Project Information:

Project Name: Pischke Motors Permeable Pavement Project
Address/City/State/Zip: 524 S. 3rd Street, La Crosse Wi 54601

Type of green infrastructure installed (check all that apply):

☐Green Roofs	☐ Rain Barrels	☐ Rain Gardens
☐ Constructed Wetlands	☐ Cisterns	☐ Soil Amendments
☐ Native Landscaping	☐ Stormwater Trees	☐ Other, Click or tap here to enter text.
☒ Porous Pavement	☐ Bioswales	

Area of specialty for this project (check all that apply):

☒Design	☐Landscaping	☐Downspouts and Gutters
☒Engineering	☐Maintenance	☐Inspection
☐Construction	☐Plumbing	

Project (Property) Owner Information:
Owner's Name: Pischke Motors of La Crosse/ Rahn Pischke
Address/City/State/Zip: 524 S. 3rd St. La Crosse WI 54601
Phone: 608-791-3006
Email: Click here to enter text.

Project Construction Information:
Construction Management Vendor: Click here to enter text.
Project Manager Name: Click here to enter text.
Project Manager's Vendor history: ☐currently employed ☐no longer employed ☐otherClick here to enter text.
Email: Click here to enter text.
Contract information (if applicable): Click here to enter text.
Final Contract Amount (contracted and amended if applicable): Click here to enter text.

Construction Start date (contracted): 8/9/2019
Construction Start date (actual): Click here to enter a date.
Construction End date (contracted): Click here to enter a date.
Construction End date (actual): unknown- completed by owner

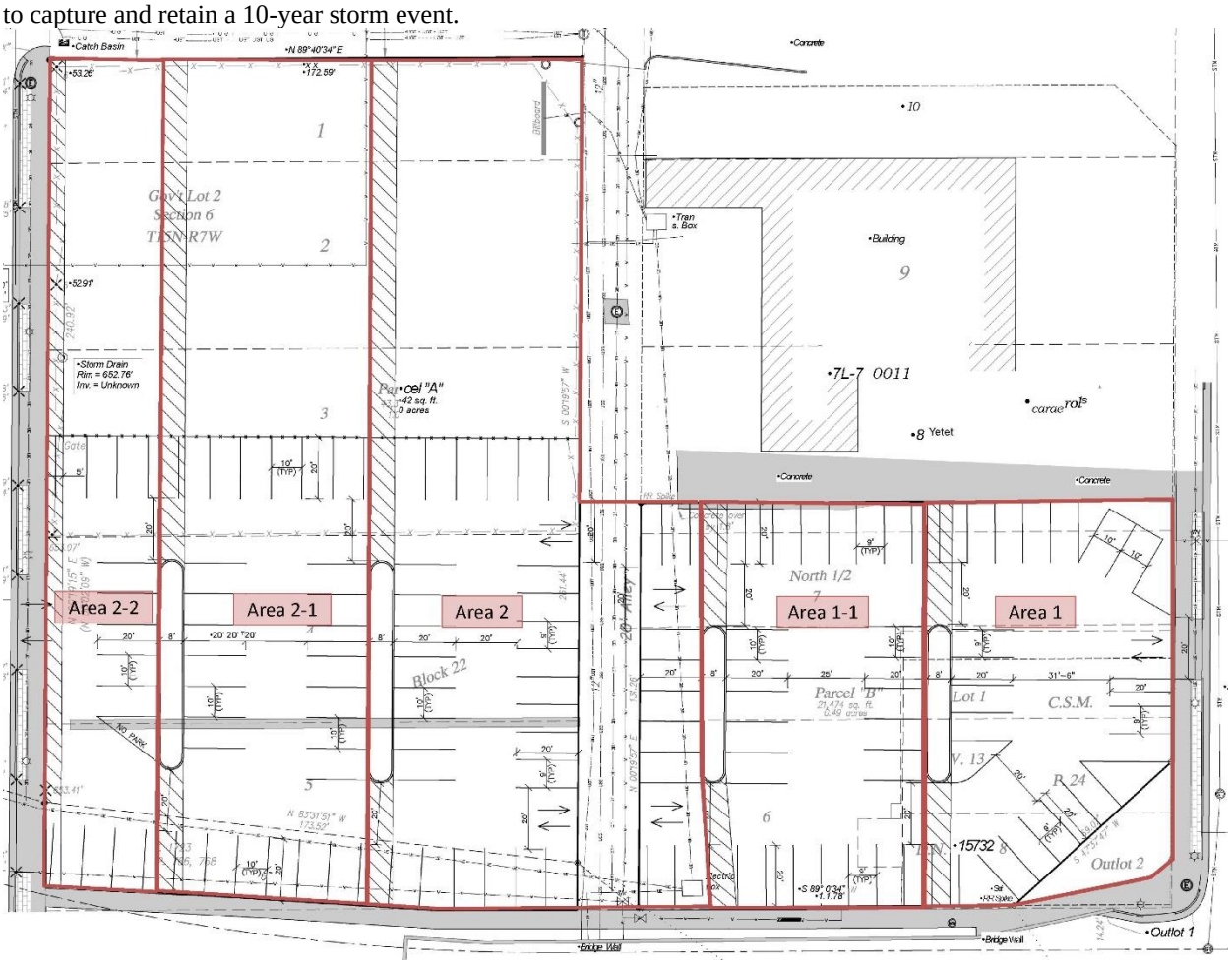
Was the project completed on time? ☒Yes ☐No; Explanation: Owner contracted and administered the project.
Was the project completed on budget? ☒Yes ☐No; Explanation: Click here to enter text.
Was the project completed to the owner's satisfaction? ☒Yes ☐No; Explanation: Click here to enter text.

