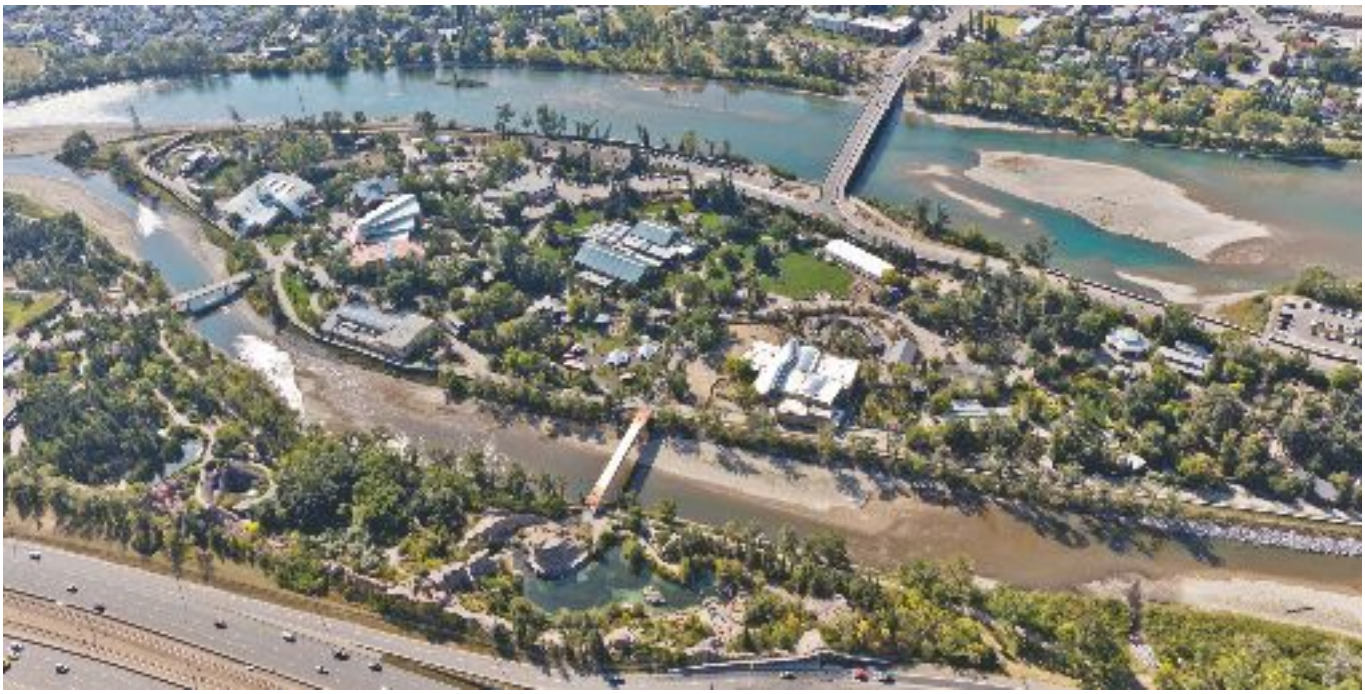


2019 CCE AWARDS

Calgary Zoo Flood Mitigation

Categories:
Water Resources

Client/Owner:
The City of Calgary

Key Partner:
The Calgary Zoological Society

Subconsultants:
Thurber Engineering Ltd.
Tetra Tech Canada Inc.
Matrix Solutions Inc.
ADP Engineering Ltd.

General Contractor:
PCL Construction Management Inc.

April 2019

Photo courtesy of the Calgary Zoo

CALGARY ZOO ON ST. GEORGE'S ISLAND

St. George's Island in the Bow River was Calgary's first public park. It has been used by the community for picnics, relaxing and socializing since the 1870s and was only accessible by ferry until 1900 when the first bridge connection was built. The island hosted its first collection of animals in 1917 with the Calgary Zoological Society officially registering as a not-for-profit society in 1929.

The Calgary Zoo was among the first zoos in Canada to be accredited by all three global Zoological Associations and receives international recognition as one of the top zoos in the world for conservation research. Moreover, the Zoo has gained recognition as one of Alberta's top three most respected organizations and top ten most beloved brands.

The City of Calgary recognizes the Calgary Zoo as a valuable cultural asset and integral contributor to The City's vision of creating and sustaining a vibrant, healthy, safe and caring community. The Zoo leverages The City's assets, operating and capital contributions and other forms of financial support in generating modest revenue for reinvestment in the Zoo's facilities. In 2012, a landmark agreement was signed by the Chinese and Canadian governments to loan giant pandas to Canada for 10 years, with 5 planned in Calgary. With arrival of the pandas expected by 2018, the Zoo unveiled a visionary new 20-year Master Plan in April 2013, which featured development of a new exhibit, the Panda Passage Habitat.

