AUGUST 28, 2000

FULL SCALE DESIGN & COST ESTIMATE PEER REVIEW REPORT

SOUTH FLORIDA WATER MANAGEMENT DISTRICT

PROTECTOR OF THE EVERGLADES SINCE 1949

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HAZEN AND SAWYER

Environmental Engineers & Scientists

FULL SCALE DESIGN & COST ESTIMATE PEER REVIEW REPORT
Contract #SFWMD/C-E018 - Chemical Treatment Peer Review
Revised August 14, 2000

INTRODUCTION

Kick-off Meeting

A kick-off meeting with District personnel and HSA consultants was held on Tuesday, June 20 from approximately 9:00 AM to 11:00 AM to initiate review of the Draft Final Report and associated documents.

Peer Review Team

The Peer Review Group consists of Parsons Brinckerhoff's William J. Conlon, P.E., DEE as Project Coordinator with additional technical expertise provided by Hazen and Sawyer's Orren D. Schneider, Ph.D., P.E. and Donald M. Brailey, P.E.

Background

Florida's 1994 Everglades Forever Act (F.S. 373.4592) and the federal Everglades Settlement Agreement (Case No. 88-1886-CIV-HOEVELER) establish both interim and long-term water quality goals designed to restore and protect the Everglades Protection Area (EPA). As defined in the Act and the Settlement Agreement, the Everglades Protection Area includes Water Conservation Areas 1, 2A, 2B, 3A, 3B, the Arthur R. Marshall Loxahatchee National Wildlife Refuge, and the Everglades National Park.

Activities are currently underway to meet the interim goal of reducing phosphorus levels in discharges from the Everglades Agricultural Area (EAA) and other sources to the Everglades Protection Area. These activities include the implementation of Everglades Agricultural Area Best Management Practices (BMPs) and the construction of over 42,000 acres of Stormwater Treatment Areas (STAs) through the Everglades Construction Project (ECP). Concurrent with implementation of the ECP, the District is implementing the Everglades Stormwater Program (ESP) to address the water quality issues associated with discharges from the remaining non-ECP Everglades tributary basins. Also concurrent with these activities, the District and other groups are conducting water quality research, advanced treatment technology research, ecosystem-wide planning (e.g., the Comprehensive Everglades Restoration Plan, or CERP), and regulatory programs to ensure a sound foundation for science-based decision-making.

The long-term goal of the Everglades Program restoration effort is to combine point source control; basin-level and regional solutions in a system-wide approach to ensure that all waters discharged into the Everglades Protection Area meet the numeric phosphorus criterion and other applicable state water quality standards by December 31, 2006.

For the purposes of planning, 10 µg/L (total phosphorus) will be used as the design parameter pending adoption of the numeric criterion by the Department of Environmental Protection or Everglades Regulatory Commission.

The District and other parties are engaged in the research and demonstration of advanced treatment technologies (ATTs) that may be used alone or in conjunction with STAs for achieving the long-term water quality goals of the Everglades. Research teams are evaluating the technical, economic and environmental feasibility for basin-scale application. Eight ATTs are being evaluated. One of the eight ATTs is Chemical Treatment-High Rate Sedimentation that is the subject of this peer review.

To enable the District to provide a scientifically defensible basis for comparative evaluation of the successful technologies, a Supplemental (Advanced) Treatment Technology Standard of Comparison (STSOC) was established. The STSOC provides an approach to comparing the effectiveness of one advanced treatment technology to another. The STSOC has evolved in four phases.

We are now in Phase IV, Compilation and evaluation of Advanced Treatment Technology data, which is scheduled to be completed. Within the next two years, data from the ATT projects will be compiled, evaluated and compared. This report addresses a peer review of the demonstration project work conducted by HSA Engineers and Scientists and their preliminary cost estimates.

HSA Engineers and Scientists, as one of their final deliverables was a report summarizing the research results, including a conceptual-level layout of a full-scale treatment system designed to treat the flows and phosphorus loads into and out of STA 2 for the period 1979-1988 (Period of Record or POR). Conceptual estimates of capital and annual operation and maintenance costs will be included in this report.

DOCUMENT REVIEW

The peer review evaluation was based on the available information. The review investigated whether the recommended solution in the Draft Final Report met the intended use and performance goals, i.e., total phosphorus discharge concentration of 10 µg/L of total phosphorus given the inflows and outflows provided for STA 2 POR (1979-88). The Peer Review Team reviewed a compilation of internal research reports and memos related to this project. The documents reviewed were:

1. Project Peer Review Guidelines, American Consulting Engineers Council, American Society of Civil Engineers, 1990
2. PEER Consultants, P.C./Brown and Caldwell Consultants, *"Desktop Evaluation of Alternative Technologies,"* Final Report under SFWMD Contract No. C-E008, Amendment 3, August 1996.
3. HSA Engineers and Scientists (former CRA) *"Chemical Treatment Followed by Solids Separation Advanced Technology Demonstration Project"* documents under Contract C-E10650:
   - Final Report Draft- May 2000.

SCOPE AND OBJECTIVE

Because of the unique nature and anticipated magnitude of the application of these advanced treatment technologies, it is the intent of the District to have the aforementioned documents "peer reviewed" by qualified individuals, independently from District staff review. The objective of the peer review is to conduct an independent review of, and provide comments on, the design concept presented in the individual advanced treatment technology draft Final Report. This review assesses:

1. The basis of design used in the scale-up from research experiments to conceptual full-scale configuration, and
2. The validity of the conceptual design for full-scale configuration.
3. The design assumptions,

Included in the review of the basis of design was:

- Phosphorus removal performance,
- Hydraulics,
- Chemical dosages
- Sludge management

Included in the review of the full-scale configuration was:

- Hydraulic features,
- Structural features,
- Operational aspects,
- Integration with existing STA features,
- Capital cost estimates,
- Annual cost estimates

ACHIEVEMENT OF CT-SS PROJECT OBJECTIVES

Project objectives were met for all of the following:

1. Achieve treated effluent of 10 ppb TP

The pilot program demonstrated that CT-SS technology could achieve less than 10 µg/L of TP.

