

TECHNICAL NOTE

Testing of Storm Water Quality Units

TN 1.04
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Introduction

For the last 20 years storm water management has become an increasingly important issue in the United States. This has affected not only the larger metropolitan communities but has begun to become important in smaller rural communities around the country. The areas of interest for these projects are not only storm water quantity but also storm water quality. The ADS Storm Water Quality Unit (SWQU) provides the first step in the treatment train: removal of floating debris, suspended solids, and contaminants.

Development

The ADS SWQU was developed to provide a simple, effective method for the control of storm water quality. The basic design of the unit is an oil grit separator. The unit consists of an upright weir for trapping sediment and an additional inverted weir for trapping the floatable particles such as oils, grease, and debris. This technology has been around for several years and is very effective until higher event storms. During intense storm events, oil grit separators are subject to resuspension of solids and washout of floating particles. Although the efficiency of the early units was fairly high, they had difficulty retaining the particles that were trapped during high volume storm events.

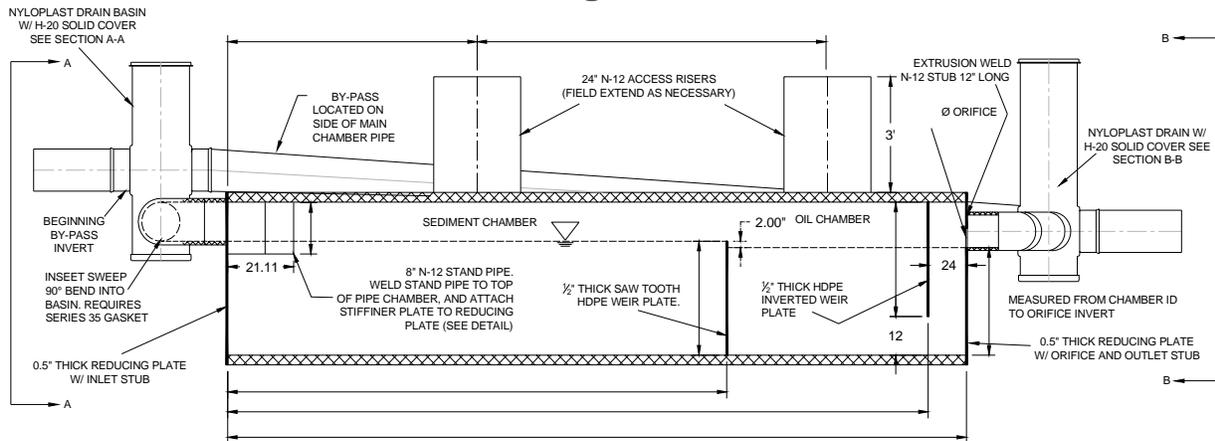
The ADS SWQU utilizes the same technology but improves upon it to provide a more efficient yet still simple method of controlling water quality. The addition of an external bypass allows higher storm volumes to be bypassed *around* the unit without passing through the unit and causing turbulent flow. This allows the lower volume storms — where most contaminants are flushed off of the pavement — to be trapped by the unit and remain there until the unit is cleaned out. In addition, the ADS SWQU is constructed of High Density Polyethylene (HDPE) which is inert and much more chemical resistant than the standard concrete Oil Grit Separators previously used for these applications.

Design

A full discussion of the SWQU design methodology is available in Technical Note 1.01: *Water Quality Units - EPA Phase II, Best Management Practices*. In summary, the SWQU utilizes Stoke's law in order to predict removal efficiencies based on particle size. The units are designed with a sediment chamber, a floatable chamber, and an outlet chamber to provide the stormwater treatment ability of the unit. All flows above the velocity required are routed through the bypass line to prevent the resuspension and removal of trapped materials from the unit. See Figure 1 for a layout of a typical SWQU.



