KENDUSKEAG EAST CSO STORAGE FACILITY IN BANGOR, MAINE

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ABSTRACT

Bangor, Maine, a community of 33,000, is one of several hundred communities nationwide undertaking projects to control Combined Sewer Overflows. The City's Long Term Control Plan recommends several control technologies for Bangor's CSO situation, including the construction of CSO storage facilities in three locations.

In 1998, Bangor constructed the 1.2 million-gallon Davis Brook CSO Storage Facility, an inline tunnel-like structure constructed of pre-cast concrete box sections and located under a future waterfront park area. The project was extremely successful from a construction and operational perspective, and very cost-effective with a construction cost at about $1.3 million.

In September 2000, construction commenced on the City's second CSO storage project, the 1.2 million-gallon Kenduskeag East CSO Storage Facility. Bangor again utilized pre-cast concrete box sections to construct this off-line structure underneath an existing public parking lot in the downtown area.

At a cost to the City of less than $2.2 million, this project is $3.1 million less than a proposed cast-in-place tank. By utilizing precast sections, the entire structure was installed within a three-month time frame, with only minimal disruption to the public. The precast units were manufactured locally under a separate contract; with over half of the units manufactured by the time installation began. Units were delivered to the project on an as needed basis. The facility fit nicely under a public parking lot, thereby requiring no additional land area. The project includes a flushing system to remove settled solids from the bottom of the tank. The facility is connected to the City's Supervisory Control and Data Acquisition (SCADA) system, which will provide real time monitoring and remote control by Treatment Plant personnel. The local economy benefited with design, precast manufacturing, and construction all accomplished locally.

This paper discusses several issues that should be of interest to other CSO (or SSO) communities contemplating storage projects, including design considerations, advantages of precast concrete, low costs, ease and speed of construction, and operational experience.

KEYWORDS

CSO, Storage, Pre-cast

INTRODUCTION

The City of Bangor, Maine, with an area of 32.9 square miles, and a population of 33,000 people, is located in east central Maine. The city consists of an urbanized central core made up of residential, commercial, and light industrial areas totaling approximately 16 square miles, concentrated essentially around the confluence of the Kenduskeag Stream and the Penobscot River. Extensive portions of the remaining area are undeveloped.

The development of Bangor occurred initially along the banks of these two major waterways. By the mid-nineteenth century, the city had grown to 20,000 people, and had evolved into a major trade center. The Penobscot River, connecting the large pine forests to the north and the Atlantic Ocean to the south became the catalyst for the development of Bangor as the largest port in the world for the shipping of lumber in the 1870's.

The early sewer records date back to around 1850, a time where cess pools and open ditches were the predominant waste disposal method. As development took place, piped sewers became more common to take residential sewage to the closest brook -- Barkersville Brook, Davis Brook, Sanford Brook, Carr Brook, Meadow Brook, or Arctic Brook. As more and more sewage entered the brooks, the conditions became intolerable, and there were requests for the City do something about the situation. The solution was to construct large brick pipes in or near the brooks to carry the combined storm and sanitary flows to either the Kenduskeag Stream or the Penobscot River.

By the early 1960s, the Stream and the River were essentially dead, with dissolved oxygen readings of zero. Fishing and water contact recreation were non-existent, and odors were atrocious. In order to alleviate this environmental, health and aesthetic nuisance, Bangor began a multiyear program to collect and treat its wastewater. The City constructed a wastewater treatment plant in 1968, and began construction of a nine-mile interceptor sewer system to collect flows from approximately 25 sewers that discharged wastewater into the Stream and River.

At 22 of these discharge points, Combined Sewer Overflow (CSO) structures were built. These structures captured approximately four times the normal dry weather flow at these locations. Flows exceeding this amount during rainfall or snowmelt events overflow untreated into the River and the Stream.

In the mid-1980s, CSOs began to be recognized as a significant source of waterway pollution, and regulations began to be developed to address the issue. Under the provisions of a Consent Decree with the State of Maine, and later with USEPA, Bangor has been working on a multi-million dollar program to abate and control Combined Sewer Overflows since 1987,

In 1992, Bangor undertook a program to develop a CSO Control Plan. The Plan identifies projects that are most cost efficient and effective to control CSO discharges and improve water quality. The plan calls for a variety of methods, such as sewer separation; treatment plant upgrade; pump station upgrade; overflow structure modification; and storage / treatment. Sewer separation has been the primary method of CSO control. To date, the City has expended in excess of $31.2 million in mostly local funds. Ten of the original twenty-two CSO locations have been eliminated, and CSO activity has been reduced by approximately sixty percent. Projects are scheduled through 2009 and capital expenditures are expected to total in excess of $50 million.

