Operational Challenges to Meeting New Copper & THM Effluent Limits at Clearwater APCFS

Viraj de Silva and John Milligan

The city of Clearwater operates and maintains three advanced pollution control facilities (APCFs). Plant capacities and discharge sources are listed in Table 1. The Northeast and East APCF effluents combine just prior to discharge.

The city renewed its Florida Department of Environmental Protection (FDEP) operating permits for the three APCFs in June of 2000. Incorporated in the permits are Chapter 62-302 "Surface Water Quality Standards" with a total recoverable copper surface-water limitation of 2.9 µg/L, a dibromochloromethane (DBCM) annual average limit of 34 µg/L, and dichlorobromomethane (DCBM) annual average limit of 22 µg/L. The new operating permits also included bi-monthly testing of whole effluent toxicity.

The APCFs' effluent copper levels ranged from 4.5 to 12 µg/L, the effluent DBCM and DCBM levels were about to exceed the annual average limits, and the toxicity results showed acute and chronic toxicity. Clearwater entered into a consent agreement with the FDEP that provided the city with interim limits for copper and trihalomethanes (THM). The consent agreement also provided a timeline that required 11 out of 12 passing toxicity tests.

Compliance Team

A diverse compliance team representing management, operations, engineering consultants, and a laboratory was created to provide a permanent solution to the city's APCF regulatory issues. Its assessment was to initiate a multi-directional approach to resolve each of the compliance issues due to the consent order timelines. The team also scheduled monthly progress meetings.

Each team member provided the following tasks:

Management—A master plan of projects was developed for needed plant improvements, including the installation of a SCADA system. Funding for pilot projects to acquire resolutions to the compliance issues was provided.

An increase in training was initiated to improve technical skills, and supervisors also received management training from the local college. A focus group was started to review personnel policies and to recommend changes that resulted in increased staff accountability.

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Tracking systems for operations were developed in the form of spreadsheets and databases. An asset management system was also installed for the maintenance and future planning of the APCFs' infrastructure. Management supplied the tools, training, and systems to improve the working environment and consistency of the APCFs' operation.

Operations—Operations personnel revised the standard operating procedure (SOP) and sampling protocols and initiated in-house training programs for new operators and shift lead operators. Operations provided technical input on compliance issues and for the city's master plan. The Operations Team also was involved with technical input for pilot projects, as well as bench-test evaluations.

Consultants—The engineering consultants provided input and developed pilot projects/evaluations from the team's ideas. Consultants prepared pilot project reports, including capital and O&M costs, helped the city with permitting, and provided technical training for staff members.

Clearwater Laboratory—The Clearwater

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Table 1: City APCF Data

Parameter	Units	Marshall Street PACF	Northeast APCF	East APCF
Permitted Capacity	MGD	10.0	13.5	5.0
Discharge Source*	-	Stevenson Creek	Old Tampa Bay	Old Tampa Bay

* Class III Surface Waters

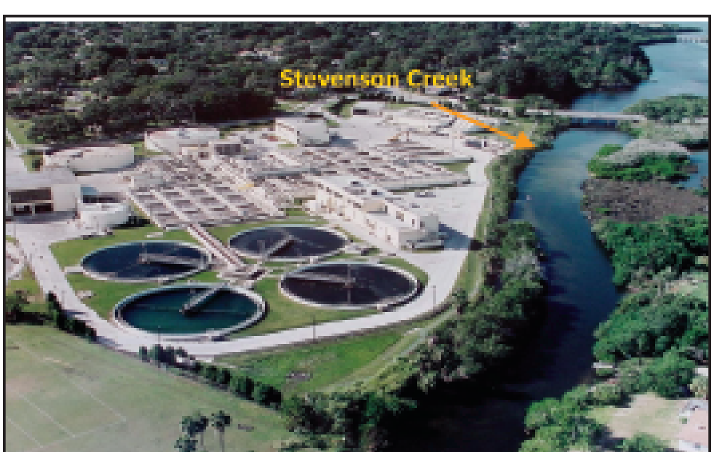

Figure 1 – 10 MGD Marshall Street APCF discharging to Stevenson Creek

Figure 2 – 5 MGD East APCF discharging combined with Northeast APCF to Old Tampa Bay

