The Narragansett Bay Commission CSO Abatement Project

The Problem

What is a Combined Sewer System? Combined sewer systems are sewers that are designed to collect rainwater runoff, domestic sewage, and industrial wastewater in the same pipe. Most of the time, combined sewer systems transport all of the wastewater to a sewage treatment plant, where it is treated and then discharged to a water body. During periods of heavy rainfall or snowmelt, however, the wastewater volume in a combined sewer system can exceed the capacity of the sewer system or treatment plant. For this reason, combined sewer systems are designed to overflow occasionally and discharge excess sewage contaminated stormwater directly to nearby streams, rivers, or other water bodies without treatment. For more information on the problem of CSO's and a diagram of how CSO's operate please refer to:
http://www.narrabay.com/en/About%20Us/Facilities/MajorInitiatives/CSO.aspx

In November of 2008, after many years of design and construction a 26 foot diameter, 3 mile long tunnel built under the city of Providence was completed and opened for operation. This large storage tunnel was designed to capture millions of gallons of untreated combined sewer and stormwater from CSOs in the Field's Point service area. This was Phase I of three planned phases of the Narragansett Bay Commission Combined Sewer Overflow Abatement Project. Phase I was designed to capture combined flow from 12 CSOs in the Field's Point Service Area and direct that captured flow to a pump station on Ernest Street in Providence. As capacity becomes available at the Field's Point WWTF, the volume of combined flow stored in the tunnel is pumped to the WWTF and is able to receive full secondary treatment. Prior to this technology, untreated combined sewer and stormwater flow would often be directed from the sewer system into overflow pipes and into local rivers or receive only primary treatment and disinfection through the wet weather capacity at the WWTF. For more information on the background and the stakeholder process of the CSO Abatement project please refer to:
http://www.narrabay.com/en/About%20Us/Facilities/MajorInitiatives/CSO.aspx

The entire CSO Abatement project is divided up into three phases; Phase I was completed in 2008, Phase II is currently under construction and is anticipated to be completed in the spring of 2015 , and Phase III is anticipated to begin after an evaluation period around 2017. As expected, this considerable investment to better the water quality of Narragansett Bay comes at a cost; Phase I cost a total of $359 million; Phase II is expected to cost $363 million, and Phase III is expected to cost $603 million for a total combined cost of $1.3 billion dollars. During the design phase of the CSO Abatement project several outcomes were predicted when the three phases were complete: a 95% reduction in number of overflows/year; overflow volume reduced by 98%; 98% reduction in CSO fecal coliform load; the CSO Total Suspended Solids (TSS) and Biological Oxygen Demand (BOD) loads reduced by 78% and 80%, respectively; and rainfall amounts for shellfish bed closure will increase. The NBC is pleased to report that the RIDEM has already increased the rainfall amounts that trigger shellfish bed closure due to the success of Phase I.

Construction – Phase I

After several years of study and stakeholder involvement, construction of Phase I began in 2001. Due to its underground construction, it was known as the "the Biggest Project You'll Never See". Phase I involved the construction of the CSO tunnel, which is approximately 300-feet underground, 26-feet in diameter, and spans three miles. To create the tunnel, a 690-ton hard rock tunnel boring machine (TBM) was utilized. The cutter head on the TBM was 30 feet in diameter, with 17 inch cutters.

Figure 1. Cutter head of the 30 ft. diameter Tunnel Boring Machine (TBM)

Once the TBM was up and running, it was able to cut approximately 40 to 45 feet per day of the main spine of the tunnel, running from 6:30 am to 6:00 pm five days a week and remove approximately 400,000 tons of ground rock from the tunnel. As the tunnel was bored through the rock, 16,000 10-inch thick segments of precast concrete were put in place to provide initial support for the tunneling operation. After the tunneling was completed, the entire tunnel was lined with a cast-in-place concrete final liner 12-inch thick.


Figure 2. Mined drop shaft adit looking towards entrance into tunnel

To connect the tunnel to the current system, seven drop shafts were bored into the ground at various locations along the three mile span of the tunnel. The rate of completion for these shafts was to bore approximately one foot per hour. At tunnel level, approximately 4,000 feet of connecting tunnels called adits were constructed through the use of drilling and blasting. All of the adits and deaeration chambers were lined with concrete.

Figure 3. Nearly completed adit (on left) into tunnel

Near the ground surface, consolidation conduits connected the existing CSO pipes to the drop shafts. These conduits were constructed using direct burial, micro-tunneling, and pipe-jacking methods. At the downstream end of the tunnel, a large underground cavern was mined by blasting methods. The cavern housed a pumping facility to send the stored tunnel flow to the Field’s Point WWTF.

