INSYSTEM STORAGE CAPACITY ENHANCES SEWER SYSTEM OPERATION

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ABSTRACT

Bangor, Maine has been addressing control of Combined Sewer Overflows since 1987. In 1992, a Combined Sewer Overflow Facilities Plan was prepared, which included a variety of recommendations for CSO Control. For three locations, insystem storage with subsequent treatment was the recommended method of controlling combined sewer overflows.

Although the specific intent of these projects was reduction of CSO discharges, operators have discovered that the additional collection system capacity has also provided significant benefits regarding management, operations, and maintenance. The experiences of the system operators should be of interest to all communities looking at options of complying with the proposed cMOM requirements.

In 1998, Bangor conceived, designed, and constructed the 1.2 million-gallon Davis Brook Storage Facility, a unique and innovative in-line tunnel-like structure constructed of V-bottom pre-cast concrete box sections. 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 total cost of only $1.3 million.

In 2000, Bangor constructed the City's second storage project, the 1.2 million-gallon Kenduskeag East Storage Facility. Bangor again utilized pre-cast concrete box sections to construct this off-line structure underneath an existing public parking lot. Constructed at a total cost of $2.4

million, this project has contributed to a significant reduction of CSO discharges in the downtown area of Bangor.

In 2002, Bangor constructed the City's third storage project, the 1.4 million-gallon Barkersville Storage Facility. This $2 million project is another in-line tunnel-like facility constructed of V-bottom precast box sections, controlled by a SCADA-operated gate system.

Bangor now has 3.8 million gallons of extra capacity within its sewer system, provided at a total cost of only $5.7 million, compared to projected costs of $18.8 million for constructed-in-place facilities. There has been considerable interest to date regarding Bangor's approach to CSO storage, especially the use of precast V-bottom box sections, and the significant time and cost savings of this method of insystem storage.

Now that the operators have gained some experience with these new facilities, they have found several benefits beyond significant reduction of CSO discharges. Some of these benefits are:

- Real-time flow management within the system,
- Leveling peak flows into the treatment plant,
- Avoiding operation of the plant's CSO by-pass function,
- Stopping flows to undertake downstream maintenance,
- Computer graphic displays of system flow levels,
- Interceptor flushing, and
- Control of peak electrical demand at the Treatment Plant.

SUMMARY:

The CSO Storage Projects in Bangor, Maine have proven to be a cost-effective approach to significant CSO discharge reduction. In addition, the extra system capacity of these facilities has provided benefits that should be of interest to other communities looking at the upcoming Capacity, Management, Operations and Management requirements of the proposed cMOM regulations.

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 to 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.

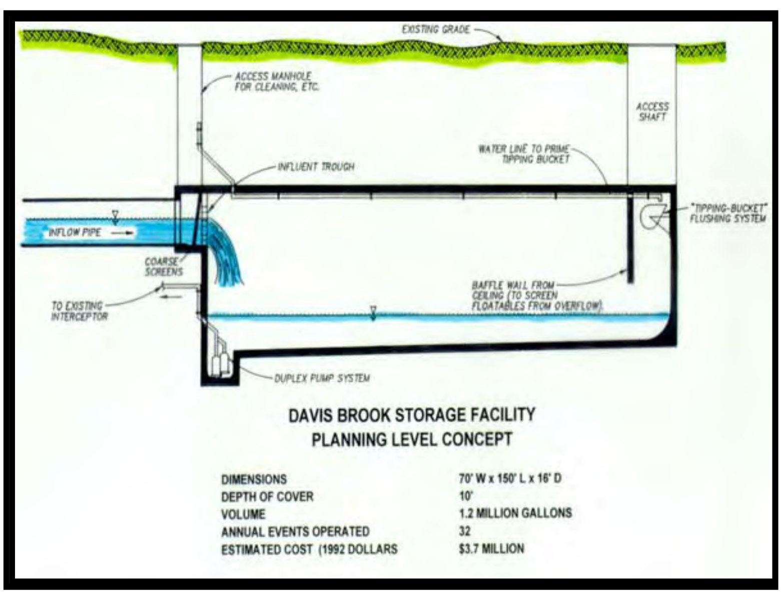
At 22 of these discharge points, Combined Sewer Overflow (CSO) structures were built. These structures captured approximately four times the normal dry weather flow at these locations. Flows exceeding this amount during rainfall or snowmelt events overflow untreated into the River and the Stream.

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, under the terms of a Consent Decree with the Federal Government, Bangor undertook a program to develop a CSO Control Plan to identify 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 $34.4 million in mostly local funds. Ten of the original twenty-two CSO locations have been eliminated, and CSO activity has been reduced by approximately seventy five percent. Projects are scheduled through 2009 and capital expenditures are expected to total in excess of $50 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.

Following a period of monitoring, testing and Storm Water Management Model (SWMM) analysis, it was determined that the most cost-effective CSO control strategy at three locations in the City's collection system would be construction of storage tanks with subsequent treatment at the wastewater treatment plant.

The concept outlined in the CSO Control Plan was three rectangular cast-in-place concrete tanks with dimensions of approximately 140 feet long by 80 feet wide by 24 feet deep, each capable of holding 1.2 to 1.4 million gallons. Each tank, through a series of structures and pipes, would capture CSO discharges in all but the most extreme of events. After the storm / snowmelt event had passed and treatment capacity became available at the wastewater treatment plant, the tanks would be pumped out into the adjacent interceptor sewer. Included in these concept-level storage tank projects 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 estimates ranged from $3.7 million to $4.7 million for each tank.



ORIGINAL TANK CONCEPT

<u>**Concept Level Projected Costs**</u>
(1992 Dollars)

Davis Brook	**$3,745,000**
Kenduskeag East	**$3,672,000**
Barkersville	**$4,732,000**
Total (1992 $)	**$12,149,000**

In 1997, Bangor embarked on the Davis Brook CSO Storage Facility, utilizing a design grant through the Army Corps of Engineers. During the design process, the Consulting Engineers retained by the Corps of Engineers undertook extensive site investigations to determine subsurface conditions. A number of site related issues arose during this process that raised the projected cost of Davis Brook to about $7 million.

