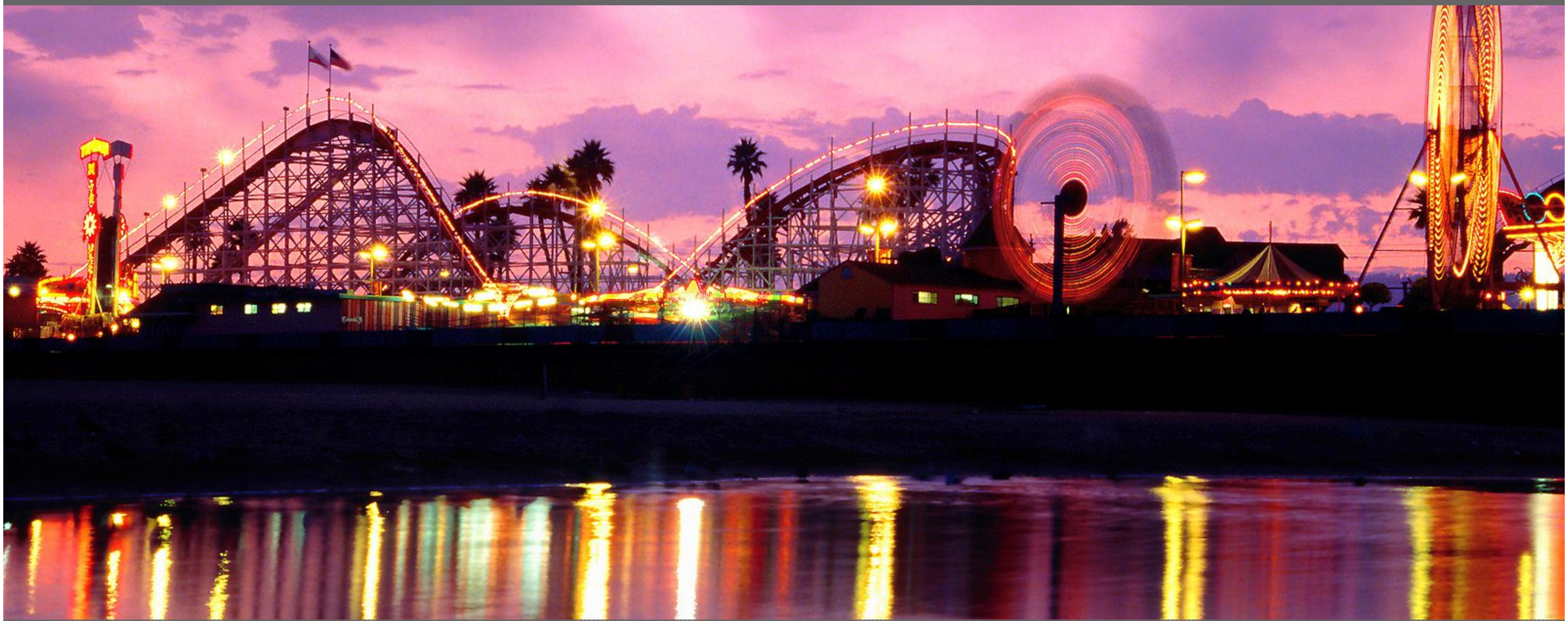
TTHM Removal Performance Comparison

2013 Fall CA/NV AWWA Section Conference

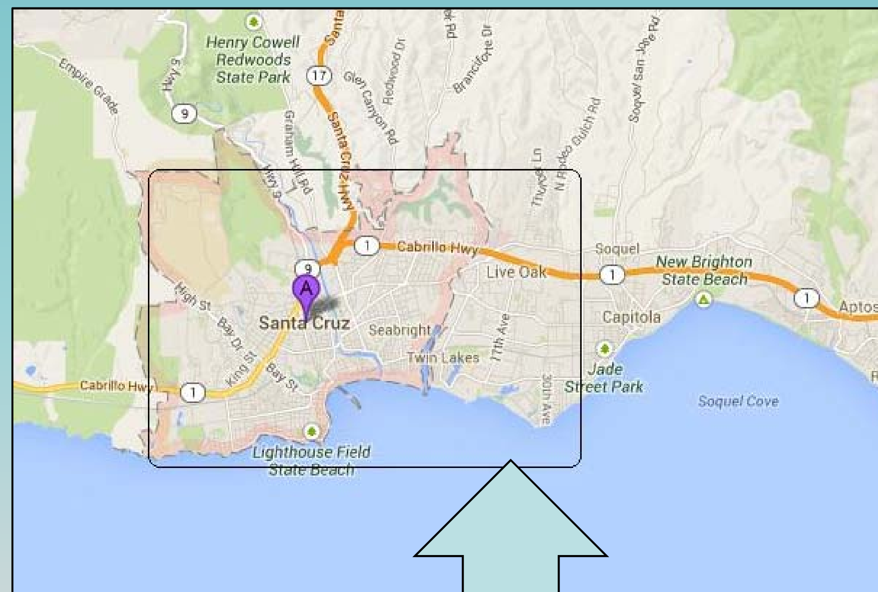


City of Santa Cruz Water Department

Background

City of Santa Cruz Service Area

Santa Cruz County



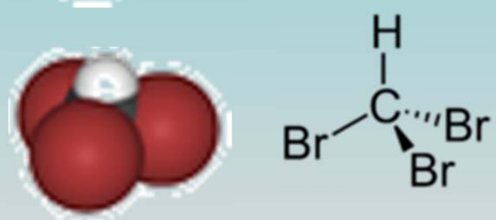
Approximate City of Santa Cruz Service Area

What are THM's?

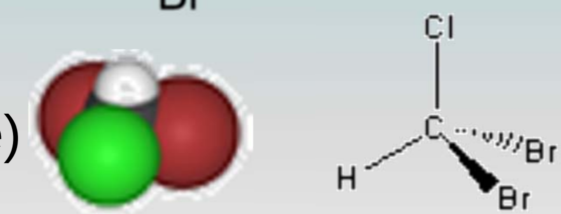
Total Trihalomethanes (TTHM's) are disinfection by-products (DBP) which are Volatile Organic Carbon in the forms of :

- $CHCl_3$ (Chloroform)

- $CHBr_3$ (Bromoform)



- $CHBr_2Cl$ (Chlorodibromomethane)

