CALGARY INTERNATIONAL AIRPORT EAST DEICING APRON

Category B | Transportation

INTRODUCTION

In the fall of 2018, WestJet and Air Canada indicated to the Calgary Airport Authority (YYC) an immediate need for a centralized deicing facility. Due to the growing demand of air traffic, and the recent purchase of WestJet's four 787 Dreamliner widebody aircrafts, at-gate deicing is no longer a viable operation to keep the busiest airport in Alberta running efficiently and without delay. When YYC handled aircraft deicing at the gates, the process could take up to 40 minutes. This delay reduced the airport's capacity during rush hour, and during peak hours, the airport would be over capacity for gating and deicing. This all contributed to an extended taxi time (total time of an aircraft movement on the ground) due to undesirable gate configuration and congestion with at-gate deicing, which ultimately negatively impacted passengers' flight experience.

Stantec's aviation engineering team tailored for this project consisted of key individuals that thoroughly understand YYC's infrastructure surrounding the project site, and the vision of a fully robust, efficient, state-of-the-art deicing facility. We worked closely with YYC for the overall deicing apron design solution, including the critical diversion structure to divert deicing glycol runoff for treatment purposes.

The project is a tremendous success from multiple angles: operational, environmental, engineering, and financial. The project ultimately achieved the goals of reducing at-gate times (the duration a plane stands at a gate), improving passenger experience, and reinforcing YYC's environmental stewardship. The East Deicing Apron (EDA) reduced taxi time to an average of 17 minutes for a single aircraft, fulfilled environmental policies, maintained consistent glycol containment, and realized more benefits in terms of recycling and optimized throughput.

The East Deicing Apron is the final piece of a complete glycol management program at the Calgary International Airport. The completion of this project means that the airport is self-sufficient in recycling spent glycol, where it can be re-used on aircraft deicing, and removes the Chemical Oxygen Demand (COD) burden on the City of Calgary's wastewater treatment plants. In return, the City of Calgary's wastewater treatment plants can service additional communities in the city without unnecessary expansions.

Q1
INNOVATION

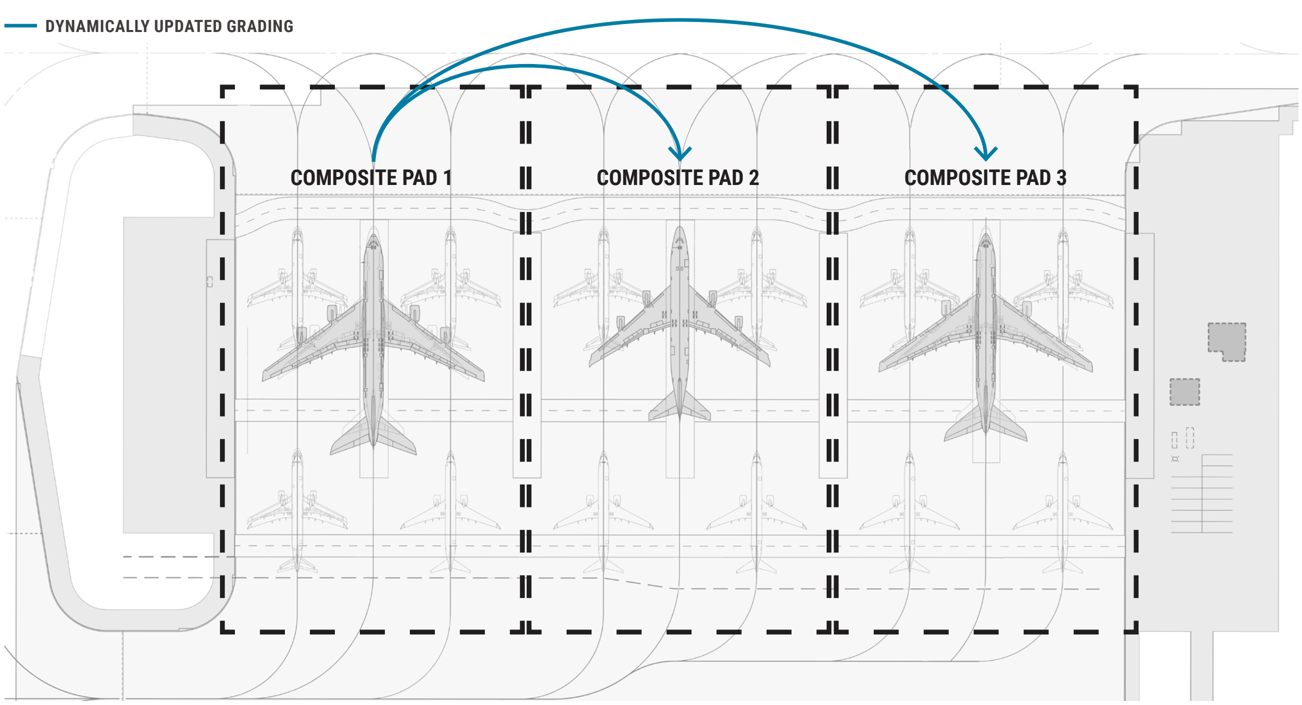
The East Deicing Apron consisted of approximately 11 hectares of airfield pavement, over 1,000 m of specialized stormwater drainage infrastructure, the new apron covering an area of approximately 110,000 m^2 just south of the new terminal, and an underground diversion structure that is over 10 m deep. With the mandate to complete the design work within six months to assist the construction schedule, the team had to be creative to incorporate constructability and staging in every step of the design, and aggressively manage the construction schedule.