Figure 1



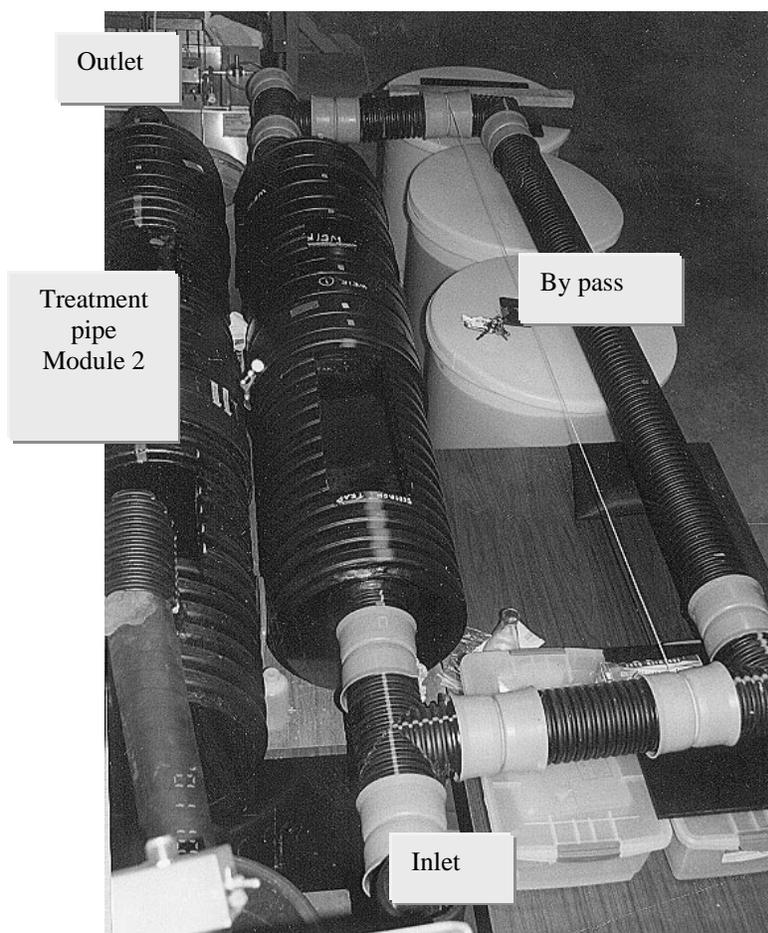
Laboratory Testing and Research

As with any device designed to treat water quality, testing should be performed to determine the removal rates and efficiencies of the device. The ADS SWQU has been subjected to of several different testing protocols to determine the removal rates for both total suspended solids (TSS) and oil and hydrocarbons. Testing has been conducted in both the laboratory and the field. The following summarizes the testing which has been initiated or completed on the ADS SWQU:

Ohio University Scale Model Lab Testing

Testing consists of a scale model test loop including the Water Quality Unit and the bypass line. The model tested was a 12" diameter Water Quality Unit with appropriate scaled appurtenances. This testing was completed in September of 2003. The model was tested for both sediment and oil removal during the evaluation. A layout of the test loop is shown below in Figure 2.

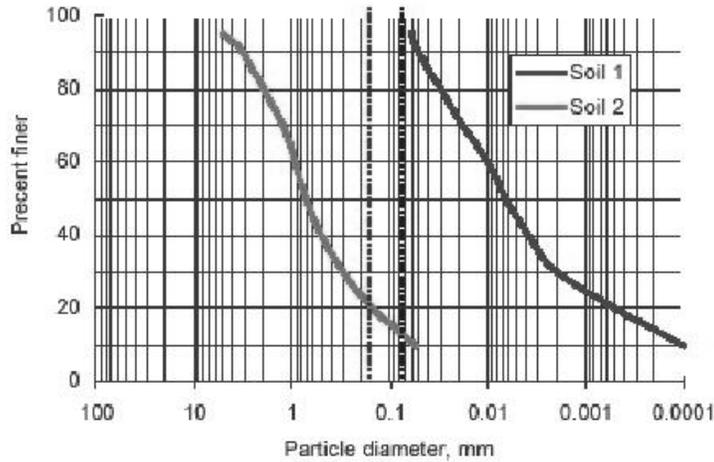
Figure 2



Two different soils were used for the evaluation in the Ohio University Lab study. The soils are shown as Type 1 and Type 2. The Type 1 soil contains particles which are generally smaller than the 200 sieve or 75 micron size. The Type 2 soil contains particles which are generally larger than the 200 sieve or 75 micron size. Sieve analyses for both soil types are shown below in Figure 3 and 4. The vertical lines represent the 140 sieve and 200 sieve particle sizes.