Project Description (Be sure to include cost information, photos, and a detailed description of the work performed by the Vendor applicant): CBC was responsible for the design and engineering of a permeable pavement system for Pischke Motors of La Crosse. The owner developed a 1.49-acre vacant lot across the street from his car dealership. The cost of the project is unknown as the owner negotiated the contract with the vendor. The Pischke Motor Group is planning to improve the vacant parcels bounded by South 2nd Street to the West, Cameron Avenue to the South, South 3rd Street to the East and Cass Street to the North.

Figure 1 presents the parcel location. **Figure 1**

Improvements to the vacant lot will include an asphalt or concrete pavement overlay, permeable parking islands and permeable pavement stormwater management systems. The permeable paving system that has been selected for use on this at this site is Pavedrain. ™. The permeable parking islands will be designed to capture stormwater and then allow that water to infiltrate into subsurface stone galleries. Based upon the direction of the City, the proposed parking lot was required

to capture and retain a 10-year storm event.



Customer Service Approach

Please provide a description of your firm's customer service approach. This section should give the reviewer a good idea of how conflicts with clients are resolved or how issues that arise during work are resolved. Please provide your customer service approach and at least one example of how your firm has implemented this approach. Our core values are centered around customer care and satisfaction. Each customer that we serve is treated with the same high degree of professional care whether it is a small private client or a large municipality. Our background and experience give us the unique ability to develop common sense solutions that are acceptable to local, state and federal regulators. We are licensed as professional Engineers in all 50 states and provide a wide array of professional services. CBC has a history of satisfied, repeat customers. If a conflict arises, we address the issue immediately and focus on the resolution that is satisfactory to the client. We recently assisted a landowner with a land division project in which he did not want to create a stormwater management facility. CBC assisted in the revision of the land division plan and negotiated with the municipality to allow for the development to occur with minor notations on the Certified Survey Map. In this case, through our efforts and negotiations, the landowner was able to move forward with the sale of land that had been stagnated for the past 5 years.

Project Information:

Project Name: Alpine Culvert Replacement
Address/City/State/Zip: Bliss Road, City of La Crosse Wi 54601

Type of green infrastructure installed (check all that apply):

☐Green Roofs	☐ Rain Barrels	☐ Rain Gardens
☐ Constructed Wetlands	☐ Cisterns	☐ Soil Amendments
☒ Native Landscaping	☐ Stormwater Trees	☒ Other,Rock armored ditch
☐ Porous Pavement	☐ Bioswales	

Area of specialty for this project (check all that apply):

☒Design	☐Landscaping	☐Downspouts and Gutters
☒Engineering	☐Maintenance	☐Inspection
☐Construction	☐Plumbing	

Project (Property) Owner Information:
Owner's Name: City of La Crosse
Address/City/State/Zip: 400 La Crosse St, La Crosse Wi 54601
Phone: 608-789-7505
Email: hainesr@cityoflacrosse.org

Project Construction Information:
Construction Management Vendor: City of La Crosse
Project Manager Name: Bob Haines
Project Manager's Vendor history: ☒currently employed ☐no longer employed ☐otherClick here to enter text.
Email: hainesr@cityoflacrosse.org
Contract information (if applicable): Click here to enter text.
Final Contract Amount (contracted and amended if applicable): Unknown

Construction Start date (contracted) Fall of 2020
Construction Start date (actual): Click here to enter a date.
Construction End date (contracted): Click here to enter a date.
Construction End date (actual): Fall of 2020
Was the project completed on time? ☒Yes ☐No; Explanation: Project was administered by the City
Was the project completed on budget? ☒Yes ☐No; Explanation: Click here to enter text.
Was the project completed to the owner's satisfaction? ☒Yes ☐No; Explanation: Click here to enter text.

Project Description (Be sure to include cost information, photos, and a detailed description of the work performed by the Vendor applicant): CBC was retained to provide a hydrologic and hydraulic analysis, alternative remediation planning and final engineering of the remediation of a failed culvert system along Bliss Road. The slope on the embankment exceeded 45% and the existing culvert had catastrophic failure. The selected alternative was to remove the culvert system and replace it with an open channel that was engineered to support heavy rip rap. The new system would provide a stabilized

ditch and provide immediate water quality improvement to the street runoff.