2. Identify and demonstrate an optimized CT-SS process for which operating conditions can be described and full scale costs projected.

The recommended CT-SS technology is plate pack sedimentation without filtration.

For potable water, Hazen and Sawyer is supervising the installation of a similar sized plate pack sedimentation treatment plant for the Detroit Water Department. The plant is being built under a Design-Build-Maintain arrangement. Loading criteria for the plate pack units are essentially the same as for the recommended CT-SS units.

In our previous work, we have found that well designed and operated sedimentation tanks (plate packs and flotation units) are capable of removing well over 90 percent of influent suspended solids. While filtration is always used in potable water, it should not be needed in this application, where the only removal criterion is for TP.

3. Conduct a Supplemental Technology Standard of Comparison (STSOC) Evaluation.

No comment.

4. *Develop process criteria and experience sufficient for preliminary design of a full-scale system.*

Layout and design criteria for the flocculation and sedimentation portions of Detroit's new Water Works Park Water Treatment Plant are attached. Design flow of this plant is 250 mgd, which falls within the range of flows being considered. Process criteria are similar to those proposed for the full-scale system.

CAPITAL COSTS

Estimated construction costs for the flocculation and sedimentation portion of the work were verified by using a factor estimate based on actual prices for the Detroit's 250 mgd Water Works Park water treatment plant which is currently under construction. This plant uses the same coagulation-flocculation-sedimentation scheme as recommended for the CT-SS project, including rectangular, common wall construction. The project was procured under a Design-Build-Maintain concept, with the primary advantage being schedule, rather than cost.

In terms of loading rate, the plant was designed for a 0.28 gpm/sf loading rate on the plates based on 80 percent of project area.

Costs were factored by using the following formula:

$$\text{Cost}(Q) = \text{Cost}(Q_0)*(Q/Q_0)^n$$

Where:

Cost (Q)	=	construction cost, $million
Q	=	design flow, mgd
Q_0	=	base design flow, in this case 250 mgd
n	=	empirical scaling factor

This analysis is similar to the common "0.6 power" relationship commonly found in estimation of the costs of chemical processes and plants. Our experience in both water and wastewater treatment plants has shown that the exponent is somewhat higher and usually falls in the range of 0.80 to 0.85.

Table 1 shows the Water Works Park costs and costs developed for the SFWMD project developed from the Water Works Park costs. It should be noted that these costs are only for the flocculation and sedimentation portion of the two projects — other parts of the projects are not similar. The Water Works Park costs can be considered as current costs (the project is approximately 50 percent complete).

The scope of services for the two projects is expected to similar, with the following exceptions:

- Design costs for SFWMD are not included in the estimate, so were deleted.
- Piles are not included in the SFWMD cost, but may be required. However, it is doubtful that the scope of work for piles will be anywhere near as costly as for the Detroit project.

- Underground tank drain lines will not be required for the SFWMD project, since the tankage will be located aboveground.
- The Detroit project required a roof over the flocculation and sedimentation tanks which will not be required for SFWMD
- The Detroit project enjoyed a very low unit price for the plate settler modules, at $7.50 per project square foot less than the $11.96 included in the SFWMD estimate and substantially less than a quote from a different plate pack vendor obtained by Hazen and Sawyer at $20-22 per projected square foot.

Table 1
Construction Cost Comparison with Water Works Park

Flow by mass balance:	250	Mgd
Gross plate area:	1,227,000	Sf
Projected plate area @ 55º:	704,000	Sf
Effective area @ 80%:	563,000	Sf

Construction Cost for the Floc/Sed Basin	**Detroit**	**Factored SFWMD Costs**	**Comments**
Design	**2,677,208**	0	included elsewhere
General Conditions	**1,666,113**	**1,666,113**	
Site Work			
General	1,043,130	**1,043,130**	
Piling (1087 piles)	2,350,807		piles not required
Total	**3,393,937**	**1,043,130**	

Construction Cost for the Floc/Sed Basin	**Detroit**	**SFWMD**	**Comments**
Concrete			
Concrete Work	7,879,294		
Precast wall panels	507,625		
Structural precast	600,000		
Total	**8,986,919**	**8,986,919**	
Masonry	**350,000**	**350,000**	
Metals			
Iron-(embed & misc..)	423,733		
Mixer Supports	606,432		
Handrails	374,892		
Erect Structural Steel	1,347,352		
Total	**2,752,409**	**2,752,409**	
Woods & Plastics	**206,142**	**206,142**	
Thermal & Moisture Protection			
Water Proof Walls	7,612	7,612	
Sealants	67,500	67,500	
Install Roof System	570,900		roof not required
Total	**646,012**	**75,112**	
Finishes	**292,304**	**292,304**	
Mechanical			
Sump Pumps	7,036	7,036	
Install Piping embeds	14,515	14,515	
Install Equipment embeds	2,419	2,419	
Install 12" UG drains	2,003,304	0	not required, aboveground construction
Install Sulfuric Acid Piping & Diffusers	45,000	45,000	
Install Coagulant piping & diffusers	75,000	75,000	
Install Mud valves	65442	65,442	
Install 16" Chem Mix Pumps	720,746	720,746	
Install 12" drain Headers	388,304	388,304	
Install Lube system for flocculators	217,728	217,728	
Install Sed. Collection Equip.	540,000	540,000	
Install Cross Collector Drives	390,000	390,000	
Install Plate Settlers	7,200,000	14,677,033	$11.96 per sf
Install Mixers	990,000	990,000	
Install 48- 4' slide gates	166,000	166,000	
Natural Gas piping	172,746	172,746	
Install HVAC (Dehumidification)	55,584	55,584	
Install Plumbing	709,632	709,632	
Install Basin Roof Conductors	232,243	232,243	
Install Gallery FD's & Sanitary Piping	65,000	65,000	
Total	**14,060,699**	**19,534,428**	
Electrical	**2,701,200**	**2,701,200**	
Instrumentation	**448,840**	**448,840**	
Total Cost of Construction for the Floc/Sed Basin	**38,181,783**	**38,056,597**	
Less Piles	35,830,976		