A similar effort was made on the Kenduskeag East CSO Storage Facility, with the preliminary design cost projection increased to about $5.3 million.

Bangor's City Manager Ed Barrett stepped in and told the project team that the cost was too much and that the City would not spend that amount of money for these projects. As the design grant had been used up, both projects were shelved at the preliminary design phase.

The City Manager then challenged the City Engineering Department to figure out how to do it cheaper.

Accepting the challenge, engineering staff looked at using precast boxes to construct a tank. The precast components could be manufactured ahead of time to be ready for Maine's short construction season. A V-shaped bottom was conceived to concentrate flows to minimize sedimentation. The boxes were designed to be bolted together to minimize movement and to properly set the sealant between boxes. Construction could be accomplished quickly, minimizing disruption to the site. And cost estimates placed the probable cost at about $2 million for the size tanks recommended by the City's CSO Control Plan.

Precast V-Bottom Boxes

DAVIS BROOK STORAGE TANK

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. 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.

Davis Brook CSO Storage Tank Under Construction

It was envisioned that the facility would operate as a surge tank that would take a wide range of inflow with a more or less constant outflow, storing up to 1.2 million gallons in the process.

City staff discussed solids deposition at great length. Box sections have a flat bottom that spreads out the flow, enhancing solids deposition. For this project, a V-shaped bottom was designed into the project to maintain velocity over a wide range of flows.

Flow control, when required, is by SCADA operated modulating sluice gates at the inlet and outlet of the tank. Generally, control is not expected to be necessary, with operation relying on the outlet capacity of the structure under most conditions. The existing 42-inch interceptor will be retained for additional storage capacity and to allow the tank to be taken out of service if necessary.

The tank has an overflow provision for high flow conditions. Overflows will be monitored for frequency, duration, and volume by ultrasonic equipment located in a small building at the point of overflow.

Inside View of Davis Brook CSO Storage Tank

On June 1, 1999, the Davis Brook CSO Tunnel was placed in operation. Approximately 80% of Bangor's sewage now flows through this facility on a continuous basis. Normal daily flows stay in the v-shaped area in the bottom of the facility. Many rain / snowmelt events have shown that the facility is operating as anticipated. Solids deposition has not been an issue in the three and one half years of operation.

KENDUSKEAG EAST STORAGE TANK

With successful experience with the Davis Brook tank, Bangor decided to use the same precast technology for the Kenduskeag East CSO Storage Facility.

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 City selected a downtown public parking lot for the site of this project. The tank was designed with six parallel bays, each 360 feet long. The first bay, constructed of 8' wide by 6" high V-bottom precast sections, is on-line at all times, replacing a 42" concrete pipe that bisected the project site. The other five bays, constructed of 8' wide by 10' high precast sections, are off-line, functioning only during rainfall / snowmelt events.

Kenduskeag East CSO Storage Tank Under Construction

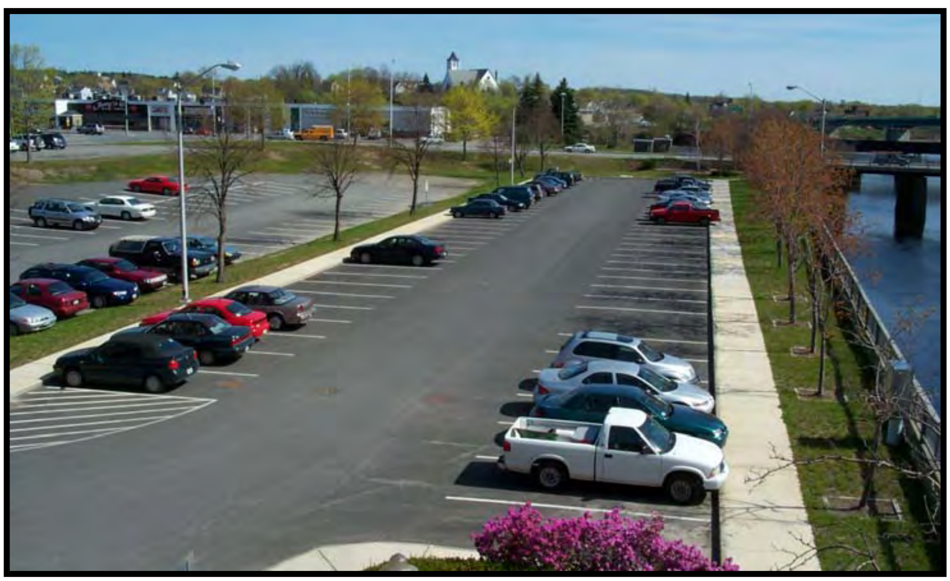
The facility fills when SCADA controls either close a downstream gate or slows down operation of the Kenduskeag Pump Station. The off-line portion of the Kenduskeag East CSO facility begins to fill when the on-line portion backs up and crests an overflow weir. The first 30,000 gallons fill flushing chambers, 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.