Following a period of monitoring, testing and Storm Water Management Model (SWMM) analysis, it was determined that there would be 52 annual CSO discharge events totaling 26.2 million gallons at the Kenduskeag East CSO discharge structure. To control CSO discharges at Kenduskeag East, the CSO Control Plan recommended the construction of a 1.2 million-gallon storage tank and subsequent treatment as the preferred method of control.

The concept outlined in the CSO Control Plan was a rectangular cast-in-place concrete tank with dimensions of 140 feet long by 80 feet wide by 24 feet deep. This size tank would fit in a City-owned lot at the edge of the Kenduskeag Stream. The tank, through a series of structures and pipes, would capture CSO discharges at the Kenduskeag East Combined Sewer Overflow. After the storm / snowmelt event had passed and treatment capacity became available at the wastewater treatment plant, the tank would be pumped out into the interceptor sewer located adjacent to the tank. Included in this storage tank project were washdown facilities, odor control equipment, and the provision for overflow out of the tank should volume of CSO discharge exceed the volume of the tank. The planning level cost estimate was $3.7 million.

Bangor has been financing both an upgrade to its wastewater treatment plant and CSO control with sewer user fees. Since 1987, these user fees have increased from $1.09 to $4.14. City administration and staff regularly look for other sources of funding for these very expensive programs.

In January, 1994, Bangor was informed that the Section 307, Water Quality Resources Development Act of 1992 provided funding for the Army Corps of Engineers to undertake several water quality projects in New England, which included the Penobscot River in the vicinity of Bangor, Maine. Initially, about $200,000 was available to Bangor for the design of projects of the city's choice. For projects, Bangor selected the design of CSO Storage Tanks at Davis Brook and at Kenduskeag East.

The Corps of Engineers selected an engineering consultant to undertake the design of the tanks, with a scope of work based on the concepts contained in the CSO Control Plan. The design work included extensive subsurface investigation to determine the adequacy of the sites for the construction of a large concrete tank.

In August 1996, the Corps of Engineers scheduled a meeting with the City to discuss the preliminary design of the Kenduskeag East CSO Storage Facility. The site investigation conducted during the early design stage had yielded a number of costly issues that needed to be addressed and resolved before the design work could continue:

- Due to the granular nature of the soils and the close proximity of the project to the stream bank, significant effort would be required for dewatering of excavations.

- The depth required for excavation, removal of existing soils, and high groundwater conditions would greatly complicate construction and substantially increase costs.

- The geotechnical investigation showed large cobbles and boulders present, which would likely preclude the use of conventional sheet piles.

- Construction cutoff walls would probably require the use of a slurry trench type of construction, work that must be undertaken by a specialty contractor.

- The potential for flotation of the tank is great. The project would need to include provisions to resist uplift forces.

- The project would require a 15-month construction period, meaning more expensive winter work and potential site flooding during high spring flows.

The net result of these issues was a significantly increased estimated cost for the project. The $3.7 million cost estimate had now become $4.7 million (1996 dollars). The project cost was too expensive and the project was put on the shelf.

Similar issues had been faced earlier on the proposed Davis Brook CSO Storage Facility. The net result of these issues was also a significantly increased estimated cost for the project. The $3.9 million cost estimate for Davis Brook had escalated to $6.97 million. Bangor City Manager Edward Barrett responded that the City would not spend that amount of money on a CSO storage tank. He then directed the City Engineering Department to find a better, cheaper way to address the Davis Brook CSO discharge issue.

Figure 1

In 1998, Bangor constructed the 1.2 million-gallon Davis Brook CSO Storage Facility, a unique and innovative tunnel-like structure constructed of pre-cast concrete box sections and located under a future waterfront park area (See Figure 1). The project was a radical departure from the conventional storage tank approach, and was extremely successful from a construction and operational perspective, and very cost-effective with a construction cost at about $1.3 million. The Davis Brook project has generated a lot of interest with CSO communities and their consultants.

With successful experience with the first tank, Bangor decided to use the same precast technology for the Kenduskeag East CSO Storage Facility. The project was taken off the shelf, approvals were obtained, and the redesign work began in early 2000 on the Kenduskeag East CSO Storage Facility.

