Civil Engineering | NEWS

TRANSPORTATION

Aerial Tramway to Be Built for City's 400th Anniversary

THE CITY OF Gothenburg, Sweden, will celebrate its 400th anniversary in 2021. As part of the celebration, the city has decided to build an aerial tramway that will connect the northern and southern sections of the city across the Göta älv, a river that extends through the city to the Kattegat, the vast sea west of the nation. With a design inspired by Gothenburg's robust harbor cranes and the creative, artistic traditions of its residents, the aerial tramway and its slender triangulated towers are a reflection of the area's history and a vision for its future.

The design selected for the tramway was created for the City of Gothenburg's Traffic and Public Transport Authority by architects at Amsterdam-based UNStudio and Kjellgren Kaminsky Architecture AB, a local firm. Structural engineering for the project was provided by Knippers Helbig Advanced Engineering, which has two offices in Germany—in Stuttgart and Berlin—and one in New York City.

"The design is a perfect reference to Gothenburg," said Boris Peter, a managing partner in charge of the Stuttgart and Berlin offices of Knippers Helbig. Peter wrote in response to questions posed by *Civil Engineering*. "This couldn't be built exactly like this in another place."

The tramway will include six towers, or masts, and four stations that will serve one aerial cable-car line that extends 3 km. Current expectations are that 36 gondolas will operate on the aerial tram system, each having a capacity of up to 25 passengers. The current expectation is that passengers will be able to travel along the entire route in just 12 minutes, with gondolas arriving as frequently as every 45 seconds, according to Ben van Berkel, the founder and principal architect of UNStudio.

The system's visually striking and asymmetrical towers will be composed of stacked octahedrons that are designed to act as cantilevering trussed girders. The towers will be created from individual members that have been partially filled with fiber-reinforced concrete and that will be fabricated off-site.

The members will be formed by injecting steel- and fiber-reinforced, ultra-high-performance, compacting concrete into a steel mold with a trapezoidal outer section shape as it is being spun, so that the concrete sets against the inside face of the mold due to centrifugal force. The benefit of this method is that the diameter, wall thickness, reinforcement, and level of prestressing in each hollow element can be adjusted according to the needs of its final location within the system.

The members will be limited in length to between 20 and 30 m to withstand the necessary wind loads and for protection against buckling while simultaneously maximizing the slenderness of their design, according to Peter. They are also economical and sustainable, with the benefit of being almost completely maintenance- and corrosion-free because of their smoothness, according to Van Berkel.

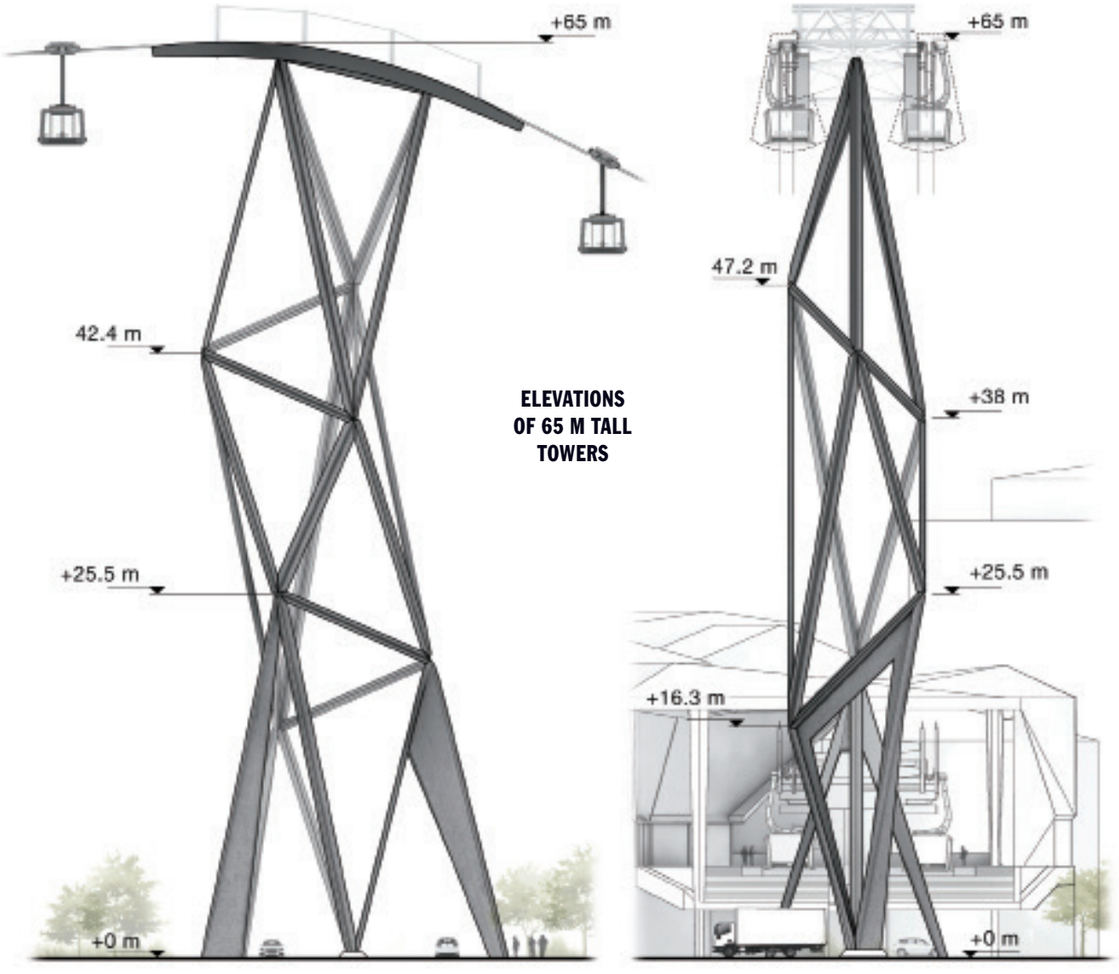
Each tower element will be created from two members paired together in asymmetrical combinations of wider and thinner members to give added protection against fluttering and vibrations induced by strong winds, according to Florian Scheible, the director of Knippers Helbig's Berlin office. A trapezoidal butterfly-style cross section between the two members will prevent transverse vibrations and resolve galloping effects by producing slightly different frequencies. The elements have also been designed so that there is sufficient mass to resist uplift to eliminate tension forces under the governing load cases, according to material provided by Knippers Helbig.