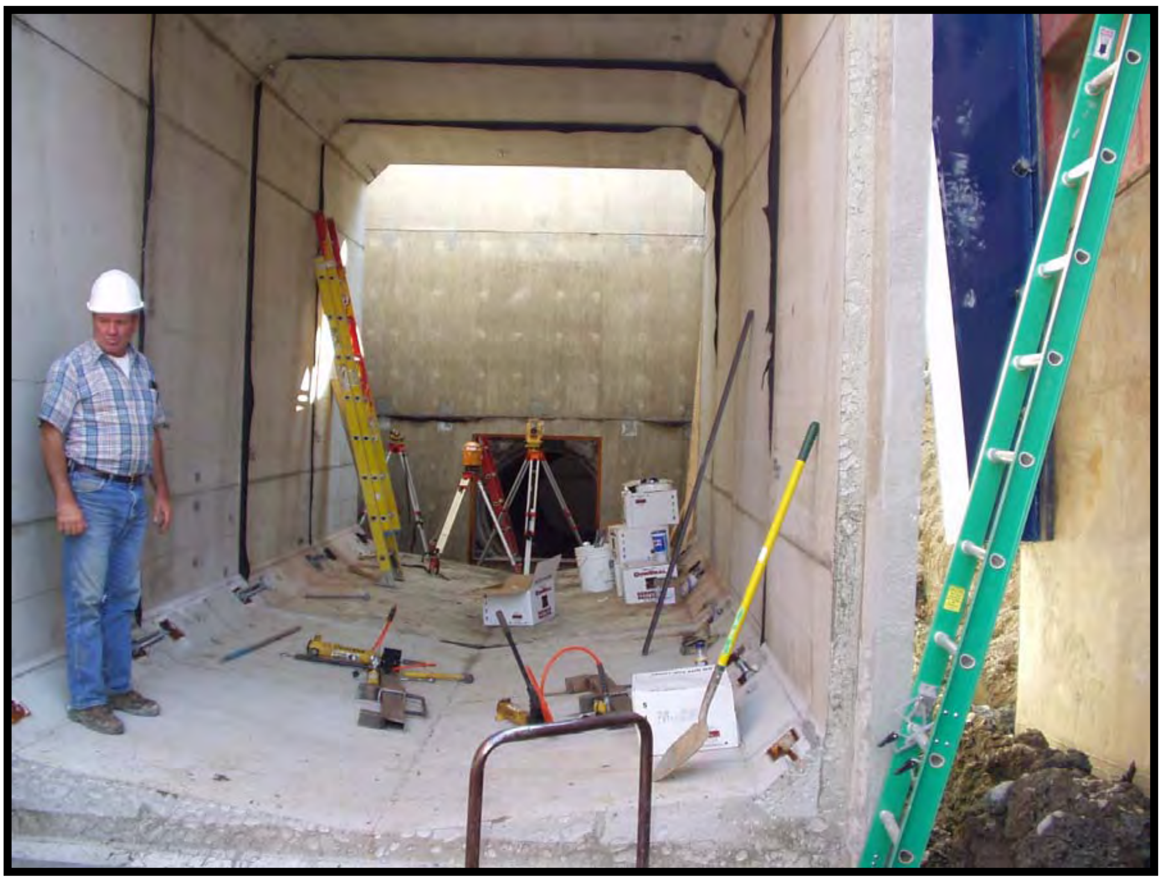
Liquid level in the facility is monitored electronically by a transducer located in a manhole located adjacent to and connected to the pumping chamber. This is connected into the treatment plant's SCADA system that records the volume of capture. If the tank event is more than 1.2 million gallons, a computer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



Kenduskeag East Parking Lot
After Completion of CSO Storage Facility

BARKERSVILLE STORAGE TANK

The City selected an open area at Bass Park for the Barkersville CSO Storage Project, near the existing trunk sewer that was constructed of brick in 1900. The tank was constructed of 10' wide by 12' high (inside dimension) precast concrete box culvert sections. 264 six-foot long sections were joined together with sealant and bolts to form a 1585-foot tunnel-like structure. The tank was connected to the existing sewer with 240 feet of 54" reinforced concrete pipe. Five access structures, two drop-structures, two connection structures, and a gatehouse were also part of the project. With the control gate open, the structure functions as a normal sewer. The V-shaped bottom concentrates flow to minimize deposition of solids, functioning as a self-cleaning mechanism. With the control gate closed, the facility will store up to 1.4 million gallons of sewage and stormwater, allowing Bangor's treatment plant operators to minimize system overflows to the Penobscot River.



Barkersville CSO Storage Tank Under Construction

Barkersville CSO Storage Tank Under Construction

This project had several challenges for the project team.

One of the first challenges for the project was to transport the 20-ton sections from the precast manufacturer to the project site. Using low-bed construction equipment trailer trucks, the sections were delivered one piece at a time without incident.

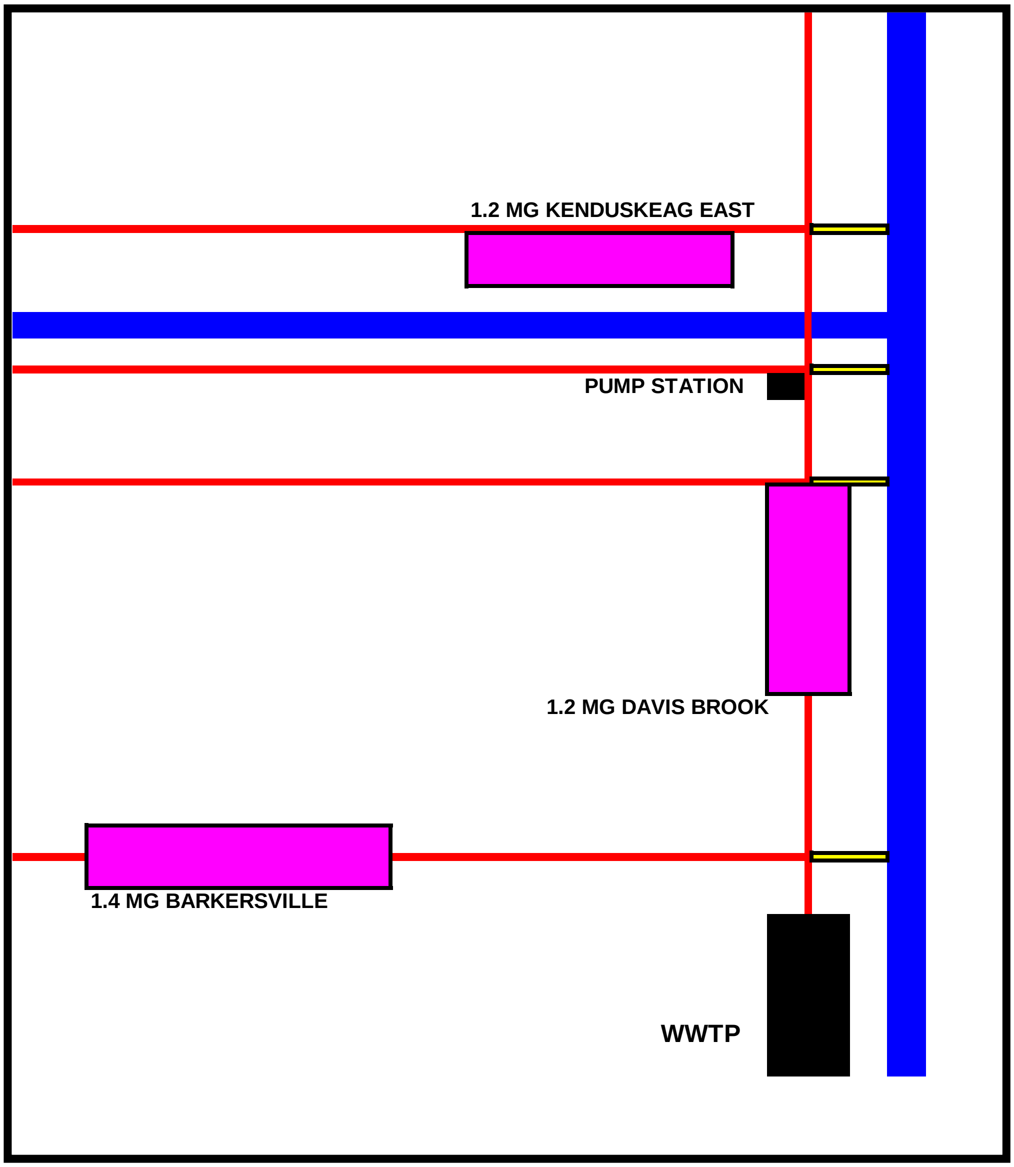
The greatest challenge for the construction contractor was to safely set these very heavy units into a deep excavation on a side slope. The Contractor benched the excavation to allow his equipment to reach subgrade, moving approximately 55,000 cubic yards of material in the process. The Contractor used a 50,000-pound forklift to move sections around the site and a 100-ton crane to set the units.