Calgary's Most Destructive Flood

With St. George's Island located at the confluence of the Bow and Elbow Rivers, the Calgary Zoo has been subject to many flood events throughout its history. In fact, the Zoo experienced its first major flood on the Bow River in its opening year of 1929, affecting many resident animals. Despite the presence of flood vulnerabilities, nearly a century of significant development has occurred on the island which now includes 60% of the Zoo's critical infrastructure, valued at upwards of $500 Million.

Along with much of Southern Alberta, record flooding occurred on the Bow and Elbow Rivers in June 2013. The Calgary Zoo was inundated and without power in the early morning hours of June 21, having had less than 10 hours' notice to enact their flood operations plan. In that time, without a single loss or incident, the Zoo evacuated as many animals as possible from the collection of more than 200 animals on the island — though a near-miss hippopotamus escape was among the day's biggest news headlines. As the floodwaters receded, the cleanup began in the days and months that followed and questions arose about the future viability of the Zoo's island home.

The flood of 2013 was unparalleled in recorded history both in terms of magnitude, as Calgary's most destructive flood, and in terms of consequential damages, as Canada's costliest natural disaster. The flood caused $50 Million in direct damages to the Zoo's critical infrastructure, structures and buildings. With much uncertainty concerning the fate of the Calgary Zoo, the non-profit organization came under a great deal of duress and was forced to make significant layoffs as losses in revenue mounted while the Zoo recovered and remained closed for repairs through the usual peak season in summer 2013.

Preservation of the Calgary Zoo

As one of Calgary's most historic and iconic landmarks, protection of the Zoo is essential to preserve its image as Canada's leader in wildlife conservation, and as a world class facility for global tourism and the enjoyment of future generations.

As initial recovery of the Zoo commenced, ISL Engineering and Land Services Ltd. (ISL) was retained by The City of Calgary to study options on how to protect the Zoo from future flood events. Associated Engineering (AE) was engaged as a key partner following the planning stage, and the ISL / AE team worked together for over four years to deliver this landmark project. Flood protection of the Calgary Zoo on St. George's Island was advanced out of necessity, not only to restore safety and confidence in preserving it as a viable long-term amenity, but also as a matter of preserving Canada's international stature, with the expectation that the flood mitigation be complete in time for the opening of the Panda Passage Habitat.

Recovery of the Zoo brought support and unity from the entire city while its preservation was symbolic of our resilience. As one of the most complex and vital projects in Calgary following the 2013 flood, it was driven by the vision of the late Calvin McClary, P.Eng. (Cal) who, as ISL's Project Manager, came to champion the project and represent Calgary's can-do spirit for the entire team.

FLOOD RISK MANAGEMENT

Following the 2013 flood, all orders of government, businesses and residents shared in their responsibility to manage flood risks and protect Calgary. An integrated approach by The City was adopted to unify watershed, community and property level flood mitigation through key economic metrics which included technical assessments, sustainability analyses and community engagement. In the months that followed the 2013 flood, discussions on the future of the Calgary Zoo covered a range of options:

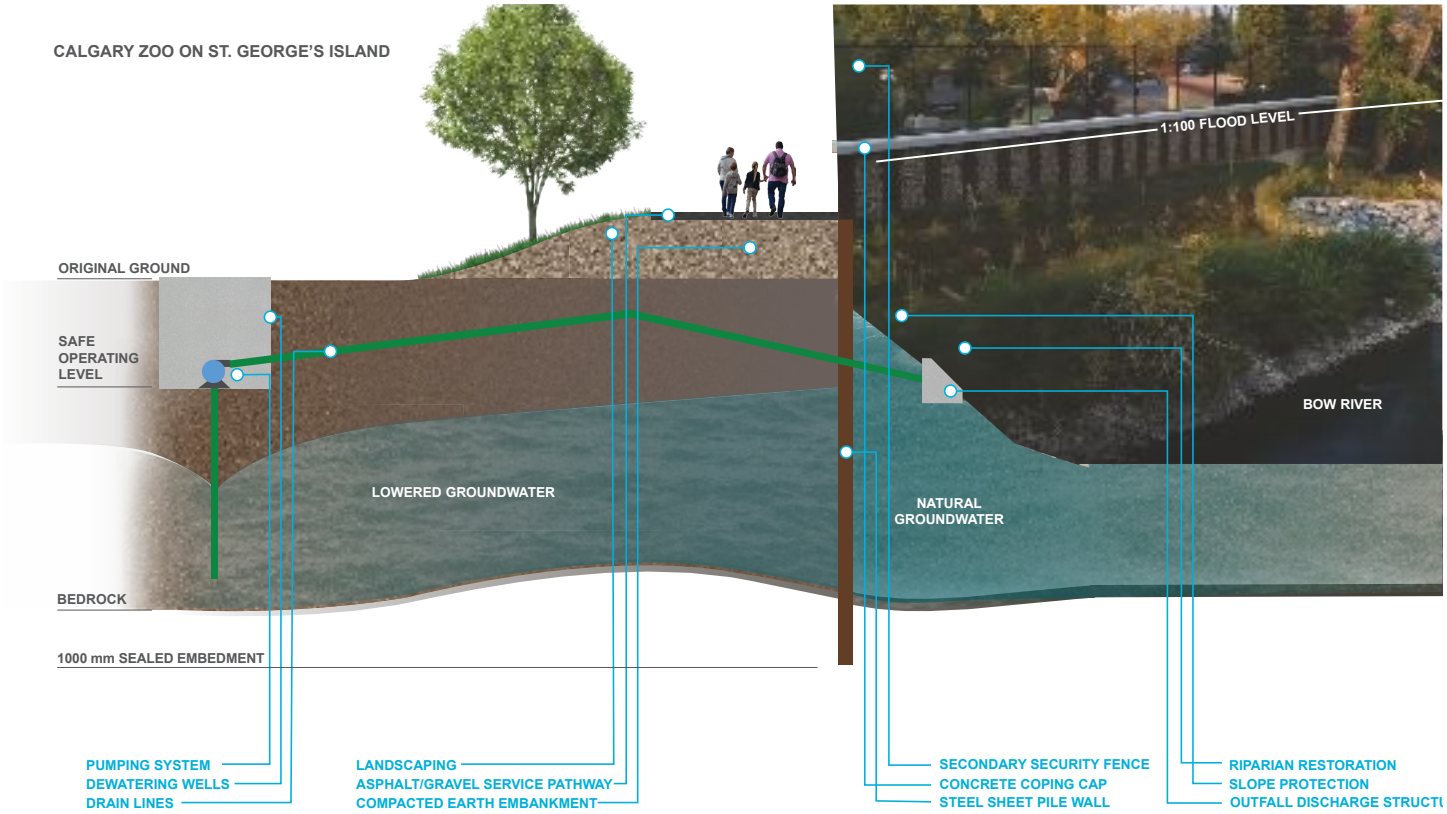
- "do nothing"
- varying levels of mitigation
- full relocation off St. George's Island

