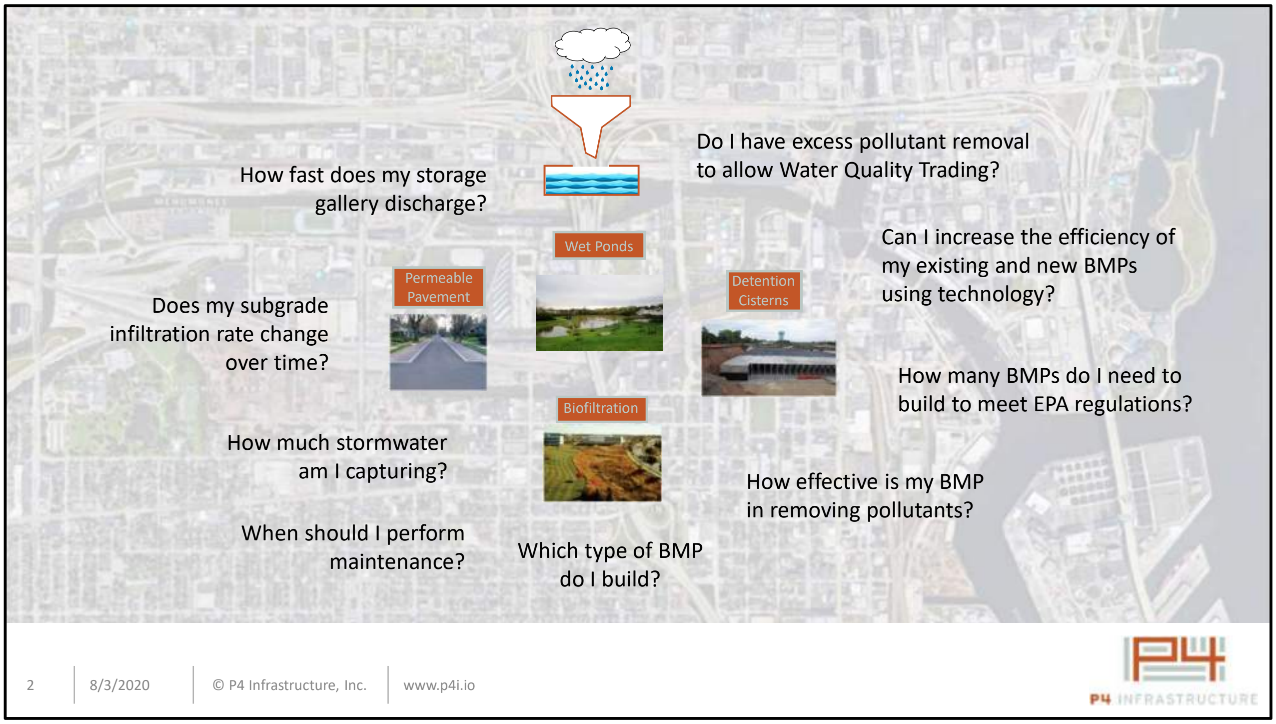
Good morning everyone.

My name is Chris Foley from P4 Infrastructure in Milwaukee, Wisconsin.

I wanted to introduce and discuss P4's products in its stormwater management suite.



Stormwater Best Management Practices (or BMPs) are often surrounded by questions.

Over the last 2 years, we've spoken with a lot of people: consultants, DPW directors, private asset owners, the Wisconsin DNR.

The questions shown here come from those conversations.

Across the nation, local governments and the US EPA have approved municipal separate storm sewer system (MS4) permits and total maximum daily load (TMDL) requirements for countless communities, counties, campuses, and drainage districts.

To comply with the permits, watersheds are delineated and BMPs are identified, designed, and implemented.

Typically, design of BMPs is based upon commonly used computer software that will compute hydrology, hydraulics, and non-point pollution annual loads such as suspended solids (TSS) and phosphorus (TP).

Rainfall distributions and intensities used in these analyses are dictated by state and local ordinances.

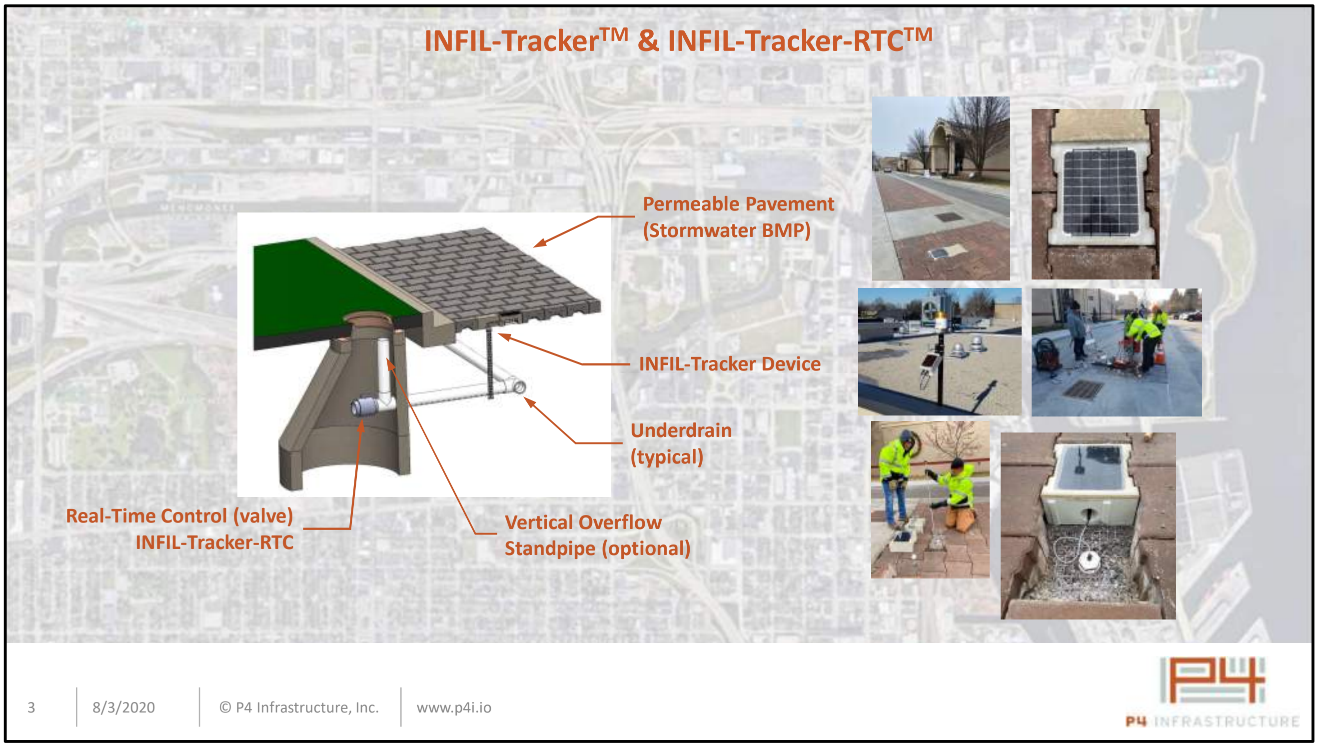
With each new BMP installed, documenting compliance is derived using these computer models.