Based on this procedure, the flocculation and sedimentation facilities for the SFWMD project are expected to cost about $40 million if they were 50 percent complete today (August 2000).

Estimated cost breakdowns presented in the HSA report for the different flows are shown in Table 2.

Based on the factored relationship, and the "apples-to-apples" cost estimate given in Table 1, anticipated costs for the flocculation and sedimentation portion of the project are shown on Figure 1 along with the HSA costs given in Table 2.

Table 2
Capital Cost Breakdowns for Different Treatment Flows*

	STSOC: Post BMP					
	120	150	200	220	270	380
Capital Costs						
Equipment**	12,899,067	15,808,671	21,196,456	23,129,595	28,339,156	40,113,750
Chemical Feed System	322,477	395,217	529,911	578,240	708,479	1,002,844
Instrumentation	1,289,907	1,580,867	2,119,646	2,312,959	2,833,916	4,011,375
Electrical Controls	644,953	790,434	1,059,823	1,156,480	1,416,958	2,005,687
Electrical Power Distribution	40,000	40,000	40,000	40,000	40,000	40,000
Subtotal	**15,196,404**	**18,615,189**	**24,945,836**	**27,217,274**	**33,338,509**	**47,173,656**
Contingencies (20%)	3,039,281	3,723,038	4,989,167	5,443,455	6,667,702	9,434,731
Total	**18,235,685**	**22,338,227**	**29,935,003**	**32,660,729**	**40,006,211**	**56,608,387**
	STSOC: Post-STA					
	80	100	140	190	260	390
Capital Costs						
Equipment**	4,992,253	6,358,463	8,524,277	11,476,845	15,526,942	23,514,587
Chemical Feed System	124,906	158,982	213,107	286,921	388,174	587,865
Instrumentation	499,225	635,846	852,428	1,147,684	1,552,694	2,351,459
Electrical Controls	249,613	317,923	426,214	573,842	776,347	1,175,729
Electrical Power Distribution	40,000	40,000	40,000	40,000	40,000	40,000
Subtotal	**5,905,997**	**7,511,214**	**10,056,026**	**13,525,292**	**18,284,157**	**27,669,640**
Contingencies (20%)	1,181,199	1,502,243	2,011,205	2,705,058	3,656,831	5,533,928
Total	**7,087,196**	**9,013,457**	**12,067,231**	**16,230,350**	**21,940,988**	**33,203,568**

* From HSA report
**Estimated on $25,000 per pack, 2090 sf/pack

Table 2A which was prepared by HSA during the comment period demonstrates the capital and 50-year present worth cost comparison and relative cost difference of HSA's and the PRG's cost estimates.

Table 2A
COST EVALUATION

Scenario	Plant Size (MGD)	Capital Costs				50-YR Present Worth		
		HSA [1]	PRG [2]	Diff	RPD	HSA	PRG Adjusted [3]	RPD
Post-BMP								
10 ppb 0 diversion	380	$54,773,660	$53,758,970	$ (1,014,690)	2%	$ 239,848,660	$ 238,833,970	0%
10 ppb 10% diversion	270	$38,738,510	$40,551,280	$ 1,812,770	-5%	$ 202,152,550	$ 203,965,320	-1%
10 ppb 20% diversion	200	$28,945,840	$31,657,690	$ 2,711,850	-9%	$ 171,300,960	$ 174,012,810	-2%
20 ppb 0 diversion	220	$31,617,270	$34,247,440	$ 2,630,170	-8%	$ 189,616,570	$ 192,246,740	-1%
20 ppb 10% diversion	150	$21,615,190	$24,969,210	$ 3,354,020	-14%	$ 159,460,220	$ 162,814,240	-2%
20 ppb 20% diversion	120	$17,596,400	$20,770,840	$ 3,174,440	-17%	$ 141,952,670	$ 145,127,110	-2%
Post-STA								
10 ppb 0 diversion	390	$35,469,640	$54,923,440	$19,453,800	-43%	$ 239,965,110	$ 259,418,910	-8%
10 ppb 10% diversion	260	$23,484,160	$39,308,140	$15,823,980	-50%	$ 203,731,830	$ 219,555,810	-7%
10 ppb 20% diversion	190	$17,325,290	$30,345,980	$13,020,690	-55%	$ 172,526,330	$ 185,547,020	-7%
20 ppb 0 diversion	140	$12,856,030	$23,587,670	$10,731,640	-59%	$ 154,173,160	$ 164,904,800	-7%
20 ppb 10% diversion	100	$ 9,511,190	$17,870,200	$ 8,359,010	-61%	$ 132,325,300	$ 140,684,310	-6%
20 ppb 20% diversion	80	$ 7,505,900	$14,865,470	$ 7,359,570	-66%	$ 118,235,040	$ 125,594,610	-6%

Notes:

1 = Capital costs include equipment, residuals management, chemical feed system, instrumentation, electrical controls, and electrical power distribution.