Project Information:

Project Name: City Hall and Squire Avenue Parking Lots and Green Alley
Address/City/State/Zip: 5050 S. Lake Drive, Cudahy, WI. 53110

Type of green infrastructure installed (check all that apply):

☐Green Roofs	☐ Rain Barrels	☐ Rain Gardens
☐ Constructed Wetlands	☐ Cisterns	☐ Soil Amendments
☐ Native Landscaping	☐ Stormwater Trees	☒ Other, phosphorus removal aggregates.
☒ Porous Pavement	☒ Bioswales	

Area of specialty for this project (check all that apply):

☒Design	☐Landscaping	☐Downspouts and Gutters
☒Engineering	☐Maintenance	☐Inspection
☐Construction	☐Plumbing	

Project (Property) Owner Information:
Owner's Name: City of Cudahy
Address/City/State/Zip: 5050 S. Lake Drive, Cudahy Wi 53110
Phone: 414-769-2200
Email: https://www.cudahy-wi.gov/

Project Construction Information:
Construction Management Vendor: City of Cudahy
Project Manager Name: Ryan Schmidt
Project Manager's Vendor history: ☒currently employed ☐no longer employed ☐otherClick here to enter text.
Email: schmidtr@ci.cudahy.wi.us
Contract information (if applicable): Click here to enter text.
Final Contract Amount (contracted and amended if applicable): Click here to enter text.

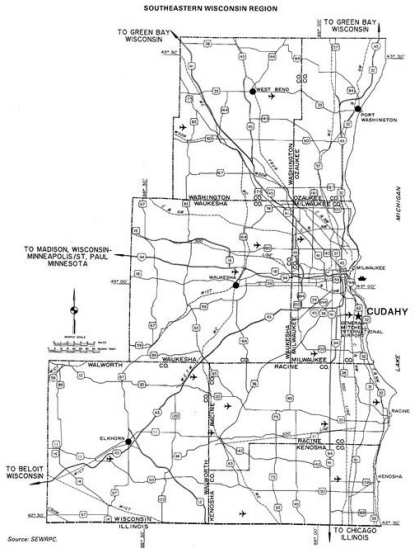
Construction Start date (contracted): 9/7/2018
Construction Start date (actual): Click here to enter a date.
Construction End date (contracted): Click here to enter a date.
Construction End date (actual): Click here to enter a date.

Was the project completed on time? ☒Yes ☐No; Explanation: The project construction administration was completed by the City. The project was completed within their timelines and CBC had no involvement
Was the project completed on budget? ☒Yes ☐No; Explanation: Click here to enter text.
Was the project completed to the owner's satisfaction? ☒Yes ☐No; Explanation: Click here to enter text.

Project Description (Be sure to include cost information, photos, and a detailed description of the work performed by the Vendor applicant): Click here to enter text.
City of Cudahy, WI
Using Blast Furnace Slag to Clean Storm Water – The Cudahy Project

City Hall and Squire Avenue Parking Lots and Green Alley
Introduction

The City of Cudahy is a 150-year-old fully developed community located along the shores of Lake Michigan in the Metro Milwaukee area. Like many older communities that are fully developed, trying to improve storm water quality is very difficult. It is even more difficult during revitalization when development of every square inch of property is necessary to make the project feasible. The "Cudahy Project" uses conventional green infrastructure with a very unconventional treatment.



The Need

As a MS4 community and part of the Milwaukee River Basin TMDL, the City of Cudahy, Wisconsin is required to implement solutions to remove suspended solids and phosphorus from stormwater runoff that enters Lake Michigan and the Kinnikinic River. To achieve the conditions of the storm water discharge permit and balance the City's redevelopment needs, the City has made a commitment to integrate green infrastructure practices into public works improvement projects that include high performance permeable pavement systems and vegetated biofilters.

Permeable pavement systems have been shown to be effective in the removal of total suspended solids, E. coli, and total phosphorus.[1] Biofiltration systems are equally effective in the removal of total suspended solid and phosphorus loads[2]. However, with higher phosphorus removal goals imposed by the Milwaukee River Basin TMDL, the City of Cudahy's Director of Public Works needed to think outside the box to achieve those goals. Conventional stormwater treatment systems were not going to cut it. The Director had to consider alternative, cost effective systems than could be integrated into a dense urban environment that would effectively capture and store runoff. Furthermore, the systems had to remove a greater amount of the total suspended solids and phosphorus loads.

In 2016, the Director of Public Works was introduced to air-cooled blast furnace slag (BFS) as a phosphorus control product. Initial laboratory tests indicated that this material, due to its chemical make-up, can remove ortho and total phosphorus from phosphorus infused solutions. The City was tentatively developing capital projects to replace an alley and two public parking lots. These projects would include green infrastructure but integrating that infrastructure into a limited footprint was going to be difficult. The alley, referred to as the "green alley" was in the heart of the City's business district that was under redevelopment. Attached to the alley was a deteriorated public parking lot referred to as the Squire Avenue Parking Lot. The City had to

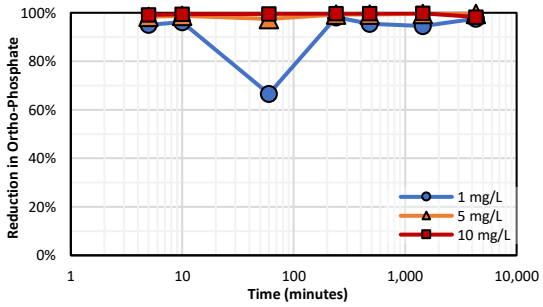
accommodate storm water management for roughly 1.9 acres of nearly impervious acreage without decreasing buildable area for development.

In addition to these projects, the City was required to replace the front of the City Hall parking lot because of severe deterioration. The City Hall parking lot is unique because it is in a residential area adjacent to Sheridan Park and the Lake Michigan lake front. Typically, these areas exhibit high phosphorus levels as a result of the heavy vegetation. The Director felt that the evidence was compelling enough to add the BFS to the City Hall parking lot and the Squire Avenue parking lot and alley referred to as the "Cudahy Project".