Figure 4. Underground cavern and pumping facility

The CSO tunnel was officially opened in November 2008 to receive flows from combined sewage overflows during storms. Phase I of the CSO Abatement Project was at the time the largest public works project in Rhode Island's history. The work for each of the different sections of the project was established to promote bidding from local construction firms. It was completed on time and under budget and was a major success for the small state of Rhode Island. The construction of the CSO Tunnel has earned the NBC various awards, including "Project of the Year" by the Underground Construction Association in 2009 and a "National Engineering Excellence Award" from the American Council of Engineering Companies in 2010. For an excellent overview of the construction project please watch the video entitled "The Biggest Project You'll Never See" by clicking here: http://www.narrabay.com/sitecore/content/Narrabay/Education/Videos/2008/April/the_biggest_project_youll_never_see.aspx

Figure 5. Completed 26 foot diameter tunnel

Field's Point and Tunnel Operation

The Field's Point WWTF is a primary and secondary treatment plant with hypochlorite disinfection. Primary treatment consists of the removal of heavy solids from the wastewater. Secondary treatment removes dissolved and suspended biological matter. The last step in the treatment process is disinfection which kills fecal coliform bacteria before the effluent leaves the plant and empties into the Providence River. The plant is currently being upgraded to tertiary treatment that will include Biological Nutrient Removal (BNR). At Field's Point, the average daily dry weather flow is 45 MGD, but the treatment plant has a capacity to treat up to a total of

200 MGD including full secondary treatment capacity and the use of the wet weather facility. The Field's Point WWTF has the capacity to treat up to 77 MGD flow within the entire primary and secondary treatment systems without overwhelming plant processes. Prior to the tunnel operation, excess wet weather flow greater than 77 MGD and up to 123 MGD would be directed to the wet weather facility at the plant where the wastewater would receive "wet weather treatment" which consists of some solids settling and full disinfection before being discharged out into the Providence River. With the extra storage capacity of the tunnel, excess flow that would have been diverted to wet weather treatment is now directed to the tunnel for storage, up to a total capacity of 65 MG. When flow at Field's Point has returned to a more optimal level, the stored volume in the tunnel is pumped to the WWTF where it receives full secondary treatment and disinfection. Prior to the tunnel going into operation, the Field's Point WWTF had an average of 38 wet weather discharge events per year; post tunnel operation the plant now has an average of 7 wet weather discharge events per year, an average decrease of 81% (Figure 6).