PRG = Peer Review Group consisting of Parsons Brinckerhoff and Hazen and Sawyer.

2 = Using 250 MGD = $38,056,597 and the equation $Cost(Q) = Cost(Qo)*(Q/Qo)^n$, with n = 0.825.

RPD = Relative Percent Difference.

3 = 50-yr Present worth calculated with PRG capital cost.

FIGURE 1A

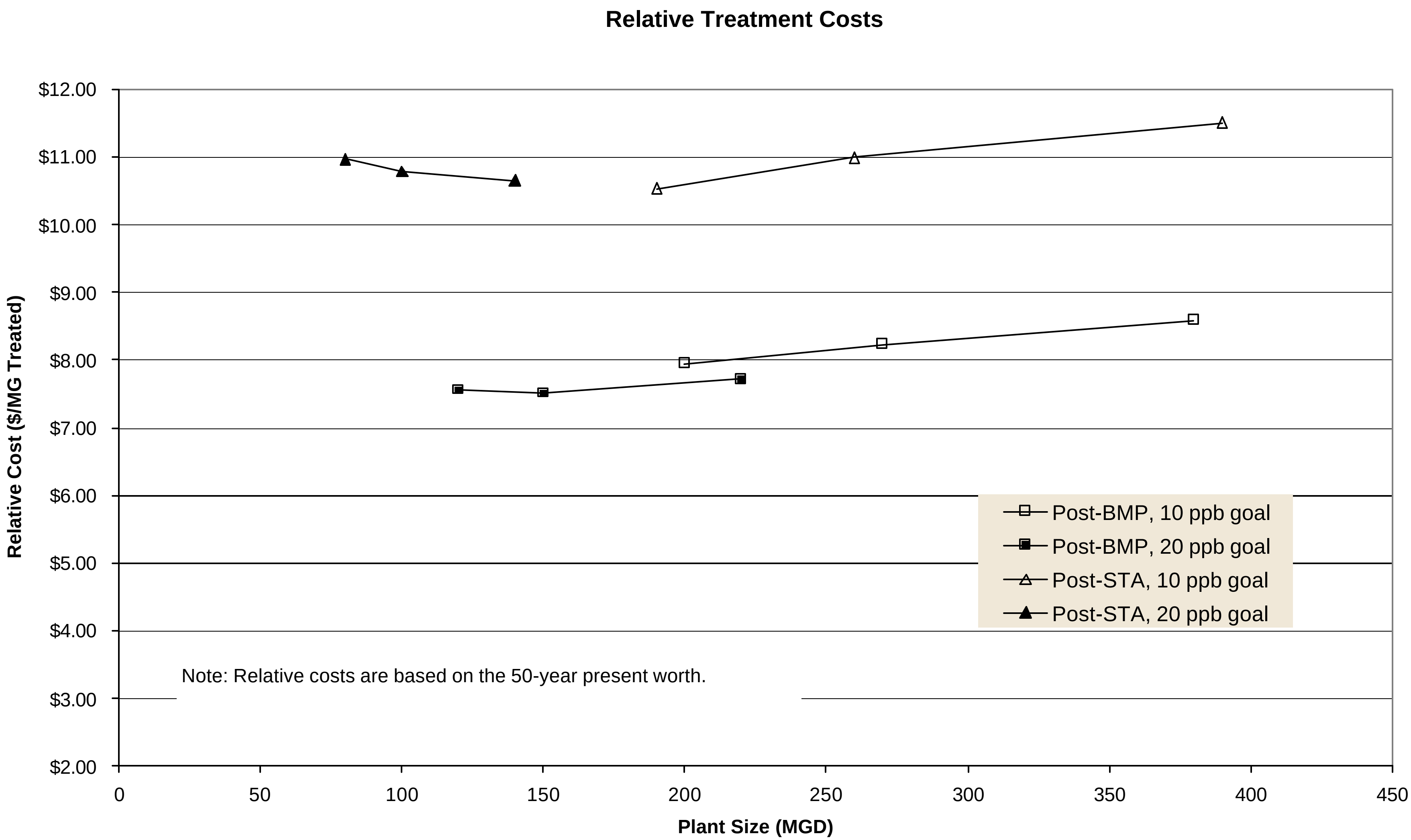

Relative Treatment Costs
$12.00
$11.00
$10.00
$9.00
$8.00
$7.00
$6.00
$5.00
$4.00
$3.00
$2.00
Relative Cost ($/MG Treated)
0
50
100
150
200
250
300
350
400
450
Plant Size (MGD)
Post-BMP, 10 ppb goal
Post-BMP, 20 ppb goal
Post-STA, 10 ppb goal
Post-STA, 20 ppb goal
Note: Relative costs are based on the 50-year present worth.