The actual performance of the BMP asset, whether it is a wet pond, permeable pavement system or a biofilter, is (for the most part) unknown.

This information is important because if the BMP is outperforming initial expectations, the owner of the asset should be able to receive those additional pollution reduction credits that are necessary to achieve permit compliance.

On the other hand, if the asset is under-performing, maintenance and retrofits may be needed to improve the performance of the asset.

These are important questions facing those that own and maintain permeable interlocking concrete pavements.



To answer these questions, P4 developed INFIL-Tracker and INFIL-Tracker-RTC to monitor in-situ performance of permeable pavement systems.

They include:

- a rainfall measurement system (Rain-mX),
- a water level measurement system (INFIL-Tracker),
- and an optional smart valve system to optimize volume control and pollutant removal (INFIL-Tracker-RTC) RTC stands for real-time control.

These systems are installed using off-the-shelf rental equipment by DPW personnel, post-pavement construction.

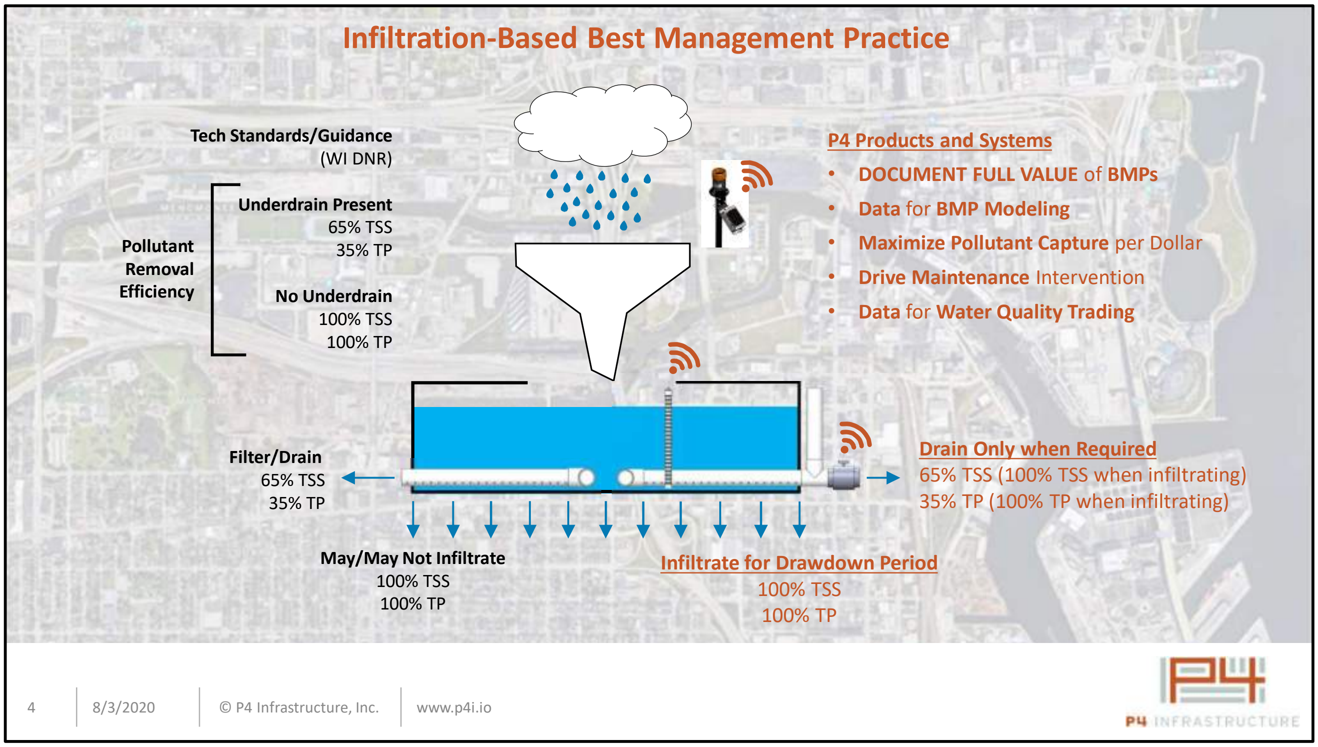
The installation shown here was done in Cudahy, Wisconsin in January of this year.

These systems were developed specifically for permeable pavement systems. An interlocking concrete paver installation would include an alternate concrete block configuration to embed solar panel, battery pack, and data acquisition computer.

P4 would love to chat with ICPI manufacturers interested in this technology to adapt the P4 systems to their concrete paver systems.

INFIL-Tracker and INFIL-Tracker-RTC are equally applicable to bioswales and other infiltration-type BMPs.

P4 also has LIQUA-Level designed for underground cisterns and wet ponds.



Here's a side-by-side scenario schematically showing a permeable pavement BMP with and without INFIL-Tracker-RTC.

On the left side, water exits through infiltration and/or underdrain discharge. The volume exiting the reservoir is a function of site conditions like subgrade seepage rate; size, number, and location of underdrains.

Permeable pavement stormwater reservoirs often include a variety of underdrain configurations.

Underdrain at the top of the reservoir can promote infiltration and serve as an "overflow" device. There are states where drawdown periods need to be maintained. If infiltration rates do not match modeling assumptions, single underdrain at the top of the reservoir will be unusable and can result in fines if the drawdown period is not met.

Underdrains at the top and bottom of the reservoir may be used to address overflow and filtered discharge. The lower underdrain can be used to facilitate filtered discharge and infiltration and the upper drain can be used for overflow.

P4 has measured stormwater movement through reservoirs with underdrains at the bottom only and infiltration rates have been found to be significantly different that what was assumed in the modeling and design of the system. Behavior of these systems will be discussed later in the presentation.