Alternative Treatment Systems

The City received grant funding from the Wisconsin Department of Natural Resources and the Milwaukee Metropolitan Sewerage District to offset the cost of green infrastructure stormwater control practices. The urban setting of the project locations and the space restrictions demanded that the practices selected would be able to function at a high level to capture and eliminate runoff, remove non-point pollution efficiently and be maintained easily with existing equipment and personal. The City chose to use a permeable articulating concrete block, tradename Pavedrain, to capture and transfer stormwater to a subsurface stormwater storage gallery under the alley and the City Hall parking lot. To meet the water quality needs of the Squire Avenue parking lot, high performance biofilters, tradename Focal Point, were used due to space constraints and its ability to infiltrate storm water at a high rate. To enhance the phosphorus removal capability of these systems, BFS was used as a support aggregate as well as a phosphorus polishing aggregate in these systems.

Air cooled blast furnace slag (BFS) is a byproduct of the initial steel making process and prior to 2017 Wisconsin Act 285, was considered a solid waste per the Wisconsin Administrative Code NR 538. To use the material in the City's projects, extensive testing for leachable elements, aquatic toxicology and phosphorus uptake had to be completed to meet NR 538 requirements.[4.] On May 8, 2017 an exemption from licensing for the use of BFS, from the ArcelorMittal Indiana steel facilities, as granular fill in pavement subgrade and stormwater control systems was granted by the Wisconsin Department of Natural Resources (FID#399107940 SW/APPR). As of April 17, 2018, iron and steel process slag is now exempt from the definition of solid waste. BFS has demonstrated the ability to act as a phosphorus absorptive aggregate.[5] Because of the phosphorus uptake ability of BFS, the aggregate subsurface storage galleries associated with the green alley and the City Hall parking lot, were composed of BFS rather than standard limestone. Calculations performed by CBC Engineers and Associates, (CBC) indicate that the life expectancy of



the phosphorus removal capabilities of the BFS would exceed 30 years. It should also be noted that BFS is a sustainable industrial byproduct that can reused in an aggregate application and does not need to be land filled.

The City of Cudahy first installed a high performance biofilter as part of their Packard Avenue Improvement Project in 2016. The Focal Point system is capable of infiltration rates of up to 100 inches per hour. The high infiltration rates reduce the footprint of the biofilter area, in relationship to the watershed, without losing the filtration capabilities of the media. However, biofiltration devices that use compost or other organic matter as part of the media mix, can increase the output of ortho phosphorus.[3.] To negate the input of phosphorus due to compost leaching and stormwater runoff, BFS material was integrated into the design of the biofilter, below the media, that would remove phosphorus prior discharging the runoff into a storm sewer system.

The City selected the Pavedrain permeable articulating concrete block as the stormwater capture system for the green alley and City Hall parking lot projects. The Pavedrian system will routinely exceed infiltration rates in excess of 1,500 inches per hour, can be easily maintained with the Cities high volume street vacuum, and can withstand winter plowing and salt applications. The subsurface BFS storage galleries were composed of ASHTO#10, ASHTO #67 and ASHTO #3 aggregates. Semipermeable geotextile membranes were installed to ensure that adequate contact time between the BFS and stormwater runoff was achieved. A perforated underdrain system collects the filtered water and discharges it to nearby storm sewer systems.

Project Accomplishments

The Squire Avenue Parking Lot, Green Alley and City Hall Parking Lot projects represent a first of its kind, high performance green infrastructure system capable of removing ortho phosphates from urban storm water runoff. The ability of stormwater best management practices to remove total suspended solids and phosphorus has been well documented. Removal of ortho phosphate, however, continues to be elusive. The introduction of BFS is a step toward the reduction or elimination of reactive phosphorus from stormwater discharges.

To document the removal capability of the systems, the City has implemented a three-year monitoring program of the discharge from both project areas. Specific stormwater catch basins were identified as sampling locations. The City has employed both grab sampling and continuous samplers to obtain preconstruction storm water samples.

The project was under construction from August through November. One post construction sample has been collected at the Squire Avenue parking lot and green alley prior to the onset of the winter months. The results of the pre and post construction sampling completed to date is presented in Table 1.

Table 1							
Squire Avenue Parking Lot and Green Alley							
Pre-Construction Sampling	**Ortho P (mg/L)**	**Total P (mg/L)**	**TSS (mg/L)**	**Chloride (mg/l)**	**Lead (ug/l)**	**Nitrate (mg/l)**	Ph
August 8, 2018	-	0.02	26	0.00	0.00	0.16	7.69
August 20, 2018	0.036	0.11	190	7.80	9.20	0.59	9.41
Post Construction Sampling	**Ortho P (mg/L)**	**Total P (mg/L)**	**TSS (mg/L)**	**Chloride (mg/l)**	**Lead (ug/l)**	**Nitrate (mg/l)**	Ph
November 5, 2018	0.000	0.011	52	0.00	0.00	0.26	7.47
City Hall Parking Lot							
Pre-Construction Sampling	**Ortho P (mg/L)**	**Total P (mg/L)**	**TSS (mg/L)**	**Chloride (mg/l)**	**Lead (ug/l)**	**Nitrate (mg/l)**	Ph
August 9, 2019		4.4	87				
August 20, 2018	0.078	0.36	380				
September 5, 2018	0.037	0.062	76				

This early sample from the Squire Avenue parking lot and green alley, indicates that the ortho phosphorus has been eliminated and the total phosphorus was reduced by 90%.