FIGURE 1B
Relative Treatment Costs

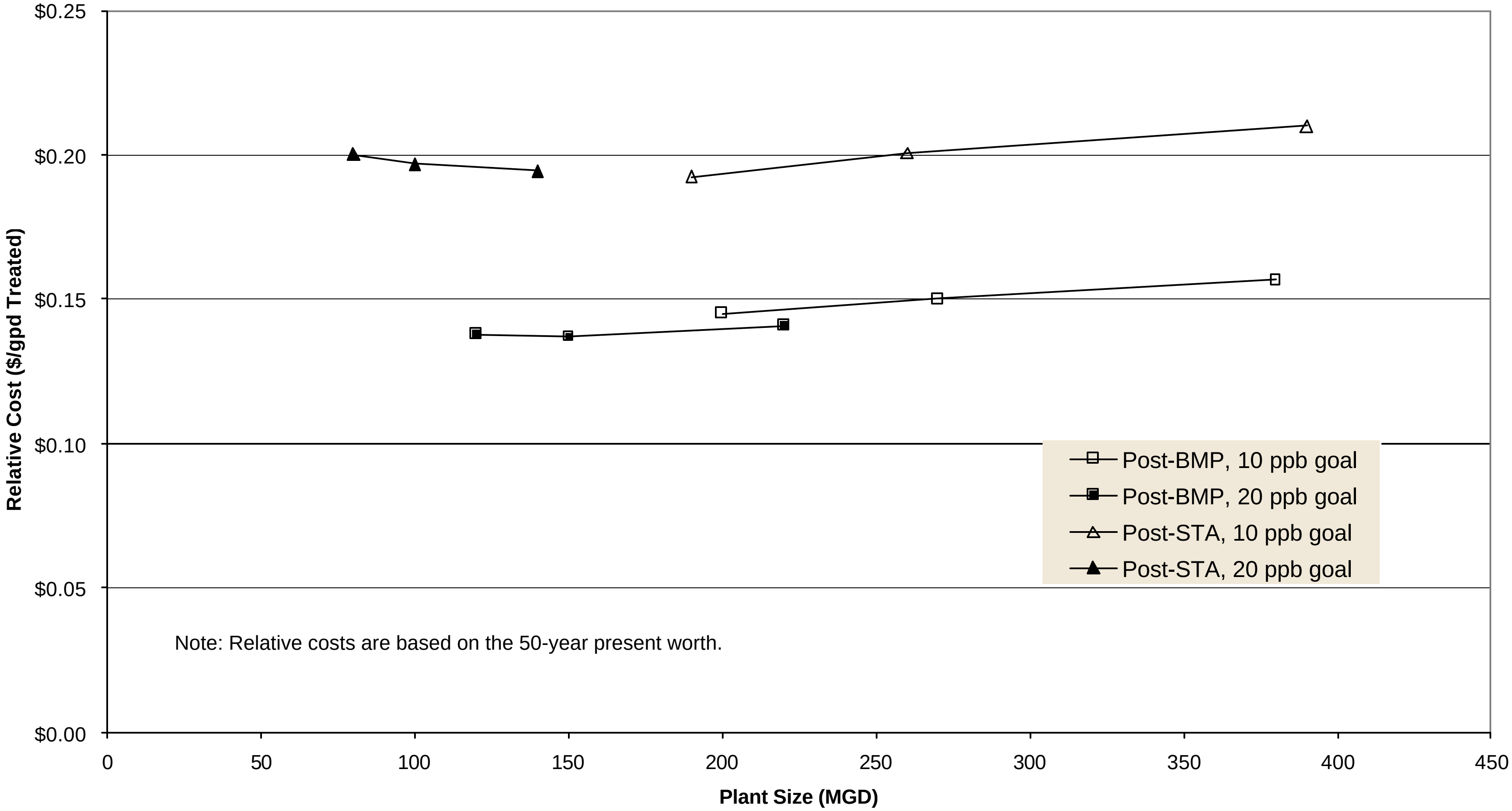
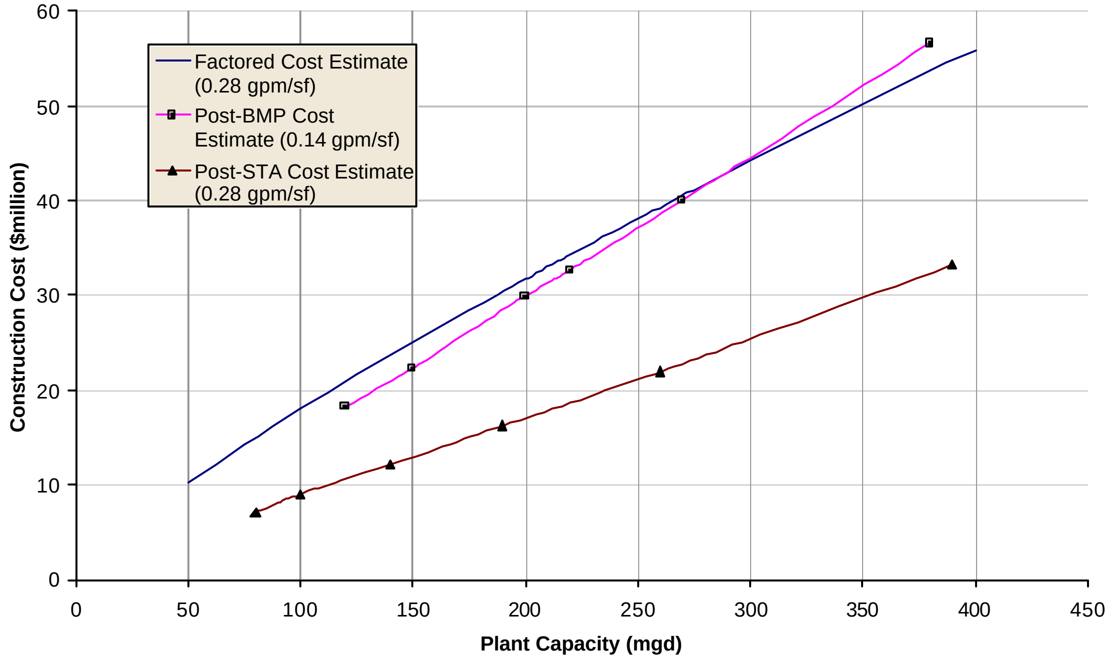


Figure 1C
Contruction Cost Comparison



Figures 1A and 1B show the relative treatment costs in terms of dollars per gpd of water treated and dollars per million gallons of water treated. These values are site specific and are lower than those in the industry for complete conventional surface water treatment plants with filters.