Movement of the towers must be strictly limited to protect the gondolas' safe operation along the cables. "One critical aspect of the whole brief was limitation of the horizontal deflections of the entire masthead," Peter said. To this end, the towers will be created from three-dimensional triangular stacks of the elements and are designed to avoid major bending moments in compression and tension. "It's basically a concept of set octahedrons," Peter said.

"As everybody knows, triangles are very stiff," Peter explained. So triangular shapes were incorporated into multiple aspects of the tower design, from the section shape of the members—and thus the elements—to the arrangement of the sets of elements that will compose each layer of the towers.

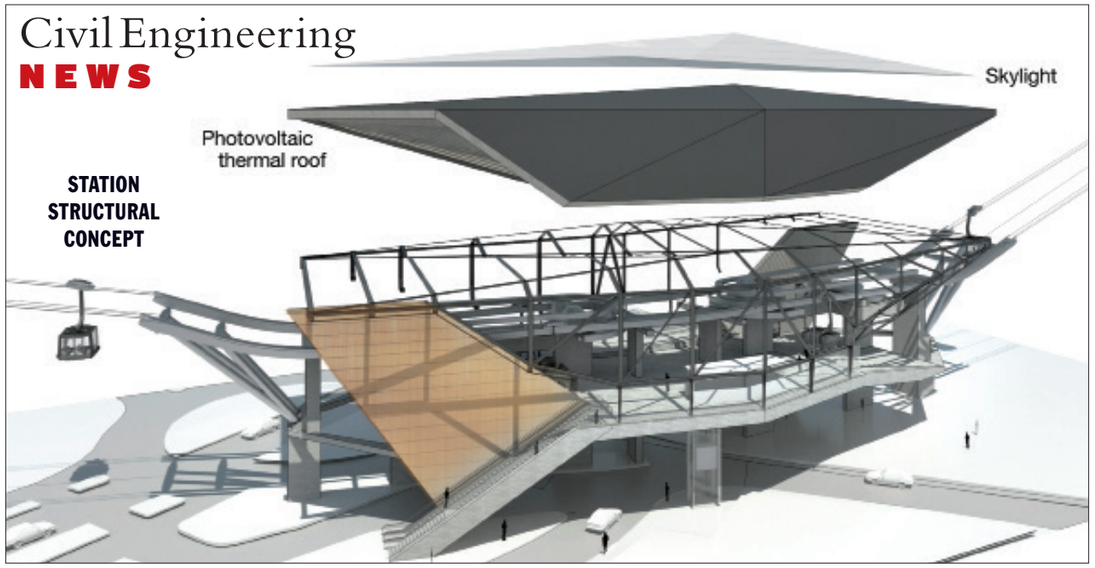
Currently, the expectation is that the towers will be founded on piles, with a pile head and foundation plate under the legs of each of the towers, according to Knippers Helbig. The legs will be larger than the prefabricated upper members and will be cast in place so that they can be designed specifically for the individual site needs and available space, he said.

The minimalist design of the towers prevents them from casting heavy shadows on the surrounding areas, while their shapes will prevent unpleasant wind conditions at their bases,



UNSTUDIO, BOTH

An aerial tramway to be built in Gothenburg, Sweden, will connect the northern and southern sections of the city across the Göta älv.



according to Knippers Helbig. They also promote safety by admitting light to the ground level, according to UNStudio.

The passenger gondolas will operate along the top of the aerial tramway on a three-cable system. Two cables will hold the gondolas while the third will move them along the system. This design was chosen by the city for its high passenger capacity and minimal noise, as well as because it enabled long tower spans and can withstand windy conditions better than other mechanical options, according to Van Berkel.

The stations will be open on either end to allow the gondolas to pass through, stopping once for disembarking passengers and again for embarking passengers. Self-supporting, "floating" roof structures pierced by skylights will protect each station's elevated platform. These roofs will be created from prefabricated three-pinned frames that will provide cross reinforcement and lateral stiffness, according to Knippers Helbig. Rooftop photovoltaic panels will generate electricity that will contribute to operating lighting and heating in the stations' floors and stairwells.

Construction of the tramway is anticipated to begin in 2021 and be complete by 2025, according to UNStudio.
—CATHERINE A. CARDNO, PH.D.

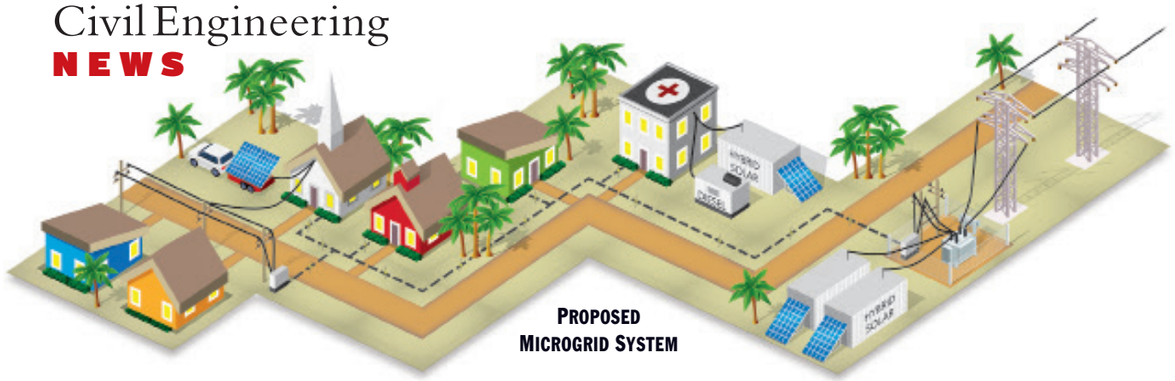
The mobile unit that was hooked up to the children's shelter featured foldable solar panels that can generate between 25 and 40 kW of power.