Table 2: Copper Mass Balance at Marshall Street APCF during September 2004

Parameter	Copper Removal Rates	
	[ppd]	[%]
Influent Cu	5.97	-
Effluent Cu	0.158	98
Cu Removal via Primary Solids	0.95	16
Cu Removal via bio-mass	4.81	81
Cu Removal Precipitant Removal	0.052	1

Operation Data:
Monthly Average Daily Flow = 5.92 mgd,
Mixed Liquor Suspended Solis = 216,000 Total Pounds
Mean Cell Residence Time (MCRT) = 54 days

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Laboratory improved its QA/QC standards by becoming NELAC certified. The laboratory provided historical data; conducted pilot testing, including bench testing; and served as a resource for technical questions. Also, laboratory data provided to operations was posted electronically and updated daily, allowing operations to react quicker in making changes to plant processes, which resulted in improved effluent quality.

Copper Reduction

The Marshall Street APCF and service area were chosen for the testing and development of the methodology that would reduce effluent copper at all three APCFs. To discover the background copper source, testing was conducted on the potable water supply. The influent copper results averaged 132 µg/L, and the primary clarifier solids revealed high levels of copper, with an average of 7.1 mg/L.

The Industrial Pretreatment Program investigated other possible industrial copper sources. The results confirmed that the major source was the copper potable-water distribution pipes of residential and commercial customers.

A copper mass balance was also performed on the plants to determine the best process control parameters for copper removal. The copper mass balance shown in Table 2 provides crucial information concerning long-term process strategies.

An innovative, multi-directional approach was utilized to improve copper removal. It included chemical addition, lab testing, primary solids removal, and chemical precipitation. A description of each program follows.

Polyphosphate Addition—Polyphosphate was increased from 2.2 to 3.2 mg/L at the three service area water reservoirs.

Laboratory Testing Procedures—The laboratory methodology and SOPs were reviewed and coupled with split sampling to improve accuracy and lower the possibility of contamination. Clean sampling techniques were also initiated by operations in the field.

Primary Solids Removal—The third approach was to rehabilitate and utilize the anaerobic digesters by pumping a portion of the primary solids that are high in copper to the digesters in order to lower the amount of copper the bio-mass would have to remove.

Chemical Precipitation—The final method was to add a chemical that would precipitate copper from the effluent postsecondary clarification before filtration in order to provide effluent copper polishing, guaranteeing compliance.

Project Costs—The annual increase in polyphosphate cost is approximately $35,000. Laboratory costs of $20,000 annually were due to the increase in copper testing and split sampling with another laboratory. Cost of modifications to the wastewater treatment plant primary pumping systems were $23,000, and the annual cost of the copper precipitant was $35,000.

Results from Copper Reduction Program

With the increase of 1 mg/L of polyphosphate in the potable water supply, the influent copper decreased at the Marshall Street APCF by 8 µg/L and at the Northeast APCF by 20 µg/L. The improved laboratory sampling and testing procedures minimized the fluctuation in copper results.

Utilizing the anaerobic digesters to remove an average of 0.95 pounds of copper per day, via pumping a portion of the primary solids to the anaerobic digesters, lowered the amount of copper the activated sludge bio-mass has to remove, producing the desired copper concentrations. The copper precipitant served as a polishing agent, insuring compliance.

Shown in Table 2 is the Marshall Street APCF copper mass balance. From the beginning of the project in November 2001 through the present, the Marshall Street APCF has remained copper compliant. See Figure 4 for the Marshall Street APCF historical copper trend. The knowledge gained from The Marshall Street Project has been applied to Clearwater's other two APCFs, resulting in their copper compliance.