Efficient Design

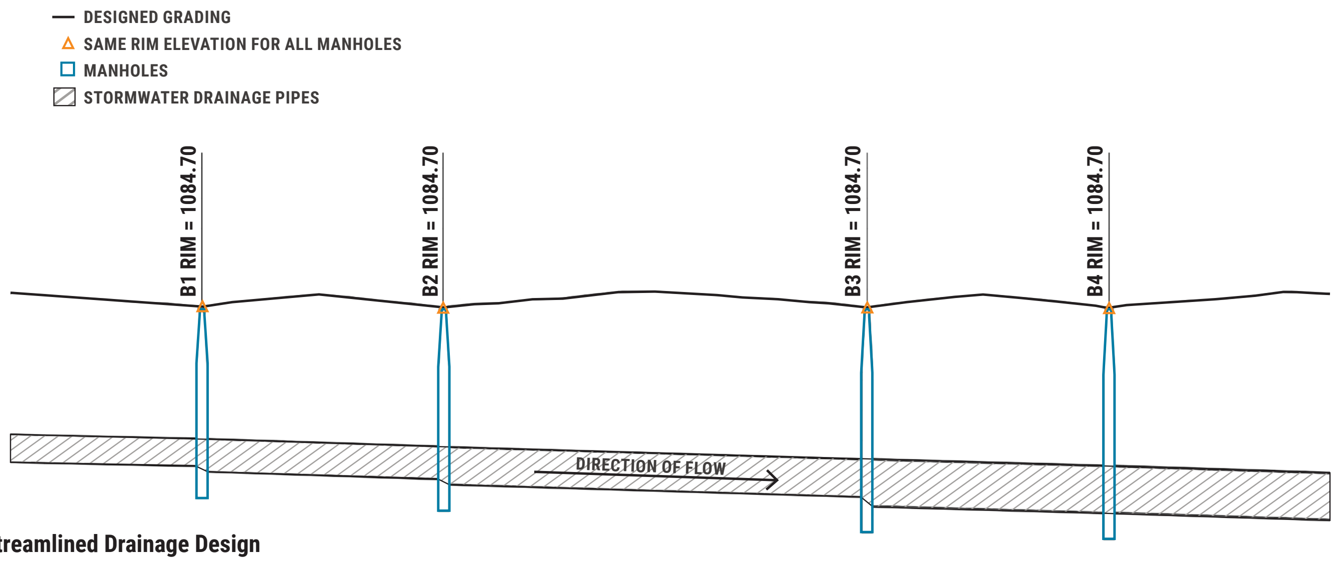
The design of the EDA commenced in October 2018. With the pressure of opening for winter operation in 2019/2020, the design team made every effort to minimize the project timeline. The apron consisted of three composite deicing pads, able to accommodate three Boeing 787 Dreamliners or six Boeing 737 aircrafts at the same time. The project site itself has the capability of an ultimate buildout of six composite pads. Our project manager and lead engineer, Joseph Chen, understood these requirements, and the nature of the topography surrounding the EDA. Combining this understanding with his technical expertise, Joseph utilized an advanced Civil 3D modeling technique that enabled the software to replicate a single composite pad grading design across all six pads. He also designed the grading with dual-lane concrete slipform pavers in mind to minimize construction coordination. With this approach, the grading design of over 110,000 m^2 of concrete apron was completed within two weeks.

