA, May, 1993.

UDFCD, "Chapter 15 - Water Quality," *Douglas County Storm Drainage Design and Technical Criteria*, jointly funded publication of the Urban Drainage and Flood Control district and Douglas County, Denver, CO, 1986.

UDFCD, *Urban Storm Drainage Criteria Manual, Volume 3 - Best Management Practices*, Urban Drainage and Flood Control, Denver, CO, 1993.

Urbonas, B.R. and Stahre, P., *STORMWATER Best Management Practices and Detention for Water Quality, Drainage and CSO Management*, Prentice Hall, Englewood Cliffs, NJ, 1993.

Urbonas, B.R., Vang, B. and Carlson, J., "Joint Pond-Wetland System Performance in Colorado," *Water Policy and Management: Solving Problems*, p. 384-387, ASCE, New York, NY, 1994.

KEY WORDS

Best Management Practices

Field Testing

Monitoring

Paramers

Performance

Standardization

Stormwater

Water Quality