Stormwater
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FEATURES

By Alan Black

The $1.1 billion to $1.2 billion Seattle-Tacoma International Airport Third Runway Project is among the largest earthwork projects in the country, the type of project that brings meaning to a day and helps define a career. The project propelled a team of highly experienced engineers to elevate their design to a new level to meet the technical, political, and regulatory challenges.

This project has had the perfect ingredients to highlight the benefits of quality stormwater engineers collaborating to help protect nearby creeks from construction runoff. In addition to its size, the development of a third "dependent" runway is also one of the most sensitive public works projects in regional history. The Port of Seattle launched the environmental process in 1994. The record of decision was reached, property acquisition began, and initial earthwork began in 1997 under substantial opposition from cities and communities neighboring the airport. As a result, the runway's completion date has slipped from 2004 to 2008. A major step in the construction is to import fill material to raise the third runway site up to the airfield elevation. Environmental protection measures, including a variety of best management practices (BMPs), monitoring, and stringent stormwater management measures, have been a key focus for the project.

Twelve years ago, the Port of Seattle selected HNTB Corp., a 91-year-old, employee-owned infrastructure firm, to provide comprehensive design, engineering, and planning services for its Third Runway Project. The plans, from HNTB's Seattle office, called for approximately 17 million cubic yards of fill material to be placed and compacted. Fourteen million cubic yards of the fill material are being imported from offsite sources. Time was critical, so construction started with small embankment projects—involving less than 1 million cubic yards of fill—that enabled the work to begin in areas where construction did not require wetland-related environmental permits. Meanwhile, the port worked through regulatory issues, permitting delays, and opposition to the runway. Those who did not want an airport expansion in their backyard targeted environmental impacts, which put pressure on the design team to deliver failsafe protection for the stream and wetlands adjacent to the work area.

Photo: Sky-Pix Aerial Photography

An aerial view of the Sea-Tac International airport under construction for its future third runway. Note storage ponds that help protect adjacent natural resources in the foreground.

The pressure was on to ensure that the temporary erosion and sediment control (TESC) measures were fail proof. These early projects provided a testing ground for many of the BMPs under the watchful eyes of the Port of Seattle, HNTB, and those who opposed the project. One mistake would halt the project, so we faced the challenge with a large investment in working through the details behind the scenes.

These early efforts included testing of various standard BMPs: mulching, silt fence, lined ditches, check dams, and sediment ponds large enough to capture 80% of the 0.01-millimeter particulates for the 25-year, 24-hour, SCS Type IA design storm. Each construction project was set up in the same way:

Embankments would begin to expand the footprint of the existing embankment. Stabilized perimeter ditches, silt fence, and wetland buffer fencing would establish the line of defense along the resources that could not be impacted. The contractor would establish these perimeter features and then have unrestricted movement within the 20- to 30-acre work area. All runoff would be directed to a large sedimentation pond to allow sediments to drop out before discharge. The Port of Seattle took full responsibility for testing and releasing the runoff to the stream. As it turned out, these common BMPs had little chance to provide the water-quality treatment that would be necessary to meet the Clean Water Act–based goal for turbidities of 5 nephelometric turbidity units (NTUs) above background conditions (as clear as drinking water). The turbidity in runoff from these projects ranged from 60 to over 2,000 NTUs. Sedimentation alone was not sufficient to meet the discharge turbidity requirement, so we turned to stormwater chemical treatment to meet the challenge.

Batch Stormwater Chemical Treatment

As the initial 460,000-cubic-yard project began in the summer of 1997, stormwater chemical treatment was new to the area. Two relatively small projects had used chemical treatment plants that were constructed to meet similar discharge requirements. With stormwater chemical treatment, the outlet from the sedimentation pond was shut off to prevent direct release of untreated stormwater runoff. The volume of the sedimentation pond equaled the 10-year, 24-hour design storm runoff. The treatment facility consisted of three treatment cells ranging from 50,000 to 75,000 gallons, pumps, valves, and piping. A lab trailer was located onsite to house instrumentation, monitoring, and dosing equipment, and a 30-kilowatt generator powered the lab and pumps. Three facilities were constructed in this manner to address the early construction projects. Each one was set up to utilize permanent detention ponds for sedimentation/storage and custom designed to serve the maximum open work area in each basin.