If the design required any alteration or modification, only one pad will need to be updated and the rest of the apron grading will automatically update, essentially **reducing the design effort by 200%**.

This design enabled minimum updates for the future ultimate buildout of the 220,000 m^2, six pad configurations, as everything can be



Dynamic Grading Update Through Advance Civil 3D Modelling



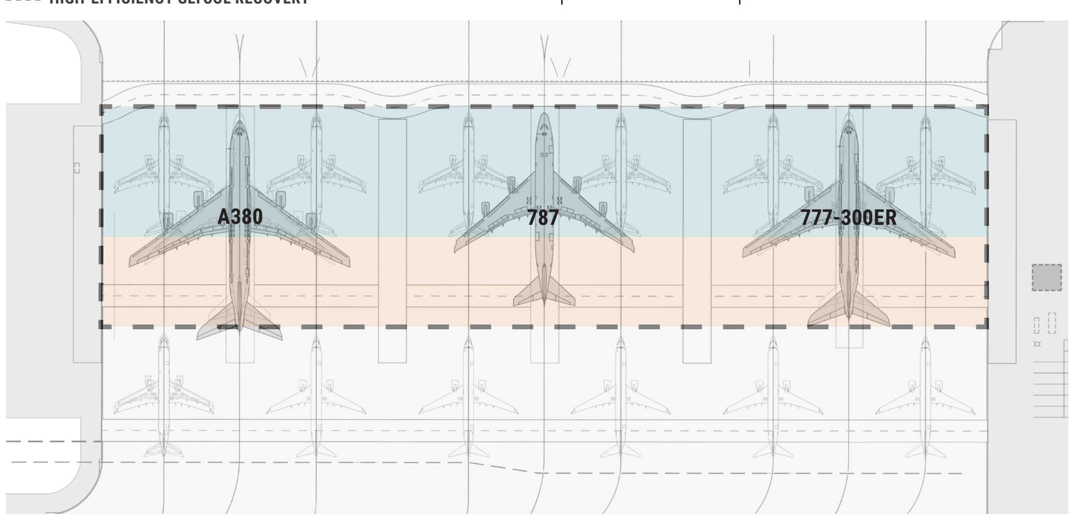
Streamlined Drainage Design

duplicated from the very first pad's grading design.

In conjunction with the grading, the underground drainage layout was also designed with efficiency in mind. The manholes along any given stormwater piping alignment were designed to have identical rim elevations, minimizing design time and reducing chances of construction error. This design approach not only minimized coordination effort between surface and underground drainage, but also provided a fast shop drawing review process during construction, as there is only one elevation to review for all manholes along one storm line.

The efficient, yet intricate design also accounted for a wholistic, sustainable perspective, minimizing mixing of ADF with precipitation. The team reviewed the percentage of aircraft mix that will frequent the EDA in the next 20 years and concluded that the Boeing 777-300ER will be responsible for 80% of the largest widebody aircraft movements. The grading was then revised during construction to further reduce stormwater catchment area that will require treatment process, further reducing stormwater contamination at the Calgary International Airport. This reduction in stormwater contamination minimized pollutants mixing with our rainwater, reducing the risk of contaminated water discharging into our water stream. Because of the dynamic grading approach implemented during the design phase, this change during construction took only one hour to update and issue a site instruction to the contractor.

The efficient design philosophy carried beyond just the proposed design, the EDA also has potential to be expanded and mirrored for



Optimized Deicing Capture Zone

future added capacity. Together with YYC, we studied the surrounding area and purposefully placed the diversion structure in the middle of the ultimate apron buildout. This meant that the grading design can be fully duplicated for the future expansion, and the stormwater conveyance system underneath the apron can be mirrored across the ultimate apron buildout, which will save a significant amount of design effort for future expansion.