UNSTUDIO, *TOP*; © LOUIS BERGER 2018

ENERGY

Pro Bono Solar Project Restores Power to Puerto Rican Shelters

A PRO BONO EFFORT by teams from the international engineering firm Louis Berger and several partners has brought electrical power back to a children's shelter and a women's shelter in a remote village in the mountains of Puerto Rico. The two shelters—Hogar El Pequeño Joshua, for children, and La Perla de Gran Precio, for women—are located in the village of Barrio Nuevo, part of the municipality of Bayamón, southwest of San Juan, Puerto Rico's capital city. Like most sites in Puerto Rico, the shelters lost their access to power from the island's main electrical grid in the aftermath of Hurricane Maria in September 2017. Afterward, the shelters had been relying on diesel generators that creat-



PROPOSED MICROGRID SYSTEM

ed pollution, cost too much to operate continuously, and were difficult to keep fueled while the rest of the island struggled to recover, notes Tom Lewis, P.E., J.D., M.ASCE, who is the U.S. Division president for Louis Berger and is based in the firm's corporate headquarters in Morristown, New Jersey.

Even before the hurricane, electrical power from Puerto Rico's main grid had been spotty in Barrio Nuevo, where the shelter buildings often lost power several times every week, says Lewis. So the goal of the current project, which was launched at the end of January, is to demonstrate how solar-hybrid technologies can provide more reliable and resilient power sources in the event of future storms as well as in the daily life of villages like Barrio Nuevo, Lewis explains. "That, in a nutshell, is what we're trying to prove with this demonstration project: that there is a better way than what they were doing previously," Lewis stresses.

Working with the office of the governor of Puerto Rico, Louis Berger considered several locations for the solar-hybrid demonstration project before selecting Barrio Nuevo.

To provide the mobile systems to the shelters, Louis Berger worked with WestGen Power Solutions LLC and Advanced Environmental Group (AEG), both based in the Los Angeles area, and Harvard University's Zofnass Program for Sustainable Infrastructure. The first phase of the demonstration project, designed to last six months, involved two hybrid systems that were each connected to an individual facility, creating a so-called nanogrid, Lewis says.

During this initial phase, Louis Berger and its partners provided two types of mobile systems to the shelters. WestGen supplied one unit, manufactured by SolaRover Inc., of Lone Tree, Colorado, that features foldable solar panels and can generate between 25 and 40 kW of power. This unit was hooked up to the children's shelter. The women's shelter is using a separate unit—manufactured by DC Solar Solutions, of Benicia, California—that was supplied by AEG. It features fixed solar panels that can provide between 5 and 15 kW of power, Lewis says.

Lewis explains that "we purposely wanted to embrace different providers to bring these solutions, so we can see which ones perform better." Both units feature small diesel generators and battery storage systems for round-the-clock power generation. An electrician connected the systems to each shelter, and small exhaust stacks were installed to divert diesel fumes away from the buildings.

During daylight hours, the nanogrid hybrid systems provide silent, clean, and essentially free electrical power; the diesel backup only has to run for a few hours a day, Lewis explains.

Because many solar panels at sites throughout Puerto Rico were damaged during the hurricane, the second-phase microgrid system will feature what Lewis calls "semimobile" panels that can be packed up and stored in a safe location during storms and then brought back out.

A second phase of the effort will involve the establishment of a microgrid system that will provide solar power to several buildings simultaneously; the microgrid will also connect to existing diesel generators and even be able to draw power from the main electrical grid, says Lewis. The second phase will feature the installation of up to 200 kW of battery storage capacity and sufficient solar panels to generate 50 kW, which will be tied together by the microgrid hub technology and also linked to the existing 100 kW diesel backup generator at the women's shelter, Lewis says. The clean, lower-cost solar and battery power will be used as the first and second options, he explains, and the diesel generator will be used only if the other two sources are not able to provide sufficient power.

Louis Berger is also working in Puerto Rico on several other power-related projects. In particular, the U.S. Army Corps of Engineers contracted with Louis Berger to provide U.S. government-supplied diesel generators to key sites around the island—what Lewis describes as "haul and install" projects. The firm is also providing maintenance and operations assistance to the users of those generators. In addition, Louis Berger is working with the Corps and the Federal Emergency Management Agency to help keep the generators in service at critical facilities in Puerto Rico even when those generators are not federally owned, Lewis notes. This includes more than 800 generators that are providing power to hospitals, water pump stations, and even entire towns.

The firm also demonstrated the viability of the microgrid concept on a community scale—albeit it, without the solar component—through the installation of a pair of 2 MW diesel generators on the Puerto Rican island of Culebra, which previously received electrical power via a marine cable that was damaged during the hurricane. The two generators were installed at the substation that had been connected to the marine cable, Lewis explains, and were able to "energize the entire community." —ROBERT L. REID

TRANSPORTATION

Key Stretch of the Long Island Rail Road Will Receive Third Track

INITIAL construction is expected to begin soon as part of efforts to add a third track to a 9.8 mi long section of the Main Line of the Long Island Rail Road in Nassau County, New York. Expected to cost $2.6 billion overall, the project aims to reduce delays on the busy commuter railway, accommodate growth, improve system reliability, enhance safety, and ease congestion along the roadways that intersect at grade with the rail lines. To this end, the project will add several rail bridges in order to eliminate a handful of at-grade intersections, expand multiple existing rail bridges to enable them to accommodate the third track, and implement such improvements as new switches, signals, and power equipment.

Currently, the Main Line of the Long Island Rail Road consists of a double-track configuration that serves more than 300,000 passengers per day. Extending between the Floral Park and Hicksville stations, the segment that is to receive the third track currently carries more than 250 trains on a normal weekday and is used by about 40 percent of the railway's passengers. During peak periods, the busy stretch of the railway is prone to congestion. With the expectation that Long Island's population will grow and jobs will be added at a steady pace in the coming decades, the situation would likely worsen in the absence of the planned improvements.

