METHODOLOGY FOR CALCULATING NUTRIENT LOAD REDUCTIONS USING THE FSA ASSESSMENT TOOL

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January 2012

The FSA Load Reduction Assessment Tool (Assessment Tool) may be used to estimate removal of nutrient loads resulting from certain municipal stormwater operation and maintenance practices in Florida. The tool provides statistically significant numeric values (mg/kg) for total nitrogen (TN) and total phosphorus (TP), that are associated with particulate matter (solids) which are typically transported by stormwater (Sansalone 2011, Final Report). These solids are deposited initially on roadways and other landscapes, and eventually accumulate in catch basins, drainage conveyances, and BMPs such as hydrodynamic separators and other sediment trapping devices (Sansalone 2007). The term BMP used herein does not refer to conventional retention or detention systems or "ponds." The routine maintenance and cleaning of stormwater conveyances and other infrastructure actually removes small amounts of TN and TP with every "bucket" of sediment collected and properly disposed of. However, the sheer volume of material removed on an annual basis results in significant nutrient load reductions to surface waters.

This Assessment Tool is based on the 2011 Final Report (Sansalone et. al. 2011), and provides quantified values of the mass fraction of TN and TP associated with solids typically accumulated in BMPs, catch basins, and those solids collected by street sweepers. The use of this tool allows municipalities to provide fairly rudimentary measurements of weight or volume of material removed, while generating scientifically defensible values for the associated TN and TP.

The values to use to convert the amount of solids into TN and TP loads are summarized below and are included in the spreadsheet Assessment Tool.

Maintenance Category	TP (mg/kg)	TN (mg/kg)
Street Sweeping	361	563
Catch Basin cleaning	417	679
BMP cleaning	364	899

COLLECTION OF SOLIDS

All nutrient calculations resulting from use of the Assessment Tool are related to the weight or volume of solids removed. ***Accordingly, operation and maintenance staff must measure either the volume or weight of material removed.*** At least initially, there is no substitute for actual measurements.

Note that it is anticipated that after some period of data collection and/or calibration of frequently used equipment, that certain “rules-of-thumb” may be used to estimate the weight or volume of solids with a high degree of confidence. For example, after numerous measurements related to the volume of a “full truck,” it should be possible to estimate the field weight of the solids, when the truck is full. Over time, perhaps one year, municipalities may have enough data collected to “calibrate” their various equipment types and transport vehicles in order to simply “count trucks” (as a simplified example).

In every case, maintenance activities and associated weights or volumes of solids must be measured or accurately estimated, and then recorded. These data should be summarized and tracked (for example, in an Excel spread sheet) by the maintenance supervisor or director’s office on a routine, regular basis.

Measurement of Weight of Solids

The most direct measurement available involves the weight of solids removed. For example, if street sweepings are collected and disposed of at a landfill, the scale at the landfill can provide the net weight of the solids that are collected. The same would be true for any maintenance activity that disposes of collected solids at a landfill. Alternatively, a municipality may have ready-access to a vehicle scale where the tare weight of the vehicle (empty truck), and the total weight (full truck), can be measured. The difference provides the field weight of the solids removed.

Measurement of Volume of Solids

In some cases, it may be more convenient to measure or estimate the volume of solids removed. One advantage of using volume measurements is that the operator does not need to estimate moisture content in order to convert from field values to equivalent dry mass. For our purposes, it may be assumed that the volume of materials is relatively unchanged with respect to the amount of sediment “wetness.”

As an example, the capacity (cubic feet) of a street sweeper should be known or should be obtainable. So, when a street sweeper is full, the volume of solids should be known with a fairly high degree of accuracy. Similarly, transport trucks have measurable bed volumes that would allow a fairly accurate estimate of the volume associated with a “full bed”. Also, volume calibrations for transport vehicles would also allow for estimates related to half-full truck beds, etc.

Alternatively, if temporary storage yards are used for “dumpage” from various vehicles (vactor trucks, etc.), material piles can be physically measured, and subsequently volumes (cubic feet) recorded.