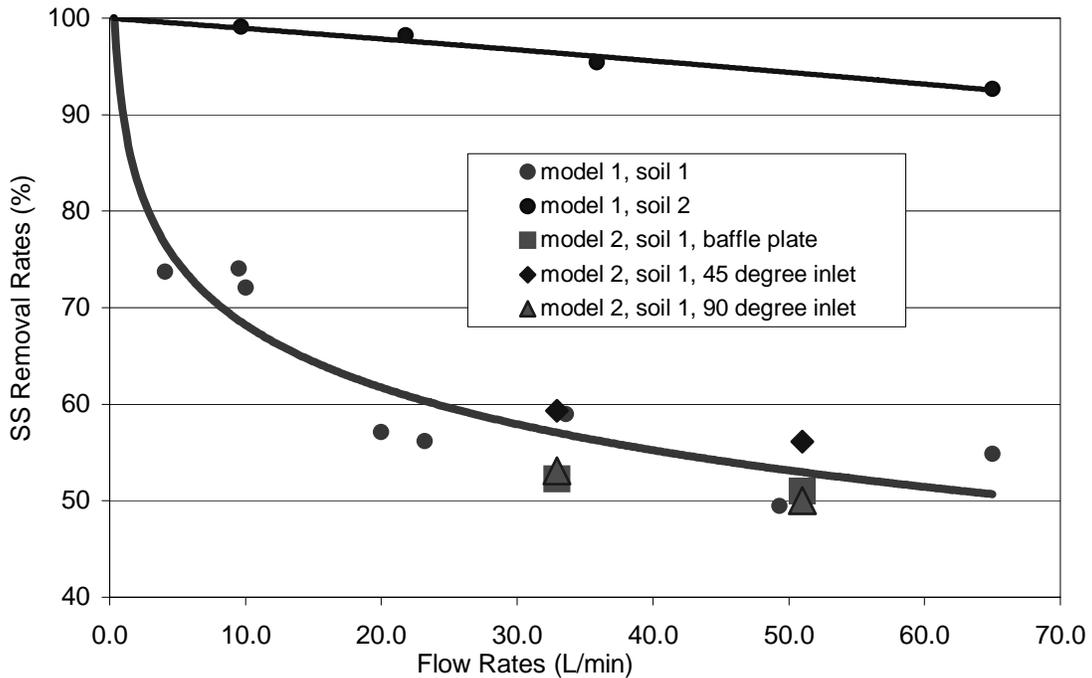


Figure 3



Soil Type 1 showed removal rates of 50 – 60% in the higher flow regimes. This would be expected for this soil type, given the smaller particle sizes and the flow rates used in the experiment. In tests with lower flow rates, the removal rates increased as the residence time increased. This again would be expected with any soil distribution which might be used in the system. Soil Type 1, for the most part, consisted of very fine particles such as silts and clays. The performance of the SWQU using these particle sizes was excellent considering they were outside the design of the unit. A graph of the removal rates for both soil types can be seen in Figure 4.

Figure 4





Soil Type 2 consisted of particles which generally were larger than the 200 sieve and larger than the soils in Type 1. These soils, because of their larger size, allowed for less residence time in the unit and still maintained high removal rates. The removal rates for these particle sizes were over 90% for the flow regimes tested. The soils which were present in this classification range were particles which are targeted for removal in the ADS Water Quality Unit.

Scaling of Lab Data

Laboratory testing is a convenient method for testing practical theories and design principles. It provides a method to use a controlled environment and change the appropriate variables to try and achieve the desired results. This is especially true when scale models can be used to reduce the cost and logistics of testing large devices. Once the testing is complete it must be scaled to the appropriate standard to produce results which can be predicted in the real world. In the case of the ADS SWQU it requires that the unit be scaled up in order for flow rates and SWQU sizes to be appropriate for application.