Two full-time Port of Seattle staff members were responsible for operating the chemical batch treatment plant, both of them on call to process batches whenever a storm passed over the project site. The process would begin with measurement of pH, turbidity, and conductivity in the storage pond. As the stormwater was pumped from the storage pond into a treatment cell, Calgon 2953 coagulant/flocculent was added. The dose would be based on the turbidity test from the pond. Sodium bicarbonate (baking soda) was added within the treatment cell to adjust the water pH and conductivity to ensure that the pH was in the optimal range for flocculation and release to the creek. The piping was offset to create a circular movement of water, which assisted in mixing. Once the cell was full, the water was recirculated for a short period to enhance mixing. Then circulation was stopped to allow the flocculent particles to settle to the bottom of the cell. Once settled, the cell was tested for turbidity and pH compliance and pumped to the discharge point (creek) at the allowed release rate for the site.

The three-cell configuration optimizes operations, because there is a three-step process per cell. The initial design allowed a six-hour cycle per cell assuming a continuous release. The allowable release rate has been the limiting factor in treatment capacity on this project. (The release rate is less than the filling and settling times per cell.)

HNTB developed a simple reference page that hung in the operations trailer. Discharge rates were set based on the contributing area, which changed over time. Typical discharge rate was set at a constant rate of 50% of the pre-project, two-year peak discharge from the site. This constant but low discharge rate would protect stream habitat while simplifying the operations. Any event greater than the 10-year recurrent storm would be considered an extreme event and justify release of treatment bypass flows at a higher discharge rate. There was also a chart showing the time to treat for any given depth in the pond and the available capacity in the storage pond given as a function of inches of rainfall on the site. This facilitated the operator’s consideration of the weather forecast and whether it was safe to go home.

The first treatment plant was in place to serve the larger, 900,000-cubic-yard embankment contract that began in 1998 and successfully addressed stormwater runoff during the 1998–1999 winter season. During the fourth week of November 1998, 7.02 inches of rain fell in eight days. During that period, 2.96 inches of rain (a 10-year recurrent event) fell on November 25, 1998. When combined with the rainfall before and after this event, the weeklong rainfall is roughly equivalent to a 30-year event. The batch plant treated all of the rainfall without the storage pond overtopping. Several improvements were made to the batch plant after November 1998. Most notably, the pumping capacity was improved by adding additional and larger pumps and by increasing the pipe size from 4 inches to 6 inches. This allowed for shorter fill time, which allowed for greater time for flocculation and settling.

Photo: Clear Water Compliance Services Inc.

Typical CESF installation. Chemical storage, controls, and the monitoring equipment are located in the white container. Two 500-gallon-per-minute CESF units are shown to the right.

Looking to Continuous Stormwater Chemical Treatment

The batch process operation worked well for work areas up to 60 acres (with a process rate of 1,050 gallons per minute) that we had for the early embankment projects. However, the process had disadvantages that would have been ominous with today's work area of more than 260 acres. Batch treatment requires a sizable flat surface to construct the treatment cell facility. The operation was very labor intensive, with valves and multiple pumps operated to simultaneously fill, mix, and release. Typical operation under full capacity would consist of 12- to 14-hour days (two employees) at each facility. Needless to say, operation of these batch plants at full capacity was a challenge. By looking ahead, the port had two years to test alternative methods and work with the regulatory agency, the Washington State Department of Ecology, to identify the best approach to meet the challenge of the larger needs that we have today.

The continuous treatment operation followed the same technical process as the batch operation: add chemical, mix, settle, and discharge. The treatment rate can be set to the allowed release rate and automated to begin when the sediment pond reaches a set level. Continuous sampling of the release water ensures meeting the water-quality requirement for all water discharged. The area required for the treatment unit is smaller, and only one primary pump can be set to the process at the allowable release rate. Quality testing data can be recorded for documentation and compliance records.