ADJUSTMENTS TO FIELD VALUES

All values gathered from the field, either by weight or volume, must be adjusted to account for the field condition of the material. The Assessment Tool requires the input of the equivalent weight of ***dry*** solids. The Tool provides an adjustment for moisture content and for specific gravity, as needed for conversion of field weights and field volumes into equivalent "dry" weights.

Adjustments to Weight Values

For weight measurements of solids removed, an estimate of the relative wetness (moisture content) is required in order to calculate the equivalent dry weight. Unfortunately, the 2011 study did not collect sufficient samples to develop statistically valid values for moisture content or bulk density. Accordingly, MS4s will need to collect additional data during the next year to help develop these values. DEP and FSA will enter the data into a data base and develop the final values once the data has been submitted to DEP. For the near-term, moisture contents of 26%, 21% and 6% should be used for BMPs, Catch Basins, and Street Sweepings, respectively, as input for the Assessment Tool. These are the median values from the Final Report (Sansalone et.al., 2011).

Adjustments to Volume Values

For volume measurements of solids removed, it is necessary to convert the volume into an equivalent dry mass. This conversion is calculated by the Assessment Tool but requires the input of a representative bulk density. As noted above the 2011 did not have sufficient data to develop a statistically valid value for bulk density and additional sampling will be needed to develop it. For the near-term, a dry bulk density of 1.36 (specific gravity) should be used. This translates into approximately 84.9 pounds of dry material per cubic foot of solids.

Sampling Protocol for Moisture Content and Bulk Density

As indicated above, a certain amount of field sampling will be required in order to confirm typical values for both moisture content and bulk density. Moisture content and bulk density are required input items in order for the Assessment Tool to calculate an equivalent "dry weight" for weight and volume measurements, respectively.

For a period of no less than one year, monthly samples should be collected and analyzed for moisture content and bulk density. This must be performed for each of the maintenance activity categories (BMPs, catch basins, and street sweeping).

In order to establish statewide values, each MS4 ***permit group (e.g. Palm Beach County)*** should perform such sampling once each month. The monthly sampling event will consist of replicate samples for each category of maintenance. This equates to one replicate sample each for BMPs, catch basins, and street sweepings for a total of six samples, performed once each month, for each permit group. If each of the maintenance categories is not conducted each month, then collect additional samples for that category in subsequent months. Each permit group needs to provide a total of 24 samples from each maintenance category to develop the statistically valid final values.

Sampling is fairly simple and should consist of a representative sample of approximately one liter (or one quart) of solids, collected in a wide-mouth plastic container (polypropylene or HDPE) with a top or lid for keeping moisture inside. The container should be washed and clean. Replicate samples should be collected in each case (i.e., two, one-quart samples). These samples should be tested for moisture content and bulk density. Any lab that performs typical wastewater treatment-type analyses or geotechnical analyses should be able to perform these tests. Equipment requirements are essentially an oven that reaches 50 to 60 degrees C; and a gravimetric balance with accuracy to 0.01 grams. See Appendix A for a description of the method to be used to determine bulk density in gm/cm^3. Be sure to track the date of sample collection and note if it has rained in the last three days prior to sample collection.

Each MS4 group should report the monthly sampling results as an attachment to their MS4 Annual Report. The attachment should consist of an Excel spreadsheet that includes the maintenance category, the date of sample collection, the rainfall conditions, the lab values for moisture content and bulk density. DEP will enter the data into a spreadsheet and will work with FSA to develop the final statistically valid values for moisture content and bulk density.

SUMMARY STEPS

In summary, the use of this Assessment Tool can be distilled into the following basic steps:

1. Perform O&M activities – collect solids, noting the date of collection.
2. Each truck load, or other load of solids removed, must be field-weighed; or the volume estimated; and recorded in a tracking system such as a spreadsheet. Be sure to track either by pounds of cubic feet of solids, as appropriate. For example, for the week of March 20, 2011, approximately 10,000 pounds of solids were collected from street sweepers.
3. For a period of one year, collect one replicate sample each month for each of the three categories of maintenance. Be sure to track the date of sample collection and the rainfall conditions. This means each permit group needs to collect a total of 72 samples; 24 from street sweepers, 24 from catch basins, and 24 from other BMPs such as hydrodynamic separators.
4. Run the Assessment Tool with the data from the period of interest, such as one week or one month. Input weight or volume values and input moisture content and bulk density. The calculation results in pounds (or kilograms) of TP and TN removed.
5. Track accumulated weekly or monthly removal values, and report cumulative values as needed (annual load reductions).