Two methods for scaling the laboratory data are discussed here. They are the “surface load method” and the “horizontal flow velocity” method.

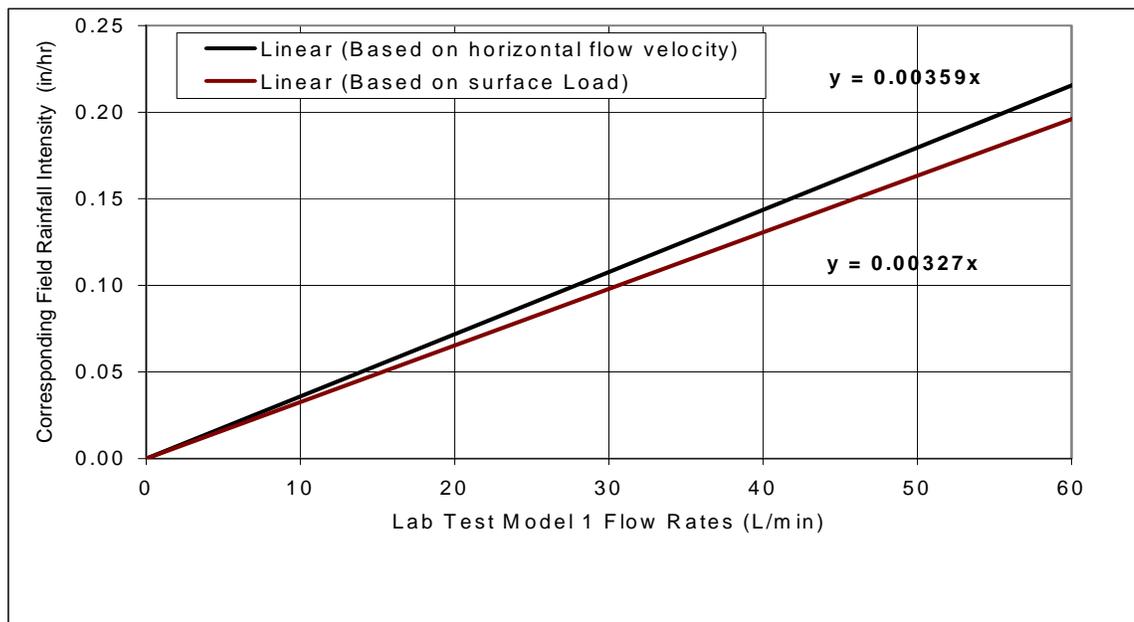
The surface flow method is defined by the following equation:

$$\text{Surface load} = \text{overflow rate} = \text{flow rate} / \text{surface area}$$

(Tchobanoglous and Franklin, 1991)

The horizontal flow velocity simply takes the runoff rate and converts it to a flow based on pipe diameter to get a flow velocity. If both of these methods are used, a chart comparing field rainfall intensity to laboratory flow data can be developed, as shown below in Figure 5.

Figure 5





Alden Labs Maine DEP Laboratory Testing Protocol:

In addition to the scale model testing which was performed at Ohio University, full scale laboratory testing was performed at Alden Laboratories in Holden, Mass. Alden Labs tested the SWQU for conformance with the Maine Department of Environmental Protection Protocol for total suspended solids (TSS) removal. The Maine DEP protocol was put in place to provide a fair and unbiased mechanism for the evaluation of competitive manufactured water quality treatment devices. The protocol calls for the injection of a test media into the treatment flow at a predetermined concentration. The concentration is held at these levels and required residence time is computed. Samples are taken for background levels, influent levels, and effluent levels. The material collected in each sample is then filtered out and appropriately dried. Once the material is dried, it is weighed and the concentration of the total suspended solids is determined.