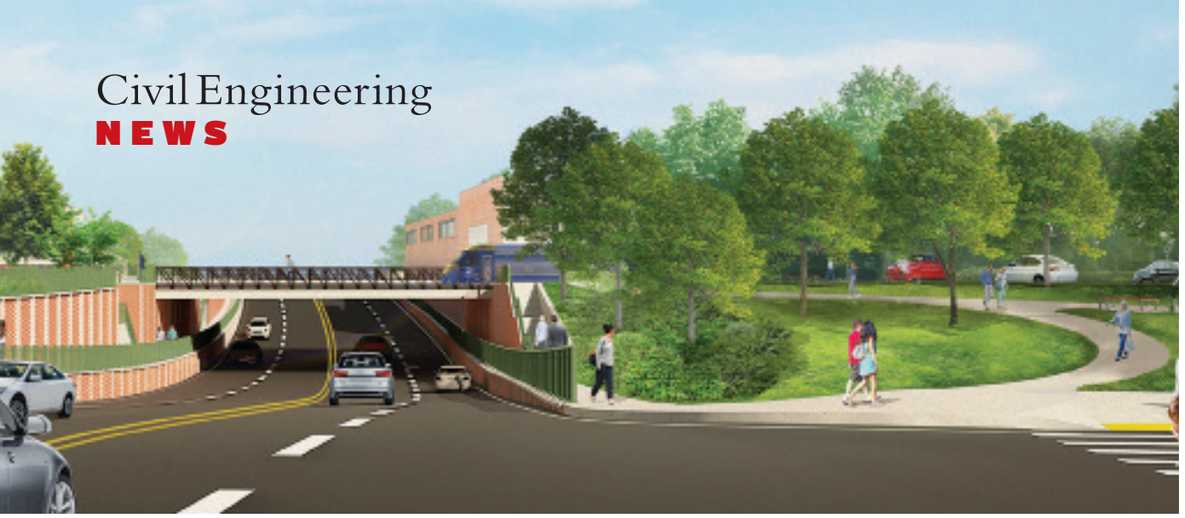
Once completed, the third track will enable the Long Island Rail Road to offer two-directional service all day on the Main Line.

Typically, travel on the Long Island Rail Road is heaviest from east to west during the morning rush hour, as commuters head into New York City, while the reverse occurs during the evening. Because only a small number of trains may travel in the opposite direction of most of the traffic during peak periods, commuters currently seeking to travel against the flow often have limited options for doing so. Once completed, the third track will enable the Long Island Rail Road to offer two-directional service all day on the Main Line.

As part of efforts to add a third track to a nearly 10 mi long section of the Long Island Rail Road, the project will improve safety and reduce slowdowns in Nassau County, New York, by eliminating seven at-grade street-level crossings, including the one in the New Hyde Park area of Long Island.

The project also will improve safety and reduce slowdowns by eliminating seven at-grade street-level crossings, where the rail lines cross busy arterial roadways. At such crossings, attempts by motorists and pedestrians to go around gates that have been lowered in advance of trains entering intersections lead to accidents and delays. Between 2013 and 2016, 127 such incidents on the Main Line resulted in 4,354 late

STANTEC



STANTEC

or canceled trains, according to the Metropolitan Transportation Authority (MTA), which owns the Long Island Rail Road as part of its mandate to provide transit services in the New York City region. Motorists using the roadways will also benefit from the elimination of the at-grade crossings. Currently, crossing gates may close roadways for up to 30 minutes in a peak hour, resulting in major congestion.

Furthermore, the project will raise certain bridges to decrease their risk of being struck by vehicles. When such an incident occurs, crews must inspect the bridge to verify its structural stability before allowing rail traffic to return, a process that can result in significant delays.

In January, the MTA finalized a $1.8-billion design/build contract with 3rd Track Constructors, the consortium that was selected to implement the improvements associated with the addition of the nearly 10 mi long third track. The consortium includes Dragados USA Inc., John P. Picone Inc., CCA Civil Inc., and Halmar International LLC. The global design firm Stantec is serving as the lead engineer for the consortium. Separately, the MTA awarded in December an approximately $100-million contract for project management consulting services pertaining to the third-track project to a joint venture comprising Arup and Jacobs.

A main focus of the project will involve eliminating seven street-level grade crossings. In two of these locations, the streets simply will be closed

At five of the existing at-grade crossings, rail bridges will be added and the roadways will be modified so as to pass beneath the bridges.

at the intersection with the railroad, doing away with the crossings altogether, says Stuart Lerner, P.E., M.ASCE, the executive vice president for infrastructure at Stantec. At the remaining five crossings, rail bridges will be added and the roadways will be modified so as to pass beneath the bridges, Lerner notes. Each of the bridges will feature superstructures consisting of steel girders with transverse floor beams and a ballasted steel deck on top of a reinforced-concrete substructure.

Additional project improvements will include upgrades to six stations as well as signal, power, and communication systems.

Construction of these five rail bridges will be conducted in a manner designed to facilitate a rapid installation process and minimize the extent to which both tracks in a given location must be shut down, Lerner says. During construction, the existing roadway will remain in service, while an area adjacent to the roadway will be excavated to the level at which the new roadway will be located. Next, a "U-shaped box" made of reinforced concrete will be constructed in the excavation, adjacent to the proposed crossing, Lerner says. To be constructed on a concrete launching slab, this box will form the substructure of the rail bridge, supporting the girders, floor beams, and deck. After the steel superstructure has been added to the top of the box, the existing tracks will be removed, the underlying soil will be excavated, and the box will be slid into position. "Once the structure is in place, the precast approach slabs, ballast, and tracks will be installed, and service will be restored," Lerner says. The roadway beneath the new bridge then will be completed.

Eight existing rail bridges will be modified to enable them to accommodate a third track, Lerner says. To minimize the deleterious effects of construction on local communities, the third track will be located within the railroad's existing right-of-way. Extensive use of retaining walls will facilitate the goal of restricting construction to the right-of-way. Additional project improvements will include upgrades to six stations as well as signal, power, and communication systems.