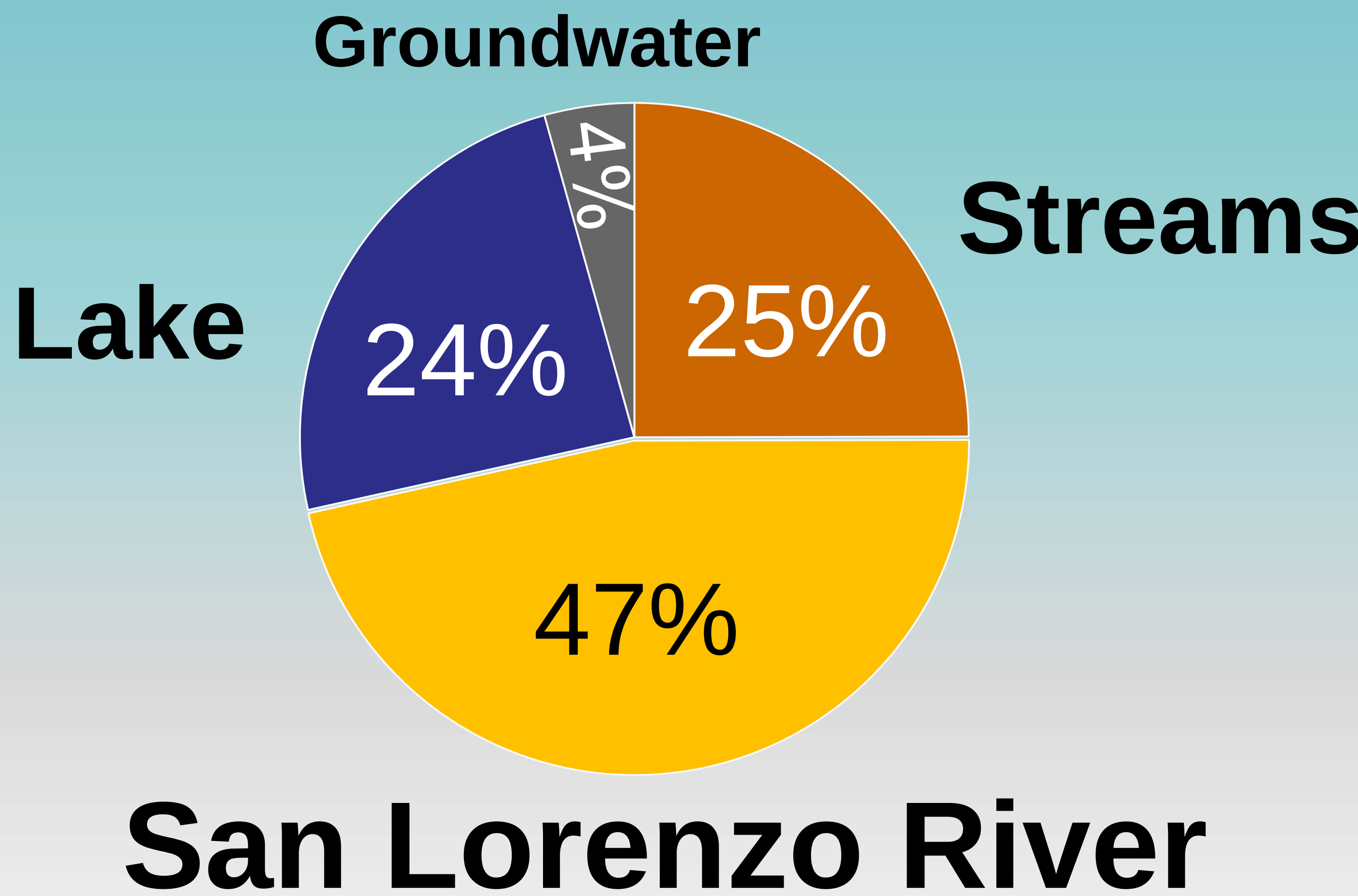


- $CHBrCl_2$ (Bromodichloromethane)

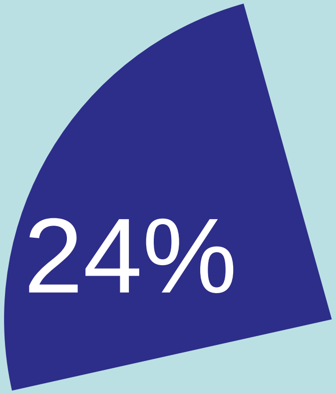
Why are THM's of Concern?

- According to the EPA, people who drink water containing total trihalomethanes in excess of the MCL over many years could experience liver, kidney, or central nervous system problems and increased risk of cancer
- The maximum contaminate level for THM's is 80 µg/L, for drinking water

City of Santa Cruz Water Sources



THM Source Formation Potentials

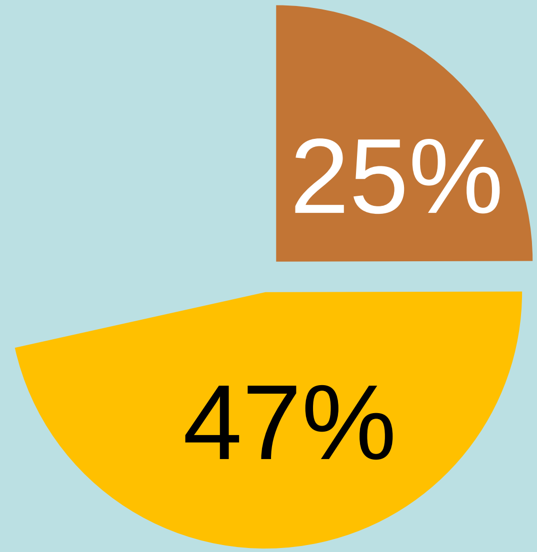


Lake

TTHM's