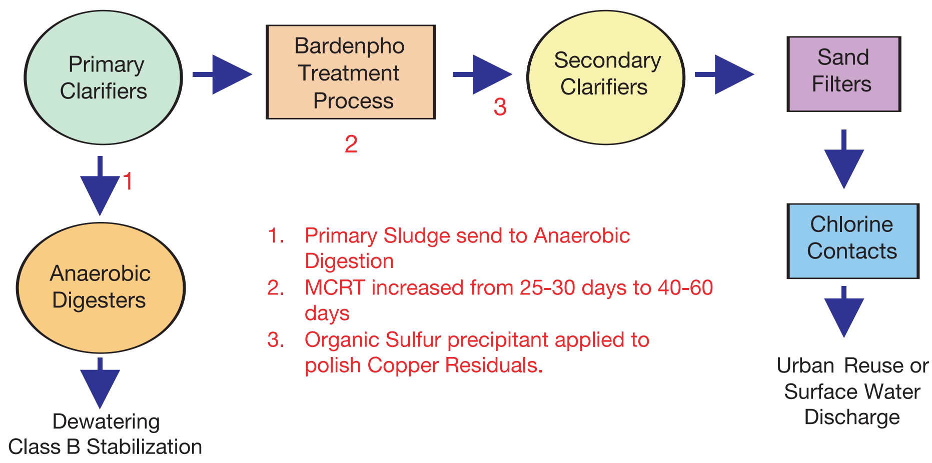

Figure 3 – Copper Removal Schematic

Trihalomethane Reduction

The city's APCFs also were experiencing difficulties in complying with the annual average permit limits for trihalomethane (THM) compounds. The annual average permit limits for dichlorobromomethane (DCBM) and dibromochloromethane (DBCM) are 22 and 34 µg/L, respectively. These THMs are byproducts of chlorine disinfection utilized at the APCFs.

Operations installed mixers in the chlorine contact tanks and the automatic chlorination and dechlorination systems. The automatic systems improved control of the chlorine feed, which resulted in lower feed rates, thus reducing THM levels.

Operations also shut down half of the chlorine contact chambers, reducing the

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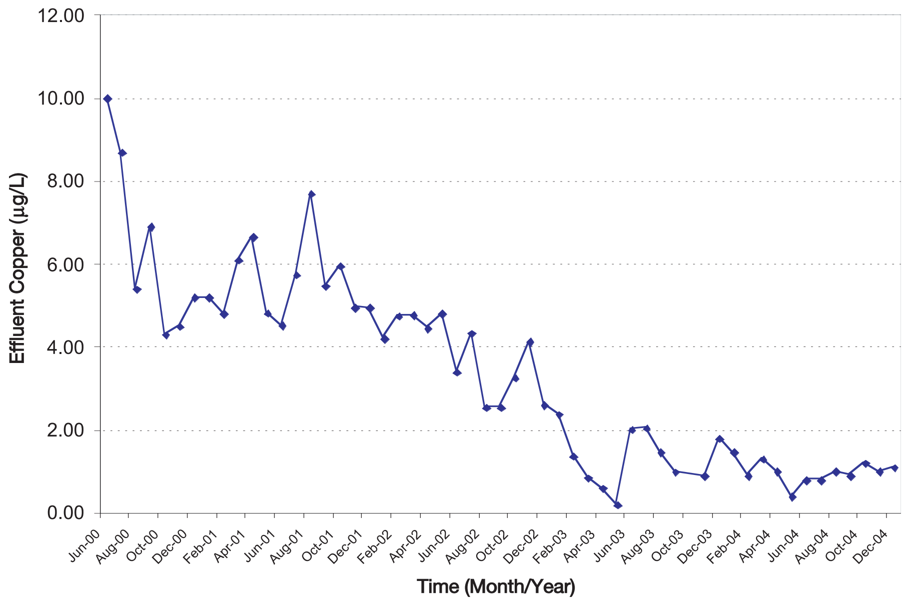
Figure 4 – Effluent Copper Levels at Marshall Street APCF between June 2000 and December 2004.



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chlorine contact detention time by half and also resulting in the further reduction of DCBM and DBCM.

Though the THM levels had been reduced, the DCBM effluent levels were ranging from 22 to 54 µg/L and the DBCM effluent results were fluctuating from 27 to 40 µg/L. Not being able to maintain compliant THM effluent levels, the city conducted a series of pilot projects to further reduce THMs. The following is the summary of the pilot projects and evaluations:

Chlorine Dioxide Pilot Study Results—The chlorine dioxide study proved successful in lowering THMs; however, the byproduct chlorite is toxic to Ceriodaphnia Dubia. Ascorbic acid will reduced chlorite to eliminate toxicity, but instrumentation must be developed in order to install a compound loop feed system to control the chlorine dioxide, chlorite, and ascorbic acid. Due to the high costs and control-system issues associated with this technology, chlorine dioxide has been dropped as a viable method to reduce THMs.