Economic Challenges

Like all cities, Cudahy must maintain its current budget levels while still meeting growing public infrastructure needs. The City was able to access the Wisconsin Department of Natural Resources Non-Point Source Pollution Grant program and the Milwaukee Metropolitan Green Infrastructure Grant program to offset the costs of the project. These grants, totaling $138,000, funded approximately 30% of the total project cost of $487,470.

To offset the cost of the BFS, the City entered into an agreement with Phoenix Services, LLC., to provide BFS material directly to the City at a cost that would be comparable to locally sourced washed limestone. This brought the cost of the delivered BFS down from $41 / ton to $17.50 / ton. As part of this agreement, the City will monitor the discharge from the City Hall parking lot and the Squire Avenue parking lot and green alley. This included providing equipment, staff and laboratory analysis for a three-year period.

The overall cost to the City to construct the permeable pavement system utilizing BFS versus limestone was negligible. This was primarily due to the agreement between Phoenix Services and the City. Due to handling unknowns by the contractor, there was an approximately 5% increase in the bid item for construction of the storage galleries which equated to an additional $18,000. This accounted for a 3% project cost increase.

Regulatory Oversight

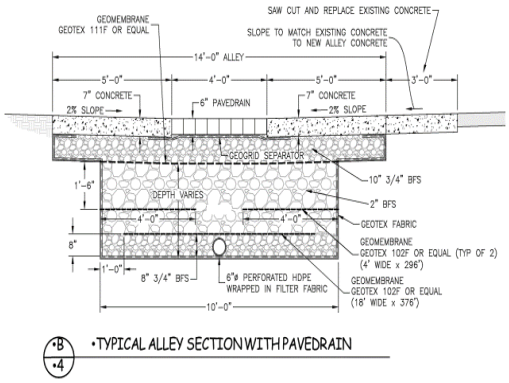
Utilizing an industrial by-product for a beneficial re-use is regulated under the Wisconsin Administrative Code NR 538. Initial discussion with the Wisconsin Department of Natural Resources were positive, but there was a strong concern by the solid waste staff, based upon past steel slag experiences, that this

material would not be safe to use in a storm water treatment application due to the leaching of hazardous materials into the environment. CBC Engineers and Phoenix Services staff, that include Dr. Dennis Grubb, a leading authority on steel slag, prepared and conducted an in-depth presentation to the Departments solid waste and stormwater staff that detailed the chemical makeup, phosphorus removal capabilities, and environmental impacts associated with BFS. This information later formed the backbone of the NR 538 permit exemption application that was submitted on September 7, 2016 by CBC Engineers. During the review process, concerns from the Department's water resources staff regarding Ph levels and the impact on fresh water fish was raised. This precipitated an extensive ecotoxicity test that resulted in less than a 5% mortality rate of water fleas and Fat Head minnows subjected to the changes in water Ph associated with the effluent of the BFS system. Additionally, a rule in NR 538 raised concerns regarding the installation of the material within 100 feet of a residential development and an animal feeding area. These conditions would have greatly reduced the effectiveness of this treatment system as a stormwater best management practice. CBC Engineers provided alternative application scenarios associated with BFS systems that included both urban and rural installations. Based upon these alternatives and the leaching and ecotoxicity testing done, the Department staff agreed that the material could be used within those limits provided it was contained. The permit exemption was granted on May 8, 2017 with limited use restrictions.

Construction Process

Squire Avenue Parking Lot and Green Alley

The alley provided access to a newly developed 57-unit apartment complex with underground parking, three separate six-family buildings with attached garages and a small commercial business. Therefore, prior to any pavement removal and excavation, it was important to ensure that building access and on-street parking was available for all the residents. Garbage collection was especially difficult and had to be worked out separately with each property manager. Once all the private vehicle parking was relocated, the entirety of the pavement was removed on the job site. The contractor installed the furthest downstream manhole for the proposed storm sewer work and laid 6" perforated SDR 35 through the parking lot to the upstream manhole in the alley. At this point, the Contractor made the decision to excavate the entire 10' wide trench to subgrade. This was the best construction sequence to fully utilize his trucking operations. No pipe was laid or BFS backfilled until the entire length of trench was excavated. Once completed, the Contractor began to lay geotextile fabric along the entire trench and begin to backfill the required layers of Blast Furnace Slag.



The cross section for the alley shows that the first lift of the BFS is only 10" high and includes the 6" drain tile. This was completed by front loading the BFS at the beginning of the trench and using a skid steer to slowly push it out for the length of the trench. This BFS was leveled and the pipe was then placed within the 10" lift at the designed pitch and elevation. The next step required an 8' wide section of geotextile fabric to be placed down the middle. Each of the next 2 lifts of BFS was determined with an elevation and a paint mark on the side of the fabric covered trench wall to easily

indicate the fill level for the contractor. The two different sized aggregates included a ¾" and 2" washed material. In addition, there was a 3/8" crushed material that was used as a baffle or "speed bump" along the bottom of the trench. The 2" washed BFS was placed in between two layers of ¾" washed BFS to help convey water to the drain pipe, but also to provide storage for larger quantities of runoff during heavy rainfall events. The final lift of ¾" washed BFS was used as a aggregate base for the proposed concrete pavement and PaveDrain block.