With nearly a century of investment and significant brand value gained from its iconic inner city island location, economic analysis by the The City clearly demonstrated that protection of the Zoo would provide important long-term economic, social and environmental benefits for Calgarians. The Calgary Zoo remained at considerable risk until St. George's Island was protected and future secured since the high relocation costs far exceeded the Zoo's insured assets; a difference of more than $300 Million.

Flood mitigation would be a vital investment to allow the Zoo to confidently plan its future at this valued site and secure excellent opportunities to generate revenue and international prestige with its proposed 20-year Master Plan and highly anticipated Panda Passage Habitat. Property level flood risk mitigation by The City, aligned with provincial flood risk management requirements, could protect the existing island infrastructure against the 1:100-year flood. Not only would the Flood Mitigation protect over $300 Million of uninsured investment, but Benefit / Cost analysis of probable floods in the next 100 years would provide a positive return on investment with a payback period of just over 30 years for the $25 Million capital project cost, since The City would otherwise incur annual costs of $0.8 Million without flood protection. The key question then became — how best to do it?

Unique Flood Mitigation System

Since high ground and berms already existed on some parts of St. George's Island that were most prone to flooding, initial mitigation concepts focused on protecting the island from overland flooding. Flood protection berms and walls were conceived as suitable flood mitigation structures to withstand the overland flooding effects while preserving as much functional space as possible for Zoo operations. As the flood mitigation design progressed, however, investigations and flood simulations confirmed that flooding in a 1:100-year flood would also occur from underground sources as a result of a direct hydraulic connection between the Bow River and the groundwater in the underlying gravels — as river levels rose, so did groundwater levels.



Proposed solutions would need to protect against both overland river flows and increased groundwater levels. Three options were considered:

- raising all high risk infrastructure
- isolating the island completely from rising groundwater
- dewatering faster than groundwater was rising

Recognizing that most of the Zoo's infrastructure was highly vulnerable and that any proposed barrier would never be completely watertight, the most effective solution to protect St. George's Island against flooding was to seal the island interior from both overland flow and groundwater ingress, combined with a dewatering system that delicately managed the water balance within the isolated area.

Flood Mitigation Structure

Isolating the island's two kilometre perimeter required a barrier capable of penetrating the highly permeable fluvial cobbles and boulders that make up most of the island and riverbed, while ensuring a reasonably watertight seal in the impermeable bedrock below. Since proposed solutions would need to protect against both overland river flows and increased groundwater levels, three options were considered:

- driven steel/vinyl sheet pile wall
- drilled concrete secant/tangent pile wall
- trenched slurry cut-off wall

Without understating challenges of drivability, the variable subsurface and uncertain bedrock, the steel sheet pile wall was found to be the most feasible and economically viable structure for sealing the island interior. Benefits of a steel sheet pile wall significantly outweighed the environmental impacts, construction complexities and economics of the other types of subsurface cut-off walls.