As of early April, the project design was about 30 percent complete, Lerner says. While preconstruction activities are set to begin this spring, substantial construction will get under way in late 2018. The overall project is scheduled to be completed by late 2022.

—JAY LANDERS

WASTEWATER

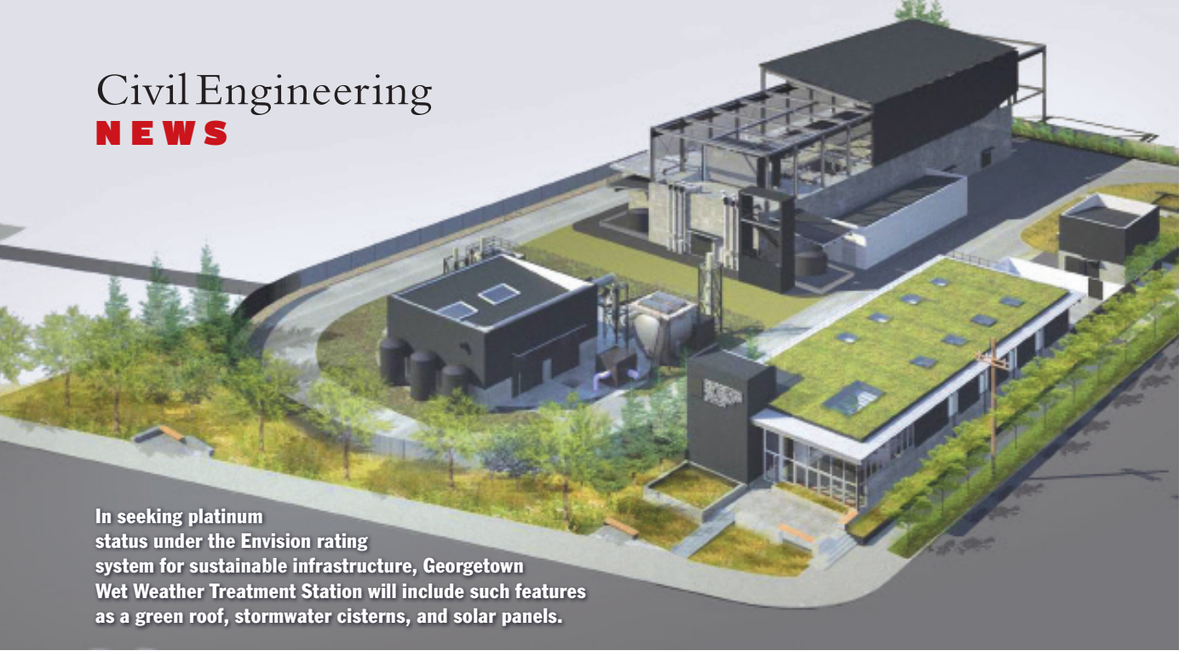
Wet Weather Treatment Station Will Reduce CSOs in King County, Washington

AS PART OF ITS longstanding commitment to reduce combined sewer overflows (CSOs), King County, Washington, held a groundbreaking ceremony in early March for its $262-million Georgetown Wet Weather Treatment Station. Designed to treat CSOs that otherwise would enter the Duwamish River untreated, the facility represents the latest effort by King County to comply with its obligations to address CSOs.

King County has decreased its CSOs by 90 percent since 1979, when it began its overflow control program known today as Protecting Our Waters. Under the terms of a 2013 consent decree signed with the U.S. Department of Justice and the U.S. Environmental Protection Agency (EPA), King County has until the end of 2030 to control its CSOs, meaning that an existing CSO outfall may experience no more than one overflow event per year on a 20-year moving average. The Georgetown Wet Weather Treatment Station is one of nine CSO control measures spelled out in the 2013 consent decree.

The treatment station will accept flows from two basins having a combined size of about 2,100 acres. Currently, one of the basins discharges CSOs at the Brandon Street outfall, while the other discharges at the South Michigan Street outfall. Together, the outfalls overflow about 40 times per year, releasing on the order of 70 million gal. to the Duwamish River during an average year. Upon the completion of the Georgetown Wet Weather Treatment Station, these overflows will be reduced by 95 percent, says Matoya Darby, the wastewater capital project manager for the King County Wastewater Treatment Division.

Because of the industrial nature of the basins they serve, the Brandon Street and South Michigan Street outfalls rapidly receive significant runoff



In seeking platinum status under the Envision rating system for sustainable infrastructure, Georgetown Wet Weather Treatment Station will include such features as a green roof, stormwater cisterns, and solar panels.

KING COUNTY WASTEWATER TREATMENT DIVISION, MILLER HULL, AND BERGER PARTNERSHIP

volumes during wet-weather events. Such conditions precluded the use of green infrastructure to reduce runoff or a tank or pipeline to store flows in advance of treatment at an existing wastewater treatment plant. Green infrastructure "would not have had that much of an impact" in terms of reducing peak flows, while attempts to detain CSOs for subsequent treatment "would have led to an unrealistically sized storage tank," says Tina Hastings, P.E., the project manager for Jacobs. In 2013, King County hired CH2M—which is now Jacobs—and HDR to design the wet-weather treatment facility. The Miller Hull Partnership served as architect, while the Berger Partnership, of Seattle, provided landscape architecture services.

CSO treatment near the outfalls was determined to be the least expensive solution that had the capability "to treat a high rate of flow to a high standard very quickly," Hastings says. As a result, King County opted to construct the Georgetown Wet Weather Treatment Station, which will be able to treat up to 70 mgd.

To convey flows from the combined sewer system to the treatment station, a new regulator and influent piping connections were added to reroute a nearby large-diameter interceptor sewer that passes near the project site. Within the regulator, gates were added that will divert flows to the station by means of a 96 in. diameter pipe. After undergoing screening, the influent will enter a 1.1 million gal equalization tank, from which a 70 mgd pump station will convey flows to the treatment system.