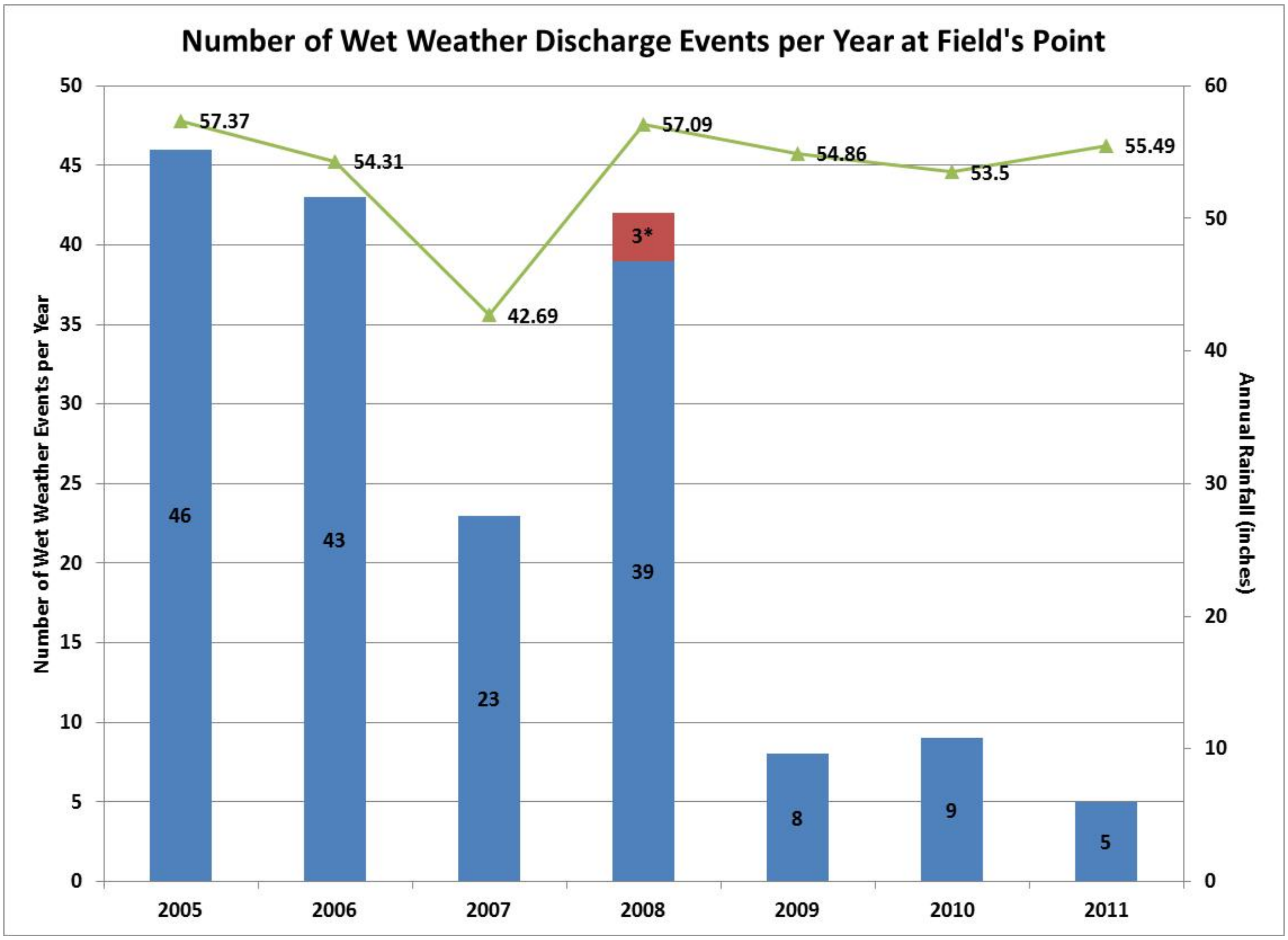

*Figure 6. The above graph shows the number of wet weather discharge events per year at Field's Point pre and post tunnel operation displayed as bars. The green line notes the amount of rainfall that occurred each year. Pre tunnel years include 2005 – 2008, with *3 events occurring after the tunnel went into operation in 2008. The years of 2009 – 2011 show years post tunnel operation.*

Before the tunnel went into operation, the Field's Point WWTF treated an average of 679 MG per year in the wet weather facility; post tunnel the average yearly flow into the wet weather facility has been reduced by 71% to an average of 197 MG per year (Figure 7). Since this flow now receives full secondary treatment and disinfection, the CSO Tunnel has prevented billions of gallons of sewage contaminated stormwater from entering urban rivers and the Bay.