Another challenge was encountering unexpected ledge during the excavation process, requiring both mechanical and blasting techniques to remove.

In spite of the challenges, the contractor was able to install 264 precast units, five access structures, and a precast control building in 30 working days, while causing no disruptions to the ongoing Bass Park activities.

OPERATION

Bangor now has 3.8 million gallons of extra capacity within its sewer system, provided at a total cost of only $5.7 million, compared to current projected costs of $18.8 million for constructed-in-place facilities.



Schematic of Bangor's CSO Storage Facilities

Now that the operators have gained some experience with these new facilities, they have found several benefits beyond significant reduction of CSO discharges. Some of these benefits, including CSO control, are described below:

- **CSO Control**

The environmental goals of Bangor's CSO Control Program are (1) the reduction of CSO events and (2) the reduction of CSO discharge volume. The constructed storage capacity has made a significant contribution to both of these goals, especially in the City's downtown and waterfront, where discharge gates are computer controlled and open only in the most severe of circumstances. Additionally, the new underground facilities and control mechanisms allow operators a measure of choice as to where the Combined Sewer Overflows occur in the sewer system.

Originally, overflows occurred at multiple points in the sewer system where weirs and flapper style tide gates were the norm. The collection system operator had essentially no control over these discharges. Some CSO discharge points were very visible to the public, such as at the public boat dock at the waterfront marina. So, one goal of the program was to limit overflows in these sensitive areas.

The new facilities allow the operator to evaluate conditions in real time within the major collector pipe, the Penobscot Interceptor. With this information, the operator can control the conveyance of combined wastewater into and within the interceptor. The insystem storage allows the operator to manipulate combined sewer overflows at the four discharge points along the Penobscot interceptor.

The control strategy for the operator is:

1. To contain (maximize insystem storage), then
2. Maximize flow to the wastewater treatment plant, and
3. If an overflow is necessary, it should be at the downstream most overflow structure.

- **SCADA System**

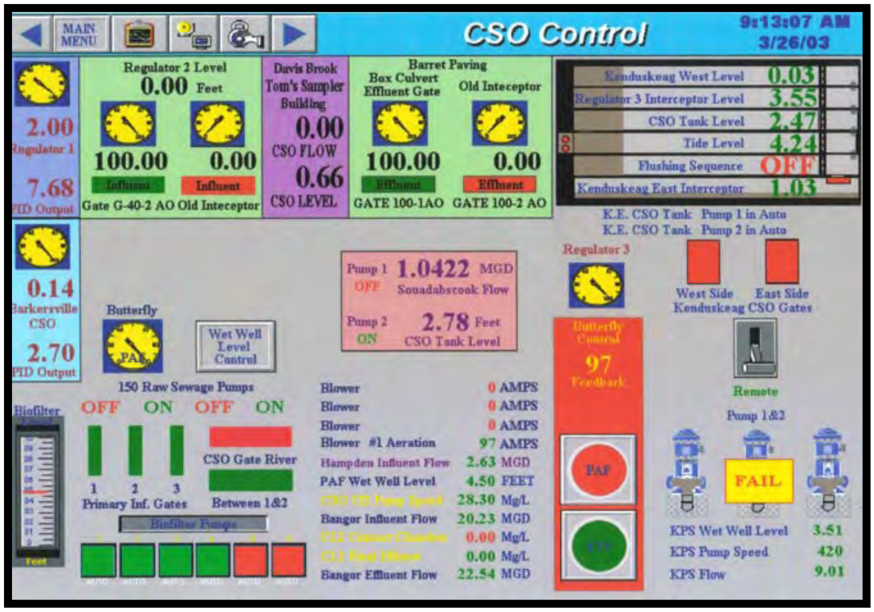
The monitoring system used by the Bangor WWTP is comprised of three major components:

A. Programmable Logic Controller -- Monitoring and control at the plant is accomplished using a Modicon 984 with remote drops throughout the treatment facility using coaxial cable.

B. Motorola/Moscad Radio Telemetry -- The plant utilizes a Motorola radio telemetry system to monitor and control 18 remote facilities including underground storage tanks used in the combined sewer overflow abatement program.