Figures 5 and 6 illustrate DCBM and DBCM reduction at the Marshall Street APCF from August 2001 to January 2002.

UV Disinfection—A UV disinfection evaluation was conducted to calculate the costs of changing from chlorine to UV disinfection at the Marshall Street, Northeast, and East APCFs as part of our WPC Master Plan. Based on samples taken at each plant, the UV transmission was determined to be 65 percent, which was used by ONDEO Degremont to size the units for each plant.

The capital costs are estimated at $10.25 million, in 2004 dollars, to install UV disinfection at all three plants. O&M costs to operate UV disinfection at all three plants are estimated at $335,000 per year. Final sizing of the UV system would be based on full-scale piloting testing at each plant.

Magnetic Ion Exchange Process (MIEX)—The MIEX process was bench tested in order to determine the costs of removing dissolved organic carbon (DOC), the disinfection byproduct precursor and reducing the formation of THMs. MIEX was capable of removing 60 to 80 percent of the DOC, and THM formation potential was reduced to below current limits for DCBM and DBCM. The estimated capital costs for the Northeast APCF are $4,262,000, the Marshall Street APCF $3,233,000, and the East APCF are $1,697,000, for a total of $9,192,000. The O&M for the Northeast APCF is estimated to $715,000 per year, the Marshall Street APCF $530,000 per year, and the East APCF $267,000 per year, for a total O&M of $1,510,000.

Carbon—Granular Activated Carbon (GAC) was pilot tested for 30 days using carbon columns to determine removal of DOC and to estimate bed adsorption life and reduction in THM formation potential. The GAC columns were very effective at removing greater than 80 percent of the DOC and reducing the THM formation potential below current and proposed THM permit limits; however, bed life was less than 30 days due to adsorption of other dissolved ions and organics in the effluent.

Capital costs to install GAC columns at all three plants were estimated at $8.5 million. Due to the short bed life, O&M costs for this alternative were very high and were estimated at $4.16 million per year at the Northeast, $2.8 million per year at Marshall St. and $1.04 million per year at East. Based on these results, GAC is not feasible and requires excessive capital O&M costs.

Powdered Activated Carbon (PAC) was evaluated using absorption isotherms jar tests to determine if PAC could be introduced at the end of the re-aeration zone (prior to final clarification and effluent filters) to reduce DOC and THM formation potential. PAC dosages ranged from 5 to 500 mg/L but were capable of reducing DOC and the

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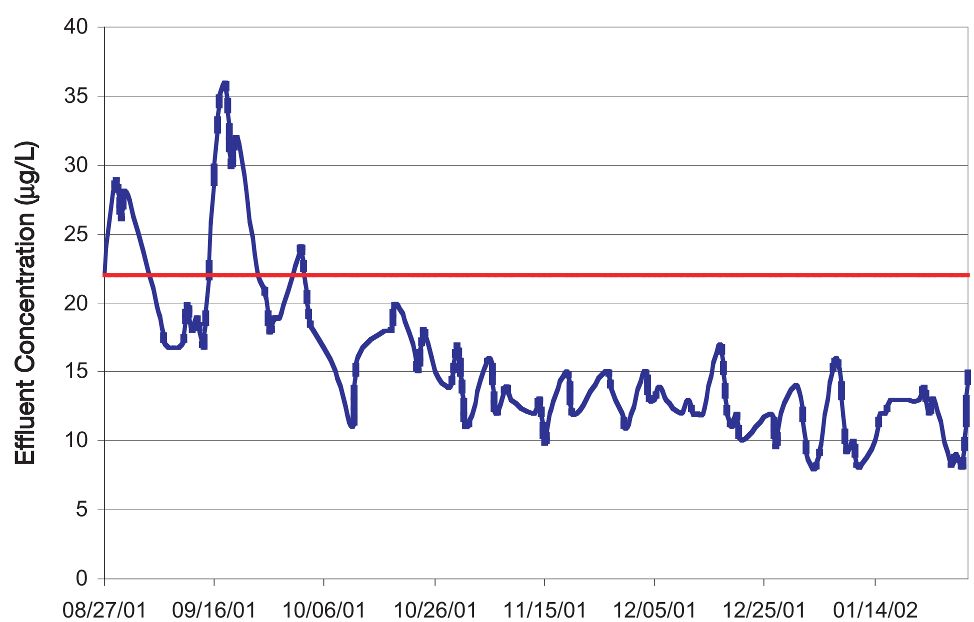