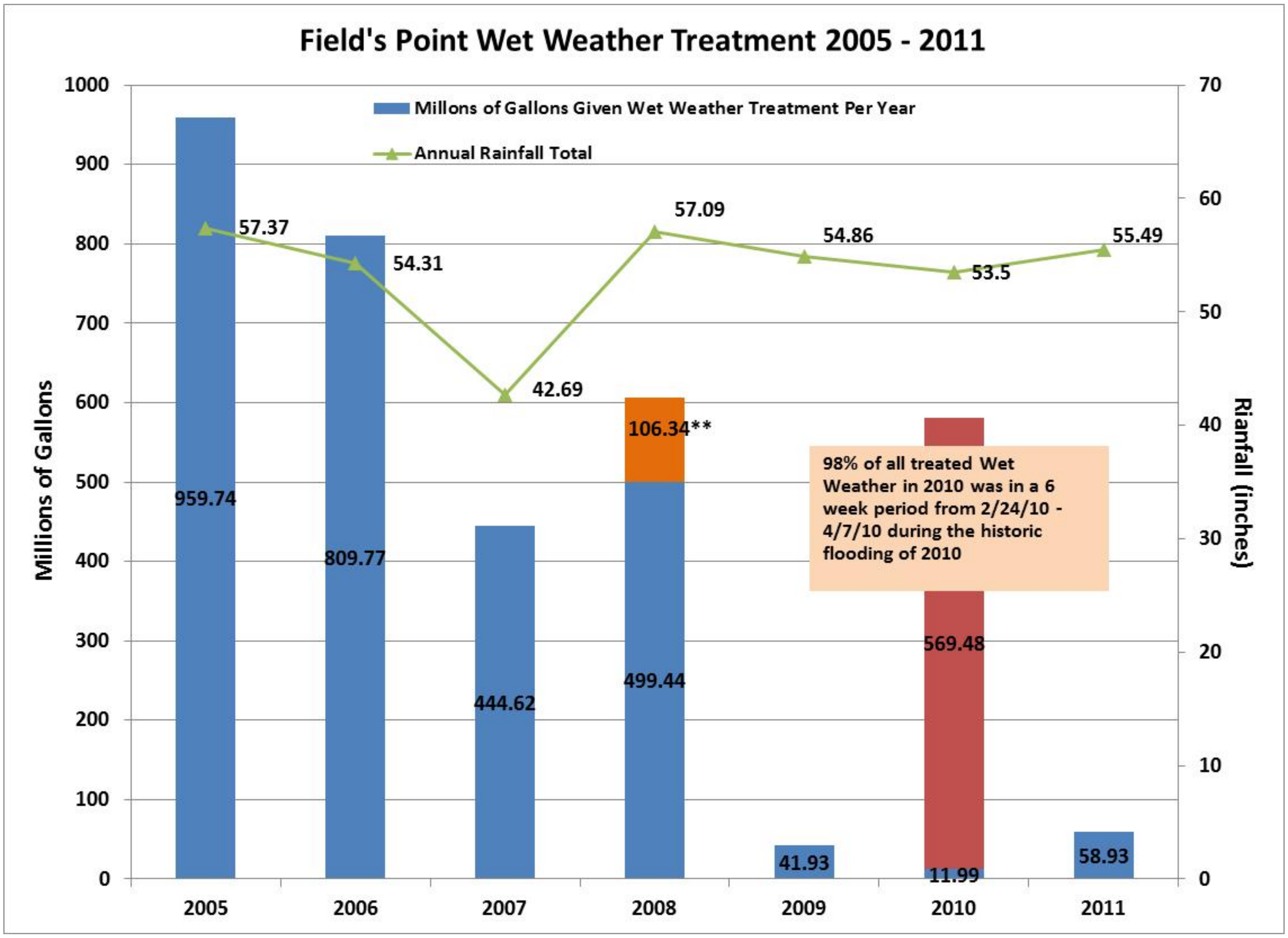

*Figure 7. Field's Point Wet Weather Treatment 2005 – 2011. This graph shows the amount of storm/wastewater the Field's Pont WWTF has treated in its wet weather facilities. The collection and storage capacity of the CSO Tunnel has enabled Field's Point to use the wet weather facilities less and give more wet weather flow full secondary treatment. ** In 2008, 499.44 MG was treated before the tunnel went into operation and 106.34 MG was treated after the tunnel went online. **98% of all treated Wet Weather in 2010 was in a 6 week period from 2/24/10 – 4/71/0 during the historic flooding of 2010.*

CSO Abatement = Water Quality Improvements

There are 12 combined sewer overflow pipes within the Field's Point service area that are currently collected into the tunnel. Seven drop shafts along the system bring the flow into the tunnel via the drop shaft adits, which are smaller tunnels built along the main tunnel to add flow into it. Before the tunnel was put into operation, these 12 CSOs would have added millions of gallons of untreated sewer and stormwater flow directly into the rivers of the Providence area during wet weather. Now, this combined flow is collected into the tunnel and then pumped to Field's Point where is can receive full secondary treatment. Since the tunnel has gone into operation and flow now received treatment at Field's Point, NBC estimates that thousands of pounds of pollutants have been prevented from entering the rivers and the Upper Bay. The table below shows the estimated amount of pollutants prevented from entering the rivers and Upper Bay from CSO discharges from November 2008 through 2011.

Pollutant	Pounds
TSS	1,004,492
BOD	898,617
Total Nitrogen	94,108
Aluminum	6,910
Cadmium	59
Chromium	222
Copper	305
Cyanide	152
Iron	32,455
Lead	261
Nickel	97
Silver	95
Zinc	784

Table 1. Estimated pounds of pollutants prevented from entering local waterways via CSOs by being treated at Field's Point WWTF instead (November 2008 through 2011)

Solids and sediment are measured by determining the total suspended solids (TSS) in the water. A high amount TSS can affect water quality by decreasing the amount of light that can penetrate into streams, rivers and the Bay. A more specific subset of sediment and solids is called organic matter, measured in water quality as biological oxygen demand (BOD). Naturally occurring organic matter can include leaves and lawn clippings which can be integrated into stormwater but can also include sewage solids and other chemicals. Though organic matter is present in every water body, when excess organic matter is present water quality can deteriorate. Nitrogen is a necessary element needed in the marine environment for plants and plankton growth. However, too much nitrogen can lead to an overabundance of plant and plankton growth. Once these organisms die they sink to the bottom where they are decomposed by bacteria that use up the available oxygen and can lead to hypoxia (low oxygen) or anoxia (no oxygen). Excess nitrogen is one of several factors involved with the development of hypoxia/anoxia; others include climatological factors such as wind and rainfall, as well as a process called stratification.

Dissolved metals found in the effluent of a WWTF can be toxic to aquatic organisms if found in high concentrations and preventing their release into the natural environment is extremely beneficial to all aquatic life.