Implementing the assessment tool as outlined above will certainly require some training and additional effort for the maintenance staff. However, the results of such tracking and reporting results in extremely large savings for any municipality that is required to reduce nutrient loading. Further, tracking load reduction values associated with various activities and land uses allows managers to focus resources on activities that result in the most efficient use of maintenance dollars.

REFERENCES

Sansalone, John J.; Raje, Saurabh; Berretta, Christian, 2011. *Quantifying Nutrient Loads Associated with Urban Particulate Matter (PM), and Biogenic/Litter Recovery Through Current MS4 Source Control and Maintenance Practices.* University of Florida College of Engineering. Final Report to the Florida Stormwater Association.

Sansalone, John J.; Rooney, Robert M., 2007. *Assessing the Environmental Benefits of Selected Source Control and Maintenance Practices for MS4 Permits.* University of Florida College of Engineering; Michael Bateman & Associates. Final Report to the Florida Stormwater Association.

APPENDIX

UF PROCEDURE FOR MEASUREMENT OF DRY BULK DENSITY IN THE LAB

The most direct measurement of stormwater solids involves the weight of the solids removed. For example, if street sweepings are collected and disposed of at a landfill, the scale at the landfill can provide the net weight of the solids that are collected. However, the Assessment Tool requires the input of the equivalent weight of ***dry*** solids which requires knowing the moisture content. The Tool provides an adjustment for moisture content and for specific gravity, as needed for conversion of field weights and field volumes into equivalent "dry" weights.

If the stormwater solids are measured by volume, then the bulk density must be known to convert dry volume of recovered material to a dry mass. This paper decribes the procedure for measuring dry bulk density in the lab.

1. Samples of solids are collected in cleaned, rinsed and dried 2-L wide-mouth polypropylene containers . Document in writing the observed state of moisture in the sample by visual observation and by touch. For example, visually dry, damp, moist, wet, saturated, mainly water. This will be important in the laboratory when estimating the drying time required. From the MS4 study, examples of collected samples with varying moisture content are shown in Figure 1.
2. Turn on the oven in the laboratory and set it to 50 to 60˚C. The oven utilized in the UF study is shown in Figure 2. Temperature is checked with a thermometer, digital or otherwise.
3. In a clean completely clean, dry Pyrex baking dish, as shown in Figure 3, pour the collected sample and evenly spread the sample across the base area of the dish. The glass dish must be large enough to contain the entire 2-L sample even if the sample is saturated.
4. Put the sample into the oven when the oven has been pre-heated to the desired temperature. The sample is to stay in the oven for at least 24 hours if the sample moisture content is no greater than moist. Based on the observations made of the collected sample, if the collected sample is dry to moist, 24 hour drying time should be enough to completely dry out the sample for measurement. In case of a very moist or wet sample, longer time duration will be needed to achieve a completely dry state.
5. At the end of the initial 24 hours, check the sample. If the sample still appears damp to moist (usually discerned by color and smell), let the sample continue to dry for another 24 hours. Another check for complete dryness can be performed later while measuring the bulk density.
6. When the sample appears visually and to touch, take the sample out of the oven and allow the sample to cool to room temperature. The sample is now ready for bulk density measurement.
7. The equipment needed to measure bulk density is a 1000 ml graduated cylinder and a 'top-loading' calibrated electronic scale (up to 3000 g with a precision of ± 0.01g) as shown in Figure 4 and Figure 5. All equipment should be clean and dry before use.
8. Zero the scale and then place the graduated cylinder on the scale. Document the weight of the clean cylinder (W_0). Take the cylinder from the balance and place the cylinder so that the dry sample can be pluviated (poured) from 0.5 m height into the cylinder. Usually this is carried out by a longer wide mouth funnel or a wide-mouth cone that is used to guide the dry sample being pluviated (dropped) into the cylinder