DESCRIPTION OF THE KENDUSKEAG EAST CSO FACILITY

The Kenduskeag East CSO Storage Facility was constructed of 294 precast box sections of various sizes.

The existing 42" interceptor on the project site was replaced with 8' wide by 6' high box sections with a V-shaped bottom to maintain velocity over a wide range of flows, thereby minimizing solids deposition. This portion of the project is on-line at all times, and is depicted by the yellow sections shown in Figure 2.

When there is no rainfall or snowmelt, the normal sewer flows stay in this portion of the facility, and the rest of the facility remains empty. During rainfall or snowmelt events, control gates downstream of this facility can be activated, either manually or automatically, that causes flow to back up in the on-line portion, causing the wastewater level to rise. When the liquid level reaches 3.5 feet in the on-line portion, wastewater spills over a baffled side weir into the off-line portion of the facility.

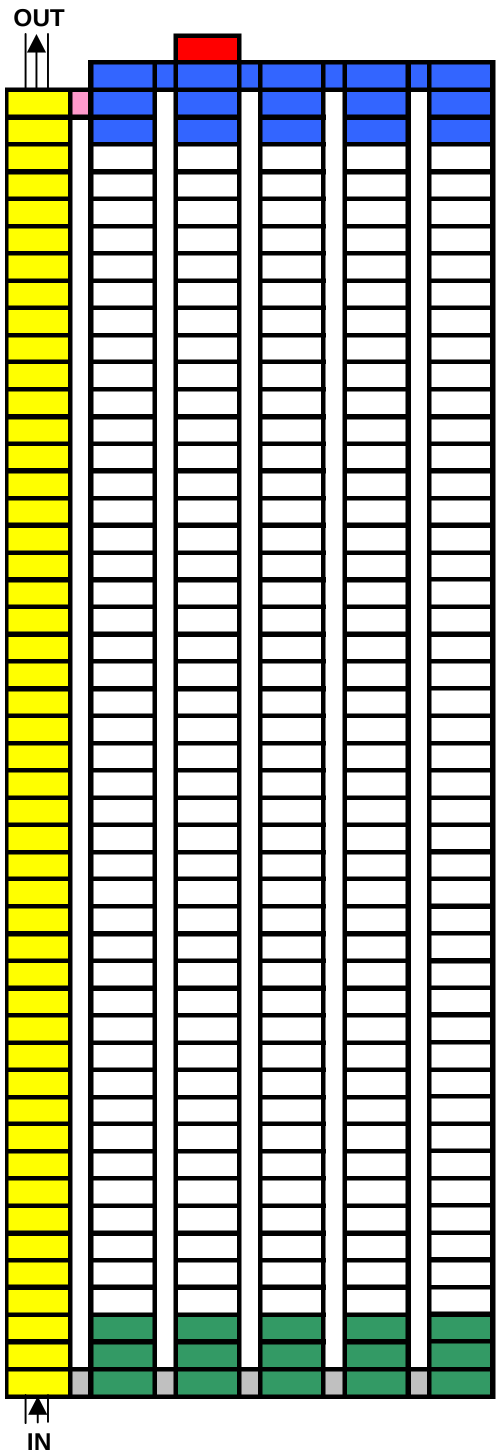
The off-line portion consists of five rows of box sections. Each row is 360 feet long, 8 feet wide inside dimension, and spaced one-foot from the adjacent row.

At the low end, each row has three sections sized 8' wide by 12' high by 5' in length, depicted by the blue sections in Figure 2. The end pieces are connected together with 3' by 3' box sections to create a common header. An additional 12' high section, depicted by the red section in Figure 2, provides space for a small duplex pump assembly. These 12' sections are partially filled with concrete that slopes toward the pump assembly for proper drainage. The partial fill also creates a sump that minimizes backwash from the flushing procedure described below.

At the high end, each row has three sections sized 8' wide by 10' high by 7.5' in length, depicted by the green sections in Figure 2. Each third section from the end has a 6'-7" high wall with a Grande-Novac Hydroself Flushing Gate assembly installed. There is concrete fill in each row that slopes from zero at the gate wall to 2'-7" high at the end wall. The resulting chamber holds approximately 6,000 gallons to be used to flush out each row following a storage event. The flushing chambers are connected together with 8" pipes installed with a check valve that allows one-way flow.

The rest of the precast sections are 8' wide by 10' high by 7.5' in length, depicted by the white sections in Figure 2. These sections have flat bottoms, which were recommended as most appropriate for the flushing operation.