For the ADS SWQU, a 60-inch diameter, full scale unit was used. The unit was placed in a test loop at Alden Labs which consisted of the SWQU and the necessary support structure to run the tests. The testing was conducted on a standard 60" unit with a few small modifications to provide for accessibility and conformance to the requirements of the system loop. The modifications included an increase in the size of the risers to 36", the introduction of flanges on the inlet and outlet sides of the unit, and the insertion of small diameter pipe at the invert on the inlet and outlet side. The 36" risers were added primarily as inspection risers and for access into the system in case modifications or changes in the monitoring and testing procedure were required. In addition, the large risers provided easier access for the system to be cleaned out between tests. The flanges were provided on the inlet and outlet side of the unit to allow the SWQU to be inserted into the test loop, and to provide a watertight connection for the testing procedure. The small diameter pipe at the invert was put in place to allow the unit to be easily drained and cleaned out for subsequent tests at differing flow rates. In all other regards the unit tested was a standard ADS SWQU with appropriate weir spacing and weir heights. A drawing of the unit is shown in Figures 6A & B.

Figure 6A

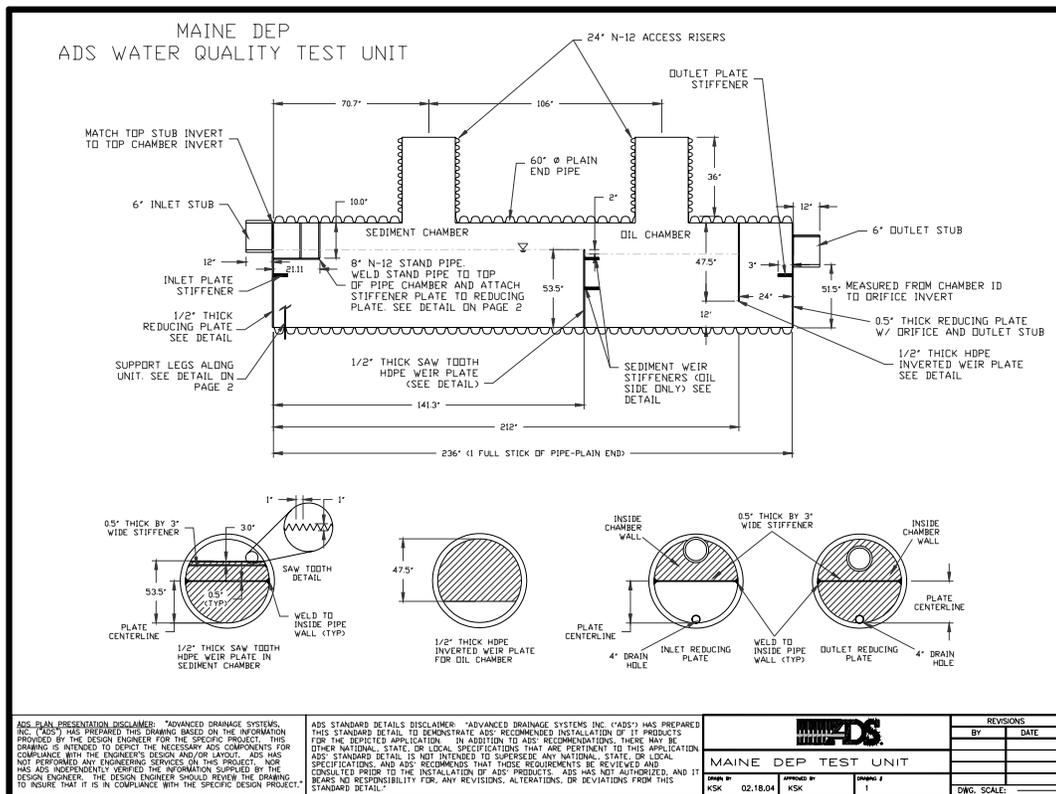
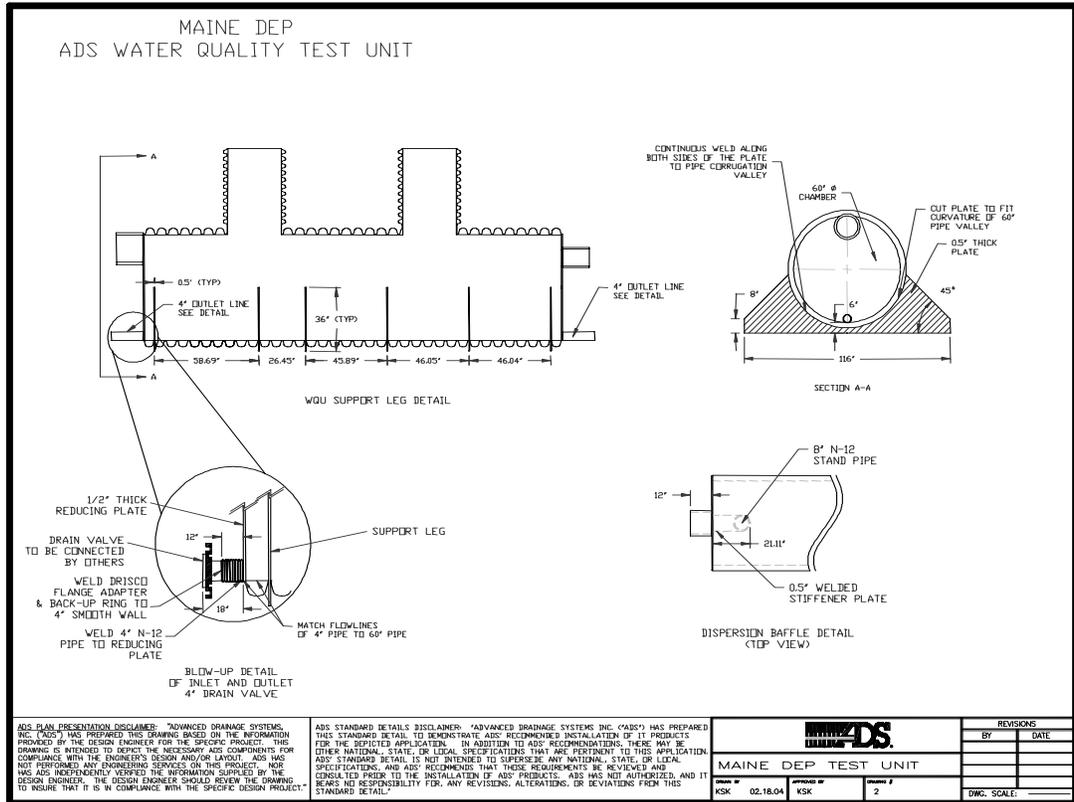