The advantage to the continuous approach is that a flow-through process can be designed to operate as an unattended system. The project site became a testing ground for several experimental facilities from suppliers. The Port of Seattle conducted two pilot tests: Lamella Plate Settler Pilot Alternative and the “Actiflo” Sand Assisted Inclined Plate Settling Alternative.

The Lamella plate unit consisted of two mixing tanks that connect to an inclined plate settling assembly. Chemicals were added to the first mixing tank. The water then flowed into the second mixing tank, where a slower rate of mixing was performed to generate the proper floc size before water continued into the base of an inclined plate unit. As the water moved upward, the floc settled onto the inclined plates and clean water was decanted off the top and discharged. The floc accumulated and slid down the plates to a sump chamber, which either would be allowed to drain slowly or was flushed on a regular interval to remove the accumulated floc.

The Actiflo pilot settling unit is a patented system using the same base process as a standard inclined plate unit, with the addition of micro sand in the second mixing tank. The sand attaches to the floc and increases the settling rate of the floc, which allows for a faster rise rate of water through the plate settling apparatus and allows for a more rapid mixing time. The sand-laden floc is collected at the base of the plates and pumped up to a hydrocyclone unit, where the floc is separated from the sand. The sand is returned to the mixing tank for continuous use, and the floc slurry is discharged to a separate line for dewatering/disposal.

In addition to the pilot systems studied, HNTB developed a third treatment alternative. This alternative is based on conversion of the batch treatment cell for use as a cascading pool operation. The stormwater flows into the first pond, where it is decanted to a second pond and so on through several ponds. The process was perceived as being higher risk because it would utilize the batch treatment cells, whereas the package plants described above had the advantage of being able to discharge to these cells in the event that the discharge requirements were not met.

In the end, each of these alternatives was insufficient to ensure performance expectations by the Port of Seattle and the regulatory agency.

Treatment Approach for Larger-Scale Projects

With the permit in hand, the Port of Seattle initiated a much larger two-year, 8-million-cubic-yard embankment project that eventually would open more than 260 acres of the site. Having taken direct responsibility for the earlier batch plant operations and seeing the pilot projects, the port saw that a clear leader for stormwater chemical treatment was not evident. Each had its advantages and disadvantages, so the Port of Seattle elected to open selection through a contractor bid process. The contractor would then assume operation of the facilities through force account once the Port of Seattle, with input from the Department of Ecology, selected the preferred proposal.

Photo: Clear Water Compliance Services Inc.

This photo illustrates the automatic discharge back into the sediment pond when them onitoring equipment senses that the stream discharge requirements have not been met.

With this change, the Port of Seattle worked with HNTB to define embankment contract work in a way that minimized risk to the environment but also minimized the constraints on the contractor's work. By this time, there were local guidelines and permit conditions in place to set requirements for stormwater chemical treatment: Storage volume must equal 150% of the runoff from the 10-year, 24-hour storm event while discharge rates were set based on pre-project, 24-hour peak flow rates or by continuous model.

Many of the rules were clear. The site improvements included various permanent ponds that would set the available storage. The challenge was in integrating this existing infrastructure into contract documents that set operational guidelines, treatment facility capacities, and maximum contributing area, and that accounted for variability in construction phasing through the life of the contract. Risk management concerns sent the team through a smorgasbord of "what if" scenarios before we could settle on how to meet the contracting challenge. Two years in practice has also added a few lessons that we will apply to this winter's embankment work.

The first priority is to ensure that the stream is protected from receiving untreated runoff. The perimeter ditches have worked well in practice, and contractors have been adept at managing stormwater within the site. The Seattle area is notorious for its rainy-season weather pattern of continuous rain showers. The influence of the bordering mountains results in low-intensity, long-duration events that add doubt to guidelines that are based on the 24-hour design storm event.

The November 1998 event highlighted the reality that Seattle does not have a weather pattern that fits neatly into the 24-hour storm format. This "single event" hydrologic model had been proven insufficient for permanent flow control facilities. This uncertainty drove the design evaluation to choose the King County Runoff Time Series (KCRTS) continuous hydrologic model. Like HSPF (Hydrologic Simulation Program Fortran), this model can take advantage of 50 years of hourly rainfall data at the airport and generalized Puget Sound runoff characteristics to facilitate statistical evaluation of pond performance.