Because the station will need to start and stop operations intermittently depending on the timing of wet-weather events, the design team wanted an approach that could conduct primary clarification rapidly, Hastings says. The design team evaluated technologies on the basis of treatment capabilities, capital and life-cycle costs, space requirements, and operation and maintenance considerations. Early in the design phase, the team selected specific equipment in order to optimize the facility design. For example, the Actiflo ballasted sedimentation technology, from Veolia Water Technologies, was chosen for its ability to remove most suspended solids quickly while occupying a relatively small footprint. For disinfection, the team opted to use ultraviolet light because it obviated the need to store large amounts of chemicals on-site and eliminated the issue of residual chemicals in the treated water, Hastings says.

Because the station will need to start and stop operations intermittently depending on the timing of wet-weather events, the design team wanted an approach that could conduct primary clarification rapidly.

After treatment, effluent will flow by gravity through a 60 in. diameter pipe to a new outfall structure about 1,500 ft away that will discharge to the Duwamish River. As for solids removed during the ballasted sedimentation process, this material will be stored temporarily on-site until the wet-weather event ends, when it will be returned to the combined sewer system for treatment at the West Point Treatment Plant. "We wanted to make sure that nothing in the treatment station caused an overflow elsewhere in the system," Hastings says.

Begun last year, demolition and site preparation work were led by Titan Earthwork, of Pacific, Washington, and completed in February. The treatment station will be constructed by Flatiron West Inc., which was awarded the contract in October 2017. The effluent pipeline and outfall will be constructed by Pacific Pile & Marine, which was awarded the contract in December. Although a contract has yet to be awarded for the construction of the influent conveyance system, work on that component of the project is expected to begin late this year. As required by the consent decree, the overall Georgetown Wet Weather Treatment Station is scheduled to be completed by the end of 2022, Darby says.

For its part, King County intends to have the treatment station certified as a platinum facility under the Envision rating system for sustainable infrastructure administered by the Institute for Sustainable Infrastructure, of Washington, D.C. To this end, Darby says, the treatment station will include such features as a green roof, cisterns to manage stormwater, and solar panels to generate electricity. Other sustainable elements include cultural resource preservation and environmental education, Darby says.

King County intends to have the treatment station certified as a platinum facility under the Envision rating system for sustainable infrastructure.

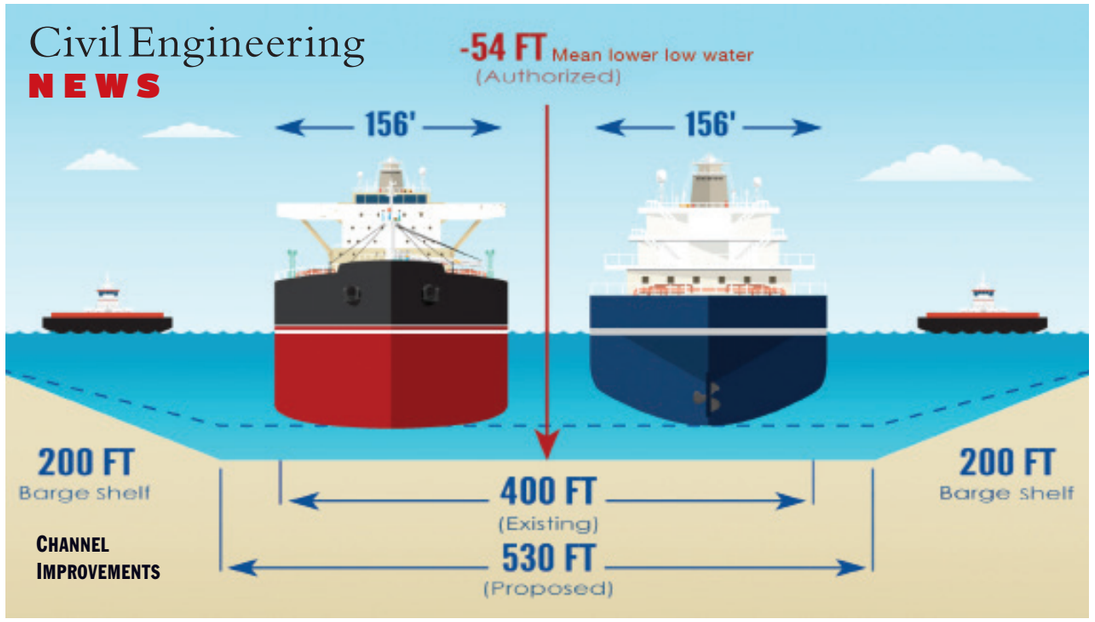
In August 2017, the EPA announced that it had selected the Georgetown Wet Weather Treatment Station as one of the first 12 projects to receive financing as part of the agency's Water Infrastructure Finance and Innovation Act (WIFIA) program. As a result, King County expects to receive a long-term loan from the EPA of about $134 million for the project. Compared with the costs associated with obtaining a similar amount of financing on the market, King County likely will save its ratepayers more than $30 million as a result of the low-interest loan from WIFIA, Darby says. —JAY LANDERS

AEDAS

INTERCONNECTED OFFICE BUILDINGS TO COMPLEMENT ZHENGZHOU SHORELINE

A TRIO OF interconnected buildings will provide office space in Zhengzhou, the provincial capital of Henan, China, and a major international air transport hub. Convenient to Zhengzhou Xinzheng International Airport, the Zhenghong Property Air Harbour Office buildings designed by Aedas will be dynamically positioned at 45-degree angles on a narrow rectangular property. A central "diamond" will be flanked by elongated offices stretching away, resulting in a symmetrical, W-shaped formation when viewed from above. Angling the buildings on the property will maximize views toward Zhenghong Central Park to the north, increase the number of ground-level open spaces, and encourage airflow. The 60 m tall project will encompass 86,831 sq m in gross floor area. Consisting of 14 aboveground and two underground floors, the main buildings will be connected by the 3rd, 12th, and 13th floors, each of which extends the length of the complex. The underground floors also span the entire complex. Rounded corners and tapering overhangs and setbacks on the main buildings will carry through horizontal and vertical contours on the connecting floors, giving the project a three-dimensional undulating profile designed to evoke the winding course of the nearby Yellow River. Rooftop terraces on the connecting floors will increase the amount of open space available to the buildings' tenants and visitors. Based in Hong Kong and with offices around the world, Aedas in March won the Tall Buildings category in the 2018 MIPIM/ *Architectural Review* Future Project Awards for its design for the Taichung Commercial Bank Headquarters mixed-use project in Taichung, Taiwan. Construction of the Zhenghong Property Air Harbour Office is scheduled for completion by 2022.