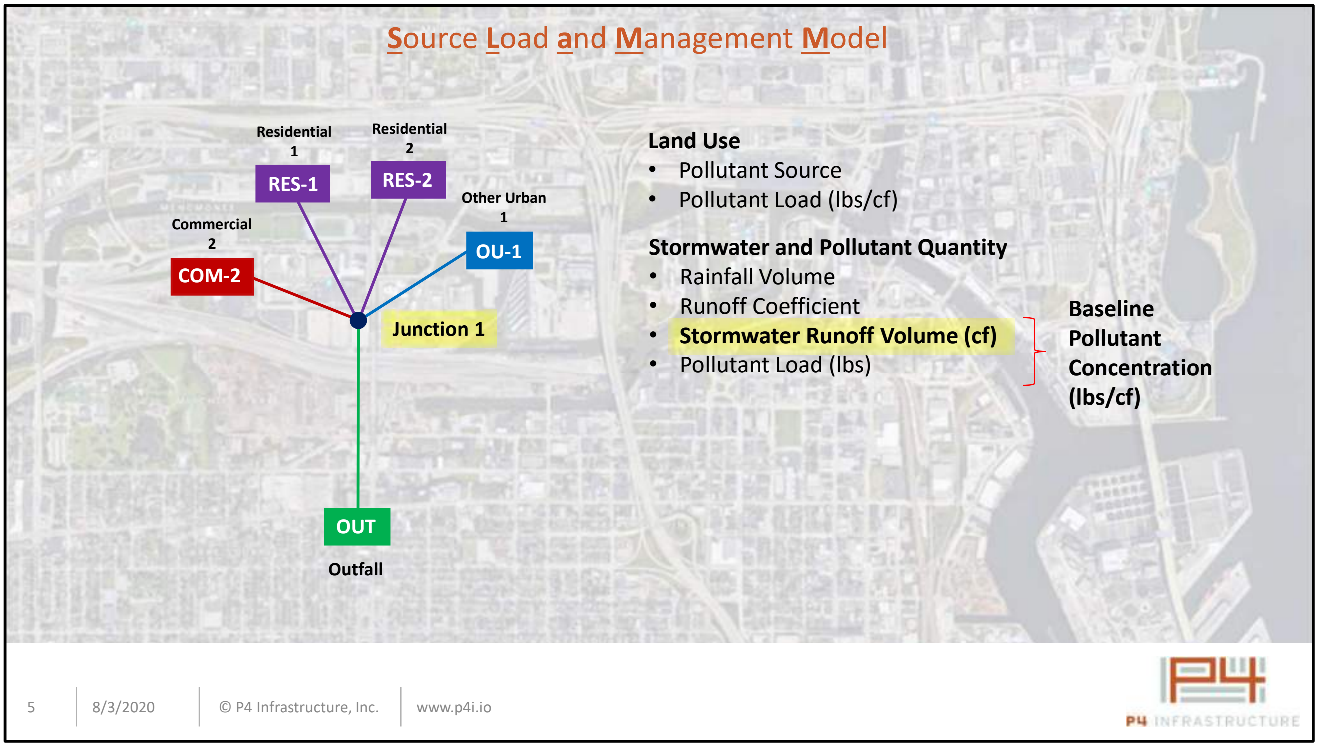
The reason the underdrain is at the bottom with real-time control will be come apparent in following slides, but a brief motivation is given here.

If underdrain is present at the bottom only to filter pollutants from stormwater discharge the pollutant removal efficiencies for suspended solids (TSS) and phosphorous (TP) are 65% and 35%, respectively (in Wisconsin – other states have similar efficiencies).

If infiltration occurs and no flow through an underdrain happens, TSS removal efficiency rises to 100% and TP removal efficiency rises to 100%.

Therefore, if infiltration can be promoted and preserved, the volume of stormwater captured has 100% of the pollutants removed. This means the storage gallery or reservoir needs to be 35% smaller to capture the targeted suspended solids and 65% smaller to capture the targeted phosphorous.

P4 believes that there is an optimal synergy between infiltration from the reservoir and underdrain discharge from the reservoir required by regulation-imposed drawdown periods. The bottom-only reservoir with discharge control helps to pursue this synergy, optimize pollutant removal, and significantly reduce the costs of storage reservoirs.



Let's see how the P4 systems complement stormwater engineering procedures.

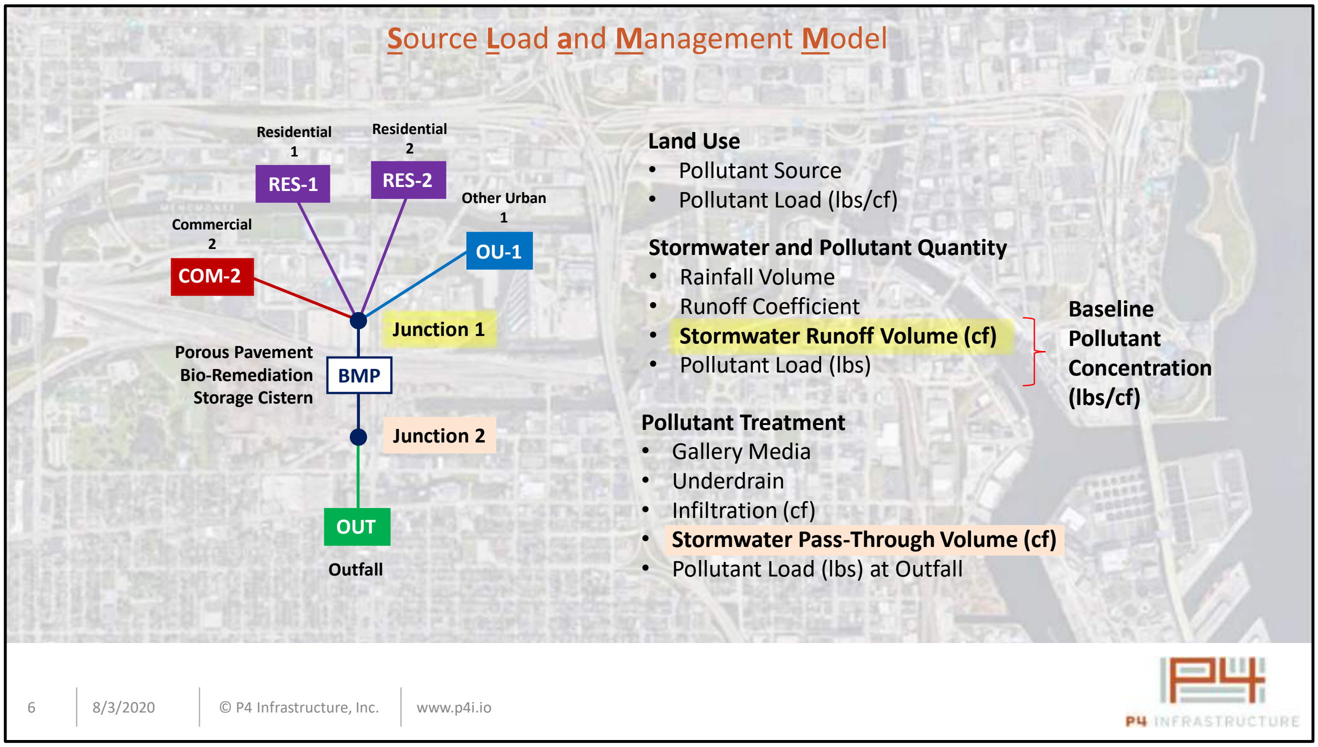
EPA water quality act compliance is often pursued using Source Load Management and Modeling (SLAMM).

Total maximum daily load limitations on watersheds affecting impaired surface bodies of water and municipal separate storm sewer system permit levels of pollutant as defined by the EPA are uniquely able to be addressed using SLAMM and analysis of the results.