C. Intellution Fix32 HMI Software -- This software is used as the graphic interface for local and remote facilities. One computer holds the development package software with view nodes throughout the plant in a local area network using fiber optics. The PLC is connected to the computer through a SA-85 card and the radio telemetry system is connected through a field interface unit using a RS-232 connection. Specter's WIN-911 is used for alarm call out during plant unstaffed hours.

- **<u>SCADA Displays</u>**



This display was developed for the operations staff to monitor the conditions in the three Insystem Storage Tanks, the Penobscot Interceptor, and the major Wastewater Treatment plant operations.

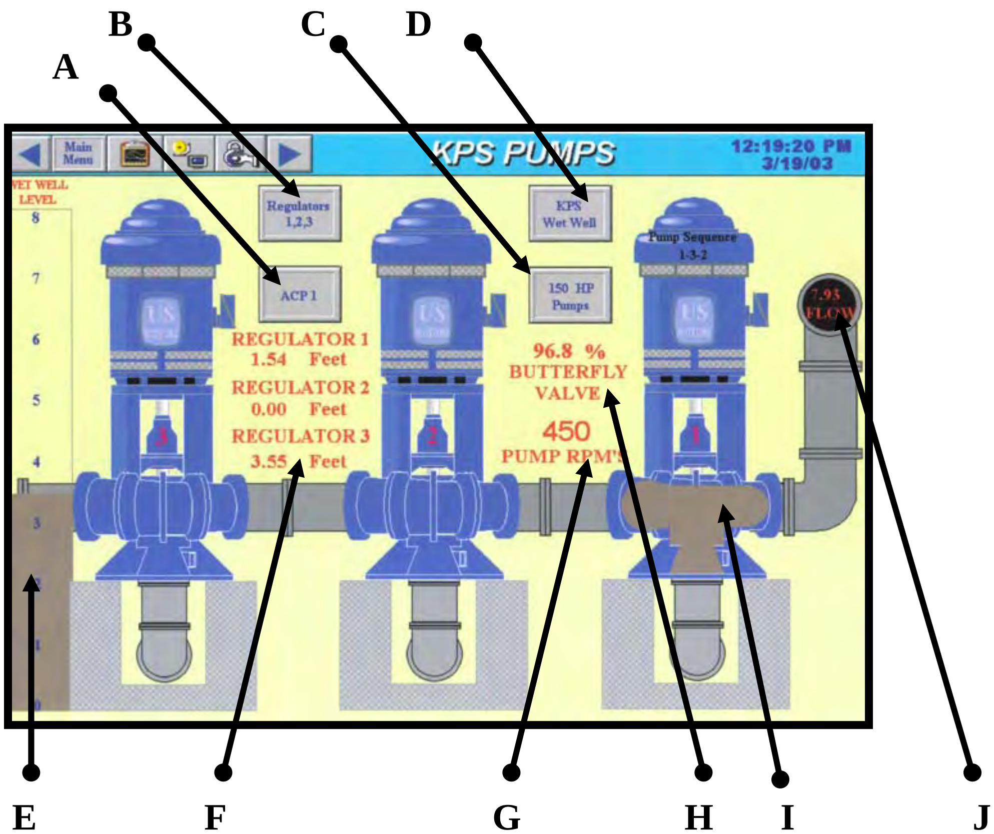
- <u>CSO Storage Tanks</u>
  Kenduskeag East CSO Tank gate controls, level indicators, pump status, and overflow gates monitor
  Davis Brook Tank gate controls, level indicators, and overflow monitor
  Barkersville CSO Tank gate controls and level indicators

- <u>Penobscot Interceptor</u>
  Regulator 1 where Barkersville Trunk Sewer joins Penobscot Interceptor
  Regulator 3 where Kenduskeag East Trunk Sewer joins Penobscot Interceptor
  Kenduskeag Pump Station influent gate status, pump status, and wet well level
  Town of Hampden Pump Station status

- <u>Wastewater Treatment Plant</u>
  Influent gate status
  Primary Tank gate status
  CSO gate status
  Influent and Biofilter pump status
  Aeration blower status
  Influent and effluent flow status

All points of control are available for operator adjustments, if necessary.

The task bar at the top of each screen has a main menu button that links to a number of displays. This is the display for the pumps at the Kenduskeag Pump Station.