Figure 6B



The testing of the unit was run at various flow rates in order to determine the variance in the levels of efficiency for the SWQU based on flow rate and residence time. The concentration of sediment was approximately 250 mg/L. Each test run consisted of 5 inlet and outlet sample pairs to provide an adequate data set for the testing on the unit. The timing of the samples was such that the residence time in the unit was taken into account to provide samples which were coordinated with each other. A picture of the test unit in the testing loop is shown in Figure 7.



Figure 7



The test media used consisted of two different sands manufactured by U.S. Silica. The F-95 sand has a larger particle size and the OK-110 sand has a smaller particle size. The sieve analysis for each product is shown Table 1.

Table 1

U.S Silica Test Media

| US Std. Sieve | % Retained | |
|---------------|------------|--------|
| | F-95 | OK-110 |
| 30 | | 0 |
| 40 | <1 | 0 |
| 50 | 1 | 0 |
| 70 | 9 | 0 |
| 100 | 60 | 1 |
| 120 | | 15 |
| 140 | 42 | 48 |
| 170 | | 24.2 |
| 200 | 15 | 9.7 |
| 270 | 3 | 1.9 |
| Pan | <1 | 0.2 |

Multiple tests were conducted on the unit to provide a comprehensive analysis of the performance of the unit at various flow rates. The targeted flow rate based on Stoke's Law for the 60-inch Water Quality Unit is 1.47 cfs. Tests were conducted on the unit above and below the unit's anticipated flow rate to determine the performance limitations. For the 1.5 cfs. test, the average removal rate for the OK-110 sand was 88.3%. As a result of this testing, a scaling factor can be used to correlate the results with different size SWQU's and indicates that the design for the units is accurate. Scaling to other size units is accomplished by the following equation:

$$Q_{treatment} = (0.016949cfs / ft^2)(area)$$



As a result, the treatment rates from testing at Alden Labs compare favorably to our recommendations for flow rates through the unit based on the theoretical design. Table 2 shows the tested flow rates compared to the recommended rate.

