About this Project
The Stormwater Solutions for Ohio project is developing science-based tools to minimize stormwater impacts on coastal communities and Lake Erie. Stormwater professionals are collaborating with the project team to generate credible and locally verified performance information about innovative stormwater systems and develop credits and incentives for use of the most effective systems. Two permeable paver installations at the Willoughby Hills community center are among several Low Impact Development (LID) stormwater control measures being monitored as part of this project.

Design
Designing for Monitoring
The original design called for installation of both PICP and bioretention. After several redesigns with community input, the City decided on a design with two bays of PICP featuring different run-on ratios. One bay was quite small and located in a corner of the parking lot where snow storage occurs. The hydraulic loading ratio for this bay is quite high (6.5:1) and will provide useful information on clogging rates under increased flow and debris from snow storage. The larger bay has a hydraulic loading ratio around 2:1, consistent with the ODNR Rainwater and Land Development Manual recommendation. The permeable paver underdrains were connected to a single catch basin in each bay to facilitate monitoring efforts. An existing catch basin positioned at the edge of the paver area receives flow directly off the impervious asphalt, allowing researchers to collect control samples in order to monitor the difference in water quality between the treated and untreated stormwater.

Support & Guidance
The hydrologic performance of the permeable paver area was enhanced to include a 6 inch sump achieved with an upturned elbow on the underdrain that increased the internal water storage layer. The decision to use an upturned elbow instead of elevating the underdrain was made because the engineer felt it would be easier to construct. Subsequent discussions about the configuration of the upturned elbow hypothesized that it would be easier to clean out an upturned elbow if the configuration also included a straight line access to the underdrain.

The project team recommended that the design include a series of baffles (steps) into the subgrade so that the bottom of each step could be constructed with a level grade. These baffles were designed with small check dams, made from #57 stone covered with geotextile, to maximize the infiltrative surface in a sloped parking lot. The final design also accounted for monitoring considerations and redevelopment plans for a pavilion area immediately adjacent to the parking lot retrofit. To effectively incorporate all these modifications, design engineers had to be adaptive and receptive to feedback.

Construction
Overview
Construction was performed by a single certified contractor. This lessened the potential for miscommunication and simplified construction sequencing.

Quick Facts

<table>
<thead>
<tr>
<th>Installed BMPs with Area:</th>
<th>Permeable Paver Large Bay - 3,978 ft²</th>
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<tr>
<td>Permeable Paver Small Bay - 482 ft²</td>
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<tr>
<td>Catchment Area &amp; Loading Ratio:</td>
<td>Large Bay Catchment - 19,651 ft² (~5:1)</td>
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<td>Small Bay Catchment - 3,595 ft² (~7:1)</td>
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<td>Installation Costs:</td>
<td>Permeable Paver Retrofit - $13.05/ ft²</td>
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<td>Recommended Maintenance:</td>
<td>Annual Vacuum Sweep</td>
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<td>Rotary Brush Sweep</td>
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<td>Steel or Hard Rubber Edged Snow Plow</td>
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<tr>
<td>Installation Dates:</td>
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<td>Monitoring - September 2013</td>
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The City of Willoughby Hills received an Ohio EPA SWIF grant to treat stormwater runoff from an existing impervious asphalt parking lot at the Community Center and Public Library by installing two permeable interlocking concrete pavement (PICP) applications. The Community Center parking lot discharges stormwater runoff into an unnamed tributary of Gulley Brook that flows into the Chagrin River. Both stormwater control measures (SCMs) have been monitored for hydrology since fall 2013. In the spring of 2014, this project will also be monitored for water quality.