At the lower end there is a 12" pipe with check valve that connects the off-line portion of the facility with the on-line portion. This allows the off-line portion to partially drain by gravity back into the sewer system for treatment.



YELLOW	8' WIDE x 6' HIGH V-BOTTOM ON-LINE KENDUSKEAG EAST SEWER.
WHITE	8' WIDE x 10' HIGH FLAT BOTTOM OFF-LINE STORAGE
BLUE	8' WIDE x 12' HIGH FLAT BOTTOM OFF-LINE STORAGE / SUMP
RED	8' WIDE x 12' HIGH FLAT BOTTOM OFF-LINE STORAGE / PUMP STATION
GREEN	8' WIDE x 10' HIGH WITH SLOPED FILL FLUSHING CHAMBER
PINK	12" DRAIN WITH CHECK VALVE -- DRAINS ABOUT HALF OF VOLUME
GRAY	TANK FILL

OPERATION

NORMAL DRY-WEATHER FLOW STAYS IN THE YELLOW ON-LINE PORTION OF THE FACILITY.

HIGH FLOWS DUE TO RAIN / SNOWMELT TRIGGER A DOWNSTREAM GATE CLOSURE CAUSING THE YELLOW PORTION TO FILL.

AT CAPACITY, COMBINED SEWAGE FLOWS THROUGH THE GRAY SEGMENTS TO FILL FIRST THE GREEN FLUSHING CHAMBERS, THEN ALL OTHER PORTIONS OF FACILITY.

AFTER EVENT IS OVER, FACILITY DRAINS ABOUT HALF THROUGH PINK DRAIN. PUMP IN RED CHAMBER COMPLETES DRAINING.

GATES IN GREEN FLUSHING CHAMBERS ARE THEN OPENED TO RELEASE FLUSHING WATER.

FIGURE 2

OPERATION OF THE OFF-LINE PORTION OF THE FACILITY

The off-line portion of the Kenduskeag East CSO facility begins to fill when the on-line portion backs up and crests an overflow weir. The first 30,000 gallons fill the flushing chambers, which remain filled until released.

Any additional flow spills over the flushing gate wall and fills the remainder of the facility up to a total volume of approximately 1.2 million gallons.

Following the rainfall / snowmelt event, and when downstream interceptor capacity becomes available, the facility will begin to drain down to the level of normal flow in the on-line portion, which is approximately half of the off-line volume. When this level is reached, one of the pumps will turn on to drain the remainder of the facility, except for the flushing chambers.

When the pump turns off, the flushing gates are activated in a sequenced operation. 6,000 gallons are released in less than 10 seconds to create a wave that cleans the bottom of each row. As soon as the water from each flush is pumped out, the next row is flushed.

Liquid level in the facility is monitored electronically by a transducer located in a manhole located adjacent to and connected to the pumping chamber. This is connected into the treatment plant's SCADA system that records the volume of capture. If the tank event is more than 1.2 million gallons, a computer controlled gate opens downstream of this facility, providing a controlled and measured CSO event.

PROCEEDING WITH THE PROJECT

Maine has a shorter construction season than many other parts of the country. For seven months of the year, there is either frozen or fully saturated ground, making construction difficult and expensive. In the late fall and winter months, the days are short. The onset of cold weather slows down productivity. In winter, construction activities either have to be protected against the climate, or suspended.

The staff of the Bangor Engineering Department is well aware of these climatic issues, and vigorously addresses them by innovative and creative methods of procurement and construction. For the Kenduskeag East project, separate contracts were issued for the precast concrete sections, for the flushing gates, and for the sluice gates. Each of these items had long lead times that could extend the project beyond the desired construction period.

Bids for the precast contract were received on June 20, 2000. The low and only bid was from American Concrete Industries (ACI) of Bangor in the amount of $757,439.00. The terms of the bid were that all precast products must be completed by October 30, 2000.

ACI informed the City that there was a long lead time to procure the reinforcing steel for this project and actual production could not begin until late August. They did, however, agree to meet the completion date. Table 1 shows the actual production schedule for this project.