As can be seen from Figure 1C, the factored cost estimate shows costs that are somewhat less than double the costs for the post-STA scenario, which has roughly the same loading rate. For the post-BMP scenario, costs are about the same, but at twice the plate settler-loading rate.

The Detroit work is being performed under a Design-Build-Maintain arrangement. Competition for provision of the plate pack settlers was intense. Unit cost of the plate packs for this work were significantly less that what was assumed for the CT-SS estimate, and substantially less than a vendor quote obtained as part of this review.

Based on recent e-mail correspondence with a plate settler vendor, for the first three flows (80, 100, 140mgd) expect a price of $23/sf (in plastic the price would be closer to $18 to $20/sf). The cost for FRP plate settlers has been similar to the cost for stainless steel plate settlers but more expensive than plastic. The square footage is based upon total projected area, so if a plate efficiency factor is used, it should be added before applying the cost per sf. For example,(100-mgd/1440)/.28 = 248,016 sf at 100% x $23/sf = $5.7M. If at 80% plate efficiency rating, the 100-mgd plant is 248,016 sf/.8 X $23/sf = $7.1M. For the three larger flows (190, 260, 390 mgd), expect a price closer to $20/sf x 1.1 = $22/sf. Therefore at 100% plate rating, use 190 mgd at $10.4M, 260 mgd at $14.2M and 390 mgd at $21M. Prices are subject to change, for example 18 to 24 months ago, on large projects the costs were $18/sf and less. The vendors are now unable to supply equipment at the value of budget prices given out 2 years ago. FRP and plastics are similar in the range of 50% raw materials increase given the rise in oil prices. If the cost of stainless steel doesn't stabilize soon and the dollar devaluates prices will return to $30/sf as seen 7-8 years ago.

Based on this analysis, we recommend that the SFWMD increase the capital cost estimates for the treatment portion of the work.

Chemical Costs

The pH was reduced from 6.8 to 6.0 at the North Site and from 7.1 to 6.4 at the South Site.

North Site simulated post-BMP; with a ferric dosage of 40 mg/L. South Site simulated post-STA, aluminum dosage of 20 mg/L. These dosages are approximately the same, on a molar basis (0.71 mmol/L for ferric, 0.77 mmol/L for alum).

The most significant cost factor for this project will costs associated with coagulation chemicals, in terms of (1) costs for the chemicals themselves; (2) costs for residuals handling and disposal/reuse; and (3) costs for correcting pH, if necessary.

A summary of chemical costs for the two sites is presented in the Appendix

South Site. The optimum pH found at the South Site is between the optimum pH for aluminum hydroxide precipitation (about 6.6 for fresh, amorphous material), and the optimum pH for aluminum phosphate precipitation (about 5.3). The pH adjustment was obtained totally with aluminum sulfate. Floc formed at this pH can be expected to be rather difficult to settle, as was shown in actual practice. It also appears from removal results that required alum dosage is controlled by the dissolved organic carbon concentration, rather than the concentration of phosphorus or suspended matter.

Cost economies may be available by using a combination of aluminum sulfate and sulfuric acid. Conceptually, alum would be dosed at the optimum rate to precipitate organics. This could be achieved by a feed-forward control arrangement based on UV254 (Absorbance of light at 254 nanometers. Offers an easy measure of organic concentration in water. Actually a measure of double bonded organic carbon.) The pH would then be controlled to a set-point by adding acid in a feedback arrangement. Alternatively, if the ratio of alum to acid required is fairly consistent, acid alum could be used. (Acid alum is a commercially available, pre-mixed combination of the two chemicals). The use of acid alum would allow the feed of both chemicals but would only require a single chemical feed system.

The use of acid with aluminum sulfate would reduce the amount of residuals (sludge) formed and therefore the amount of material that needs to be disposed of. Thus, capital costs (required land) and possibly operational costs (chemicals, sludge pumping) could be reduced.

The amount of reduction of aluminum dosage available from acid addition cannot be estimated with available data, but could be easily estimated by performing jar tests, and using analyzing filtered water samples for phosphorous.

North Site. The optimum pH found at the North Site is between the optimum pH for ferric hydroxide precipitation (about 7.6 for fresh, amorphous material), and the optimum pH for ferric phosphate precipitation (about 4.5). The pH adjustment was obtained totally with ferric chloride. Floc formed at this pH can be expected to be rather difficult to settle, as was shown in actual practice. It also appears from removal results that required ferric chloride dosage is controlled by the dissolved organic carbon concentration, rather than the concentration of phosphorus or suspended matter.

Cost economies may be available by using a combination of ferric chloride and hydrochloric acid. Conceptually, ferric would be dosed at the optimum rate to precipitate organics. This could be achieved by a feed-forward control arrangement based on UV254. The pH would then be controlled to a setpoint by adding acid in a feedback arrangement. Alternatively, if the ratio of ferric to acid required is fairly consistent, an acid ferric product could be used (the iron analog of acid alum). The use of an acid ferric product would allow the feed of both chemicals but would only require a single chemical feed system.