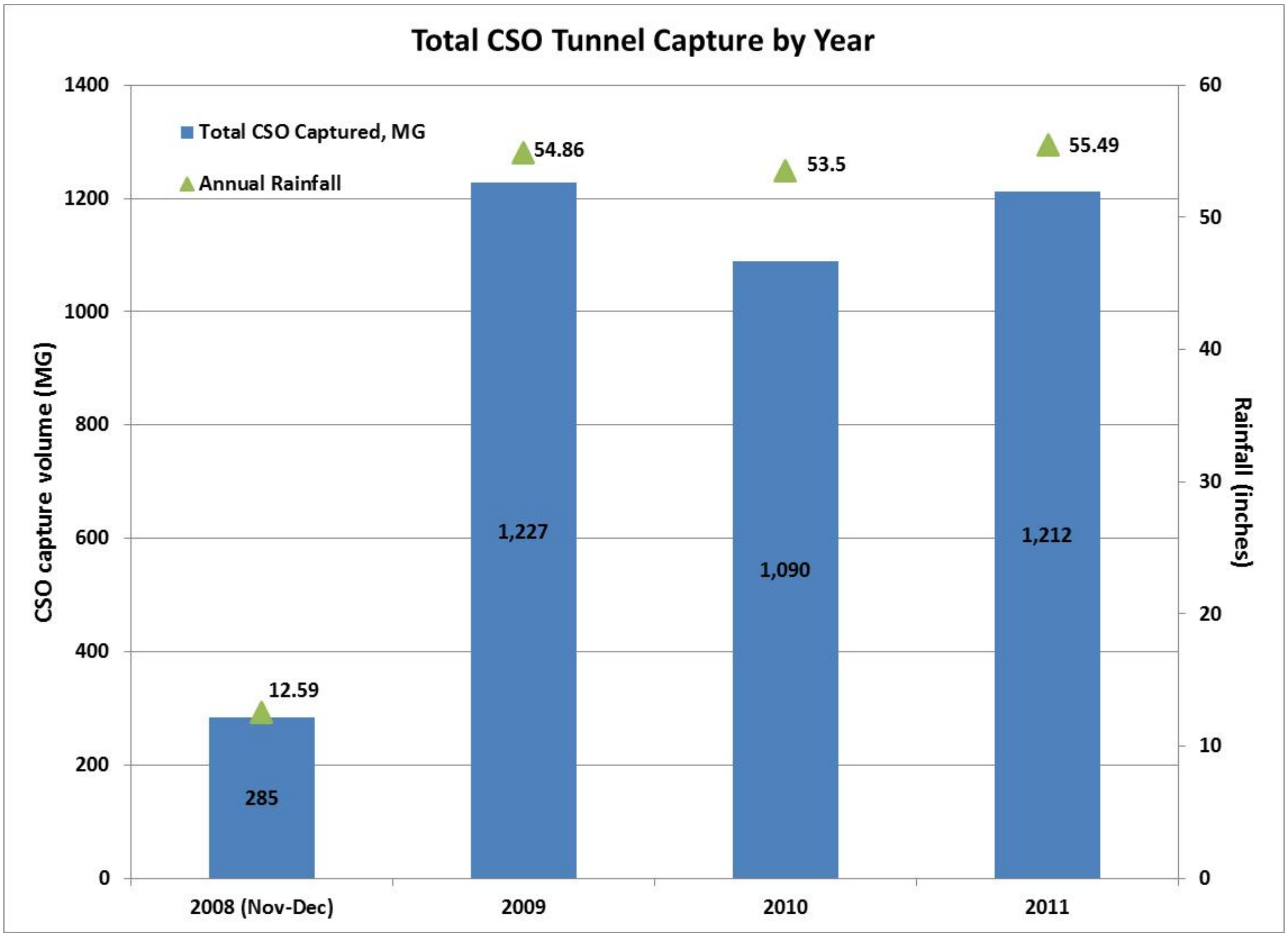

Figure 8. Total CSO Tunnel Capture by Year. This graph shows the amount of storm/wastewater the CSO tunnel has captured (in millions of gallons) since going into operation in November of 2008 along with annual rainfall totals.

As part of an ongoing monitoring program, the NBC conducts routine collection and analyzing of fecal coliform bacteria in the Upper Bay. CSO discharges are a major source of pathogen bacteria in the Upper Bay. Pathogen pollution can lead to public health risks including gastrointestinal illness and contamination of local shellfish. Since the CSO tunnel has gone into operation, the NBC has seen a 26% reduction in fecal coliform bacteria in the Upper Bay (from the Point Street Bridge south to Conimicut Point). The historic statewide floods of March 2010 had a significant impact on fecal coliform bacteria in the Upper Bay due to the failure of two WWTFs in the state and the failure of a major pumping station at another during the time of the flooding. During this time the NBC conducted extra sampling in the Upper Bay to determine the impacts the floods had on bacteria levels in the Upper Bay and found that fecal coliform levels in the Upper Bay were approximately 87% higher than normal bacteria levels. Taking this into consideration and removing the high bacteria counts during the flood, the actual decrease in fecal coliform bacteria in the bay is 34%. Specifically, there has been a 40% reduction in the Upper Providence River (Point Street Bridge to Gaspee Pt.) which increases to 44% if data taken during the March 2010 flood is not included. In the Lower Providence River (Gaspee Pt. to Conimicut Pt.), there has been a lower impact seen post tunnel than in the areas north of Gaspee Pt., where including flood data fecal coliform geomeans have decreased by 2%, and by 16% excluding flood data. This data can be seen in Figure 9.