KENDUSKEAG EAST CSO STORAGE FACILITY
PRECAST PRODUCTION SCHEDULE

DAY	DATE	8x10x7.5	SPECIAL	8x6x7.5	SPECIAL	8x12x5	SPECIAL	TOTAL
1	08/28/2000	1						1
2	08/29/2000	2						2
3	08/30/2000	2						2
4	08/31/2000	2						2
5	09/01/2000	2						2
6	09/05/2000	2						2
7	09/06/2000	2				1		3
8	09/07/2000	4				1		5
9	09/08/2000	4				1		5
10	09/11/2000	4				1		5
11	09/12/2000	4				1		5
12	09/13/2000	4				1		5
13	09/14/2000	4				1	END	5
14	09/15/2000	6				1	END	7
15	09/18/2000	6				1	END	7
16	09/19/2000	6		2		1	END	9
17	09/20/2000	6		2		1	END	9
18	09/21/2000	6		2		1	TRANSITION	9
19	09/22/2000	6	END	2		1	TRANSITION	9
20	09/25/2000	6		2		1	TRANSITION	9
21	09/26/2000	6	END	2		1	TRANSITION	9
22	09/27/2000	6		2		1	TRANSITION	9
23	09/28/2000	6	END	2				8
24	09/29/2000	6		2				8
25	10/02/2000	8	END	2				10
26	10/03/2000	8		2				10
27	10/04/2000	8	END	2				10
28	10/05/2000	8		2				10
29	10/06/2000	8		2				10
30	10/09/2000	8		2	END			10
31	10/10/2000	8		2				10
32	10/11/2000	8		2	END			10
33	10/12/2000	8		2				10
34	10/13/2000	8		2				10
35	10/16/2000	8		2				10
36	10/17/2000	8		2				10
37	10/18/2000	8		2				10
38	10/19/2000	6		2				8
39	10/20/2000	6		2				8
40	10/23/2000	6						6
41	10/24/2000	5						5
TOTALS		**230**		**48**		**16**		**294**

Table 1

PRELIMINARY CONSTRUCTION ACTIVITIES

Figure 3

The Kenduskeag East CSO Storage Facility was designed to capture and store up to 1.2 million gallons of combined sewage that would have previously overflowed untreated into the Kenduskeag Stream.

The Kenduskeag Stream flows in a channel formed by concrete retaining walls in the downtown area of Bangor. Directly adjacent to the retaining walls on each side of the Stream are public parking lots. The project is located on the east side (See Figure 3).

Bisecting the parking lot is the 42" Kenduskeag East Interceptor Sewer. (See Figure 4) The presence of this sewer required the contractor to install a temporary relocation (we used the word "bypass" on our drawings, but since "bypass" is already a designated EPA word with an explicit meaning, we use "relocation" here) to an adjacent vacant lot. Next, the vacant lot was paved and striped, and the users of the parking lot were relocated to that area while the CSO Storage Facility was constructed.

Figure 4

Figure 5

Two eight-foot manhole structures were installed at each end of the project site (See Figure 5). Initially, these structures were used to direct the interceptor flow to the temporary sewer.

At the completion of construction, these structures were modified to direct flows into the on-line portion of the Kenduskeag East CSO Storage Facility and to connect the project back into the existing interceptor sewer.

Figure 6

A major preliminary construction activity was the installation of a row of sheet piling on the stream side of the parking lot. (See Figure 6) This was done to protect the row of trees between the project and the stream, to provide protection for workers in the excavation, and to help address seepage from the stream into the excavation. Dewatering the site, with the Kenduskeag Stream and its thirteen-foot tides only a few feet away, was a requirement. The Contractor's plan was to install well points at the lowest elevations; however, the well points wouldn't penetrate into the subsurface strata. Instead of well points, the contractor installed a series of vertical culverts in crushed stone lined sumps, each with a pump.

CONSTRUCTION OF THE FACILITY

Figure 7

One of the drawbacks to the project site was the almost total lack of on-site storage space. The City's contract with American Concrete Industries specified interim storage at the manufacturer's location and carefully coordinated delivery schedules with the general contractor S. E. MacMillan Company. The first precast sections arrived on site on October 2, 2000 (See Figure 7). After the first few deliveries on an as-needed basis, the precast contractor began night deliveries of those units that were planned for the following day.

The weight of the precast sections (in the 30,000-pound range) required a large crane to lift and set the sections (See Figure 8). At this point of time, the contractor had excavated a 25' long area to subgrade and had installed 12" of crushed rock. The crushed rock was spread and brought to proper grade for the installation of the box sections. The first sixteen sections installed were twelve feet high, eight feet wide, and five feet long.