Figure 5 – DCBM reduction at Marshall Street APCF between August 2001 and January 2002 (Limit 22 µg/L)

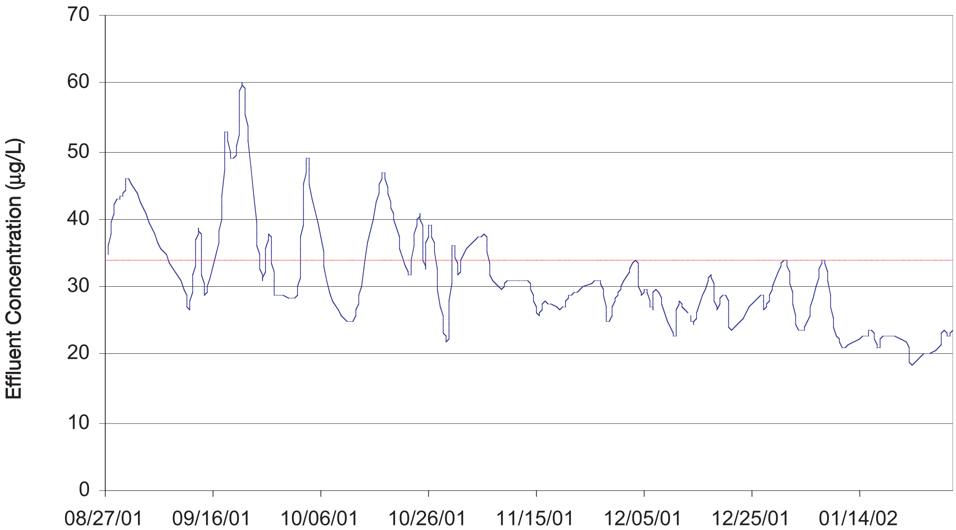

Figure 6 – DBCM reduction at Marshall Street APCF between August 2001 and January 2002 (Limit 32 µg/L)

Figure 7 - Old Tampa Bay Mixing Zone DBCM Percent Reduction

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DCBM THM formation potential by only approximately 60 percent at a PAC dose of 500 mg/L.

At highest PAC dose, the DBCM limits actually increased above the current permit limits. Based on these results, PAC introduction prior to final clarification is not feasible and requires excessive O&M costs for no benefit.

Enhanced Coagulation—The coagulants alum, ferric chloride, and ferric sulfate were jar tested at dosages ranging from 25 to 150 mg/L to determine if enhanced coagulation of advanced secondary effluent was effective at reducing both DOC and THM formation potential. Coagulants were dosed into the mixed liquor from the re-aeration zone, reacted for 30 minutes, settled to simulate final clarification, and filtered through a 0.45 micron filter to remove absorbed DOC and chlorinated.

Results indicated that with the highest alum coagulant dosages, DOC removal was approximately 20 percent. Based on these results, it was determined that enhanced coagulation was not a feasible option for DOC or THM formation potential reduction.

THM Mixing Zones—As a result of the pilot projects demonstrating high capital and O&M costs, the city submitted to the FDEP a permit modification requesting a two-meter DCBM mixing zone for Old Tampa Bay (Northeast/East APCF combined outfall) and a four-meter mixing zone for Stevenson's Creek (Marshall Street's outfall). The FDEP permitted both outfalls with four-meter mixing zones utilizing the same justification methodology. This article will address only the Old Tampa Bay two-meter mixing zone.

A sampling plan was submitted to the FDEP and approved. All samples were taken in August 2004 at slack high and low tides to evaluate mixing for the time period in which the least mixing would occur due to tidal currents and high temperatures.