—MATT BOYLE, *ASCE director of publications production*



PORTS

Army Corps to Widen, Deepen Channel in Port of Corpus Christi

THE MAIN navigation channel that services the Port of Corpus Christi in Texas, will be widened and deepened as part of a $327-million dredging project that is designed to enable ships to enter or leave the port with larger loads. The port will also be improved via the addition of spaces known as barge shelves that will be excavated on either side of the channel. Currently, the largest ships—especially oil tankers but also certain vessels carrying such cargoes as liquid natural gas or iron briquettes—must wait at an offshore location to have some portion of their cargoes removed by service vessels before they can enter the port. Likewise, such vessels must wait until they have left the port to fully load their cargoes via service vessels. This is because the port's current draft is just –47 ft mean lower low water (MLLW), explains Nicholas Laskowski, P.G., a project manager at the U.S. Army Corps of Engineers' Galveston District.

The Corps is directing the channel dredging project under a project partnership agreement with the Port of Corpus Christi Authority.

The dredging project aims to deepen the 36 mi long main navigation channel to –54 ft MLLW. It will also widen the passage in the Redfish Bay area known as Lower Bay Reach near the port entrance from 500 to 530 ft; in Corpus Christi Bay itself, the area known as Upper Bay Reach will be widened from 400 to 530 ft. On either side of the Upper Bay Reach channel, the project will excavate 200 ft wide barge shelves at –14 ft MLLW. These shelves will provide space on the sides of the channel for barges to move over and wait as a deep-draft vessel goes by—essentially, forming the water equivalent of shoulders on a highway, Laskowski explains. The project will also extend the channel entrance—located at the city of Port Aransas, east of Corpus Christi—by approximately 10,000 ft and deepen it from –49 to –56 ft MLLW.

The first contracts for the project will be awarded sometime this year, and the work is expected to be completed by 2022. "The deeper channel will increase the transportation efficiency and ultimately lower costs" at the leading crude oil export port in the United States, Laskowski notes. Once completed, the project will make Corpus Christi "a more viable port to attract more business and overall improve the economy of the area, the state, and the nation in general," he says.

The port will also be improved via the addition of spaces known as barge shelves that will be excavated on either side of the channel.

The project currently features eight separate contracts, but some of those contracts might be combined or separated further, he adds.

Widening and deepening the channel will involve dredging an estimated 35 million cu yd of material that will be deposited in multiple existing and new placement areas, as well as so-called beneficial use sites, Laskowski says. Some of these sites will be protected partially or entirely by riprap, levees, dikes, and other systems that can confine the dredged material and create breakwaters to provide protection for the shore.

Other sites will be unconfined, especially those outside the port entrance and within the Upper Bay Reach area. The placement of sediment in those unconfined sites will be especially challenging, Laskowski notes, because "we don't want to put material directly on the side of the channel that will immediately go back into the channel." So the Corps will be carefully studying the existing tidal flow patterns and variations in the water flow to determine the optimum sites for open bay placements.

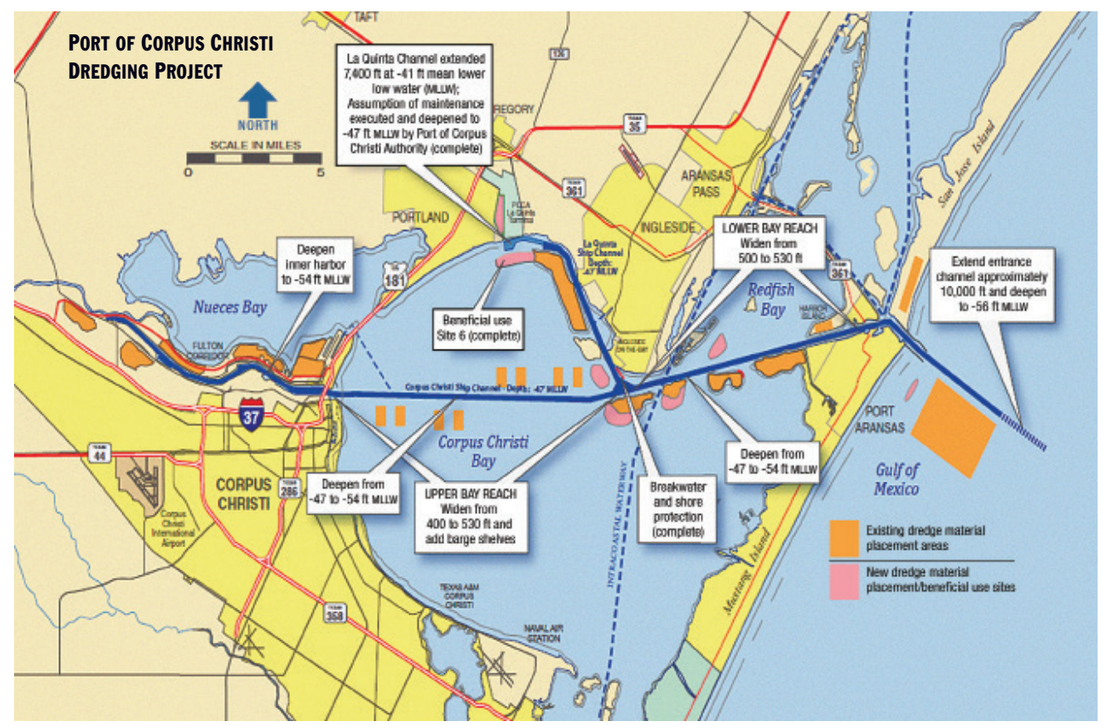
The riprap and other protective systems will be adaptable in the event of subsidence or sea-level rise, Laskowski says, because it will be easy to add more riprap and build a breakwater higher, for example. At the same time, "when you start stacking up riprap, that can get expensive," he notes. So the Corps is trying to determine the best ways to accommodate wave energy and wind while minimizing the costs for the protective material.