Site Evaluation
ODNR conducted infiltration testing during construction to verify the infiltration rates of soils beneath each parking area. Infiltration rates varied from 0.00-0.06 in/hr and soils appeared to be compacted fill.
During excavation, the operator scarified the underlying soil using the teeth of the excavator bucket to loosen the soil and reduce compaction of the subgrade, allowing for greater exfiltration post-construction. Next, the underdrains were installed and connected to the existing catch basins. Then Tensar BX1200 Geogrid was laid down on subgrade, water table wells were installed, and the excavated area was filled with a mixture of clean #1 and #2 limestone as the subbase. This layer was graded and a plate compactor was used to interlock the stone. Installation of the concrete curbs followed and was performed by hand to ensure that the curbs were formed correctly and dimensions were in accordance with the design. After curb installation, a 6 inch layer of #57 angular limestone was installed and topped with a 1.5 inch layer of #8 limestone. The last phase of the construction was to install the PICP using a Probst VM-series “PaverMAX” mechanical paver installation system to lower the cost and increase the speed of installation. Areas adjacent to curbs had to be cut by hand and manually fit into place. A layer of #8 stone was swept onto the paving surface to fill the interstitial spaces between the pavers and prevent any movement of the pavers.

Compaction or smearing of the soil surface can decrease infiltration if not properly loosened following excavation.

Construction of a pavilion immediately adjacent to the parking area necessitated a change in curb design. The problem was resolved by using red line mark ups on the site plans to avoid additional design costs. The ability of the contractor to adapt to the new design was crucial in this situation, and experience ensured that the installation was performed correctly without additional cost. Installation of the concrete curbs was made even more challenging by weather conditions. A 27 ft. section of curb had to be replaced because it dried too rapidly during the initial curing process and cracked as a result. The failed section of curb was poured on a day that exceeded 100°F. All the curbs were installed by hand because machine installation is not feasible for a parking lot retrofit unless a margin of error is allowed in the site design to account for variation in curb width.

**Monitoring**

**Equipment & Methods**

Monitoring equipment installation occurred both during and after construction. Water table monitoring wells and time-domain reflectometers (TDRs) were installed during construction, which necessitated coordination between the monitoring team and contractor. The water table wells had to be installed by the contractor during construction so the wells would extend into the subgrade to monitor ponding depth. The TDRs were also installed during construction because they needed to be buried a couple inches deep in the base course of #57 stone. They were positioned along three transects at distances of 1, 3, 5, and 10 feet from the interface between the permeable pavers and the asphalt to measure the progression of clogging across the paver surface. Since clogging may occur more rapidly when there is a higher hydraulic loading ratio, the locations of the three transects all had different loading ratios. Using these measurements, the project team hopes to be able to determine a rate of clogging as a function of the amount of run-on from impervious asphalt. After construction, NCSU researchers fabricated two V-notch weir boxes, and installed them in two separate catch basins to monitor underdrain outflow from each PICP section.

In spring 2014, water quality will also be monitored in addition to hydrology. A broad crested weir box was installed into a catch basin draining a portion of the impervious asphalt to catch untreated water and act as an experimental control. Portable samplers will be used to gather flow-proportional water quality samples from the untreated runoff location, the underdrain of the smaller PICP application, and the underdrain of the larger PICP application. This will enable the project team to characterize the hydrologic characteristics, pollutant concentrations, and pollutant load reduction from this parking lot.

**Preliminary Results**

During the first two months of monitoring, 8 outflow producing events were recorded for the West permeable pavement application at Willoughby Hills. Only three such events were noted at the East application. Two factors probably influenced this: (1) the West application has a much higher hydraulic loading ratio, meaning that more stormwater is forced through a smaller stormwater control measure; this would drive more frequent outflow (2) the West application is used for disposal of snow, whereas much of the snow on the East application was pushed over the back of curb. Each snowmelt occurred, outflow was recorded at the West application, but it often was not observed at the East application. The two largest events (11/17 and 12/22) showed that the East application generally produced greater drainage and larger peak flow rates. These results are related to the greater volume of water and higher flow rate that the East application received during rainfall events.

For questions, please contact:  
Chagrin River Watershed Partners (440) 975-3870  
Old Woman Creek National Estuarine Research Reserve (419) 433-4601  
For more information, please visit the Chagrin River Watershed Partners website (www.crwp.org). Project information can be accessed by selecting “Research Projects” from the “Projects” menu and then clicking on “NERRS Science Collaborative.”