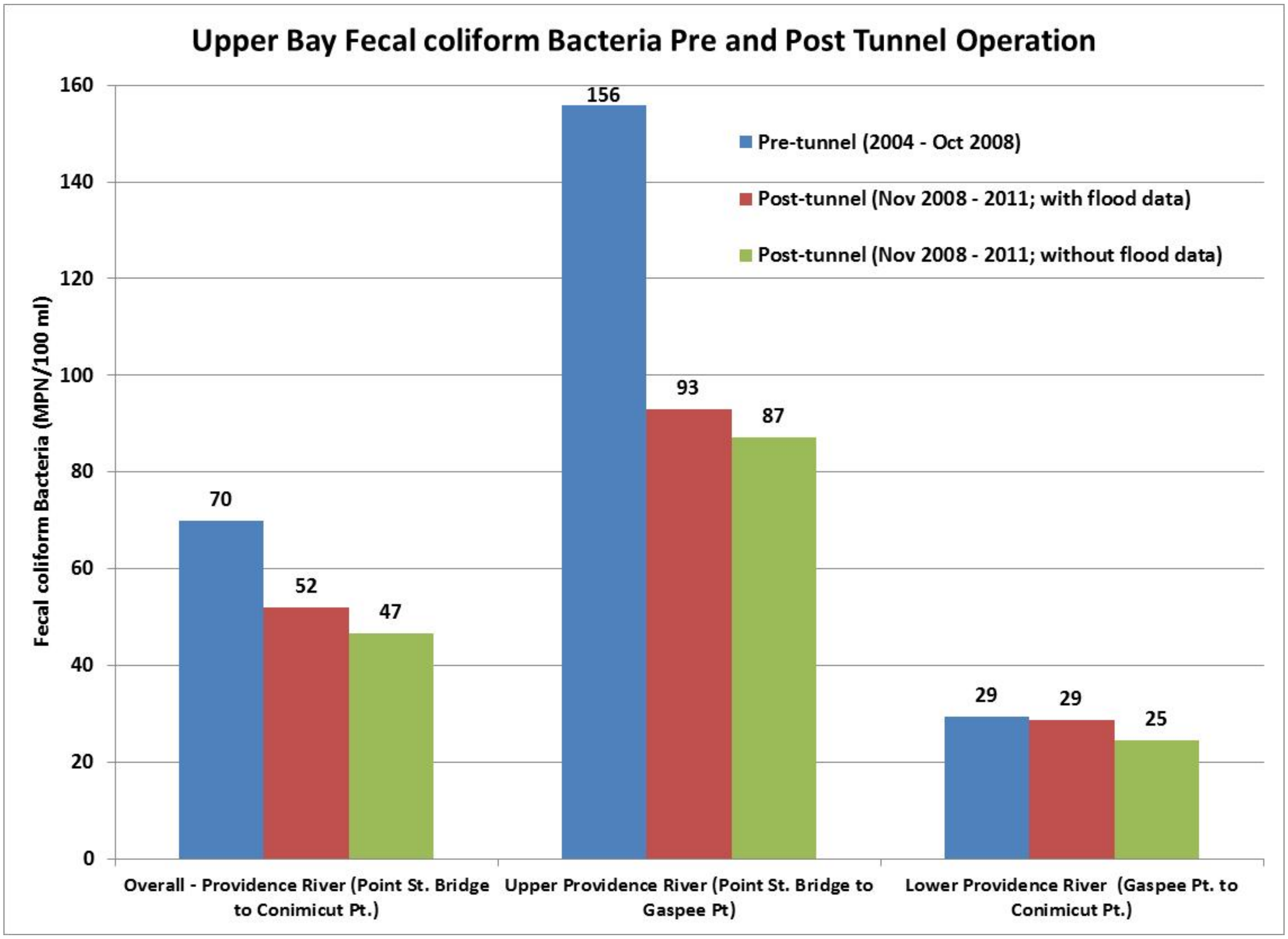

Figure 9. This graph represents Fecal coliform bacteria results from 2004 – 2011, pre and post tunnel operation. Also depicted is data with and without data from the flood of 2010 which had a dramatic impact on fecal coliform levels throughout the Providence River.

Since the CSO tunnel began operation, yearly geomeans of fecal coliform has dropped significantly as can be seen in Figure 10 below. For example as seen in Figure 10, the years of 2006 and 2009 had similar annual rainfall amounts, however, the fecal geomean for the year was 53% lower in 2009 as compared to 2006. Compared to years of less rainfall such as 2004 and 2007, fecal coliform has not reached the levels of these two years in any of the 3 full years (2009 – 2011) post tunnel operation.