140 ppb

EPA

MCL
80 ppb



River/Stream

TTHM's
70 ppb

Addressing Future Challenges

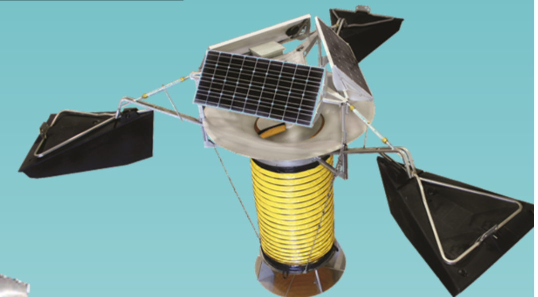
- Rigorous EPA/CDPH regulations on Maximum Contamination Level (MCL) of DBP's

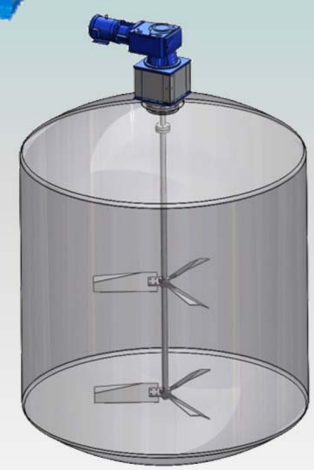
- More Stringent regulations by California Department of Fish and Wildlife
  - Decreased supply from stream and river sources
  - Increased reliance on lake source

- Expensive treatment plant upgrades
  - Distribution treatment options

TTHM Control

Commercially Available Technology





Build an own In-House unit?