Specialized Stormwater Modelling

Stormwater modelling is a tried-and-true design analysis performed in all new developments across the developed world. The stormwater modelling used for the EDA is designed for both the stormwater conveyance and glycol recycling system, with special considerations given due to the uniqueness of the diversion system. Specialized stormwater engineers from our team perform modelling based on historical Intensity Duration Frequency (IDF) curves of a given area to predict required stormwater pipe sizing for the conveyance system, and design the piping system accordingly to provide adequate hydraulic performance based on the return period (i.e., average estimated recurrence interval) of the stormwater event chosen. As airports are often required to operate in poor weather conditions, the minor system needs to handle larger than typical city storm events to continue operating even during tough weather conditions. The existing system that the EDA's stormwater piping ties into can handle a 1:100-year return period; however, during deicing operation, the design has a completely different set of criteria. A 1:100-year storm event is unlikely to occur during the winter months (i.e., deicing season), and should an extreme weather event occur, the airport will likely cancel its flights due to dangerous freezing conditions. With this understanding, our aviation engineers looked at the historical precipitation data during deicing season through Environment Canada's records, recorded directly at the Calgary International Airport. This data is overlaid with the historically applied spent Aircraft Deicing Fluid (ADF) volume, to paint a more accurate picture required for the EDA's recycling piping design. This analysis transferred into a design tailored specifically for the EDA, while reducing the cost of the piping system compared to a design based on a 1:100-year storm event.

Further to the glycol recovery system, our aviation engineers looked for ways to reduce the piping requirement during the summer—during non-deicing season. To comply with the 1:100-year return period design criteria, the team utilized parts of the 12 m x 12 m x 10 m diversion structure's cells for storage, which requires the entire system to be hydraulically connected, reducing pipe sizes upstream of the diversion structure.

This approach not only **reduced over $300,000 in construction cost**, but also significantly decreased material procurement lead time often seen with large pipe sizes.

Thanks to our in-house, multi-disciplinary engineering team, combined with our lead engineer's understanding of all aspects of a deicing facility design, our approach enabled an efficient use of all components of the apron without any wasted opportunities. With an all-encompassing perspective, the deicing apron is innovatively designed and built to be efficiently and effectively utilized all year round.

Virtual Reality Technology

We developed a 3D model of the diversion structure and invited the project team to Stantec's Innovation Lab to walk through the design in Virtual Reality (VR). The model included all process piping and electrical conduit connections around the diversion structure, the nearby control building, and the proposed excavation limit to construct the structure. This innovative strategy not only allowed the project team to visualize the size and details of the diversion structure, but also inspired productive discussions regarding constructability of the structure amongst the project team.

One of the key items that came out of this walkthrough was the orientation of the actuated, automatically operated valves, and how they would be lifted into the structure prior to the roof construction. In another instance, the project team contemplated relocating the control building closer to the structure (closer

Virtual Reality Engagement Session

to the excavation limit). With the visual aid of the VR model and its open excavation limit, it soon became apparent that the building was designed to be located away from the excavation limit to minimize construction schedule, helping the project team avoid a potential schedule risk.

Diversion Structure

The diversion structure is a key component of the EDA project. Sized at 12 m x 12 m x 10 m, it is the heart of the deicing facility's recovery system, where it consolidates incoming contaminated stormwater from deicing operation, then intelligently diverts the runoff, based on concentration of glycol, to recycle, treatment, or stormwater discharge. This multi-cell, intricate structure contains two 750 mm actuator valves, and has a sampling system that can direct contaminated stormwater accurately to its respective compartment. This creates less strain on the recycling and treatment systems downstream of the EDA, and clean stormwater through this structure can efficiently discharge into Nose Creek. The structure consists of three components, two of which are used for pumping medium- and high-concentration glycol to a nearby glycol recycling facility for recycling back to aircraft deicing grade, or a glycol treatment facility to treat to stormwater quality. A third compartment diverts low concentration glycol flow by gravity to a nearby storm pond. Variable Frequency Drive (VFD) pumps are installed for each of the two cells, that diverts high- and medium-concentration glycol. An automated sampling system assists the operators by automatically closing motorized actuated valves of incoming flows in 750 mm diameter pipes, allow for sampling, before directing the flow to the downstream systems. The structure is 10 m below grade and the entire operation is controlled remotely in a nearby control building.