Land use defines the pollutant source and the source area defines the pollutant load as shown in the tree diagram. The simplistic diagram omits for clarity other important parameters used in SLAMM (*e.g.* rainfall, pollutant distribution, runoff coefficients, etc.).

SLAMM-based software computes total pollutant load and total stormwater volume generated by each land use and aggregates these at junctions (like Junction 1 shown here).

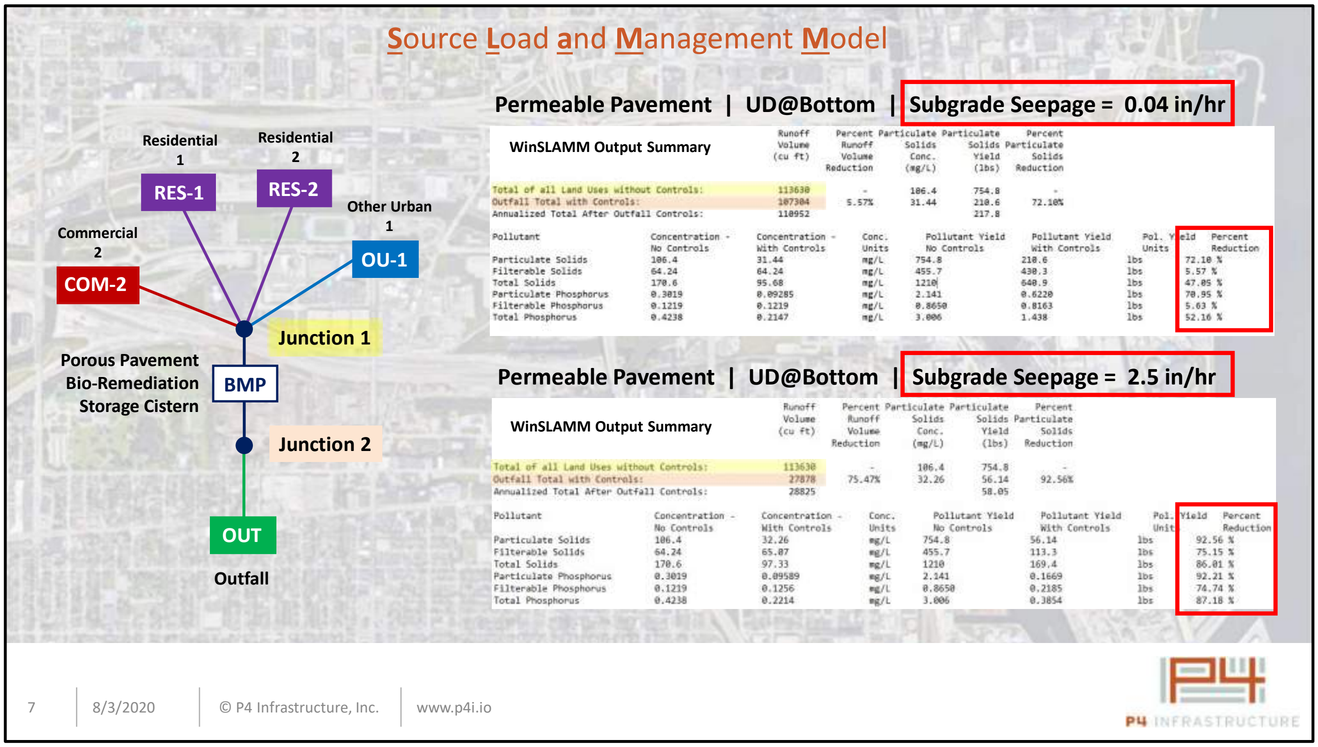
After this information is entered into the model, a baseline conditions analysis (with/without stormwater BMPs) is performed to estimate the amount of pollutant load and stormwater volume reaching the outfall.



After the no-controls analysis, proposed stormwater best management practices (BMPs) are added to the model.

These new BMPs either retain, filter or infiltrate stormwater which reduces the amount of pollutant making it to the outfall.

Adding a BMP DOES NOT change the amount of stormwater volume making it to Junction 1; however, it could (and usually does) reduce the volume at the outfall (Junction 2).



Here is where P4s systems augment SLAMM analysis with measured data.

What you are looking at is an output summary for a permeable pavement site in Cudahy, Wisconsin.

It’s a permeable pavement site with a single underdrain at the bottom and an assumed subgrade infiltration rate of 0.04 in/hr.

The junction volumes are shown on the left in yellow and orange highlights.

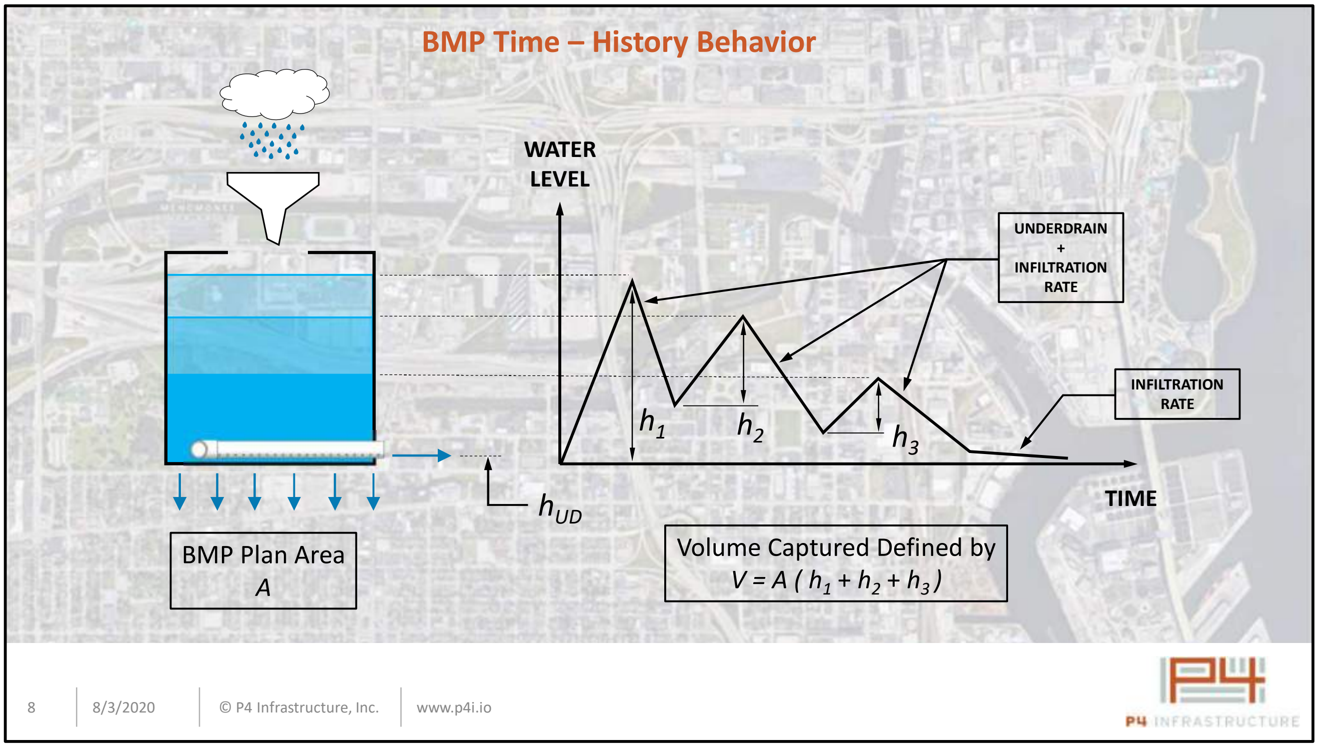
BMP performance is shown on the right inside the red box, in terms of percent reduction from baseline values.