Figure 8

Figure 9

It was important that the first section installed (See Figure 9) was placed with correct location, grade, and alignment. The contractor took great care to assure that it was in the correct position. The first row sections were cast with an integral solid end. A square hole in the sides of the end units allowed installation of a short piece of 36" square box section to the adjacent row to create the common header at the lower end. The common header allowed the facility to maintain equal water levels in all rows.

Figure 10 shows the installed 12' high sections and the first few 10' high sections. Most of the remaining box sections were 8' wide by 10' high (inside dimensions) by 7.5' long. Due to the weight of the units (30,000 pounds each) and the reach limit of the crane, the excavation could only proceed about 25 feet ahead of the boxes, space enough for three sections longitudinally. Once a routine became established, the excavation took place in the afternoons, with the removal of approximately 700 cubic yards of material, which was trucked about half a mile away to a stockpile site. The bottom foot of the excavation was filled with crushed stone, spread and leveled to grade. The following morning, the contractor could install as many as 15 boxes, depending on weather and other conditions. When finished, the crane was moved out of the way, and excavation began for the next 15 boxes. During the first week, 40 of the 10' boxes were installed.

Figure 10

Figure 11

The rows of boxes were spaced 12" apart. This allowed each row to be aligned independently and to address minor deviations in fabrication and grade. Figure 11 shows the excavator digging, the crane set back out of the way, and several installed box sections with the required 12" spacing.

The issue of flotation was a concern due to the close proximity of the Kenduskeag Stream and the high water table during high tide. This was addressed by pouring concrete between the rows of boxes and by installing a 15" concrete cap over the top of the completed rows. The capping was first undertaken after about one-third of the boxes had been installed, then again after two-thirds, and at the completion. Figure 12 shows one of the capping operations. The work was accomplished using a concrete pump truck. At the completion of the project, the concrete was covered with about 12" of gravel and 3" of pavement to reestablish the public parking lot.

Figure 12

Figure 13

Figure 13 shows the 6' high V-bottom on-line portion of the facility (at left) directly beside the first row of the 10' high off-line portion of the facility. The completed cap can be seen in the background with vehicles and construction equipment parked on it. The trees at the left indicate the very tight construction limits of the project. The workers are installing the 1" thick by 4" wide joint sealer on the face of the 10' high box in preparation for the installation of the next section.

The inside of each row of the facility resembles a square tunnel, as can be seen in Figure 14. The bottom is flat with haunches at the corners. There is a joint every 7.5 feet with varying amounts of butyl rubber sealant extruded into the interior of the tunnel. The corners are connected together with threaded rods, washers, and nuts. As the project progressed, all extruded sealer was cut back, the bottom joint was grouted, and the bolt pockets were grouted. Any observed leaks were chipped out and sealed with waterplug. At the conclusion of the project, the interior was smooth and watertight.

Figure 14

Figure 15 is another inside photo showing the flushing gate. On the other side of the 6-foot high wall is the flushing chamber, which is about twenty feet long with a sloped bottom and a capacity of about 6000 gallons. The gate is hydraulically operated and controlled by the Treatment Plant's SCADA system. Following a tank event, the gate will spring open, releasing the stored flushing water in a surging wave that travels the length of the tank row to wash solids to the pump at the lower end. The controller flushes each row in a timed sequence. The gate closes automatically. Provisions have been made to fill the flushing chambers independently of storm events in case additional cleaning is required.