Our engineering team proudly developed this sophisticated design, enabling an efficient process control that sorts the ADF contaminated stormwater based on the degree of its contamination in real time, and diverts them accordingly for recycling, treatment, or discharge. The complexity of this structure enables YYC and the facility operators to minimize mixing unwanted pollutant in stormwater discharge, while securely capturing and redirecting contaminated stormwater for treatment and recycling.

Construction Management

Following the initial civil design, our team and YYC explored a Construction Management model to address the aggressive construction schedule. This delivery model enabled the design team to coordinate with potential contractors to discuss constructability of the design, and the discussion was not limited to just the Construction Manager's (CM) expertise. Civil and Mechanical construction specialists were included as a part of the design discussion to further facilitate and expedite the schedule, providing a holistic perspective on constructability. This inclusive approach, combined with early construction consultation, resulted in time and cost saving recommendations early on in the design process to mitigate rework. For instance, instead of using traditional concrete grouting at the HDPE pipe and manhole connection points,

Pump Quick Disconnect

link seals coupled with pipe restraints were used for a water-tight installation. This atypical engineering solution in stormwater piping design minimized the chance of contaminated stormwater leakage into our soil, which in turn minimized possible risk of soil contamination.

Diversion Structure: Medium Concentration Bypass Pipe in High Concentration Cell

Q2
COMPLEXITY

As the largest airport in Alberta by passenger volume, YYC is the only airport in our province equipped with a comprehensive deicing facility that includes smart operation, onsite treatment, and recycling of ADF-contaminated stormwater. This facility consolidated all the airport's deicing needs to a central location and enabled full recycling and treatment; a first in Alberta. We worked closely with YYC to research deicing facilities across North America, including Toronto Pearson International Airport and Denver International Airport. A design was then prepared that uniquely fit into YYC's land-locked footprint, with engineering lessons learned from other world-class deicing facilities.

Apron grading criteria for aircrafts has a very tight tolerance, between 0.5% to 1.0%. If the grade is too flat, it will not drain; if it is too steep, the aircraft will exhaust too much fuel to maneuver, and generate significant tire wear. This limited tolerance was coupled with the site challenge where grades are locked by all four sides of the facility. Our lead engineer designed an apron that not only met all criteria but built undisclosed tolerances in the grading design to account for the contractor potentially missing the grading tolerance target. This variance actually occurred during construction, where a particular manhole was set slightly higher than designed, which resulted in the pavement grade being flatter to tie to the manhole, but because the design accounted for this, the apron with the flatter grade still drained adequately.

The project was landlocked by a Non-Passenger Screening Vehicle (NPSV) facility, and taxiways Bravo, Juliet, and Romeo. Taxiways Romeo and Juliet are the two critical taxiways that connect the east and west airfield. We specifically designed the grade tie-in at these taxiways such that there is no need to perform any concrete panel construction on these taxiways, which would have increased disruption to operations at the airport. During construction, the project team also planned

Open Excavation of the Diversion Structure

the construction operation, and coordinated a Notice to Airmen (NOTAM) to alert aircraft pilots of potential hazards along the flight route, one week in advance to minimize air traffic disruptions along the three taxiways.

With only a six-month construction schedule, right from the beginning, this challenge posed as a seemingly impossible feat. The diversion structure required five months of construction while the apron paving required three months of construction. To expedite this process, we designed the grading with the paving plan in mind, while simultaneously working with the rest of the project team to plan the paving operation, allowing paving to start as soon as underground infrastructure was completed, while the diversion structure was still under construction. This approach enabled the construction of the diversion structure to start early to meet the deadline. The backfill of the structure was completed by the time paving reached the excavation limit of the structure.