Collaborative Procurement Strategy

Since the scope of the assignment demanded significant sheet piling and cut-off wall expertise, general contractor PCL Construction Management Inc. and its major subcontractor Keller Foundations Ltd. were prequalified and later selected as partners through a competitive RFP process. This included a live, measureable demonstration of the piling operation at a downtown site with comparable subsurface conditions, to illustrate the viability of their proposed construction means and methods. Once the contracting team was selected, a formal Project Innovation and Partnering phase allowed the unified team to refine the design, verify constructability and proactively mitigate risk. Once the design was finalized, procurement strategies secured significant steel quantities in a market with highly volatile steel commodity prices and foreign currency fluctuations. Construction sequencing was explicitly coordinated with supply chain availability, leading to an optimum program that staged three piling crews in separate zones around the island. This allowed the team to accelerate piling completion six months ahead of schedule, all while adhering to strict daytime construction hours that minimized noise disturbance for our neighbours — human and animal alike.

Unconventional Sheet Pile Cofferdam

In essence, the steel sheet pile wall creates a permanent cofferdam around the perimeter of St. George's Island to isolate the Calgary Zoo from rising floodwaters in the Bow River. Though the sheet pile wall extends no more than a few metres above ground, there is far more than meets the eye below ground as over 1,500 pairs of sheet piles (about 4,000 tonnes of steel) were driven up to 20 metres below grade around the entire two kilometre perimeter of the island. While the upper and lower extents of the wall were bound by the 1:100-year design flood elevation and termination into bedrock, respectively, hydrogeological and geotechnical complexities of the variable subsurface and unknown bedrock across the island required special attention.

Given the importance of a continuous watertight seal within the bedrock to minimize leakage, critical sheet piling installation data was systematically tracked to support a sign-off process that relied on live bedrock profile updates. Complexities were intensified as all utility services feeding St. George's Island needed to be temporarily bypassed until the permanent services were reconnected through the wall, but only after the sheet piles had been installed and approved; all while assuring the continued year-round operation of the Zoo that minimized construction disturbance to visitors, animals and neighbouring communities.

While cofferdams are normally designed as temporary enclosed structures that can be sealed, pumped out and excavated dry to permit construction below water within an isolated area, we recognized early that in the absence of any excavation for the permanent sheet pile cofferdam, it would be impossible to quantify the actual leakage rates or detect high leakage areas during installation. The actual leakage rates, and final system performance requirements, could only be confirmed after aquifer pumping and recovery testing at the end of construction, and therefore any proposed dewatering system would need to be readily adaptable to meet these "known unknowns."

FLOOD MITIGATION OPERATIONAL PHILOSOPHY

With the Calgary Zoo ultimately responsible as the operator of the flood mitigation system, simplicity and reliability of operation were important priorities when considering passive (pumping prior to a flood) versus active (pumping during a flood) operational dewatering options. Operational philosophies were contingent, however, on the highly variable "known unknown" final system performance requirements, as any proposed dewatering system would need to be conservatively designed for a range of leakage rates.

Passive Option

Operation of the passive option involved maintaining a substantially lowered island groundwater level throughout the annual flood season to protect the Zoo infrastructure by creating a deep underground storage reservoir, but with high hydraulic heads of up to 8 metres across the dike walls. By maintaining lower groundwater levels, the passive option provides proactive mitigation in advance of a flood and would be ideal in cases where the flood barrier is nearly water-tight and the storage reservoir would fill very slowly during a flood, when the pumping system was shut off. Passive operation would not rely upon electrical and mechanical systems if pumping were required during a flood, hence its "passivity".