What happens when the infiltration rate is much higher than assumed – let’s say instead of 0.04 in/hr, it’s closer to 2.5 in/hr.

As more water infiltrates, pollutant reduction increases significantly.

Filterable solids removal efficiency rises from 5.6% to 75.2%. Filterable phosphorous removal 5.6% to 74.7%. This suggests that the storage reservoir volume can be 70% smaller if this infiltration rate occurs.

This means that the existing BMP (if it is already built) contributes 70% more pollutant removal. There is significant impact to this and we'll talk more about this in the presentation.



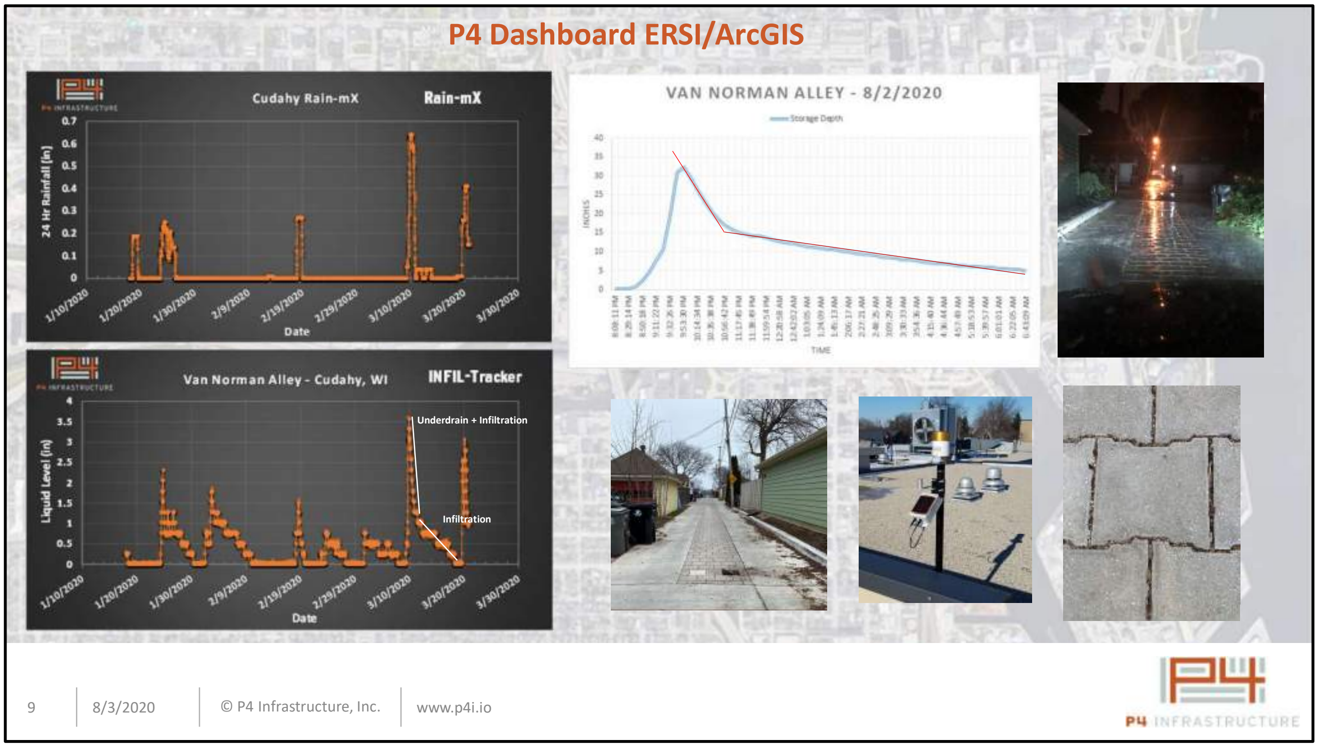
This schematic is the behavior of a permeable pavement storage reservoir over time.

In this example, there is an underdrain at the bottom of the BMP.

The image illustrates how stormwater volume captured and discharged is measured through variation in water level measured by the INFIL-Tracker device.

Even with high subgrade infiltration rates, the underdrain provides a very easy path for water to follow.

What we've seen monitoring a site in Cudahy, Wisconsin is that there is a bifurcation that occurs when water level reaches underdrain invert elevation.



Here is data from one of the three permeable pavement sites in Cudahy, Wisconsin.

The bifurcations are the kinks that you see in the time histories and the kink corresponds to underdrain invert locations within the storage reservoir.

The behavior in this system has changed recently because the main underdrain was closed off with a ball valve in late July 2020.

There are two additional underdrain “stubs” located at the low end of the reservoir that were left open. These underdrain stubs do not run the length of the reservoir but facilitate flow from the aggregate storage gallery into the side of a catch basin at the low end of the permeable pavement gallery.

4.79 inches of rain fell at Mitchell Field in Milwaukee on August 2nd. The Cudahy, Wisconsin Rain-mX system measured 2+ inches of rainfall for a 12-hour period.