To determine the order of mixing that occurs, samples were taken at the outfall and at 2, 5, 20, 100, and 200 meters from the outfall in north, south, east, and west directions. Samples were taken at the point of contact in the Tampa Bay, and an ambient sample was also taken 200 meters south of the outfall. The outfall location of the East APCF is shown in Figure 7.

The sampling results and the calculated percent reduction achieved by mixing for DCBM are listed in Table 3 and shown in Figures 8 and 9. Based on the sampling results, the majority of the mixing occurs within two meters of the outfall, with a high-tide and low-tide average of 75 percent reduction in DCBM.

The maximum effluent concentration to meet the FDEP limitation of an annual average of 22 µg/L would be 89 µg/L. Historical data shows the effluent concentration of DCBM as high as 54 µg/L, which would require a reduction of 59 percent, leaving a 16.08-percent safety margin.

The city recommended a reduction of 56 percent, resulting in an effluent limitation of 50 µg/L. The FDEP and the city settled on a DCBM effluent annual average concentration for the East/Northeast APCF Old Tampa Bay outfall of 43 µg/L. The Marshall Street APCF's Stevenson's Creek outfall effluent concentration for DCBM was permitted for 24 µg/L, and the effluent concentration for DBCM was permitted for 43 µg/L.

Results from THM Reduction Program

The reduction of DCBM and DBCM were based mainly on the operational improvements at the APCFs. The present technologies that are capable of reducing THM formation have high capital and O&M costs that present a financial burden to the to the city's public utilities capital program and operating budgets.

By improving contact tank efficiencies, mixing, introducing automated chemical feed systems, and reducing contact tank detention times, coupled with mixing zones, the city of Clearwater achieved THM permit compliance.

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Conclusion

Based on the sampling results, it was recommended that the city request revised permit limitations equivalent to 25 µg/L for DCBM and 50 µg/L for DBCM at the Marshall Street APCF. These permit limitations would be based on an annual average and require that a 24-percent reduction of DCBM and a 32-percent reduction of DBCM be achieved within 20 meters of the outfall.

A mixing zone request has also been submitted for the East-Northeast APCFs, requesting a revised permit limitation for DCBM of 32 µg/L. Ambient quarterly monitoring could also be performed for these parameters to ensure that the water-quality standards are not compromised by the proposed limitations.

The U.S. Environmental Protection Agency recently published an updated compilation of its national recommended water quality criteria (November 2002) that reduces the recommended criteria for DBCM to 13 µg/L and DCBM to 17 µg/L, based on the human health for the consumption of organisms only. The criteria within this document have been published as guidance to states authorized to establish water-quality standards under the Clean Water Act.

Although these criteria have not been adopted by the state of Florida, a potential does exist; therefore, application for mixing zones may become much more prevalent for these compounds for utilities using chlorine as their primary disinfectant, despite improved operational performance.

With the increase of polyphosphate in the potable water supply, the influent copper decreased at two APCFs. Also, pumping a portion of the primary solids to the anaerobic digesters lowered the amount of copper the activated sludge bio-mass has to remove, producing the desired copper concentrations. The copper precipitant was also used as a polishing agent, ensuring compliance. The improved laboratory sampling and testing procedures minimized the fluctuation in copper results.

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Table 3: Ambient Reduction of Dichlorobromomethane (DCBM) at Various

Sampling Location	North		East		South		West	
	(µg /L)	%	(µg /L)	%	(µg /L)	%	(µg /L)	%
200 meters/Low Tide	NT	NA	NT	NA	0.54	98.4	NT	NA
100 meters/Low Tide	1.2	96.4	0.43	98.7	3.8	88.5	2.4	92.7
20 meters/Low Tide	3.5	89.4	4.5	86.4	4.3	87.0	3.1	90.6
5 meters/Low Tide	2.1	93.6	6.2	81.2	6.4	80.6	4.4	86.7
2 meters/Low tide	7.2	78.2	7.2	78.2	12	63.6	11	66.7
Point of Contact/Low Tide	16	51.5	16	51.5	16	51.5	16	51.5
Outfall/Low Tide	33	0.0	33	0.0	33	0.0	33	0.0
200 meters/High Tide	NT	NA	NT	NA	0.3	99.2	NT	NA
100 meters/High Tide	1.8	95.3	2.4	93.7	0.97	97.5	2.1	94.5
20 meters/High Tide	3.3	91.3	2.6	93.2	2.7	92.9	2.1	94.5
5 meters/ High Tide	4.7	87.6	5.2	86.3	1.6	95.8	3.7	90.3
2 meters/ High Tide	5.8	84.7	9.4	75.3	9.1	76.1	8.4	77.9
Point of Contact/High Tide	13	65.8	13	65.8	13	65.8	13	65.8
Outfall/High Tide	38	0.0	38	0.0	38	0.0	38	0.0