Table 2

| Product No. | Minimum Treatment Chamber Area (sf) | Maximum treated flow (cfs) (tested) | Design Treated Flow (cfs) (recommended) |
|-------------|-------------------------------------|-------------------------------------|---|
| 3620WQB | 55.50 | 0.94 | 0.7 |
| 3640WQB | 111.00 | 1.88 | 1.6 |
| 4220WQB | 64.43 | 1.09 | 0.86 |
| 4240WQB | 128.86 | 2.18 | 1.83 |
| 4820WQB | 71.40 | 1.21 | 1.13 |
| 4840WQB | 142.80 | 2.42 | 2.39 |
| 6020WQB | 88.50 | 1.50 | 1.47 |
| 6040WQB | 177.00 | 3.00 | 3.12 |

For design purposes the Design Treated Flow rate should be used. As a follow up to the total suspended solids testing, further study of the Water Quality Unit was conducted to determine the oil removal efficiency of the unit.

Alden Labs Oil Removal Testing

The same 60-inch diameter SWQU that was used in the total suspended solids removal testing at Alden Labs was also used for the oil removal study. The unit was again slightly modified to provide for an accurate determination of the oil removal efficiency of the unit. A skimmer wall, retraction assembly, and sidewall blockage areas were added to confine the oil collected so that it could be easily identified

Soybean based vegetable oil was used as the test medium. The density of the oil was approximately 0.92 g/ml. Oil was introduced into the system by use of a pump, which was calibrated prior to testing to determine the relationship between pump speed and the oil feed rate. Once again, the background levels were recorded to determine any influence from the water used in the system. The SWQU was tested with flow rates ranging from 0.5 cfs. to 2 cfs. The oil injection concentration ranged from 50 to 100mg/L. The tests were run for a period of 1 to 2 hours, depending on the influent flow, until approximately 10 liters of oil were injected into the unit. After the flow oil was discontinued, the unit was allowed to operate for a period of time to make sure that all of the oil had been injected into the unit and that the water volume carrying the oil had passed through. Flow rates and removal efficiencies are shown in Table 3.



Table 3

Oil Removal Efficiencies

| Flow Rate (cfs) | Removal Efficiency (%) |
|----------------------------|-----------------------------------|
| 0.5 | 95 |
| 1 | 87 |
| 1.5 | 80 |
| 2 | 57 |

Once again the flow rate targeted for design purposes is 1.5 cfs for the 60" unit. This would show an 80% removal rate. The scaling of this information remains the same as shown in the previous section.

Field Testing and Research

Due to the complexities of field research and the dependence on the weather for cooperation, field testing requires more time and resources. Also, because of the lack of control on all of the variables, the results can be somewhat inconsistent and often require more analysis when completed. However, the field data and testing when approached correctly, can provide valuable information for further enhancements and improvements. The SWQU is being tested in several field installations. Because of the time required to complete these studies none of the current field studies have been completed, but some of them are yielding preliminary information. The studies currently underway are as follows:

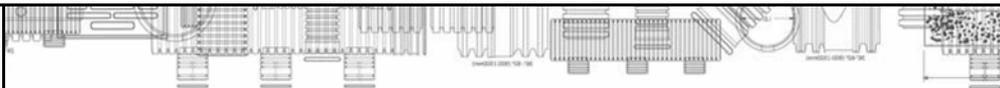
- University of New Hampshire Center for Stormwater Technology**
- Nashville Study of Eight Water Quality Units**
- Mississippi Testing of Water Quality Units**

The status of each study is summarized below.

University of New Hampshire Center for Stormwater Technology

This study consists of a Water Quality Unit and a perforated retention system in series on the site. The site is a study area for several different manufactured and natural stormwater treatment and control devices. The entire 8 acres that the property is located on is the drainage area from a parking lot for the University. The runoff collected from the site is urban and generates sediment, oil and grease. The storm water is metered to all the different devices on the site so that each treatment device receives 1 cfs. The stormwater is sampled on the influent and effluent sides to provide TSS and Floatable Removal Rate. Several other parameters are also tested at this site, including heavy metals, organics, and nutrients. The samplers used are automatic and the information is collected centrally for ease of access.