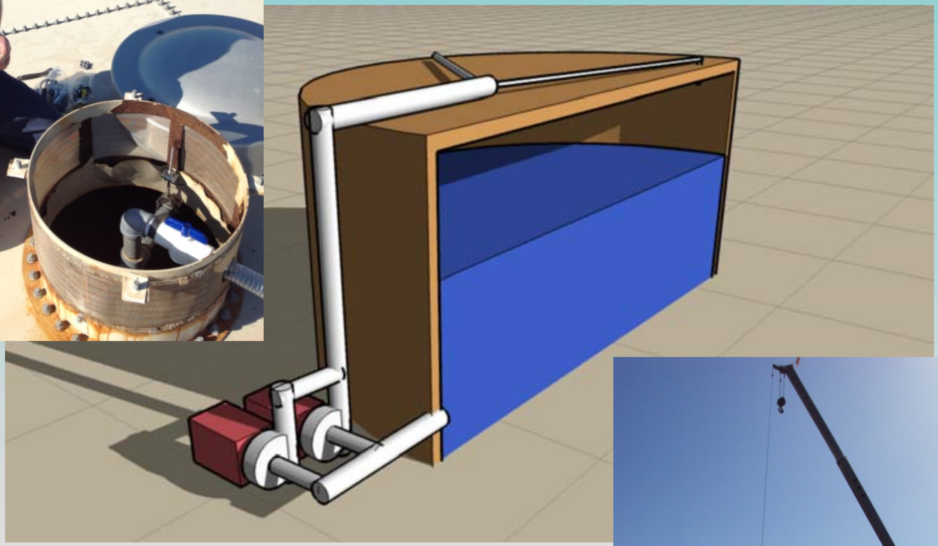
I. "Storage Tank Aeration Eliminates TTHM's"
   - Walfoort, Messina, Miner
     - Suisun-Solano Water Authority
   - Opflow May 2008

II. "Posttreatment to Reduce THM's"
   - Ethan Brooke
   - JAWWA 2011

"…spray Aeration appears to be a more efficient approach to THM stripping"

Challenges for an In-House unit

- **Material**
  - NSF approval
- **Personnel**
  - Fabrication
- **Design**
  - Criteria
- **Installation**
  - Constraints



Investigative Study

- Find the most effective unit that best meets our needs
- Compare the performance of commercially available products to an In-House unit
- Provide qualitative and quantitative data for meeting EPA/CDPH Stage 2 requirements

Performance Evaluation

Quantitative

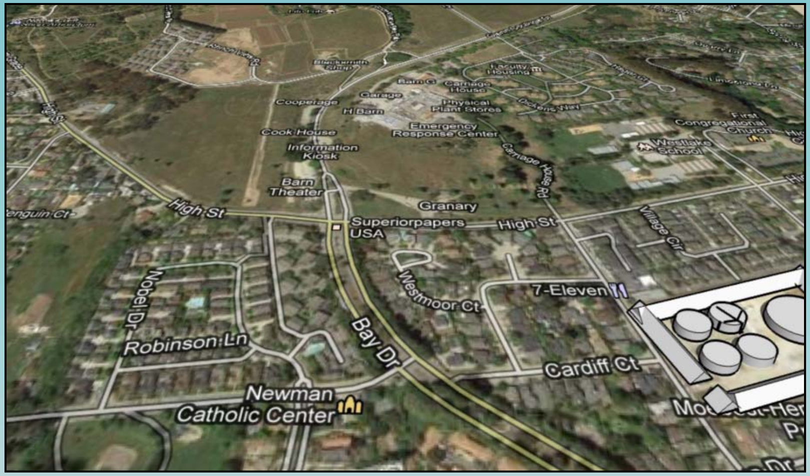
- TTHM Reduction
- Life Cycle Cost
- Stratification Reduction
- Chlorine Residual