Concrete and PaveDrain installation began once the BFS was brought to grade in the alley. The design of the alley was to allow for a 4' wide section of pavers down most of its length. These blocks have an actual dimension of 4.1' wide when laid down per the manufacturer's plans. The alley was designed to accommodate this by pouring the north half first and then offsetting that finished edge by 4.1'. The contractor then set his forms per the staked elevations and tied in the existing driveways at the end. Once the concrete was finished, the crews could begin placing the PaveDrain blocks. It first required the crews to finish grade and compact the center section of the alley. When the grading was complete, the contractor could place geogrid down and begin placing the block. The goal of these blocks is to allow for the direct transfer of storm water runoff into the drainage system below, where it could be cleaned and returned to Lake Michigan.

The City also reconstructed the municipally owned Squire Avenue parking lot. The storm sewer had to be trenched through this lot and as a result, the City decided to improve the lot and add additional green infrastructure. The green infrastructure of choice was to install two Focal Point bioretention basins. These bioretention basins would be 30 square feet each and fit inside the grass island that was to be installed in the new lot. Surface water from the parking lot would be conveyed into the grass median, where it would be stored, treated and conveyed to an existing storm sewer. The cross section consisted of 3/4" washed BFS at the base of the bio-basin which also contained the 6" perforated pipe. The layer of BFS consisted of approximately 2' of ¾" BFS aggregate, followed by a geotextile fabric Type F. Above this was 18" of an engineered soil called Focal Point. In order to construct these basins, wood frames were installed to contain the media and insure critical elevations were met.

City Hall Parking Lot

Construction on the City Hall parking lot began nearly identical to that of the green alley. The pavement was removed first by means of pulverizing the asphalt. The major difference in this project was the ability to maintain pedestrian foot traffic to all areas of the building (Police, Health, DPW, Water, Inspection, Treasury, etc.). Once the pavement was removed, access had to be maintained for vehicles, especially police vehicles. Parking for residents was moved into the back and sides of the building, employees were moved to the adjacent high school parking lot and one driveway access was maintained for the duration of the project.

The storm sewer/BFS trench was excavated for the entire project and the other areas of the site were brought to subgrade. Pipe was installed the exact same way as the green alley project area, but this time it was tied into separate catch basins instead of one manhole. There were 3 distinct sections of pipe to be laid because they each tied into a catch basin and carried water in a different direction than the other. Fabric and BFS were placed as soon as the pipe was installed. All the trenches were then backfilled up to subgrade and prepared for pavement installation.

The major difference between the two projects cross sections' is that City Hall had an 8' wide PaveDrain section compared to 4' in the alley. This was to accommodate better plowing strategies for the parking lot due to accommodating an 8' wide plow blade to span the width of the blocks. The parking lot was designed to be an asphalt surface but as recommended by the PaveDrain manufacturer, the blocks would need a hard surface edge to build against and provide structural integrity to the cross section under freeze-thaw conditions. The City designed a 2' wide and 7" thick concrete ribbon that surrounded the proposed area of PaveDrain. Once again, this ribbon was adjusted for the actual size of blocks, which for this project ended up being 8.25' wide. The project was anticipated to be complete prior to the November 6th Election Day and was completed on November 5th, just in time for residents to park and get their votes in.

Municipal Resources

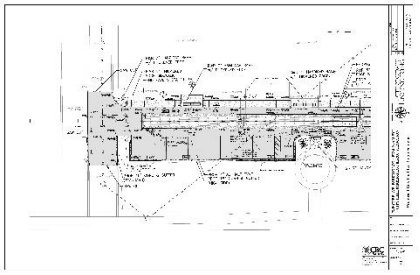
The City has a robust engineering department that preforms many tasks that include planning, design, and construction oversight of the City's public works projects. The City retained the services of CBC Engineers and Associates, Ltd. to complete the design, construction plans and specifications associated with the Squire Avenue parking lot and green alley. The design and construction plans for the City Hall parking lot were completed by the City Engineering staff. To control engineering costs, the City compiled the plans, prepared the project manual and publicly bid the project. Additionally, the City provided all construction survey, observation and administration duties.

Community Outreach

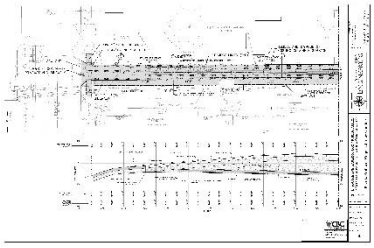
The project impacts included access to the City Hall and to private housing developments as well as a few businesses. The Community was informed of the impending construction through the City's Newsletter and postings at City Hall. The City provided letters to the affected tenants and offered alternative parking options that included a nearby local public parking lot. Alternative parking and access to the City Hall was developed to insure the public continued to have access to the City Hall and its services. The project was done in two phases; the Squire Avenue parking lot and green alley was constructed between August and September and the City Hall parking lot was completed between September and November. This staggered project construction schedule minimized access impacts to the City Hall, downtown businesses and private housing developments.