The use of acid with ferric chloride would reduce the amount of residuals (sludge) formed and therefore the amount of material that needs to be disposed of. Thus, capital costs (required land) and possibly operational costs (chemicals, sludge pumping) could be reduced.

The amount of reduction of iron dosage available from acid addition cannot be estimated with available data, but could be easily estimated by performing jar tests, and using analyzing filtered water samples for phosphorous.

OPERATING COSTS

Hazen and Sawyer conducted an independent operating cost evaluation. Results are shown in Table 3. An itemized breakdown of the estimated operating costs is given in Table 4. As can be seen from the Table, the independent evaluation fell well within the expected range of variation for all scenarios. HSA's cost estimate was sufficient for the engineering budgetary cost estimate as defined as within +30% to –15% (according to the American Association of Cost Engineers).

Table 3
Comparison of Estimated and Reported Operating Costs

Site	Blended Effluent TP Concentration (μg/L)	Diversion of 10 year POR Flow	Treatment Plant Design Average Daily Flow (mgd)	Treated Flow (mgal)	Annual O&M Cost (Million $)	Report Cost (Million $)	Difference
Post-BMP	10	No diversion	380	556,049	8.17	7.76	-5.3%
		10%	270	495,729	7.36	6.98	-5.4%
		20%	200	437,936	6.58	6.14	-7.3%
	20	No diversion	220	498,196	7.39	6.83	-8.2%
		10%	150	433,336	6.52	6.03	-8.1%
		20%	120	384,168	5.86	5.46	-7.3%
Post-STA	10	No diversion	390	450,802	9.09	8.99	-1.1%
		10%	260	399,425	8.13	8.01	-1.5%
		20%	190	352,097	7.25	6.92	-4.8%
	20	No diversion	140	309,496	6.45	6.32	-2.1%
		10%	100	260,916	5.55	5.50	-0.9%
		20%	80	229,005	4.95	4.96	0.1%

Table 4
Itemized Operations and Maintenance Costs*

	Post-STA	Post-BMP
Average Yearly Flow Rate (mgd)	200	200
Personnel	1,393,658	1,393,658
Treatment Chemicals		
Alum	10,046,000	
Ferric Chloride		6,268,000
Polymer	608,820	608,820
Subtotal	**10,654,820**	**6,876,820**
Materials and Supplies		
Repair and Maintenance-Water Treatment	138,000	138,000
Sampling and Monitoring	200,000	200,000
Miscellaneous	240,000	240,000
Subtotal	**578,000**	**578,000**
Electric Power		
Water Treatment	1,562,000	1,562,000
Other	105,000	105,000
Subtotal	**1,667,000**	**1,667,000**
Waste Solids Treatment and Disposal		
Total Fixed Cost	**683,000**	**683,000**
Total Variable Cost	**13,610,478**	**9,832,478**
TOTAL ANNUAL O&M COST	**14,293,478**	**10,515,478**
Variable cost per million gallons	186.44	134.69

***From HSA report**

RESULTS OF FINDINGS

1. The pilot project met its four stated objectives of (1 and 2) finding a process to obtain 10 µg/L of phosphorous in treated water; (3) conducting an evaluation of alternatives; and (4) determining conceptual design criteria and costs.

2. Capital costs developed for the flocculation-sedimentation portion of the project appear to be low. We do not believe that this affected the comparison of alternatives. For planning purposes, to assure that enough money is available for construction, a more detailed conceptual design (and associated cost estimate) should be considered.

3. Estimated operating costs were confirmed via an independent estimate.

4. Cost economies may be available through the use of metal salt/acid combinations.

5. Additional research should be performed to determine viable methods of metal salt recovery, given its potential major cost impact.

ENVIRONMENTAL ISSUES

No unmitigable environmental issues should be encountered.

One positive environmental impact will be that most of the reactive phosphorous that passes through the facility will be tied up in an unavailable form, i.e., essentially insoluble aluminum phosphate, even if the sedimentation process does not separate the floc.

ADDITIONAL OBSERVATIONS

Chemical Dosages

The chemical doses shown from the pilot testing are consistent with doses that might be expected in waters with high dissolved organic carbon (DOC) concentrations. The high DOC concentrations appear to be controlling the required chemical doses, rather than the phosphorus or suspended solids. However, because ferric chloride and aluminum sulfate (alum) are considered weak acids, the use of hydrochloric or sulfuric acid to depress the pH to the optimal range for metal hydroxide precipitation could reduce chemical usage significantly. The use of acid would allow for lower metal salt doses and would thereby reduce the amount of sludge formed. Thus, the capital cost for land would be reduced.

Jar Testing

The pilot testing showed that the plate settling process without subsequent filtration could remove a substantial percentage of suspended solids. Based on this testing, the process has been proven effective. Periodically (more often during variable raw water quality periods), jar tests to determine proper metal salt and acid doses should be conducted.

Practicality

Because other water treatment plants are using plate sedimentation with alum or ferric salts, this process appears to be practical for the SFWMD. Other installations exist where pilot scale plate settlers have been scaled-up to full-scale, e.g. Detroit Water Department's Water Works Park.

Other Technologies

Sedimentation. One concern raised during the review was the inability of the pilot testing to identify another clarification process as a viable technology. While the jar testing and pilot testing identified a proper alum dose, the tested technologies could not remove sufficient suspended solids to meet the phosphorus goal. It is especially puzzling that dissolved air flotation (DAF) could not be optimized for particle removal. According to the testing team, the floc was very fragile and the DAF process broke up the floc and prevented removal by flotation. The use of non-ionic or anionic polymers added in the flocculation step can often overcome mechanical strength issues with alum flocs. While it is not certain if DAF could compete economically with plate sedimentation, the lack of a viable alternate process makes a cost comparison impossible. However, we feel that additional pilot testing of alternative sedimentation is not warranted, and that plate pack sedimentation is the most cost-effective alternative.