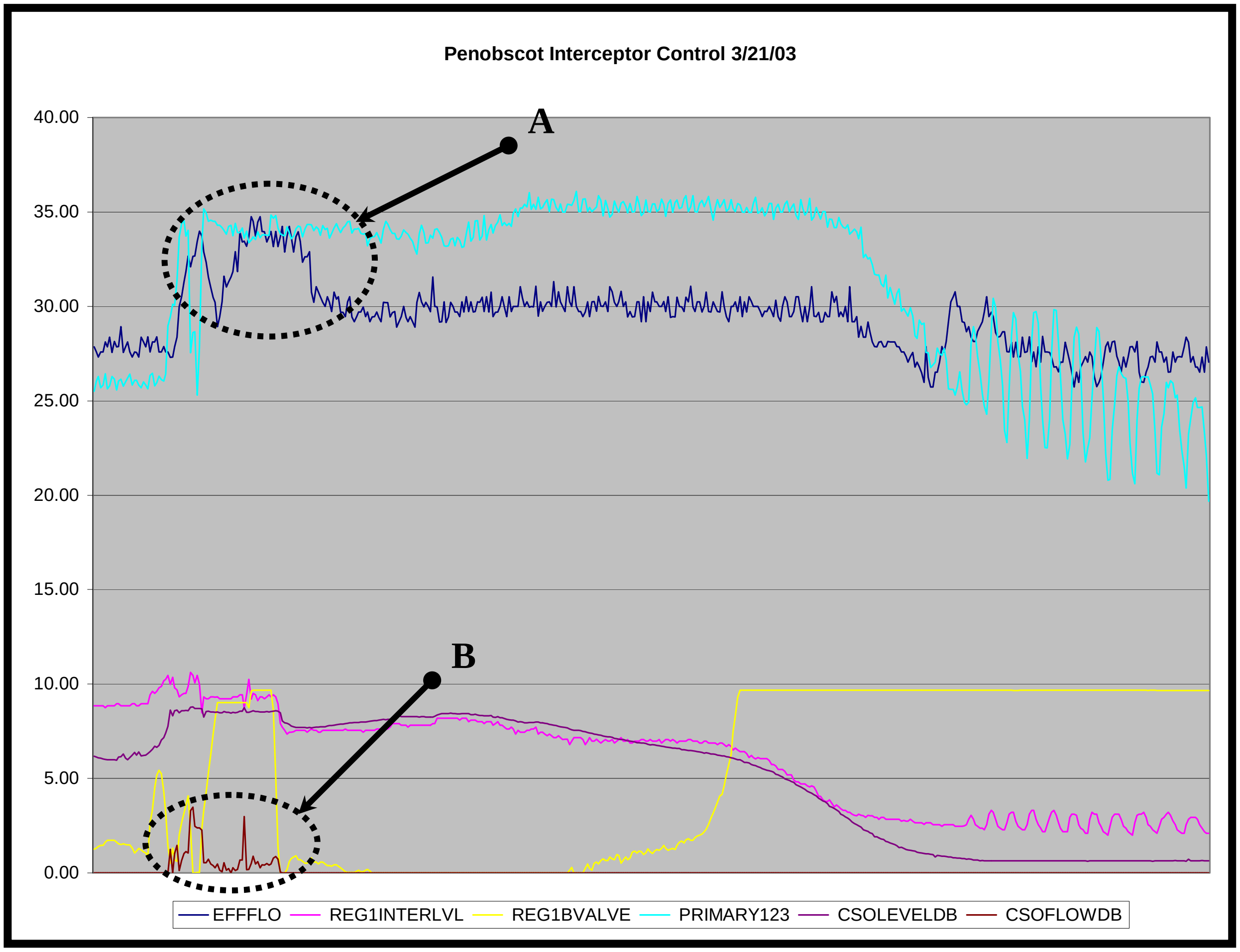


This display is an example of the detail available to the operations staff to look at specific sites along the Penobscot Interceptor. The Kenduskeag Pump Station is shown here with indicators and applicable buttons to move to other parts of the station and the interceptor.

A	Button to view display of Area Control Panel #1 at Wastewater Treatment Plant
B	Button to view detail displays of three Regulator Structures
C	Button to view display of Influent Pumps at Wastewater Treatment Plant
D	Button to view display of Kenduskeag Pump Station wetwell and climber screen
E	Indicator of Kenduskeag Pump Station wetwell level
F	Indicator of level of flow at three regulator structures
G	Indicator of pump speed at Kenduskeag Pump Station
H	Indicator of Influent Valve Position at Kenduskeag Pump Station
I	Indicator (Solid Gray Color) that pump is on
J	Indicator of flow at Kenduskeag pump Station

- **<u>Real-time flow management within the system.</u>**

The new facilities are monitored with the SCADA system that brings real time information to the operator at the treatment plant. The operator can view system conditions and control the conveyance of combined wastewater through the system. This ability has eliminated many combined sewer overflows.

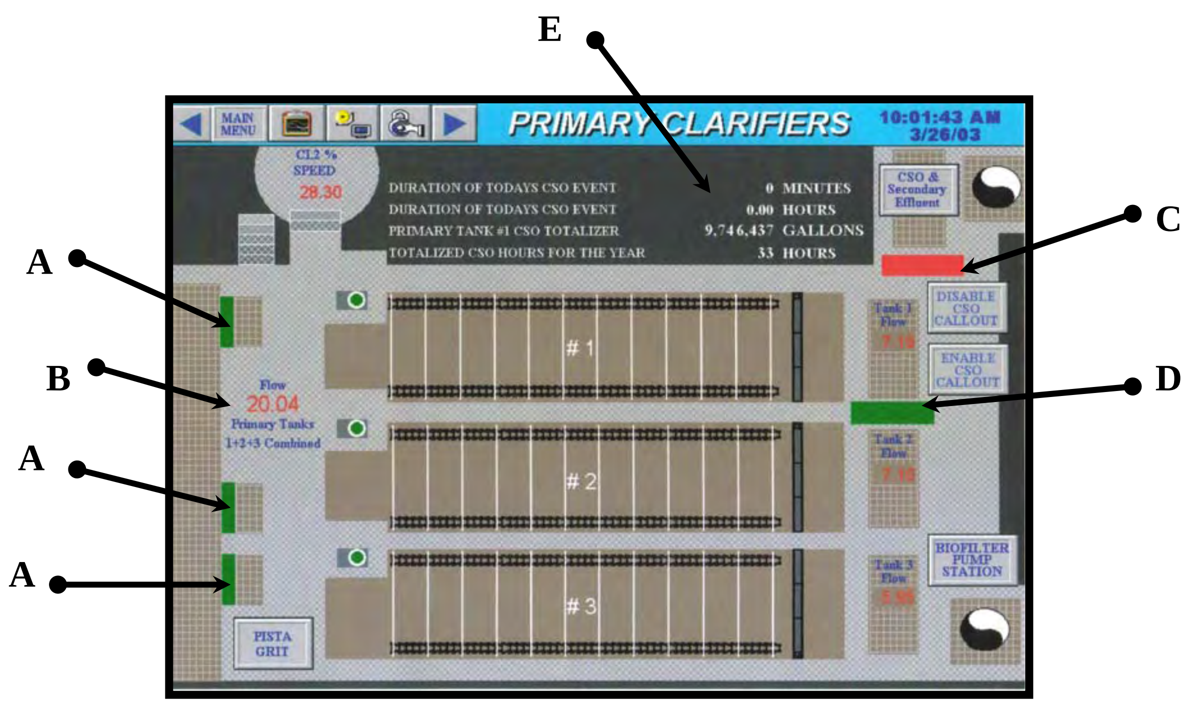


EFFLOW	WWTP Effluent Flow	
REG1INTERLVL	Regulator 1 Interceptor Level	
REG1BVALVE	Regulator 1 Gate Valve Position	
PRIMARY123	Flow at Primary WWTP Tanks	
CSOLEVELDB	Davis Brook Tank Level	
CSOFLOWDB	Davis Brook Tank Overflow	

This display shows an example of operators manipulating flow at the treatment plant in an attempt to reduce overflow at the Davis Brook tank. Flow through secondary was increased to 35-MGD (**A**), which is allowed by S.O.P. for short periods of time. Overflow at Davis Brook (**B**) was reduced. The operators used this opportunity to stress the system and to check the operation. There were no more overflows although the storm continued.