Design Considerations

The use of BFS to remove phosphorus from stormwater is a relatively new technology. Ortho phosphorus is chemically bonded with the highly calcified BFS, which is dependent of the contact time of the water with the material. Laboratory testing has shown that ASHTO #67 BFS can capture up to 100% of ortho phosphorus with as little as 10 minutes of contact time.[5] To accomplish this, the subsurface aggregate storage gallery under the Pavedrain blocks was modified with semi-permeable geotextile membranes that allowed water to pass through them at 175 gallons per minute. This caused the captured stormwater to fully saturate the gallery section, but also controlled the rate at which the water would pass through the system and thus guaranteeing appropriate, reactive contact time. Additionally, ASHTO #10 check dams were placed at the bottom of the trenches to provide additional phosphorus removal or "polishing" prior to the stormwater being discharged into the subsurface drainage system.



Additional design considerations included a trench width of 10' wide to make it easier to construct. This allowed for easy installation of the material as dump trucks were able to back directly into the trench area and discharge their loads without the use of additionally handling equipment. Front end loaders and skid steers could easily navigate the trenches which allowed for easy spreading of the materials. This saved the contractor and the City a significant amount of money. But the ultimate goal was for plowing. Paver type systems get chipped up under Midwestern winter weather conditions because of plow blades. Some of this has to do with the type of plow blade used and the other is the angle to which the plow hits the paver bed. It was discovered that if you design the paver system the way that a parking lot is plowed that it reduces the angle to which the plow hits the paver bed. A 10' width is the length of the City's plow truck blade which is equipped with a rubber blade.



Environmental Considerations & Opportunities

The BFS material went through extensive environmental testing to prove that it was not a hazardous waste material. Additionally, this testing showed that the material could be used for aggregate applications for future road or sidewalk construction once the phosphorus removal capabilities are exhausted. By using the Pavedrain pavers, removal of the blocks for access to the BFS was another important design and environmental consideration. The block could be removed, the BFS replenished, and then reinstalled with ease. The entire system is sustainable and environmentally friendly.

The use of multicolored paver blocks at City Hall not only adds curb appeal to the property but draws a lot of attention as to why and what the blocks are for. The City is currently putting up informational signage near the paver system to explain the purpose and to educate the public on the re-use

of a discarded waste to help clean storm water. The visual and tactic tile differences also aide the physically handicapped when negotiating the parking lot area.

Construction Process that Minimized impacts to the Community

One difficult construction issue was the temporary storage of the BFS which was purchased by the City ahead of the construction schedule. The amount of BFS aggregate that was installed was approximately 2000 tons. This is a great deal of material that needed to be stockpiled in a location that was near the project site. The City granted Phoenix Services the use of a vacant, City owned industrial site, approximately 1 block from the Squire Avenue site and approximately 6 blocks from the City Hall site. This location was large enough for the contractor to easily load material for delivery to the site as well as it provided a location that was beneficial to construction activities without impacting residential properties.

Although the project was bid as a single prime contract, the Squire Avenue parking lot and green alley were constructed in August and September and the City Hall Parking lot was constructed in September and November. This scheduling was discussed with the City and approved as the least impactful to the residents affected by the project.

Impacts to business and residents in the Squire Avenue area was minimal as parking and access were provided to those entities by the City. Alternative access routes into and around the City Hall were developed and put in place to insure that City services were not impacted during the construction and residents could easily and safely access City Hall. Additionally, because the Pavedrain system is a precast concrete block, once installed, the alley and parking lot was instantly available for use.

Additional Efforts made by the City DPW

The Director of Public Works understood that green initiates do not come favorably amongst Department of Public Works since there are inherent maintenance issues. The Director knew that members of the DPW needed to understand and be part of the development, design and construction of the projects to get the buy –in necessary to make it sustainable. During the design process the employees who plow the alleys and parking lots and those that maintain the parkways were included. Issues with how to protect the pavers from plowing damage was researched and the engineers found out that the Department needed to use rubber blades and plow in a certain direction. Rubber blades for the alley & parking lot plows were purchased and installed. However, expecting someone to plow in a certain direction was not realistic. So the plowing had to dictate the design. It was discovered through discussions with the plow drivers that an 8’ wide area of pavers within the isle area of the parking lot would allow the blade on the plow to ride over the pavers. So the paver width was located in the direction that they would normally plow and was sized for the width of the plow blade.

The high-performance bioretention filter also provided some challenges that were solved by the Department of Public Works. Typically the lighting for the parking lot is designed within the islands of the parking lot. But electrical wires could not be located from pole to pole down the center of the island because of the high performance bioretention filter. The engineering staff worked with the City's electrician on the placement of the parking lot lighting and conduit as not to interfere with the long-range maintenance of the electrical system or long range maintenance of the bioretention filter. Since the construction of the bioretention filter was completed in fall, the DPW will plant the bioretention filters in the spring of 2019. Typically, when the DPW crews build it they are more likely to take care of it.

Lastly the Storm Water Utility worked with the PaveDrain representative to determine what type of vacuum head should be used to clean the system. The Storm Water Utility then purchased a vacuum head that can be attached to the City owned street vacuum truck and then be used for cleaning and maintenance of the PaveDrain system. The cost and the maintenance of the system will be funded through storm water fees collected by the Storm Water Utility**.**

Lessons Learned by the DPW staff

One of the first lessons learned involved the installation of PaveDrain. There are multiple sources of information describing the width of the blocks when laid down. The alley project utilized a sheet that showed 4.06' for width of the blocks but the plan set they submitted showed 4.1'. This 4.1' distance still wasn't the most accurate as most blocks had to be cut for the entire length of the alley. This added a few days to the project that could have been avoided. We recommend having some blocks on site in order to properly set concrete forms and ensure proper width for placement. The City Hall parking lot was designed slightly wider in order to compensate for this adjustment.