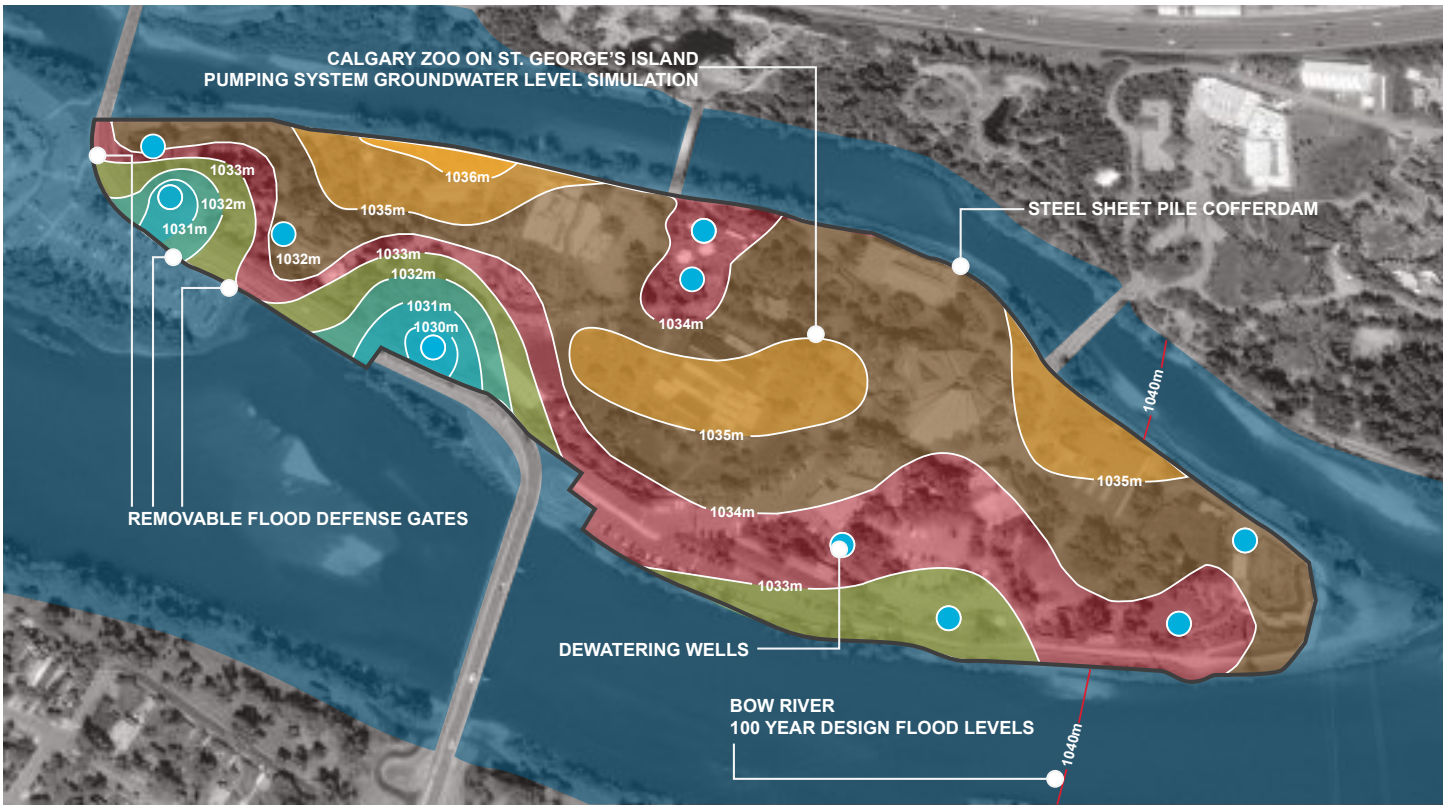
Active Option

Operation of the active option would protect the Zoo Infrastructure by pumping at greater rates than the rising groundwater only during periods of infrequent and short-lived floods. Given the reactive immediacy of this system, on-demand pump operation would be subject to high peak pumping rates and absolute reliance on mechanical and electrical systems. With redundancy in the number of pumps and a reliable power source, however, active operation would be a much more conservative option than passive operation as it is not reliant on the water-tightness of the barrier.

Hybrid Solution – Benefits of Both Options

Evaluation of the "passive" or "active" options prioritized trade-offs and balanced risk tolerance to develop a final dewatering system design. The passive option would benefit from an available reservoir in advance of a flood, thereby reducing peak pumping rates and the need for a reliable power source, but would need to continuously operate the pumps for several months every year for the life of the system. The active option offered no reservoir capacity in advance of a flood, but reduced overall operational demands, instead relying on higher peak pumping rates and a reliable power source during the flood event itself.

Both the passive and active options would be significantly affected by final leakage rates through the cofferdam, largely a function of how well the wall could attain a continuous watertight seal within the bedrock. To design solely for one system or the other prior to construction could have posed significant risk, hence the chosen design was a combination of the two, essentially a hybrid solution that could be adaptable to an entire range of expected actual leakage rates.



By adopting the benefits of both options, groundwater would be lowered by approximately one metre in advance of a flood to minimize the hydraulic head differential across the dike walls, thus minimizing leakage inflows and reducing the ongoing pumping capacity needed to sustain the passive reservoir. The resulting empty volume in the gravels would be sufficient to store expected leakage volumes, such that the river flood could pass without increasing groundwater to critical levels, even with a catastrophic power failure. This solution reflected the best of both options since the risks of losing power and pumping capabilities during a flood would be mitigated, while not having to rely entirely on a watertight barrier and extensive and costly ongoing dewatering through the annual flood season.

Flood Mitigation Dewatering System

The effectiveness of the pumping system was optimized by dividing the large island area into quadrants. By deploying two wells in each quadrant, the dewatering system consists of eight pumps connected via forcemains to four new riparian outfalls that discharge directly to the Bow River. Final dewatering well locations were sited with the Contractor's input to optimize well spacing, facilitate drill rig access, and reduce excavation and disturbance limits, since construction would be very disruptive to Zoo operations and the animals. Realizing that the Zoo's existing infrastructure contained many unmapped underground utilities, it was also important to minimize total length of excavation for the forcemains within the island interior.

To simplify operation, pumps were outfitted with high and low level sensors to automatically cycle the pumps on and off and maintain groundwater levels within a prescribed range, determined from modelled flood simulations. With integration of the pumping system's operational parameters into the Zoo's Metasys SCADA control system, pumping-related events are logged and recorded in the digital database while any critical operational issues are automatically flagged by built-in alarms.