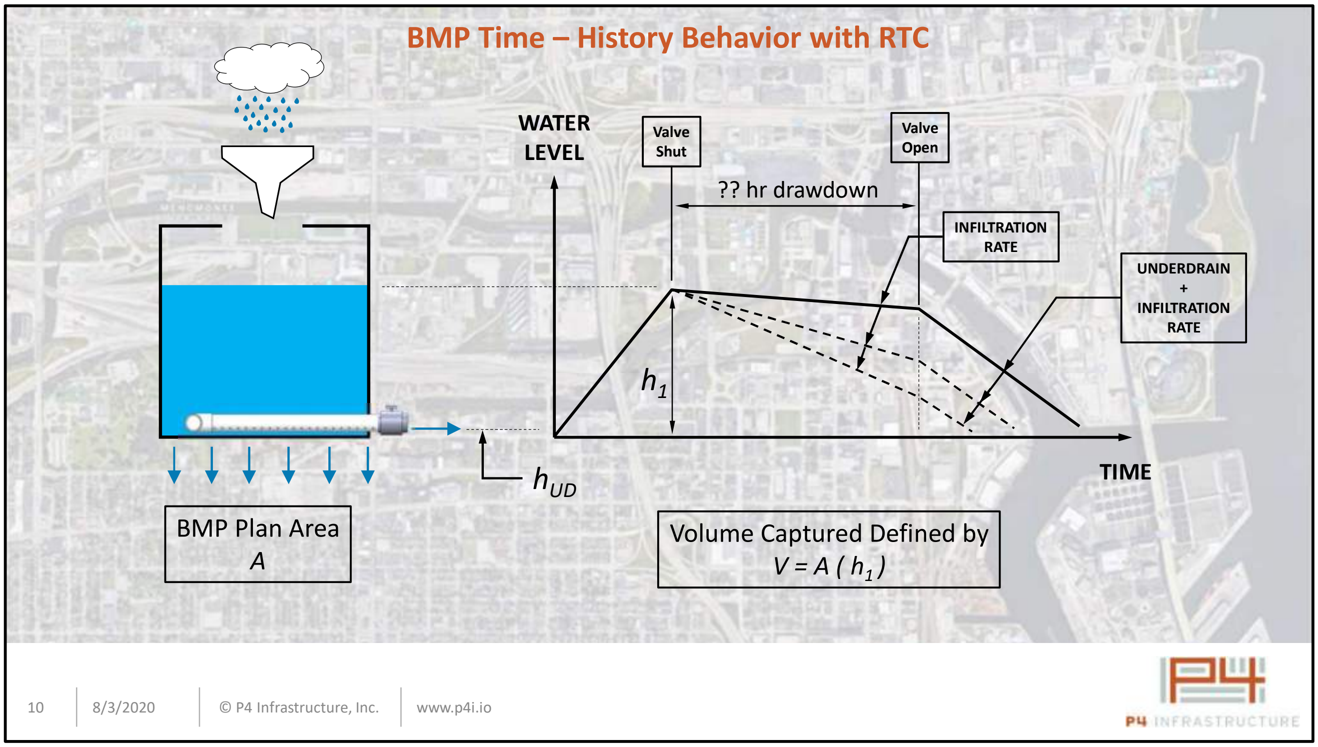
The recent large rain event on August 2nd illustrated that the gallery is capable of completely filling with the main underdrain shut off (the reservoir depth is 37 inches).

The August 2nd event illustrates that the secondary underdrain stubs at the end of the storage gallery create a pressurized discharge of the stormwater reservoir through these underdrains.

When singular (main) underdrain at the bottom of reservoir exists gallery discharge rates are:
- 0.05 in/hr initial (main underdrain + vertical infiltration)
- 0.01 in/hr secondary (vertical infiltration)

When secondary underdrain at the catch basin is the only source of discharge of the gallery the discharge rates are:
- 17.5 in/hr initial (lateral infiltration + secondary underdrain)
- 1.26 in/hr secondary (lateral and vertical infiltration)

It is interesting to note that if you look at the surface of the permeable pavement, it looks clogged… but clearly water is getting through the surface and into the gallery. There was no water ponding on the permeable surface during the August 2nd rain event.



This is the behavior of the BMP with real-time control (RTC) added.

The goal of real-time control is promoting infiltration and pollutant removal at the highest efficiency for as long as possible.

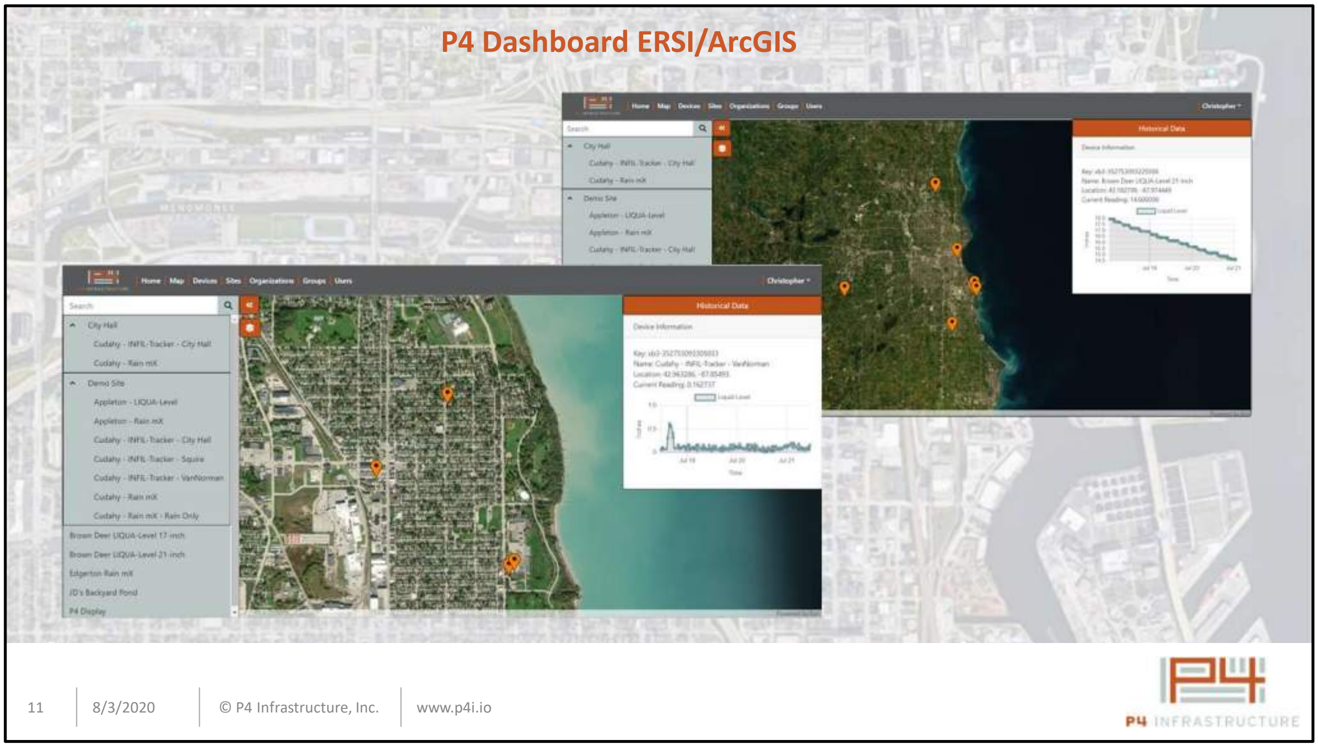
When underdrain is at the top of the storage reservoir an installation runs the risk of not meeting drawdown regulations.

With RTC, if the storage gallery doesn't drain within the drawdown period required, the system will autonomously drain itself by opening the valve.

The volume of water infiltrated, and the volume of water discharged are documented continuously.

We can also correlate volume measured to rainfall intensity and duration continuously and adjust pollutant concentration and removal accordingly.

This is how the P4 system maximizes BMP efficiency and make sure communities receive the pollutant credit they are due as provided by local and state stormwater regulations.