Another lesson learned was that setting forms on a clear BFS resulted in concrete expanding the forms once concrete poured. The expansion was not great, but noticeable once the forms were stripped. This directly affected the designed gap for laying the block, and lead to block cutting. Therefore, during the City Hall Project, the Engineering staff made sure to triple-check form distance before the placement of concrete and during the concrete pour, adding braces and kickers to support the forms. In addition to a built-in tolerance, this obstacle was overcome through constant inspection. As a result, very few blocks were cut at City Hall.

There were few issues with the installation of blast furnace slag for the first time. It is lightweight and easy to manipulate. However, vehicles can get stuck in it if not well compacted. Some vehicles and equipment with large distributed loads can easily track over the BFS trenches but small vehicles would tend to get stuck. Pouring concrete in sections, were smaller equipment was used, resulted in the equipment being continually stuck. A modification to the design section might consider utilizing typical limestone aggregates under concrete and asphalt surfaces.

Another lesson learned was that placing pink paint lines at the proposed elevations of BFS in the excavated cross section was extremely helpful for the contractor. The elevation demarcations, represented in the field, led to a much more accurate installation of the project.

The last lesson learned relates to the concrete ribbon that surrounded the PaveDrain block at the City Hall Project. The design boxed out the portions of the parking lot that would normally be accessible to a paving machine and quad axle truck. Therefore, the trucks and paving machine had to drive over the concrete ribbon many times which resulted in some minor cracking. The ribbon gap was filled with BFS prior to the paving so that the contractor could manage the constant movement of equipment. An alternative installation process should be considered in future construction projects of similar nature.

References:

1. Abdollahian, Sam, Kazemi, H., Rockway, T., Gullapalli, V. 2018. Stormwater Quality Benefits of Permeable Pavement Systems with Deep Aggregate Layers. Environments 2018.

2. Bioretention Manual, Prince Georges County, MD., Environmental Services Division, Department of Environmental Resources, 2007, pages 6-7.

3. Shrestha, Paliza, Hurley, S.E., Wemple, B.C., 2017. Effects of Different Soil Media, Vegetation, and Hydrologic Treatments on Nutrient and Sediment Removal in Roadside Bioretention Systems, J. Ecological Engineering, 2017.

4. Grubb, Dennis G., Berggren, D.R.V., 2018. Air-Cooled Blast Furnace Slag. I: Characterization and Leaching Context. ASCE, J. Hazardous, Toxic and Radioactive Waste, 2018.

5. Grubb, Dennis G., Berggren, D.R.V., Weik, T.B., 2018 Air-Cooled Blast Furnace Slag II: Phosphate Removal from Simulated Rainfall Events, ASCE, J Hazardous, Toxic, and Radioactive Waste, 2

Project Information:

Project Name: High Performance Biofilter
Address/City/State/Zip: Packard Avenue, Cudahy Wi 53110

Type of green infrastructure installed (check all that apply):

☐Green Roofs	☐ Rain Barrels	☐ Rain Gardens
☐ Constructed Wetlands	☐ Cisterns	☐ Soil Amendments
☐ Native Landscaping	☐ Stormwater Trees	☐ Other, Click or tap here to enter text.
☐ Porous Pavement	☒ Bioswales	

Area of specialty for this project (check all that apply):

☒Design	☐Landscaping	☐Downspouts and Gutters
☒Engineering	☐Maintenance	☐Inspection
☐Construction	☐Plumbing	

Project (Property) Owner Information:
Owner's Name: City of Cudahy
Address/City/State/Zip: 5050 S. Lake Drive, Cudahy Wi 53110
Phone: 414-769-2200
Email: : https://www.cudahy-wi.gov

Project Construction Information:
Construction Management Vendor: City of Cudahy
Project Manager Name: Ryan Schmidt
Project Manager's Vendor history: ☒currently employed ☐no longer employed ☐otherClick here to enter text.
Email: schmidtr@ci.cudahy.wi.us
Contract information (if applicable): Click here to enter text.
Final Contract Amount (contracted and amended if applicable): Click here to enter text.

Construction Start date (contracted Spring 2016
Construction Start date (actual): Unknown
Construction End date (contracted): unknonw
Construction End date (actual): Click here to enter a date.

Was the project completed on time? ☒Yes ☐No; Explanation: Project was administered by the City. CBC was not involved beyond design and engineering
Was the project completed on budget? ☒Yes ☐No; Explanation: Click here to enter text.
Was the project completed to the owner's satisfaction? ☒Yes ☐No; Explanation: Click here to enter text.

Project Description (Be sure to include cost information, photos, and a detailed description of the work performed by the Vendor applicant): The city retained CBC to complete the planning, design and engineering of a high performance biofilter to improve water runoff from the downtown area. The system was designed to infiltrate at 100 inches per hour, which reduces its footprint and lowers maintenance while being able to treat runoff from a ½ acre site in a 56 square foot biofilter.