State-Of-The-Art Hydrogeological Flood Model

The success of the project relied on a clear understanding of the highly complex island hydrogeology, the effectiveness of the cut-off wall, and pump performance. Having undertaken groundwater composition testing around the island to rule out the possibility of an alternative source of inflow from the bedrock, a state-of-the-art 3D numerical groundwater model was developed to analyze the combined effects of the river flood hydrograph, the number of wells, their locations and pumping rates. The system was analyzed for an expected range of leakage rates, while variations of the hybrid operational philosophy were also simulated to optimize the overall system performance and minimize operation and maintenance costs. The envelope of results allowed the dewatering system to be designed with confidence and, since leakage could not be gauged until the overall system was commissioned, flexibility for expansion. Since the ultimate pumping capacity to enable annual drawdown of the groundwater levels within the sheet pile perimeter wall was a "known unknown," only in-field commissioning and performance testing after construction would provide the "missing" data needed to calibrate and refine the flood model to confirm protection from a 1:100-year flood event.

Ease of Pumping Capacity Expansion

With a total pumping capacity of 120 L/s to handle the modelled groundwater inflows expected during the design flood, the system was also designed to be readily expandable to include larger or more pumps, if required. Initial drawdown and recovery testing in September 2017 indicated that initial performance of the installed system would not provide the required 1:100-year flood protection, likely due to low groundwater migration within the gravels that surrounded the wells. While some groundwater lowering was achieved, its rebound was very quick, which meant that the required aquifer storage would not be provided when the pumps shut off in a flood. Hydrogeological model refinements showed that the system would sufficiently protect the Zoo by adding 80 L/s of pumping capacity. With the opening of the Panda Passage Habitat scheduled for May 2018, the project team worked on an accelerated schedule to expand the system by adding two new wells and upgrading a third. Final performance tests in April 2018 confirmed that the 1:100-year flood protection had been achieved, and full turn-over to Zoo operations was completed ahead of the grand opening.

Zoo Operations Integration and Automation

Automation of the pumping system provides the Zoo's operators with a simple, reliable and low-cost operation and maintenance solution. While the system is designed to be autonomous, five separate wells were drilled to monitor the groundwater level between the dewatering wells. Although not required for overall dewatering system operation, these wells provide an independent check of system performance. Each monitoring well is fitted with electronic groundwater level probes and a cellphone telemetric system that records groundwater levels in real time and uploads them to cloud servers that are accessible remotely, providing the Zoo's operators with an accessible, interactive platform to navigate and remotely monitor performance of the flood mitigation system and groundwater levels across the island at their central control room.

Emergency Preparedness and Knowledge Transfer

Operational capabilities of the system were incorporated into the Zoo's flood response procedures to ensure a state of readiness by providing for annual exercises for emergency preparedness and response. To enhance the Calgary Zoo's capacity to maintain and control the flood mitigation system and integrate the flood protection and pumping infrastructure, progressive transfer of critical knowledge was facilitated through a hands-on training program. This consisted of operations and maintenance instructions, training exercises, and work shadowing over a 2-year period.

BENEFITS OF BUILDING PARTNERSHIPS AND EMBRACING CHALLENGES

While most people welcomed The City's flood mitigation plan, stakeholder and community engagement elicited both optimistic and concerned feedback. The project had a number of risks, the most significant being: sheet piling feasibility, noise concerns for visitors and animals, heavy construction impacts to the normal operation of the Calgary Zoo, constrained island access and work areas between the Zoo's existing aging infrastructure and environmentally sensitive riparian areas of the Bow River, and disruption to residents of the oldest and most established residential neighbourhoods in Calgary. The procurement strategy incentivized innovative project delivery and design alternatives that minimized the risks from constructability, operational interruptions, habitat disturbance and construction noise impacts.

With the monumental changes being undertaken through the Flood Mitigation project, both The City and Calgary Zoo had the advantageous opportunity to leverage public and private investment and advance a number of priority infrastructure improvements. With clear concern from the public to minimize disruption and "get it done once, and right" the number and complexity of area projects grew throughout the entire delivery period, particularly since, to the average citizen or Zoo visitor, all of the construction "chaos" would appear as one project — ultimately resulting in a dozen major infrastructure projects both inside the Zoo and in the surrounding public realm.

To connect all competing priorities on the island, our team took on the additional role of interfacing with and coordinating all of the owner representatives, Zoo operations, consulting teams and contracting forces who were working on the island over the two and a half year construction period. By accelerating piling completion, the schedule float gained was particularly advantageous in allowing the Flood Mitigation project to act as the central hub for coordinating all major infrastructure projects, optimizing their schedules and achieving common cost reductions.