Figure 15

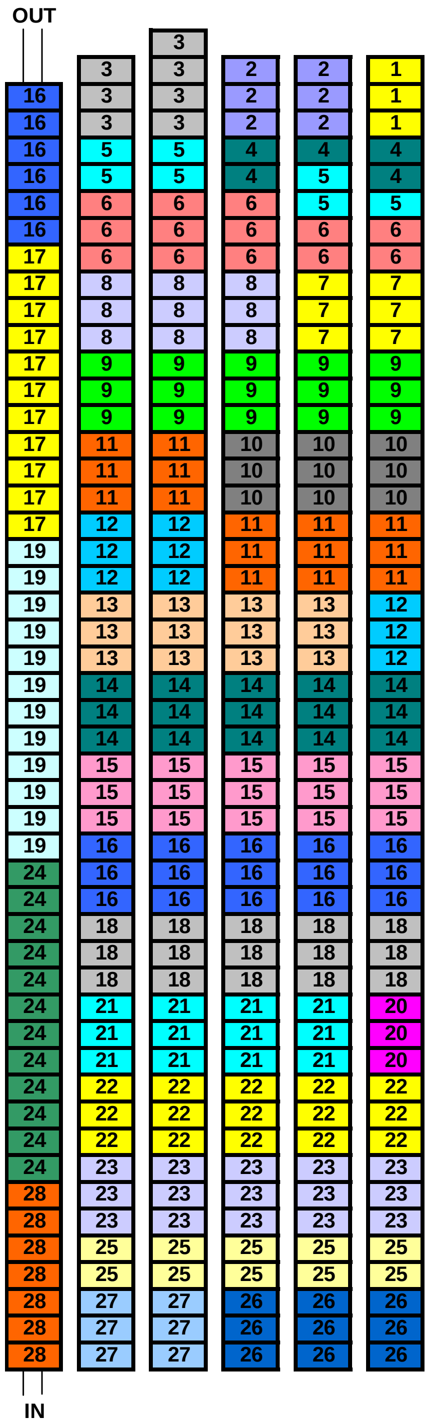
At the other end of the facility is the pump chamber. Two five-horsepower submersible pumps, shown in Figure 16, provide the means to fully drain the facility. The pumps are mounted on guide rails, allowing removal for service and preventive maintenance as required. At the bottom corners are the three-foot square passageways to the adjacent rows of the facility. Just beyond the pumps on the right is a 12" pipe that connects to the transducer manhole just outside the pump chamber. The transducer manhole maintains the same water level as the storage facility and has the electronic equipment to measure the liquid level elevation.

Figure 16

Figure 17

Across the street from the CSO storage structure is the Penobscot Interceptor and Kenduskeag Pump Station. Controls for the operation of the CSO Storage Facility are located in two small structures located at the Kenduskeag West and Kenduskeag East CSO discharge structures. Figure 17 shows the installation of a 10' x 10' precast building on the West Side. It is being set on the foundation in the foreground and will house controls for a sluice gate and a transducer to measure tide level. A similar structure was placed at the Kenduskeag East CSO discharge structure for gate controls at that point. Both buildings match the exterior appearance of the existing pump station.

The construction of the Kenduskeag East CSO Storage Facility went very well. Construction began in September and was completed in May, with wastewater flowing through the on-line portion of the facility on May 10, 2001. All precast units were in the ground by November 22, 2000. Figure 18 shows the actual installation schedule of the precast units.



DAY	DATE	INSTALLED	TOTAL	%
1	10/02/2000	3	3	1%
2	10/03/2000	6	9	3%
3	10/04/2000	7	16	5%
4	10/09/2000	5	21	7%
5	10/10/2000	7	28	10%
6	10/11/2000	13	41	14%
7	10/12/2000	6	47	16%
8	10/13/2000	9	56	19%
9	10/16/2000	15	71	24%
10	10/17/2000	9	80	27%
11	10/18/2000	15	95	32%
12	10/19/2000	9	104	35%
13	10/20/2000	12	116	39%
14	10/24/2000	15	131	45%
15	10/25/2000	15	146	50%
16	10/26/2000	21	167	57%
17	10/27/2000	11	178	61%
18	10/31/2000	15	193	66%
19	11/06/2000	12	205	70%
20	11/07/2000	3	208	71%
21	11/08/2000	12	220	75%
22	11/09/2000	15	235	80%
23	11/13/2000	15	250	85%
24	11/14/2000	12	262	89%
25	11/16/2000	10	272	93%
26	11/20/2000	9	281	96%
27	11/21/2000	6	287	98%
28	11/22/2000	7	294	100%

Figure 18

CONSTRUCTION ISSUES

There were a few minor problems experienced during construction and a few changes made along the way to improve the project.