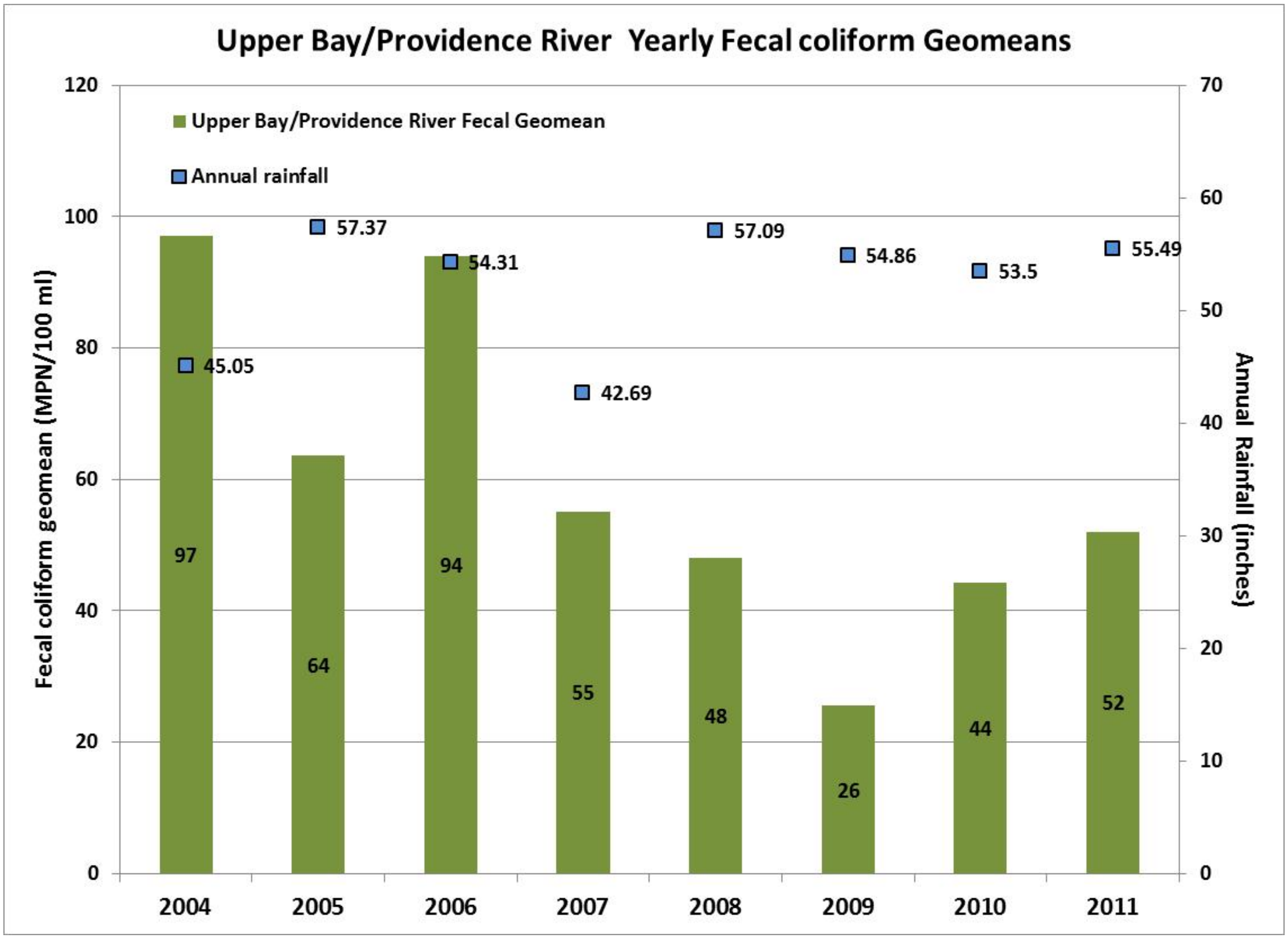

Figure 10. Yearly fecal coliform geomeans in the Upper Bay/Providence River with annual rainfall totals. 2009 – 2011 are considered to be years with a fully operational tunnel. The years 2004 – 2008 are considered "pre-tunnel operation" and the years 2009 – 2011 are "post-tunnel operation".

Shellfishing is a multi-million dollar industry in Rhode Island, and clean water is essential to the business. The industry is managed by the RI Department of Environmental Management (RIDEM) and monitored by the RI Department of Health (RIDOH). Historically when wet weather and CSO discharges occurred from the NBC treatment facilities, RIDEM would close the two most northern shellfishing areas in Narragansett Bay, Areas A and B. Area A was traditionally closed with 0.5 inches of rainfall within a 24 hour period and Area B with 1.0 inches of rain. Due to the success of the CSO Tunnel, the RIDEM changed these regulations to higher rainfall amounts. On May 26th, 2011 RIDEM announced that Conditional Area A would now close with ≥0.8 inches of rain and Conditional Area B with ≥1.5 inches of rain. On average, Area A is expected to be open 65 more days/year and Area B is projected to be open 45 more days/year. In a press release from the RIDEM announcing these changes, the CSO tunnel was specifically highlighted as a reason the historic changes happened; *"the changes are a result of water quality improvements associated with the completion of Phase I of the three-phase*

Narragansett Bay Commission (NBC) combined sewer overflow (CSO) program in 2008"(DEM Press Release, May 26th, 2011). The ability to open these areas for more days during the year is good news for Narragansett Bay shellfishermen.

In addition to sampling for fecal coliform bacteria in the Upper Providence River north of Conimicut Point, the NBC occasionally samples Conditional Shellfishing Areas A and B as part of the fecal monitoring program as well as sometimes in conjunction with the RIDEM. With this sampling, the data shows that there has also been a considerable decrease in fecal coliform bacteria post tunnel operation in these areas as well. Overall there has been a 38% decrease in bacteria counts including the 2010 flood data, and a much more substantial decrease of 62% excluding the fecal data taken during the flood.