Securing the Calgary Zoo's Future Together

The ability to protect the Calgary Zoo from floodwaters comparable to those experienced in June 2013 was an open question in the months following that remarkable event. The risk of losing more than a century of investment — both financial and spiritual — in the Zoo's home on St. George's Island was a palpable concern to The City of Calgary, the Calgary Zoological Society and Calgarians at large. Continued investment in the island, including the internationally significant Panda Passage Habitat, was very much contingent on being able to assure the long-term protection and viability of critical Zoo infrastructure and its animal inhabitants from a repeat event, and to get it done fast and with as little disruption as possible. The development and ultimate implementation of the Calgary Zoo Flood Mitigation program rose to this significant task by solving a wide range of technical and management challenges.

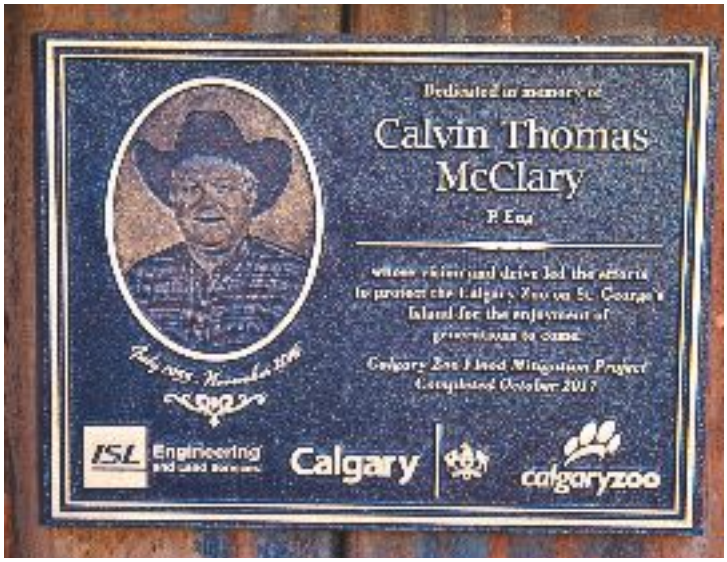
The Flood Mitigation project represents the technical leadership of the consulting engineering team both in its early recognition that flood protection was needed both above and below the ground surface, and then in developing a unique solution to protect the island within a sealed sheet pile wall, with a dewatering system that has been field-tested to ensure protection of critical zoo infrastructure and animals from a 1:100-year flood event. The team balanced many technical elements to develop and implement the specialized flood mitigation infrastructure required to meet the highly variable "known unknown" final performance needs for protecting over $300 Million of uninsured Zoo infrastructure from overland flooding and rising groundwater ahead of the Panda Passage Habitat grand opening, all while ensuring the continued year-round operation of the Zoo with minimal disturbance to visitors, animals and neighbouring communities. Although securing the Calgary Zoo's future was the crowning achievement of the project, St. George's Island underwent a once-in-a-lifetime renewal of its infrastructure, providing additional economic, social and environmental benefits for all Calgarians at this, its oldest park space.

It was a testament of Cal McClary's project leadership that, when he unexpectedly passed in November 2016, the rest of the team were able to overcome extraordinary circumstances while continuing to execute his vision through the final construction and commissioning phases. The project was dedicated in Cal's honour recognizing his critical role in preserving and protecting the Calgary Zoo on St. George's Island. As one of the city's most iconic landmarks with nearly a century of history, the Calgary Zoo will remain in its founding location, operating a world class facility as Canada's leader in wildlife conservation and a destination for global tourism for the enjoyment of future generations.

The unique technical and construction solutions developed and implemented for a complex, constrained work site under tight time and budget constraints was handled very well by the consultant team, particularly considering the seemingly ever-changing demands for additional related upgrades.

There were so many components of this project that were a challenge and necessitated an inordinate amount of coordination and collaboration. Well done to this joint submission by AE and ISL consulting firms.

Judges' Comments
2019 Consulting Engineers of Alberta Showcase Awards
Award of Excellence: Water Resources
Award of Merit: Project Management



On behalf of the Calgary Zoo Management Team, I would like to personally thank you and each and every team member for their commitment, their level of professionalism and most importantly their level of respect displayed for each other during the entire execution of the projects.

Whether it's an organization or a project, for me its "all about people" and that philosophy leads to these type of successes and this project was very successful! I am also happy to say that I believe Cal would be very proud of not only what was accomplished but how it was accomplished!

