

# INCLINED PLATE SETTLERS TO TREAT STORMWATER SOLIDS

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## Introduction

- Sedimentation is the preferred treatment method for removing solids from stormwater runoff, either as the sole treatment or as pre-treatment prior to filtration.
- Stormwater sedimentation design typically assumes traditional Type I (discrete) particle settling. Design equations are based on Stokes' Law. Complete sedimentation is assumed for all particles whose settling velocity is greater than the surface overflow rate. The primary controlling factor is the surface area available for settling.
- Various methods – inclined plates, hydrodynamic separators, chemically-enhanced coagulation followed by detention – have been used to enhance sedimentation.
  - Inclined plates increase solids removal by reducing the distance particles travel to the settling point (on the plate) and by slowing the flow rate in the sedimentation area. Their stacked design reduce the footprint required for the sedimentation device. This reduced footprint is optimal for stormwater treatment devices because of the premium placed on urban land area. Inclined plate devices can be installed in traditional catch basins.
- Stokes' Law does not account for the potential of resuspension and transport of previously deposited particles, yet these dynamics are important in the operation of a sedimentation device and in quantifying its efficiency.
  - Stacked inclined plate design redirects the flow to the side of the plates to avoid scour of sediment from the storage area below.
- The Hjulström diagram (Figure 4 shown with results), typically used to determine solids movement from a flat surface such as streambed erosion, graphically represents the interaction of the three processes – sedimentation, solids transport, and erosion – by relating flow rate/velocity to particle size for the three processes.
  - Can the Hjulstrom diagram be used to predict performance of stacked inclined plate device treating urban stormwater runoff?

## Research Objectives

- Evaluate the potential of a stacked inclined plate sedimentation device (Figure 1) to remove solids from simulated stormwater runoff under varying but controlled flow/load conditions (full-scale laboratory test) (Figure 2).
- Evaluate the potential of the same proprietary device (Figure 2) to remove solids from stormwater runoff under varying flow/load conditions at the Harrisburg Public Works Yard.
- Determine if the Hjulstrom diagram (used for bed erosion and transport calculations) could be used to predict the removal efficiency of this stacked inclined-plate sedimentation device.



Figure 1. Model and Full-Scale Inclined Plate Settlers: Terre Kleen™ Treatment Device.



Figure 2. Laboratory set-up for testing full-scale device.



Figure 3. Harrisburg Public Works Yard. Aerial View with Watershed Delineated (L). Upper End of Watershed (R).

## Methods

- Analytes and Analytical Methods:
  - Total Suspended Solids (TSS) – *Standard Methods* 2540D.
  - Suspended Sediment Concentration (SSC) – ASTM-3977
  - Particle Size Distribution (PSD) – Cascading Sieves combined with Coulter Multisizer 3 Analysis for particles between 0.6 – 240  $\mu\text{m}$ .
- Full-scale Laboratory Testing: Three grab samples of influent and effluent collected for each flow/load condition. Triplicates used to assess variability in performance measurement.
- Field Sample Collection: Flow-weighted grab samples collected by automatic sampler throughout the storm. Compositing and per-bottle (bottles not included in compositing process) grab samples analyzed for 15 storm events. Periodic field grab and sampler grab samples collected and analyzed.

## Acknowledgements

- ◆ The authors would like to thank the City of Harrisburg for assisting in the installation and maintenance of the device at the Public Works Yard.
- ◆ The device tested during this research project was the Terre Kleen TK 09 (U.S. Patent 6,676,832 B2), manufactured and distributed by Terre Hill Concrete Products, Terre Hill, Pennsylvania. The funding for the overall project was through the Environmental Technology Verification Program (NSF International, Inc.) and Terre Hill Concrete Products. The results from the ETV phase of the project will be published as a verification statement by NSF International.

## Results and Discussion

- Results of composite samples will be reported as part of ETV Verification Statement and accompanying report. The results reported here are for grab samples collected in conjunction with ETV composite samples and full-scale laboratory testing following NJDEP protocols.
- The sedimentation line on the Hjulström diagram (Figure 4) relates the largest particle that settles in the system to the flow rate.
  - As sedimentation is adversely affected by water temperature, poorer correlation are seen in the winter for both laboratory and field samples. Good correlation seen during other seasons for predicted lines vs. samples.

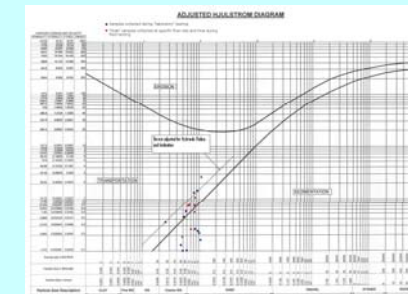


Figure 4. Hjulström diagram relating maximum effluent sample particle size to instantaneous effluent flow rate.

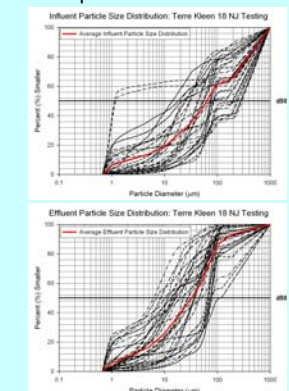


Figure 5. Laboratory particle size distribution – influent (top) versus effluent (bottom).

## Conclusions

- The Hjulström diagram can be used to predict performance of inclined plate settlers treating stormwater runoff. This information, when combined with a characterization of the solids running off the site, can be used to predict overall pollutant removals in the device.
- The tested Terre Kleens were capable of performing at design criteria (removing >95% particles greater than 200  $\mu\text{m}$  when flows were less than 25  $\text{gpm}/\text{ft}^2$ ).
- The laboratory-tested TK 18 reduced the median particle diameter entering the device of 70  $\mu\text{m}$  to a median particle diameter in the effluent of 30, while the field-tested TK09 reduced the influent median particle diameter of 30  $\mu\text{m}$  to an effluent median particle diameter of 7  $\mu\text{m}$ .