- **<u>Avoiding operation of the plant's CSO by-pass function</u>.**

This is a display of the three primary clarifiers at the wastewater treatment plant under normal (not high-flow) conditions. **B** is an indicator showing flow through the primary clarifiers at 20.04 MGD. Primary tank influent gates (**A**) are open, depicted by the green color.



When flows approach 30 MGD and the weather forecast is for continuing rainfall / snowmelt, control gate **C** (normally closed, colored red) opens (color change to green) and control gate **D** (normally open, colored green) closes (color change to red).

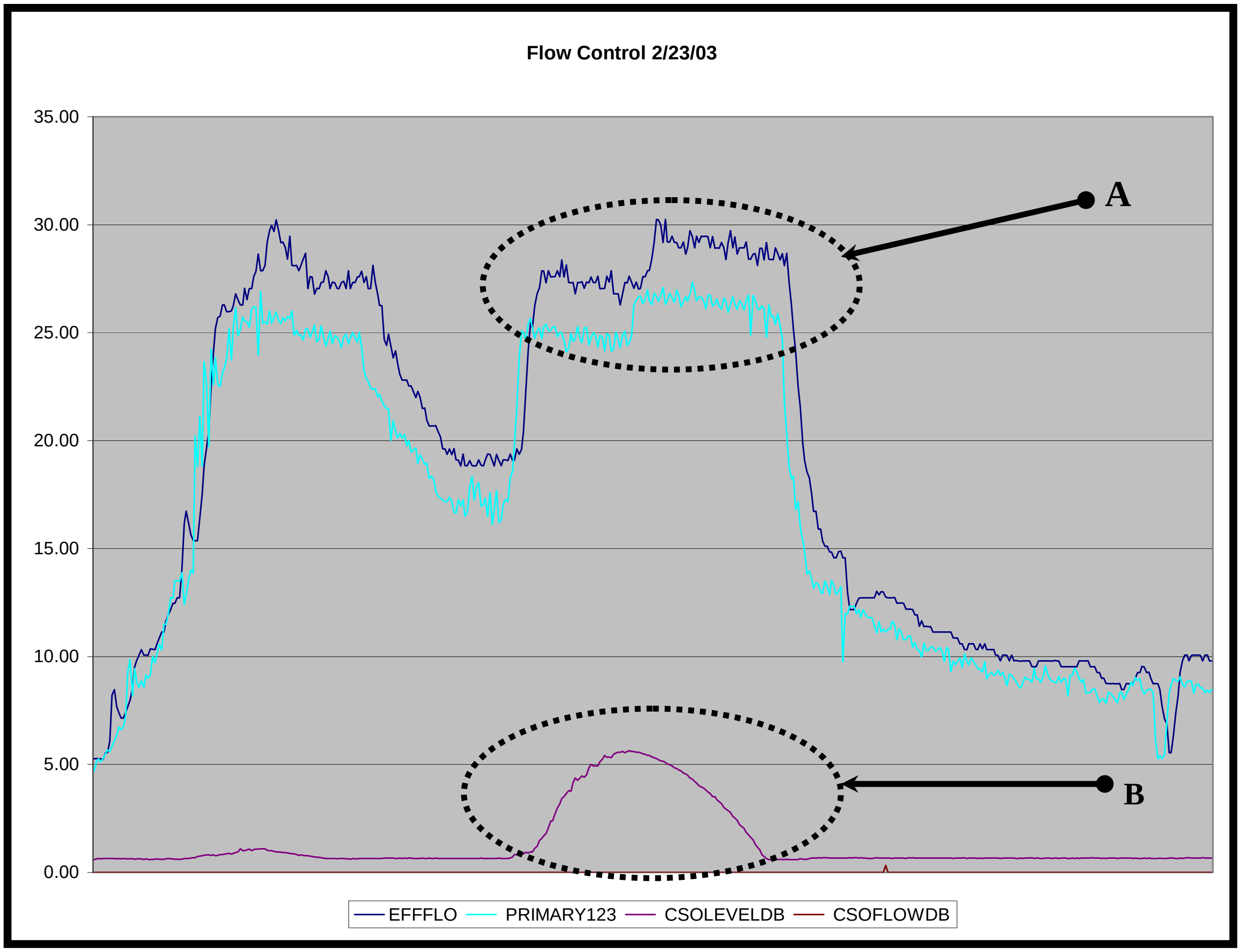
This initiates the wet-weather high flow management procedure, also known as a CSO bypass. Flows that go through clarifier #1 (up to about 13 MGD) receive high-rate disinfection and are blended with secondary effluent for discharge to the Penobscot River. Flows that go through clarifiers #2 and #3 (up to about 30 MGD) receive full secondary treatment.

Indicator **E** shows current and year-to-date activity for this wet-weather procedure.

Using the insystem storage facilities, operators are able to reduce influent flows below 30 MGD and at times have been able to avoid using the CSO bypass provision in our permit.