In addition, the site has been studied from a hydrologic standpoint to provide detailed data on rainfall and runoff rates. From this data, storms which provide adequate parameters are selected to provide the sample data set. A full set of data and the parameters for testing are available upon request. Preliminary results are not publicly available at this time.



Nashville Study of Eight Water Quality Units

This study consists of eight Water Quality Units located at various sites around the metro Nashville area. The testing was conducted by Qore Property Sciences and the final report was issued on June 23, 2005. The eight units were each tested for one storm event within each unit's treatment capacity. The samples were collected in accordance with the Technology Acceptance Reciprocity Partnership (TARP) Protocol for Stormwater BMP demonstrations. The testing was done in accordance with ASTM 3977-97, Standard Test Method for Determining Sediment Concentration in Water Samples, for the range of particles specified by Nashville using the No.10 to the No.140 sieve. Results from the testing are shown in the Table 4.

Table 4

| Location | Unit Diameter | Sieve # | Weight Retained Influent (Grams) | Weight Retained Effluent (Grams) | Percent Removed |
|---|---------------|---------|----------------------------------|----------------------------------|-----------------|
| Occupational Health 4300 Sidco Drive | 48" | 140 | 8.28 | 0.14 | 98 |
| Jim and Nick's BBQ 7004 Charlotte Pike | 60" | 140 | 2.99 | 0.05 | 98 |
| Autowash 7006 Charlotte Pike | 36" | 140 | 1.5 | 0.3 | 80 |
| Shurgard Storage 2360 Gallatin Road | 48" | 140 | 4.59 | 0.21 | 95 |
| Southern Unit: Walgreen's HWY 100 at Old Harding Pike | 48" | 140 | 1.81 | 0.13 | 93 |
| Taco Bell 2904 Gallatin Road | 48" | 140 | 1.21 | 0.08 | 93 |
| High Tech Institute 560 Royal Parkway | 42" | 140 | 0.88 | 0.08 | 91 |
| DMW Expedite 1850 Elm Hill Pike | 48" | 140 | 1.22 | 0.21 | 83 |

In addition to the results summarized in Table 4, an analysis of particle sizes ranging from the No.10 to the No.200 sieve was also conducted. The samples taken were in accordance with TARP protocol and ASTM 3977-97 was used to determine the resulting efficiencies. A summary of the results is shown in Table 5.



Table 5

| Location | Unit Diameter | Sieve # | Weight Retained Influent (Grams) | Weight Retained Effluent (Grams) | Percent Removed |
|---|---------------|---------|----------------------------------|----------------------------------|-----------------|
| Occupational Health 4300 Sidco Drive | 48" | 200 | 8.29 | 0.15 | 98 |
| Jim and Nick's BBQ 7004 Charlotte Pike | 60" | 200 | 3.29 | 0.07 | 98 |
| Autowash 7006 Charlotte Pike | 36" | 200 | 1.7 | 0.31 | 82 |
| Shurgard Storage 2360 Gallatin Road | 48" | 200 | 4.6 | 0.21 | 95 |
| Southern Unit: Walgreen's HWY 100 at Old Harding Pike | 48" | 200 | 1.99 | 0.15 | 93 |
| Taco Bell 2904 Gallatin Road | 48" | 200 | 1.2 | 0.1 | 92 |
| High Tech Institute 560 Royal Parkway | 42" | 200 | 0.94 | 0.1 | 89 |
| DMW Expedite 1850 Elm Hill Pike | 48" | 200 | 1.62 | 0.34 | 79 |

Mississippi Testing of Water Quality Units

The Mississippi testing consists of 5 individual Water Quality Units on a single site in Mississippi. The units are located on a Lowes commercial building site. The units have been installed, have been cleaned out from construction operations, and are ready to begin testing. No results are available at this time.

Conclusions

The ADS SWQU can provide significant treatment for stormwater quality on a variety of stormwater projects. The treatment of both settling and floating pollutants provides a good first level management technique. This provides the opportunity to use the device in both a stand-alone configuration or as the first step in a treatment train.