The placement areas will be used on an ongoing basis for future maintenance dredging. But the beneficial use sites will be one-time use areas that are designed to create new habitats that can be planted with sea grass or *Spartina alterniflora*, a perennial deciduous grass that grows in intertidal wetlands. "We'll pump the material in, let it settle, plant the [vegetation], and then monitor it for success—to make sure it's growing well, established, and holding the material together," Laskowski explains.

In a western portion of the port known as the Inner Harbor, a special challenge will involve the presence of numerous pipelines buried in the harbor bottom. While there are only a handful of such pipes at the port entrance, there are an estimated 26 pipes, ranging in size from 4 to 20 in. in diameter, at the Inner Harbor portion that will have to be relocated to deeper positions, Laskowski says. Although the actual pipeline relocation work and costs will be handled by the Port of Corpus Christi Authority and the pipeline owners, the Corps can help facilitate the effort, Laskowski adds.

In a western portion of the port known as the Inner Harbor, a special challenge will involve the presence of numerous pipelines buried in the harbor bottom.

The origins of the current dredging project date to 1990 when Congress began to consider a deeper channel in the port, Laskowski says. An earlier project partnership agreement between the Corps and the port authority is considered part of the overall project. It resulted in an approximately 7,400 ft long extension to another channel within the Corpus Christi Bay area known as the La Quinta Channel. Substantially completed in 2013, the La Quinta Channel extension also involved work by the Corps to deepen the channel to –41 ft MLLW; the port authority itself later took responsibility to deepen the extension by another 6 ft to –47 ft MLLW, Laskowski says. The remaining work in the La Quinta Channel includes the planting of 15 acres of sea grass as a mitigation effort, but that cannot be done until the sediment has settled sufficiently, probably later this year, Laskowski says. —ROBERT L. REID



PORT OF CORPUS CHRISTI AUTHORITY, *ABOVE*; PORT OF CORPUS CHRISTI AUTHORITY, MDR, DON RODMAN, *OPPOSITE*

RÉSEAU EXPRESS MÉTROPOLITAIN (REM)/V2COM

A REMEDY FOR MONTREAL'S TRANSPORTATION NETWORK

IN APRIL, construction began on the Réseau express métropolitain (REM), a new 67 km long light-rail transit system that will connect downtown Montreal, its surrounding suburbs, and Montréal-Trudeau International Airport. With trains leaving every 2.5 minutes, the system is expected to transport passengers from downtown to the airport in 20 minutes. One of North America's largest public transportation projects, the REM is expected to cost C$6.3 billion (U.S.$5 billion) to construct. The project is owned by CDPQ Infra, a wholly owned subsidiary of Caisse de dépôt et placement du Québec, a Montreal-based public entity that manages funds, primarily for pension plans and public and parapublic insurance plans. Consisting of 26 stations, the system will comprise an integrated, multimodal network that links to the Montreal Metro, the city's underground transit system, at three locations. In addition, the REM will connect to existing commuter train lines and bus lines while facilitating pedestrian and cyclist access. Designed with an emphasis on transparency, the stations will feature ample glazing to maximize daylight, enhance security, and facilitate wayfinding. This design feature also "optimizes the visual connection between the stations, the railway cars and their environment," according to an April 12 statement from Lemay, Perkins+Will, and Bisson Fortin. The three architecture firms are part of the NouvLR General Partnership, the consortium selected by CDPQ Infra in February to receive the infrastructure engineering, procurement, and construction contract for the REM project. The consortium is led by SNC-Lavalin, Dragados Canada Inc., Groupe Aecon Québec Ltée, Pomerleau Inc., and EBC Inc. Each station was "designed to be built as a unique configuration of shared modular components," according to the April 12 statement. "These innovative, pre-fabricated components will allow for easy, efficient, and environmentally sustainable construction, as well as cost-effective customization to account for local context, topology, and geography." Although individual stations will have their own unique design elements, the entire network will maintain a unified appearance overall. In homage to the historical importance of Quebec's wood industry, the stations will include wood in their ceilings, adding warmth and emphasizing aesthetic continuity. Envisioned as a series of linked biodiverse ecosystems, the areas around each station will form a green urban continuum. Construction is scheduled to conclude by the end of 2020, and operations are to begin in summer 2021.

BUSINESS BRIEFS

Jacobs Engineering Group Inc., a multidisciplinary architecture, engineering, and construction firm with more than 54,000 employees in more than 230 offices around the word, has completed its acquisition of CH2M, a 26,000-employee engineering firm based in Englewood, Colorado, with more than 150 offices. The purchase creates a $15-billion corporate entity with expanded service offerings and geographic reach.

WSP Global Inc., the Montreal-based multidisciplinary engineering firm, has acquired the Olso, Norway-based firm UnionConsult Gruppen AS and its affiliated entities. The move adds 160 employees to WSP's 42,000 and expands WSP's presence in Scandinavia with nine offices located throughout Norway.

Stantec, a 22,000-employee design firm based in Edmonton, Alberta, Canada, has acquired ESI Consulting, an environmental consulting firm based in Shrewsbury, England. ESI has more than 50 staff members in three offices in the United Kingdom, including its headquarters; Reading, England; and Cardiff, Wales. ESI specializes in groundwater, land use, and sustainable development.

Brierley Associates, a geotechnical and structural design and consulting firm based in Denver, with offices in 13 states, has added another: Hawaii. The firm opened its first office in the Aloha State in April. The office, which is headed by senior construction professional Don Painter, is located in Honolulu.

Kimley-Horn, a 3,000-person planning and design consulting firm with more than 80 offices nationwide, has acquired Remenschneider Associates Inc., a planning and landscape architecture firm based in Indianapolis. The move enables Kimley-Horn to expand its services throughout the Midwest.