9. Now gradually pluviate the dried sample into the graduated cylinder; we usually do this with a glass beaker used to scoop up dry sample from the Pyrex Dish. Do not exceed the maximum volume marking on the cylinder (1000 mL). We normally fill in the range of 800 to 900 mL, measured to the nearest 5 mL. Take care that the sample surface is level WITHOUT tamping the cylinder (which will change the pluviated dry density). Place the cylinder back on the scale.
10. When a level surface, record the volume (V) indicated on the graduated cylinder by viewing the surface of the sample at eye-level. Also make a note of the corresponding weight measurement on the weighing scale (W_T) to the nearest 0.1 g.
11. The dry weight of the sample (W_S) is the difference between the final weight W_T and the cylinder weight $W_{0.}$

12. The dry bulk density (ρ_B) of the solids is obtained by dividing the sample weight W_S by the measured volume V.

13. Note: If while pluviating (pouring), it is observed that the sample is adhering to the walls of the graduated cylinder, it is a sign of remnant moisture in the sample. This sample needs to be dried further before the bulk density measurement. If this is simply fine dry dust that is attracted to the charged surface of the glass (glass is charged) this is not a concern.

Figures are shown on the following pages. For most MS4s my advice is to work with the MS4 lab associated with their WWTP that has everything they will need. My advice is not to outsource this work; it is carried out far more economically by the MS4, but that is only a recommendation.

Figure 1: Visual indication of moisture content variability that can be observed in collected samples of solids that have been recovered during the MS4 study (can vary from dry to wet (top left)

Figure 2: Oven set to 50 to 60 degrees C for drying out the collected sample placed in Pyrex dishes

Figure 3: Pyrex baking dish for drying collected sample (clean and dry before pouring in sample)

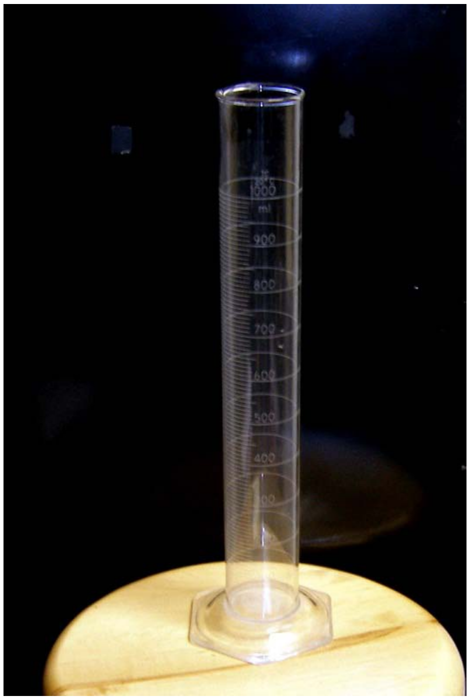
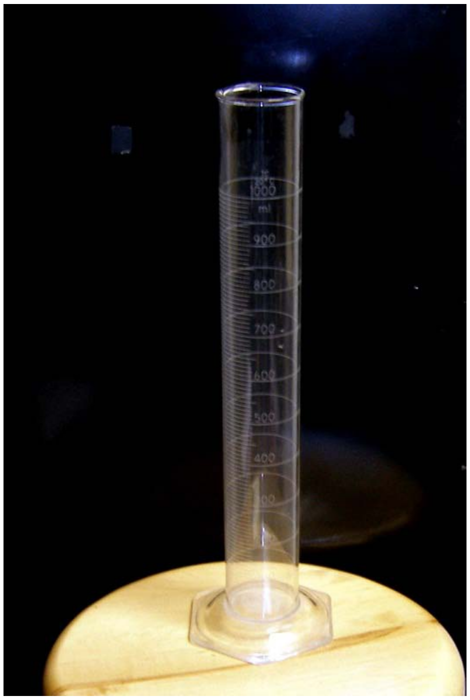


Figure 4: Graduated measuring cylinder (clean and dry before using for measurement of dry bulk density)

Figure 5: Top-loading weighing scale ('zero' scale before using)



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