With sediment pond storage based on permanent detention storage requirements, HNTB evaluated the performance of various work area and allowable discharge scenarios. The design focus had been to ensure that the storage and treatment facilities would be adequate to prevent overtopping during the 10-year storm event (following the intent behind the Washington State Department of Ecology guidelines). This resulted in the contract requirements for maximum contributing work area and minimum treatment capacity for each storage pond.

As the much larger embankment project began, the selection process resulted in abandonment of the old batch plants and installation of relatively new chitosan-enhanced sand filtration (CESF) systems. Chitosan is a biopolymer made from crustacean shells and has been used in the wastewater treatment industry for many years. The system includes floating intake line to allow the treatment pumps to take water from the top of the storage pond. Chitosan is added in advance of three cascading 50,000- to 70,000-gallon storage ponds that provide pre-settlement before the water is sampled and pumped into the sand filter units. The sand filter is composed of 54-inch sand filtration units designed for a process rate of 10 gallons per minute per square foot of filtration media. The understanding is that the chitosan forms a slurry at the face of the filtration media that produces the 2- to 5-NTU results that would not be attainable without chitosan. The four-unit systems on this project have a theoretical capacity of 636 gallons per minute, but backwash cycles result in an actual discharge rate in the range of 500 gallons per minute.

Programmable logic controllers, sampling equipment, backwash systems, and remote monitoring allow the operation to be fairly simple once started and dialed in at the beginning of each day. Even with this automation, the chemical treatment subcontractor, Clear Water Compliance Services, still has full-time staff on hand to proactively take manual samples for turbidity, pH, residual chitosan, and arsenic; check for visible sheen; calibrate dosing; and document weekly performance.

During last winter’s wet season (November 2005 to May 2006), there were more than 263 acres of open construction site, three ponds totaling 33 acre-feet of storage, and seven CESF units. The project can brag about discharging more than 46 million gallons, achieving water-quality values well below the 5-NTU discharge requirement. However, there was one very close call where we learned more about how the actual operation differed from the continuous hydrologic model conditions. The models are very good at predicting surface runoff response from an area but are challenged in predicting human influences. Examples include dewatering contributions, changes in contributing area as the embankment work progresses, decisions on when to process the stormwater runoff, and attention to minimizing dead storage.

After two years of operation with the proven performance of the CESF treatment systems, the port has turned its attention to creating tools that help in the day-to-day operation as well as increase protection from storm events and human influences that are different from the model conditions. HNTB has developed an interactive spreadsheet that uses the stage-storage relation of the pond, linear relationship between the contributing work area and the rainfall runoff volume, and actual treatment process rate to predict the capacity available for impending storms. With relatively simple input, the contractor can use the spreadsheet to understand the storage available and pond volume transfers necessary to prepare for rainfall predictions in the weather forecast. The Port of Seattle is also able to anticipate, document, and take early action for events that would otherwise overtop the storage ponds.

By October 2006, the Port of Seattle will call for Clear Water Compliance Services to treat runoff from 376 acres through 12 CESF treatment systems with a total processing rate of 7,200 gallons per minute. In spite of the huge magnitude of the effort, we are confident that this will be another year that we can meet the challenge.

Closing Thoughts

The project success continues to be a collaborative effort between the owner, engineers, and contractor. This combined effort is one of many examples of how the Port of Seattle has risen to the challenge and persevered through all of the hurdles, twists, and turns in the process of constructing a third runway at Seattle-Tacoma International Airport.

In the case of stormwater treatment, this has not been a simple case of choosing the right BMP. The design goes beyond the one-size-fits-all guidelines in the local criteria by verifying with continuous models and validating that facilities match the specific contractor and client performance needs for the site. By anticipating the variability in contributing areas and setting performance guidelines such as maximum contributing area and minimum treatment rate, the contractors were able to understand the expectations and bid the project without surprises. This collaborative effort has been a great success for each of us involved in the project as well as the precious natural resources that inspire the work.

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