NT........Not Tested NA........Not Applicable

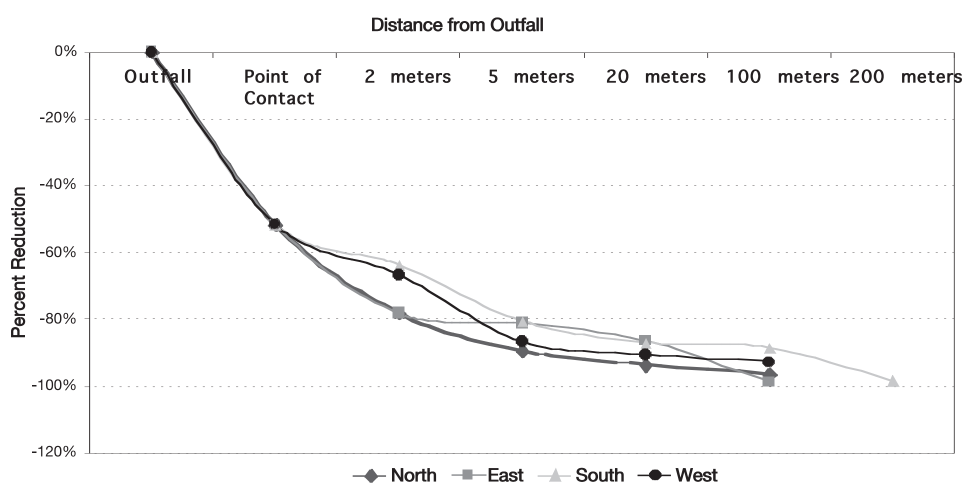

Figure 8 - Old Tampa Bay Mixing Zone DCBM Percent Reduction during Low Tide

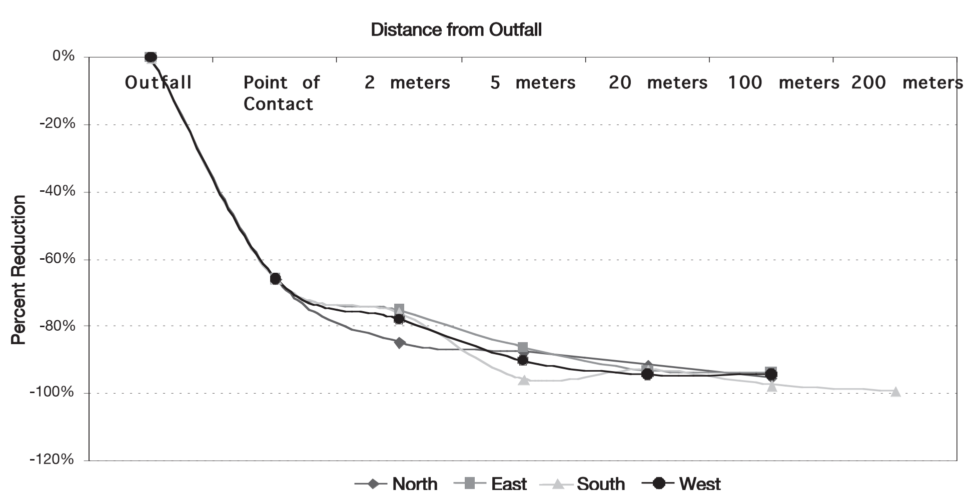

Figure 9 - Old Tampa Bay Mixing Zone DCBM Percent Reduction during High Tide