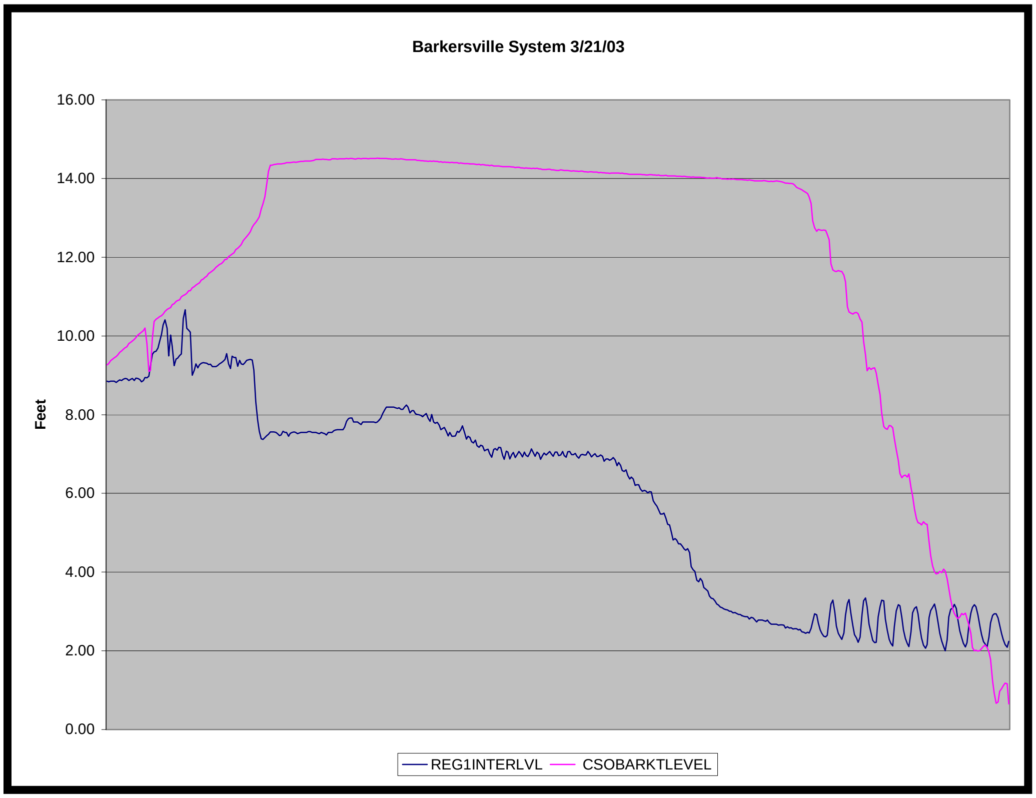
- **<u>Leveling peak flows into the treatment plant.</u>**

System operators can control flow into the wastewater treatment plant by adjusting the influent butterfly gate and influent pumping systems. During short-term high intensity storms, influent flows to the plant can be limited to 26 MGD. Flows in excess of 26 MGD are stored within the sewer system.



In this display, flow into the plant (Light Blue Line) has been restricted to about 26 MGD during a wet-weather event (**A**). This has caused the water level in the Davis Brook Tank (Purple Line) to rise to slightly more than five feet, storing for a short time about 600,000 gallons (**B**). When the event was over, the tank drained down to normal flow levels.

- **<u>Computer graphic displays of system flow levels.</u>**



REG1INTERLVL	Regulator 1 Interceptor Level	
CSOBARKTLEVEL	Water level in Barkersville Tank	

This display is one that is currently under development.

It shows two concurrent trends within the sewer system for a 24-hour period beginning at 8:00 am on March 21, 2003. The display shows the Barkersville tank filling and staying full (Pink Line) until such time as there is capacity in the Penobscot Interceptor (Dark Blue Line). Then the sluice gate at the Barkersville Tank Gate begins to modulate open and closed to drain the tank down at a preset flow rate. As the tank empties in discrete amounts, the flow level in the Penobscot Interceptor also modulates up and down.

Other displays too numerous to include here assist system operators with real time-data that allows prudent decisions to be made during wet weather / snowmelt events to maximize the amount of flow to be treated and to minimize overflow events.

- **Stopping flows to undertake downstream maintenance.**

Insystem storage facilities allow the flow into the wastewater treatment plant to be temporarily suspended. Maintenance staff can accomplish tasks anywhere in the plant unimpeded by raw influent wastewater. During low flow periods, flow into the plant can be suspended for up to 4 hours, a sufficient amount of time to accomplish many routine maintenance operations.

- **Interceptor flushing.**

The Penobscot Interceptor follows the Penobscot River for some 7500 feet from the Wastewater Treatment Plant to Downtown Bangor. The lower 3600 feet is a 48" pipe at a .0019 slope. After 30 years of service, the pipe was nearly half full of sediment. Due to accessibility issues and the inability to shut off flow in the interceptor, there was no reasonable way to clean the pipe.

All that changed when the Davis Brook Storage Tank was placed into service. During the initial tests of the facility, the tank was filled and emptied several times. The Wastewater Treatment Plant was inundated with silt, sediment, and grit (and hundreds of the old-style pop-tops from beer cans). The great surge of water from the rapid emptying of the tank several times had thoroughly cleaned the interceptor pipe.

Today, the operators routinely 'store' wastewater and then release it to produce scouring velocities in the main interceptor. Systemic flushing during dry periods reduces solids deposition, provides reduction of odors, and minimizes impact to the treatment plant when wet weather eventually arrives.

- **Control of peak electrical demand at the Treatment Plant.**

Pumping wastewater is a major component of the electrical bill in Bangor's Wastewater Treatment Plant. As mentioned earlier, with inground storage, operators have the ability to control flow into the plant to a certain degree.

System operators believe that controlling flow into the plant provides the opportunity to control electrical demand costs. This is theory only, as not enough wet weather events with all three tanks in service have occurred to prove this theory.

The Wastewater Treatment Plant is on a time-of-use rate, so the possibility also exists to pump stored combined wastewater when electrical rates are lowest. Bangor's insystem storage capacity certainly offers opportunities to manage electrical costs, and as time goes by, this theory will also be evaluated.

CONCLUSIONS

The CSO Storage Projects in Bangor, Maine have proven to be a cost-effective approach to significant CSO discharge reduction. In addition, the extra system capacity of these facilities has provided benefits that should be of interest to other communities looking at the upcoming Capacity, Management, Operations and Management requirements of the proposed cMOM regulations.

Bangor now has 3.8 million gallons of extra capacity within its sewer system, provided at a total cost of only $5.7 million, compared to projected costs of $18.8 million for constructed-in-place facilities. There has been considerable interest to date regarding Bangor's approach to CSO storage, especially the use of precast V-bottom box sections, and the significant time and cost savings of this method of insystem storage.

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- Control of peak electrical demand at the Treatment Plant.