- There were some dust complaints from users of the adjacent parking lot. Often, the construction equipment, especially dump trucks, had to travel through the parking lot between cars. Cars were occasionally covered with dust, but no vehicles were damaged.
- During the initial stages of excavation, there were not enough dump trucks to keep the excavator working efficiently. This issue was resolved when the contractor completed another project, which freed up the needed number of dump trucks.
- The contractor ran out of joint sealer, requiring the procurement of an additional quantity. There were a variety of reasons for this. Double sealant was required occasionally to maintain alignment. Cold weather caused problems with the material adhering properly to the concrete. If a piece fell off, it could not be reused.
- The specifications required the contractor to plug the weep holes in the channel wall at the edge of the Kenduskeag Stream. This was overlooked, and the excavation was partially flooded during one afternoon at high tide. The weep holes were plugged at the next low tide.
- Pouring concrete between rows required considerable bracing to prevent movement of the boxes by the force exerted by ten feet of wet concrete. At the upper end of the project, concrete was poured with no bracing, causing five boxes to shift laterally about four inches. This was subsequently corrected.
- The upper end has a vent manifold, originally designed with PVC pipe. The contractor recommended a change to ductile iron to avoid problems caused by frost action. This change was approved and put into place to avoid future problems.
- The two small control buildings were originally planned to be site constructed. Due to the schedule, this activity occurred in the middle of the winter. Outdoor winter construction is something that all local contractors like to avoid if at all possible. American Concrete Industries suggested a precast building, precast foundation, and precast floor slab. This alternative was accepted, with good results.
- Near the end of the project, the crane broke down. With winter closing in, and delays in repair parts, things did not look good. The contractor was able to share a crane with another contractor in an adjoining town to get the precast boxes in the ground before freeze-up.
- The delivery of the Programmable Logic Controller (PLC) for the SCADA control of the facility was delayed several times, with arrival at the site in early May. The reason that we were told for the delay is that the controller used the same computer chip as the Sony Playstation II. The popularity of the Playstation created a chip shortage. You just never know what will affect your sewer construction project!
- The weather throughout the project was ideal for construction, with virtually no rainfall and a very slow snowmelt in the spring. Unfortunately, the ideal weather continued into the time when the contractor needed lots of rain to test out the facility to make sure that everything functioned properly.

CONSTRUCTION TIME

Construction of the project commenced on September 5, 2000. All of the precast boxes were in the ground by November 22, 2000. Final completion of the construction, including clean up and restoration, was on May 18, 2001.

The total on-site construction time of 8 months compares very well with the projected construction time of 15 months for a cast-in-place facility.

OPERATION

The on-line portion of the facility was placed into operation on May 10, 2001. The temporary bypass pipe was disconnected and abandoned in place.

As of June 1, 2001, there has been no rain to test the Kenduskeag East CSO Storage Facility.

The similar Davis Brook CSO Storage Facility mentioned earlier has performed very satisfactorily over its two years of service.

CONSTRUCTION COST

Following is a tabulation of the construction cost of the project as of June 5, 2001:

• Precast Concrete Box Sections	
American Concrete Industries, Bangor, Maine	$ 761,224.46
• Sluice Gates	
Rodney Hunt Company, Orange, Massachusetts	$ 18,057.00
• Flushing Gates	
Grande-Novac Associates, Montreal, Quebec, Canada	$ 114,900.00
• General Construction	
S. E. MacMillan Company, Bangor, Maine	$1,270,743.46
• Parking Lot Paving	
Lane Construction Company, Bangor, Maine	$ 21,763.46
Jordan Striping Service, Presque Isle, ME	$ 264.70
Total Construction Cost	$2,186,953.08

The total construction cost of $2.2 million compares very well with the projected cost of $5.3 million (current dollars) for a cast-in-place facility.

CONCLUSIONS

The concept of a precast concrete storage facility should be of interest to any community considering CSO (or SSO) storage and treatment projects. For the City of Bangor, there have been numerous benefits, some of which are as follows:

- The total cost of this facility will be less than $2.2 million. This is significantly less than either the planning level cost projection of $3.7 million or the preliminary design cost estimate of $5.3 million (current dollars). Bangor has saved approximately $3.1 million by the use of this concept.

  The Davis Brook Facility, constructed in 1998 using the same precast concrete technology, was constructed at a saving of $5.7 million over a cast in place structure.

  The combined saving of $8.8 million for these two storage facilities is extremely significant for this small community!

- Most of the project expenditures will provide local economic benefit

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  (a) The project was conceived and designed LOCALLY by the City of Bangor engineering staff.

  (b) A LOCAL fabricator, American Concrete Industries, manufactured the pre-cast concrete sections.

  (c) A LOCAL contractor, S. E. MacMillan Company, Inc., constructed the project.

- Specialty (foundation, dewatering, and mechanical) contractors were not required.

- The project was constructed in a relatively shallow excavation (top is 3' below grade) avoiding expensive shoring and dewatering costs.

- Construction time was only about eight months, creating only minimal disruption of the parking in the parking lot.

- Only two small structures were required for SCADA control and monitoring equipment.

- With its location under an existing parking lot, no additional land was required for the storage facility.

- Operating and maintenance expenses will be lower than the original storage tank concept.

- The project provided a complete reconstruction of a heavily used but deteriorating public parking lot.