Environment Contamination

Due to the toxicity of Ethylene Glycol, a toxic chemical within the ADF's composition, Environment Canada's mandate for this fluid discharge into nearby waterbody is limited to 100 parts per million, an extremely low concentration of 0.01%. As a steward of our community's wellbeing, the risk of killing fish and organisms within the nearby waterbody due to oxygen deprivation caused by this chemical is unacceptable to YYC. We designed the entire stormwater recovery system using water retaining structure specifications that are typically used for a pressurized system, while employing HDPE pipes that utilized butt-joint fusion to eliminate potential glycol leakage through pipe joints. All concrete structures were also designed to be waterproof so that glycol is not absorbed and cannot potentially leak out from the concrete structures. The entire recovery system, starting at the manholes of stormwater pipes, through the diversion structure valves, to the discharging forcemains, is wholistically designed to be water retaining, minimizing any potential leakage.

Accelerated Schedule

This project had a demanding schedule requiring substantial completion of construction by the end of 2019, only a one-year turnaround time (final construction completion in January 2020). This tight deadline is in response to the City of Calgary's (The City) mandate that the airport will not have any glycol discharge to the city's wastewater treatment plant by the winter of 2019. To meet this deadline, our design team utilized replication efficiencies in design to expedite the process, while maintaining design requirements. Stantec and YYC worked with the CM where long lead items like the aircraft-rated manholes were procured during the design phase (rather than during construction), and a handover process of the materials to the bid winning contractor was in place to ensure a smooth transfer of responsibility. In another instance, the design team engaged the airfield electrical suppliers prior to tender to confirm system compatibility. This early engagement allowed the lighting system to be installed in time with the construction schedule. The team's design experience, combined with the strategic use of the construction management model ultimately helped the team bring the EDA to substantial completion within the one-year turnaround.

Dewatering

Our team understood that groundwater is relatively high within the apron footprint. This issue could significantly slow down construction with a rigorous dewatering program during construction if groundwater seeps through the subgrade. The design team anticipated this and designed a subdrainage system for a dual purpose: protection to the longevity of the pavement structure, and dewatering of the subgrade during construction. As construction progressed, prior to concrete pavement, the project site experienced numerous summer rainstorms in June and July 2019 that were in the range of 53 to 54 mm—Calgary's highest level of rainfall since 2007 . By this time, the subdrain system designed by our team was already constructed in place and assisted with dewatering efforts during construction, which further reduced risk to the construction schedule.

Q3 SOCIAL AND/ OR ECONOMIC BENEFITS

As a result of this state-of-the-art deicing facility, YYC successfully reduced the overall taxi time during the winter season from 40 minutes down to 17 minutes. This achievement not only means shorter deicing, taxi, and at-gate times for the airport, but also enables passengers to arrive at their destinations sooner and safer. The deicing apron's effective recovery system, coupled with the onsite treatment and recycling features, means that the airport eliminates its reliance on the City of Calgary's wastewater treatment plants. The City of Calgary's water treatment systems can then serve more communities without the need to expand.

As Alberta's largest centralized deicing facility, this project solidifies YYC's position as an environmentally responsible steward for our city, province, and country. Our engineering design had the benefit of the public in mind, which lived through the entire project's lifecycle. Calgarians, Albertans, Canadians, and international travelers all around the globe benefit from the behind-the-scenes operation of this critical facility, upholding Calgary's commitment to the environment and sustainability, while setting the stage for airports across North America.

Q4 ENVIRONMENTAL BENEFITS

Limiting Glycol Contamination

One of the objectives of a centralized deicing facility is to minimize the mixing of precipitation and glycol contamination. Ethelene Glycol, a toxic, green chemical, makes up 88% of Aircraft Deicing Fluid's composition. After ADF mixes with stormwater runoff, and discharges into a nearby waterbody, it depletes oxygen in the water stream, effectively killing living organisms while also producing a rotten egg smell. We prepared, reviewed, and presented five conceptual facility options to the Consortium of Airlines and YYC prior to design commencement to obtain the most cost effective, but more importantly, environmentally responsible solution.

The solution ultimately reduced the would-be glycol contaminated area from 55-hectares of the original apron (Apron I), down to the 11-hectares East Deicing Apron—an **over 80% reduction through our stormwater diversion design approach**.