Now let’s look at P4’s technology for viewing sensor data through its ESRI/ArcGIS based dashboard technology.

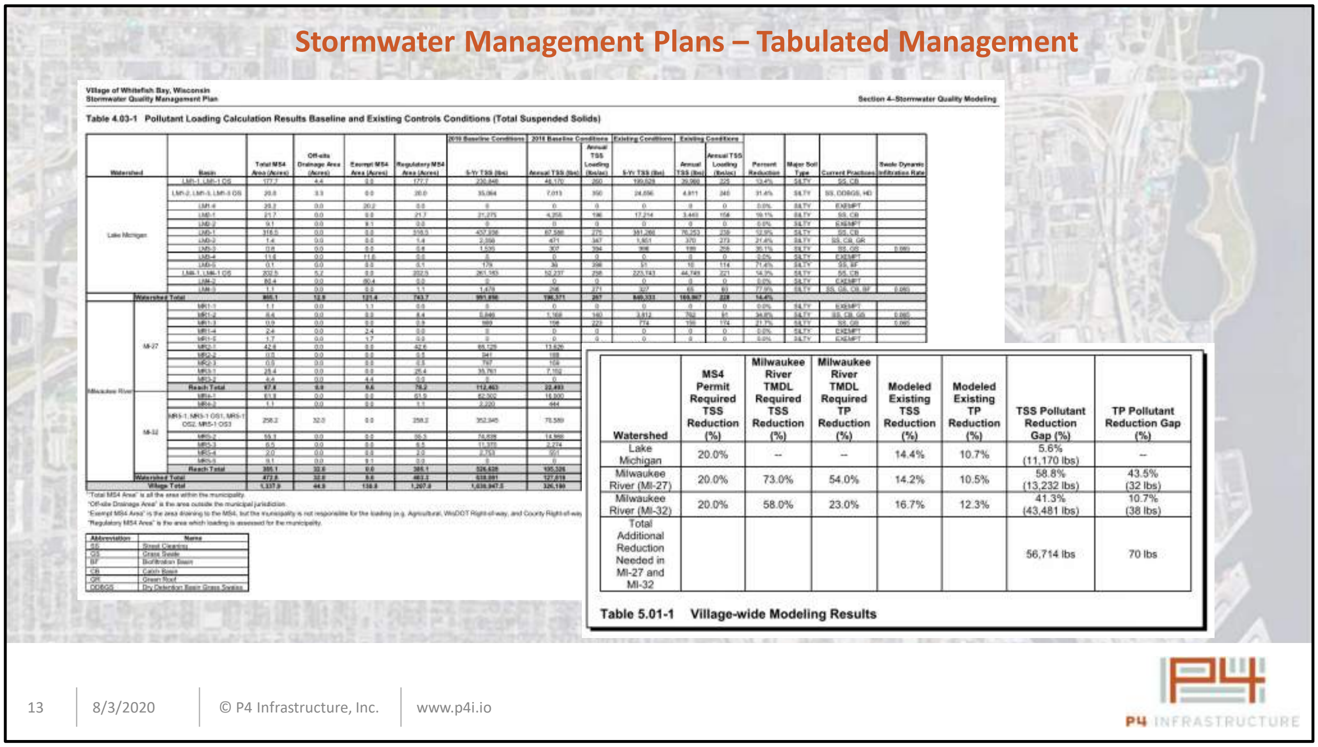
This is a demonstration of P4’s dashboard technology.

Meeting Municipal Separate Storm Sewer System (MS4) permit requirements and Total Maximum Daily Load (TMDL) targets often begins with stormwater management plans generated by consultants on behalf of the MS4 permittee and TMDL community.

These reports are often very comprehensive and include recommended non-structural and structural stormwater best management practices needed to achieve MS4 permits and TMDL compliance.

These reports also include comprehensive discussion of alternative BMP scenarios and expected costs associated with these alternatives.

Stormwater Management Plans – Tabulated Management



Village of Whitefish Bay, Wisconsin
Stormwater Quality Management Plan

Section 4—Stormwater Quality Modeling

Table 4.03-1 Pollutant Loading Calculation Results Baseline and Existing Controls Conditions (Total Suspended Solids)

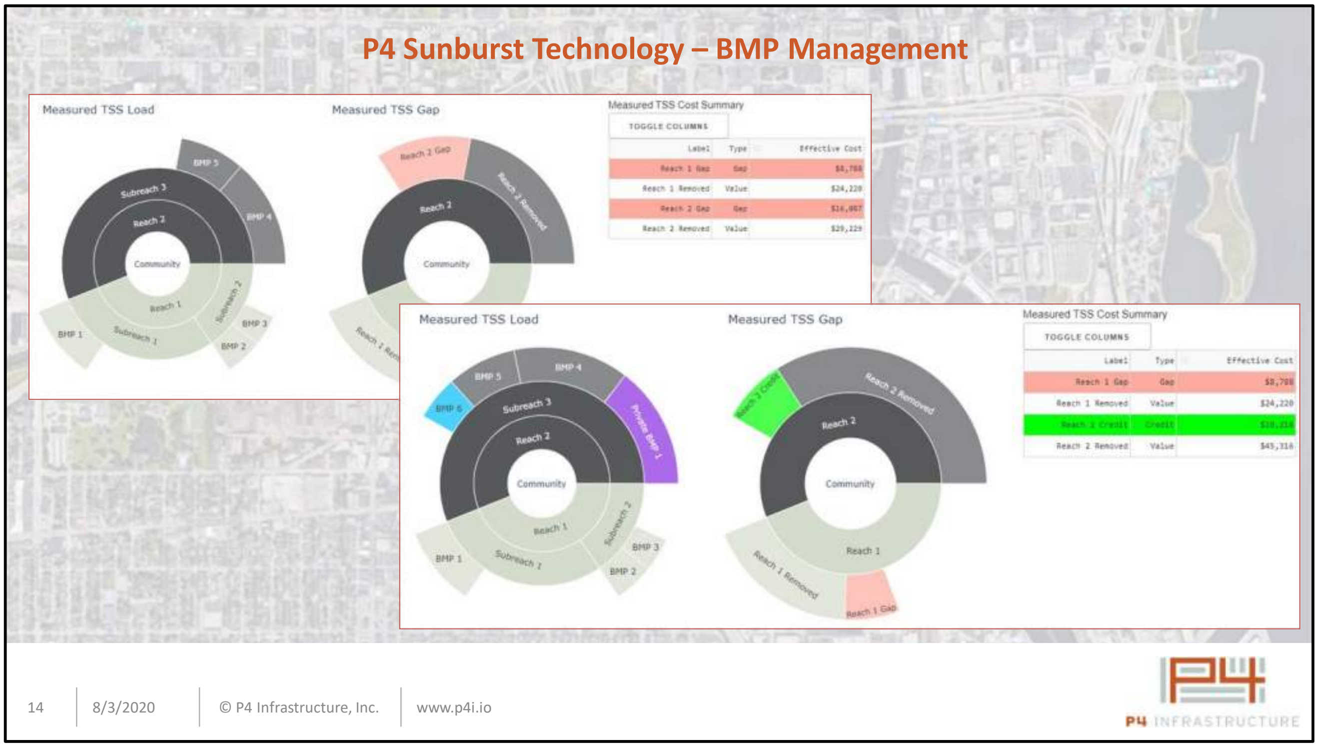
Watershed	MS4 Permit Required TSS Reduction (%)	Milwaukee River TMDL Required TSS Reduction (%)	Milwaukee River TMDL Required TP Reduction (%)	Modeled Existing TSS Reduction (%)	Modeled Existing TP Reduction (%)	TSS Pollutant Reduction Gap (%)	TP Pollutant Reduction Gap (%)
Lake Michigan	20.0%	--	--	14.4%	10.7%	5.6% (11,170 lbs)	--
Milwaukee River (MI-27)	20.0%	73.0%	54.0%	14.2%	10.5%	58.8% (13,232 lbs)	43.5% (32 lbs)
Milwaukee River (MI-32)	20.0%	58.0%	23.0%	16.7%	12.3%	41.3% (43,481 lbs)	10.7% (38 lbs)
Total Additional Reduction Needed in MI-27 and MI-32						56,714 lbs	70 lbs