Metal Salt Recovery. The required chemical doses shown by the piloting effort result in a large chemical cost. If the aluminum or iron used could be recovered, substantial cost savings might be realized. Two patented processes exist for alum recovery from water treatment plant residuals. Both processes involve acidification of aluminum hydroxide sludge to re-solubilize the aluminum.

The Jersey City (New Jersey) water treatment plant has facilities installing for the Fulton alum recovery process (patented by George Fulton circa 1974). Except for acceptance testing, to our knowledge it was never used. This system uses acidification (addition of sulfuric acid) of alum sludge followed by filtration through precoated, recessed plate filter presses to recover the alum. Fly ash may also be used as a filter aid.The aluminum is then recovered and reused. A similar process could be used here. The metal salt sludge would be acidified and the phosphate ions separated from the aluminum or iron by swings in pH or ion exchange. More effort on theoretical, conceptual, and practical bases would be required to develop this concept.

The Cornwell process, developed Dr. David Cornwell, uses acidulation followed by separation of aluminum using a chelant carrier. This process has been studied under AWWARF funding, but, to our knowledge, has not been used commercially. It may have direct application the SFWMD project, and should be further investigated.

The sludge production rates will be what they are and specific to the water being treated, therefore should be used for determining residual costs.

Table A-1
Estimated Chemical Usage Costs

	Post- STA	Post-BMP	Comments
Alum			
Dose, mg/l as Al	20.0		
Use, lb/Mgal	1834.8		
Cost, $/lb	0.075		$150/dry ton
Cost $/Mgal	137.61		
Ferric Chloride			
Dose, mg/l		40.0	
Use, lb/Mgal		954.1	
Cost, $/lb		0.09	$180/dry ton
Cost $/Mgal		85.87	
Polymer			
Dose, mg/l	0.50	0.50	
Use, lb/Mgal	4017	4017	
Cost, $/lb	2.00	2.00	
Cost $/Mgal	8.34	8.34	
Total, $/Mgal	145.95	94.21	

Table A-2
Estimated Electrical Usage Costs

	Post-STA	Post-BMP
Unit power cost, $/kwh	0.080	0.080
Average Yearly Flow Rate (mgd)	200	200
Low-Lift Pumping		
Headloss through plant, ft.	10	10
Power, ft-lb/sec-mgd	965	965
Pump efficiency, %	80%	80%
Pump horsepower, HP/mgd	2.19	2.19
Motor efficiency, %	94%	94%
Motor power, kw/mgd	1.74	1.74
Power used, kwh/Mgal	41.8	41.8
Rapid Mixing		
Number of units	4	4
Number of stages	1	1
1st stage "G", 1/sec	500	500
Volume of each stage, cu.ft.	7,737	7,737
Total volume, cu. ft.	30,947	30,947
1st stage power used, ft-lb/sec	52,900	52,900
Mixing power efficiency, %	80%	80%
1st stage HP	120	120
Motor efficiency, %	92%	92%
1st stage kw	97	97
Detention time, sec	100	100
Capacity, mgd	50.00	50.00
Power usage, kwh/Mgal	46.8	46.8

	Post-STA	Post-BMP
Flocculation		
Total detention time, min	30	30
Number of basins	4	4
Number of stages	2	2
1st Stage "G", 1/sec	100	100
2nd Stage "G", 1/sec	40	40
Volume of each stage, cu.ft.	69,630	69,630
Total volume, cu. ft.	557,041	557,041
1st Stage power used, ft-lb/sec	19,044	19,044
2nd Stage power used, ft-lb/sec	3,047	3,047
Mixing power efficiency, %	80%	80%
1st Stage HP	43.28	43.28
2nd Stage HP	6.93	6.93
Motor efficiency, %	92%	92%
1st Stage kw	35.08	35.08
2nd Stage kw	5.61	5.61
Total power usage, kw	162.78	162.78
Power usage, kwh/Mgal	19.5	19.5
Lamella Settling		
Number of units	4	4
Collector Drive HP	5	5
Drive service factor	0.6	0.6
Motor efficiency	0.92	92%
Total power usage, kw	9.73	9.73
Power usage, kwh/Mgal	1.2	1.2
Total Power Use (Water Treatment), kw		
Total Power Use (Water Treatment), kwh/Mgal	267.5	267.5
Miscellaneous Electrical Energy (All)		
Estimated average other use, kw	150	150
Power use, kwh/yr	1,314,000	1,314,000

Table A-3
Estimated Waste Solids Treatment and Disposal Costs

DIVISION 5 **WASTE SOLIDS TREATMENT AND DISPOSAL**	Post-STA 0	Post-BMP 0
Waste Solids Generation (All)		
Average SS removal, mg/l	4.3	26.5
Average TOC precipitated, mg/l	17.0	10.0
Total from raw water solids, lb/Mgal	350.9	406.3
Alum dose, mg/l	20.0	0.0
From alum, lb/Mgal	926.7	0.0
Ferric dose, mg/l		40.00
From ferric, lb/Mgal	0.0	959.1
Polymer dose, mg/L	0.5	0.5
% Active	40.0	40.0
From polymer, lb/Mgal	1.7	1.7
Total, lb/Mgal	1279.3	1367.1
Total, mg/l	153.4	163.9
Waste Solids Disposal (All)		
Total cost, $/dry ton	0.00	0.00
Total cost, $/million gallons	0.00	0.00