This design is a popular approach being adopted across North America as it provides containment of ADF without the need to accommodate inefficient treatment of ADF contaminated stormwater.

Decreased Carbon Dioxide

The ultimate design solution had sustainability in mind, but the design team did not stop there. YYC and Stantec reached out to a concrete technology company that worked with the project team to inject a precise dosage of recycled carbon dioxide (CO_2) into fresh concrete to reduce its carbon footprint without compromising performance. This recycled CO_2 content came from Fort St. John's industrial sites and were accounted for in the concrete mixing process. With the benefit of the carbon injection, the overall cement content within the concrete was able to be dropped while still meeting the strength requirements of the design. This decrease in cement content reduced the potential carbon emission due to cement production by 246 tons.

Including the 13 tons of CO_2 injected into the production mix, the total carbon reduction experienced by this project is over 259 tons, **equivalent to 138 hectares of forest absorbing CO_2 over the course of one year**.

The deicing vehicles operated by the facility manager are fully Electrical Vehicles (EV) by design. The project team prepared EV charging stations for 14 vehicle stalls to further reduce GHG emissions. Based on the Environmental Protection Agency (EPA) statistics of 4.6 tons of CO_2 produced per year per gas-powered vehicle, utilizing 14 EV vehicles for half a year further reduces 32,200 kg of CO_2 emission every year. This means that over a 20-year operation span, the EV will further save the equivalent of 342 hectares of forest from absorbing harmful GHG emissions.

Industrial Waste Carbon Dioxide Tank

Type I (Green) Aircraft Deicing Fluid Applied on Aircraft

Minimizing Waste

The EDA is designed to accommodate future expansion plans with minimal design and construction efforts. The entire apron and underground infrastructure design can be mirrored for future expansion plans, while the diversion structure has the capability to receive additional stormwater piping to divert ADF-contaminated stormwater from future apron expansion. The design philosophy minimizes future design work, while also reducing potential construction work for future expansion. This design approach not only presents cost savings and lowers the project's environmental footprint with less electricity, paper, and vehicle use, but also echoes these savings for future expansion plans.

Q5 MEETING CLIENT'S NEEDS

YYC's objective for the design of this project was to keep the capital budget low while complete the project by the 2019/2020 deicing season. To meet this objective, Stantec engaged the would-be operators of the facility during the design phase, such that all design elements considered ease of operation and maintenance, so training can be minimized to get the operator going for the deicing season.

The efficient design philosophy carried beyond just the proposed design, the EDA also has potential to be expanded and mirrored for future added capacity. Together with YYC, we studied the surrounding area and purposefully placed the diversion structure in the middle of the ultimate apron buildout. This meant that the grading design can be fully duplicated for the future expansion, and the stormwater conveyance system underneath the apron can be mirrored across the ultimate apron buildout, which will save a significant amount of design effort for future expansion, and further decrease taxi time and improve passenger experience.

This strategic civil design methodology proved to be a huge success in maintaining the scope, reduced schedule, and minimized budget.

As demonstrated through the fees, the engineering fee for the **civil design is only approximately 0.27%** of the civil construction cost. The **overall consulting fee**, including full-time construction, is only approximately **2.0% of the total capital budget** of the project; far below industry standards.

Our technical excellence in aviation civil design provided YYC an unbeatable value, while drastically reducing design schedule to meet the project deadlines.

East Deicing Apron by the numbers:

11 hectares of apron; equivalent of **22 football fields**

460 m in length, **240 m** in width, with a **1 m** deep pavement structure

600 inset lights and airfield electrical lighting

A **12 m** in length, **12 m** in width, **10 m** deep diversion structure, similar to a **3-story-tall building**

A **100 m²** control building

14 EV charging stations

East Deicing Apron is one of YYC's most advanced and key infrastructure which sets the road map for the airport's future growth by entertaining efficient deicing protocols and reducing taxi times for the aircrafts. This state-of-the-art facility, accomplished by Stantec and Calgary Airport Authority's in-house design teams, upholds Calgary's unmatchable hospitality and YYC's promise of delivering the best customer experience.

—Muhammad Kaleem, Civil Engineer, Infrastructure Calgary Airport Authority

Concrete Apron Construction

Design with
community in mind