Table 5.01-1 Village-wide Modeling Results

Alternatives analysis and compliance needs are expressed in tabular format.

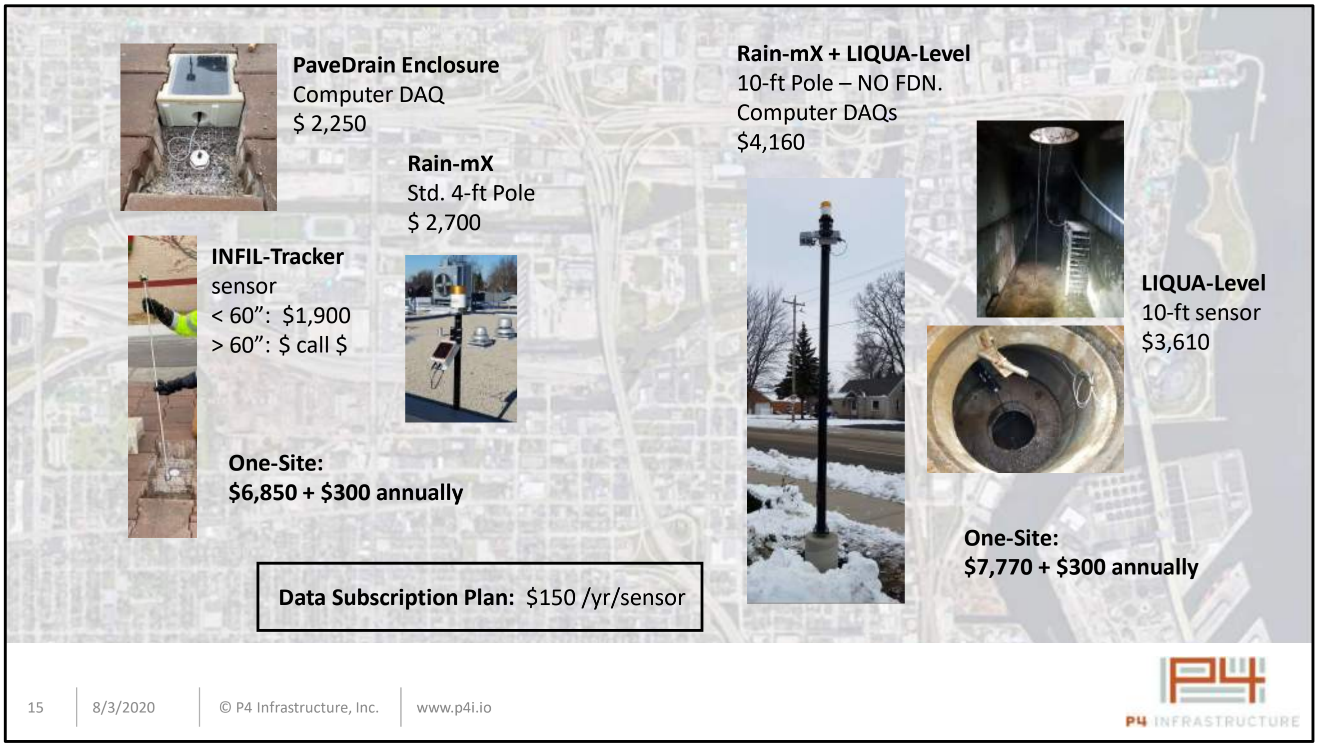
The management of stormwater BMPs and understanding compliance over time can be a very complicated process when these tabulated expressions of alternatives and data are implemented.

P4 has worked very hard to develop a dashboard viewing tool for the data present in these stormwater management reports that give MS4 permittees and TMDL communities a more detailed understanding of how to manage stormwater BMPs and be able to demonstrate stormwater infrastructure expenses in a manner understandable by more than those in the engineering arena.



Now let's see how a community can view the impact of measured data on BMP performance and use it to manage EPA compliance using P4's sunburst technology.

This is also a demonstration of the technology.



This slide outlines the costs for the P4 sensor systems.

The costs for INFIL-Tracker and Rain-mX systems typical for permeable pavement are given.

The costs for LIQUA-Level and Rain-mX systems typical for underground cisterns are also provided.

It should be noted that the Capital Expenditures for devices are shown for systems that are relatively unique. The LIQUA-Level system included the 10-foot mounting pole to prevent tampering with the Rain-mX system and the computers for the LIQUA-Level system.

P4’s devices also include a recurring annual subscription plan for the software license to view a device’s data (think Google Nest thermostat devices).

P4 does this because consultants and regulatory agencies would like to view and document large scale implementation of green infrastructure without purchasing sensors and this allows those that do not own devices to subscribe to data streams.

P4's INFIL-Tracker system is in place in the City of Cudahy, Wisconsin in three locations. P4's Rain-mX system is also operational in Cudahy, Wisconsin.

P4 also has LIQUA-Level and Rain-mX systems in Appleton, Wisconsin providing liquid levels in an underground storage cistern.

P4 has four more LIQUA-Level systems being installed in Cudahy, Wisconsin; INFIL-Tracker systems being installed in Milwaukee's Green Tech Station; and two LIQUA-Level systems being installed by AECOM/Gilbane at Milwaukee's City Hall.

P4 has had a series of three meetings with the Wisconsin Department of Natural Resources (WI DNR) outlining the P4 systems and their capabilities. P4 is awaiting a support letter from the Wisconsin DNR allowing the use of P4's systems by communities and private owners.

Thank you very much, we would love to take questions and discuss P4's technologies further.

We also would LOVE to become involved with ICPI members and get P4's technologies spread throughout the private and public use of permeable pavement surfaces.