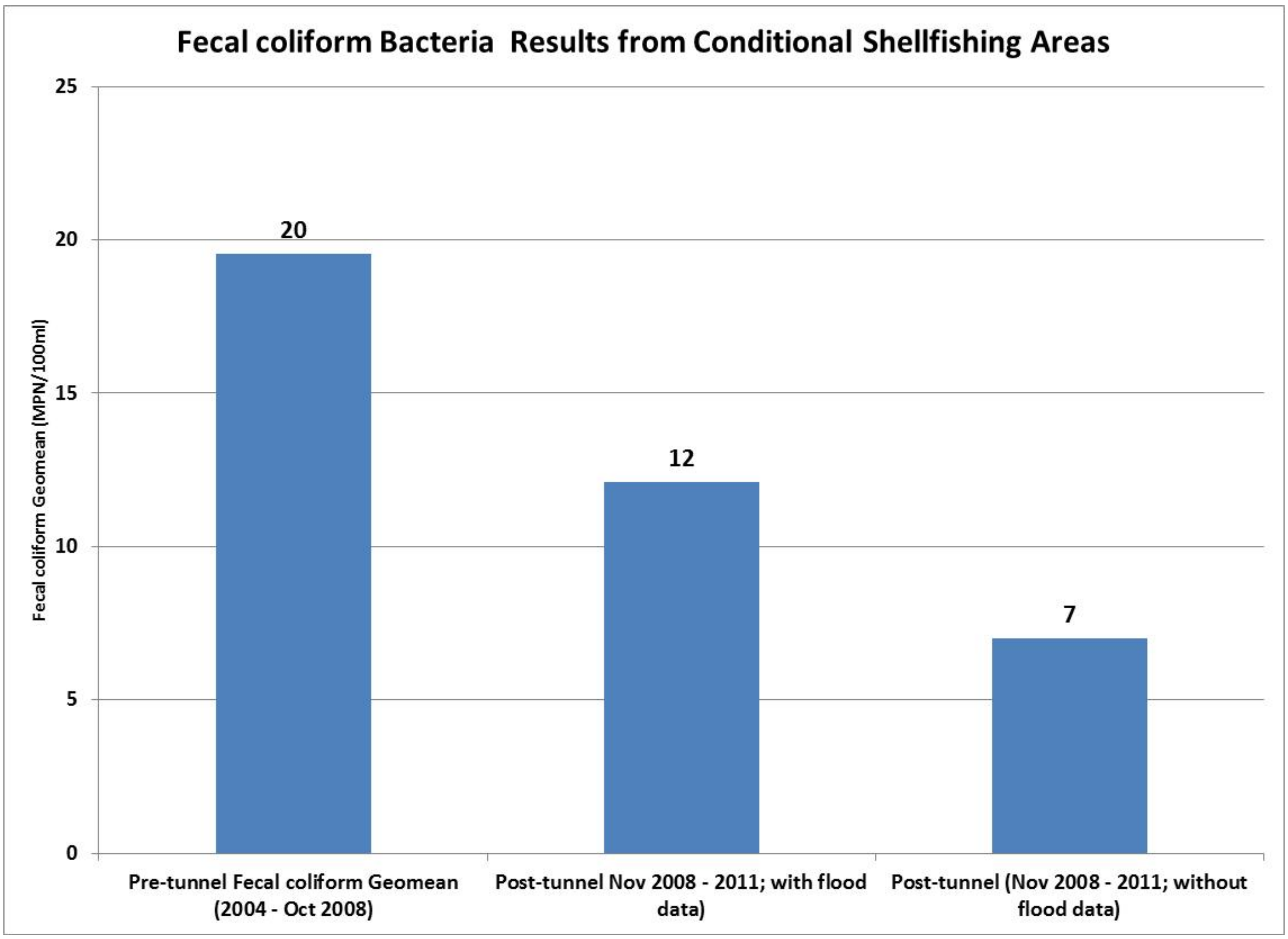

Figure 11. Fecal coliform geomeans from the Conditional Shellfishing Areas pre tunnel and post tunnel operation. The current shellfishing regulations are a geomean of 14 MPN/100 mL for fecal Coliform bacteria.

<u>Beach Closures</u>

In the Upper Narragansett Bay there are three beaches that the RIDOH considers to be impacted by the CSOs within the Narragansett Bay Commission service area, Bristol Town Beach, Barrington Town Beach, and Conimicut Beach. During the 2010 beach season, the RIDOH found marked improvement in the number of beach closures they identified that season. When they compared the data from 2010 to the summer of 2006, a summer of similar rainfall amounts and two years before the tunnel opened, they found a 36% decrease in closure events and a 73% decrease in closure days in 2010. Specifically at the 3 Upper Bay beaches affected by CSOs the decrease was even greater; a 44% decrease in closure events and an 82% decrease in closure days. In March 2011, the RIDOH cited the CSO Tunnel Project as one reason for beach improvements: *"Improvements in water quality and decrease in beach closures can be attributed to implementation of the Providence CSO Tunnel Project" (From a presentation entitled Rhode Island Department of Health Beach Program: 2011 Land and Water Conservation Summit March 26, 2011).* Also in 2010, the RIDOH initiated a study entitled the "Urban Beach Initiative", which sampled three beaches in the Providence River area for their potential use as licensed beaches. They found that these beaches had an approximately 85% compliance rate with pathogen standards, similar to what was found in beaches in areas with less pollution impacts.

What's Next: Phase II and Phase III

With Phase I of the Combined Sewer Overflow Abatement Project now complete, construction on Phase II began in the summer of 2011. Phase II will collect 14 more CSOs in the Field's Point service area into the tunnel, via the construction of two new near surface interceptors along the Woonasquatucket River and the lower Seekonk River. Also included in Phase II is the separation of storm and sewer lines of two CSOs and the construction of a wetlands treatment facility in Higginson Park in Central Falls. Phase II is expected to be complete in the spring of 2015. Once Phase II has been completed and evaluated, NBC anticipates beginning Phase III of the CSO Abatement Project. This will be another large scale project to design and build a new deep rock tunnel to direct flow to the Bucklin Point Facility in East Providence.