Darryl Dziadyk, P.Eng., PMP
Director, Facilities and Grounds
Calgary Zoological Society

Innovation / Technology Advancement	• Specialized flood mitigation infrastructure consists of complete overland and subsurface sealing of St. George's Island, combined with a dual purpose dewatering system that delicately manages interior storm runoff and groundwater levels throughout the annual flood season. • Sheet piling pre-feasibility test program undertaken before construction resources were fully mobilized to confirm that drivability of the steel sheets would achieve a watertight seal within bedrock, while a collaborative procurement strategy involved the contractor in final design decisions to align means and methods that minimized operational interruptions, habitat disturbance and construction noise impacts. • Dewatering system that was conservatively designed to meet the highly variable "known unknown" final system performance with redundancy in the number of wells, their capacity and, since actual leakage could not be gauged until isolating the wall and commissioning the system, flexibility for expansion. • Integration of the dewatering system's controls into the Zoo's automated Metasys SCADA control system to provide the Zoo's operators with a familiar, simple and reliable interface to monitor performance of the system in real-time and respond to any issues flagged by built-in alarms from their central control room. • Critical knowledge transfer facilitated through a hands-on training program, consisting of operations and maintenance instructions, training exercises and work shadowing over a 2-year period to ensure preparedness in advance of a flood emergency and mitigate risks from transitioning the new system into the Zoo's routine operations. • The project advanced the state-of-the-art for 3D numerical hydrogeological modelling to support the engineering design for arguably the most complex flood mitigation system known of its kind in Alberta. The model not only supported the mitigation design, but also advanced The City's understanding of groundwater flow and flooding below the city, which has enhanced future flood mitigation planning throughout Calgary.
Complexity	• Many highly complex technical elements were balanced to develop and implement the flood mitigation infrastructure required to meet the highly variable "known unknown" final performance needs for protecting the Calgary Zoo from sources of overland river flooding and rising groundwater in a 1:100-year design flood. • Meticulous quality management process that assured a continuous watertight seal within bedrock by systematically tracking critical installation data for over 1,500 sheet pile pairs driven up to 20m in depth around the two kilometer perimeter to support a sign-off process that relied on live bedrock profile updates. • Continuity of the sheet pile perimeter cofferdam required that all utility services feeding St. George's Island were temporarily bypassed until the permanent services were cutover and reconnected through the wall, but only after the sheet piles had been installed and approved. • Design of the groundwater dewatering system for flexibility for adaptation, to address the "known unknown" final system performance. The initial drawdown and recovery testing, and related flood model calibration and refinement allowed the system to be quickly expanded by adding two new wells and upgrading a third. • The project was completed within an extremely constrained footprint that assured uninterrupted continuity for Zoo operations and also avoided construction in the Zoo's peak summer seasons to minimize disturbances to the adjacent communities, Zoo visitors and animal inhabitants. • The project team continually adapted and responded to take on additional infrastructure projects as funding became available to "get it done once, and right", ultimately resulting in a once-in-a-lifetime renewal of Zoo and City infrastructure on St. George's Island.
Social and/or Economic Benefits	• As the Calgary Zoo is a vital City asset contributing to its vision of sustaining a vibrant, caring and healthy community, the Flood Mitigation project was essential for allowing the Zoo to confidently plan its future at this valued site as the Zoo had excellent opportunities to generate revenue and international prestige with its proposed 20-year Master Plan and highly anticipated Panda Passage Habitat. • Economic analysis covered a range of options from "do nothing" to full relocation off St. George's Island. Not only was the Flood Mitigation project instrumental in protecting over $300 Million of uninsured investment, but Benefit / Cost analysis provided positive returns on the capital investment with a project payback period of just over 30 years, far less than its 100-year design life. • With the Zoo protected against a major flood, its operational window now extends through the flood season to safeguard its revenue stream and to allow uninterrupted year-round operation.
Environmental Benefits	• Preservation of Calgary's first developed park space, sensitive riparian habitat, mature trees and native vegetation were key factors in selecting the least invasive and most effective flood mitigation solution. • Benefits of a sheet pile cofferdam perimeter wall significantly outweighed the environmental impacts, construction complexities of similar subsurface cut-off walls such as drilled concrete pile walls and trenched slurry walls. • Restoration of essential riparian edges between the riverbank and sheet pile wall largely returned the site to its natural pre-development condition. In the small number of cases where removal of mature trees were truly unavoidable, the removed trees were incorporated within the Calgary Zoo's exhibits or repurposed as bioengineered habitat along riverbanks in other parts of the city.
Meeting the Client's Needs	• The Flood Mitigation project was instrumental in protecting over $300 Million of uninsured investment on St. George's Island, securing lower flood insurance rates, optimizing costs of flood protection based on in-field performance and creating efficiencies across all major infrastructure projects. • The project faced a critical May 2018 deadline for the highly anticipated opening of the Zoo's Panda Passage Habitat. With the Calgary Zoo's flood vulnerabilities recognized after the 2013 flood, completion of the project on-time had no room for error, as a matter of Canada's international relations with China. • The Calgary Zoo announced its "Best Year Ever" in 2018, breaking attendance and membership records after the Flood Mitigation project was completed ahead of the Panda Passage Habitat grand opening. • As one of the city's most iconic landmarks with nearly a century of history, the Calgary Zoo will remain in its founding location, operating a world class facility as Canada's leader in wildlife conservation and a destination for global tourism for the enjoyment of future generations in the decades to come. • Although securing the Calgary Zoo's future was the crowning achievement of the project, St. George's Island underwent a once-in-a-lifetime renewal of its infrastructure, providing additional economic, social and environmental benefits for all Calgarians at this, its oldest park space.