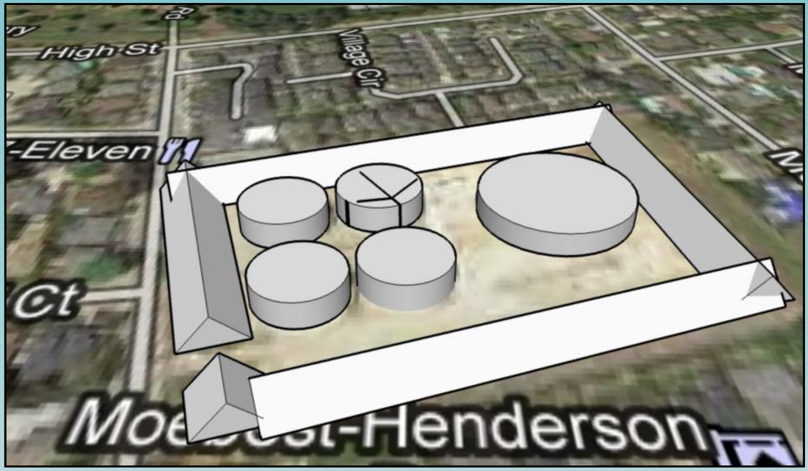
Qualitative

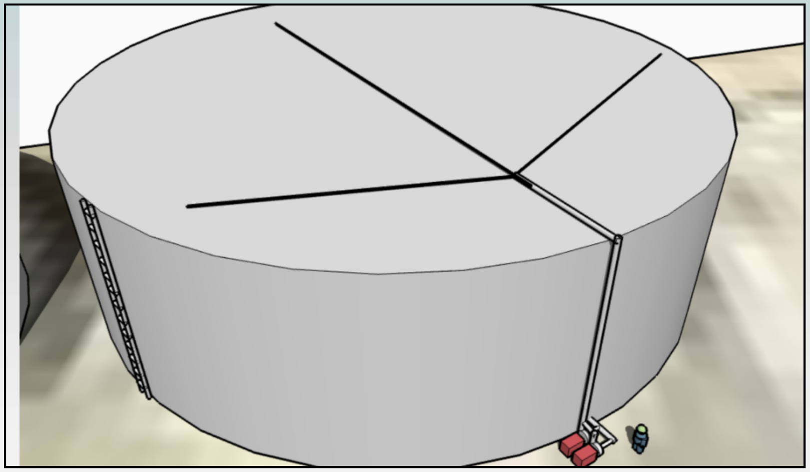
- Ease of Installation/Removal
- Maintenance Required
- Noise Threshold

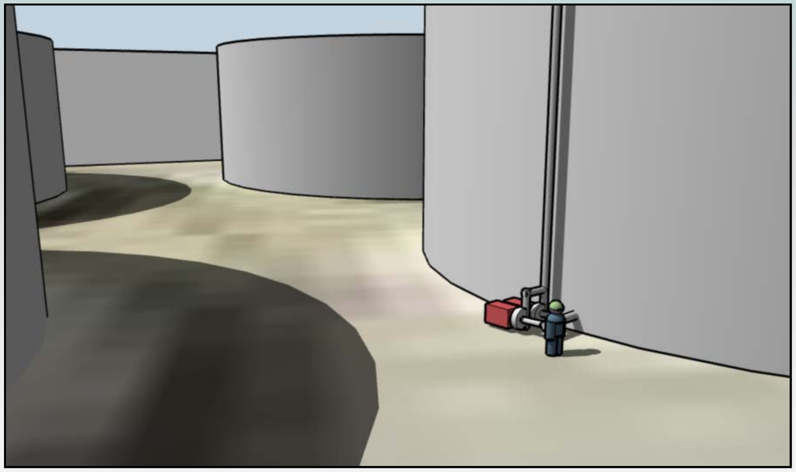
Testing Site:

Bay Street Reservoir









Testing Site

- (2) planned 6 MG pre-stressed reinforced concrete tanks
- (4) existing 1.5 MG temporary bolted steel tanks
- Common influent
- Isolated system of tanks

Results

In-house Results

Pros

- **Serviceability**
  - Accessibility
- **Installation**
- **ON/OFF Toggling**
- **Site Specific Considerations**
  - Pump/Pipe/Power
- **Modification Possibilities**
- **Weight of Unit**

Cons

- **Power Consumption**
- **Material Certification**
  - NSF/ANSI/FDA
- **Noise Pollution**
- **Aesthetics**
- **Warranty**
- **Design Flaws**

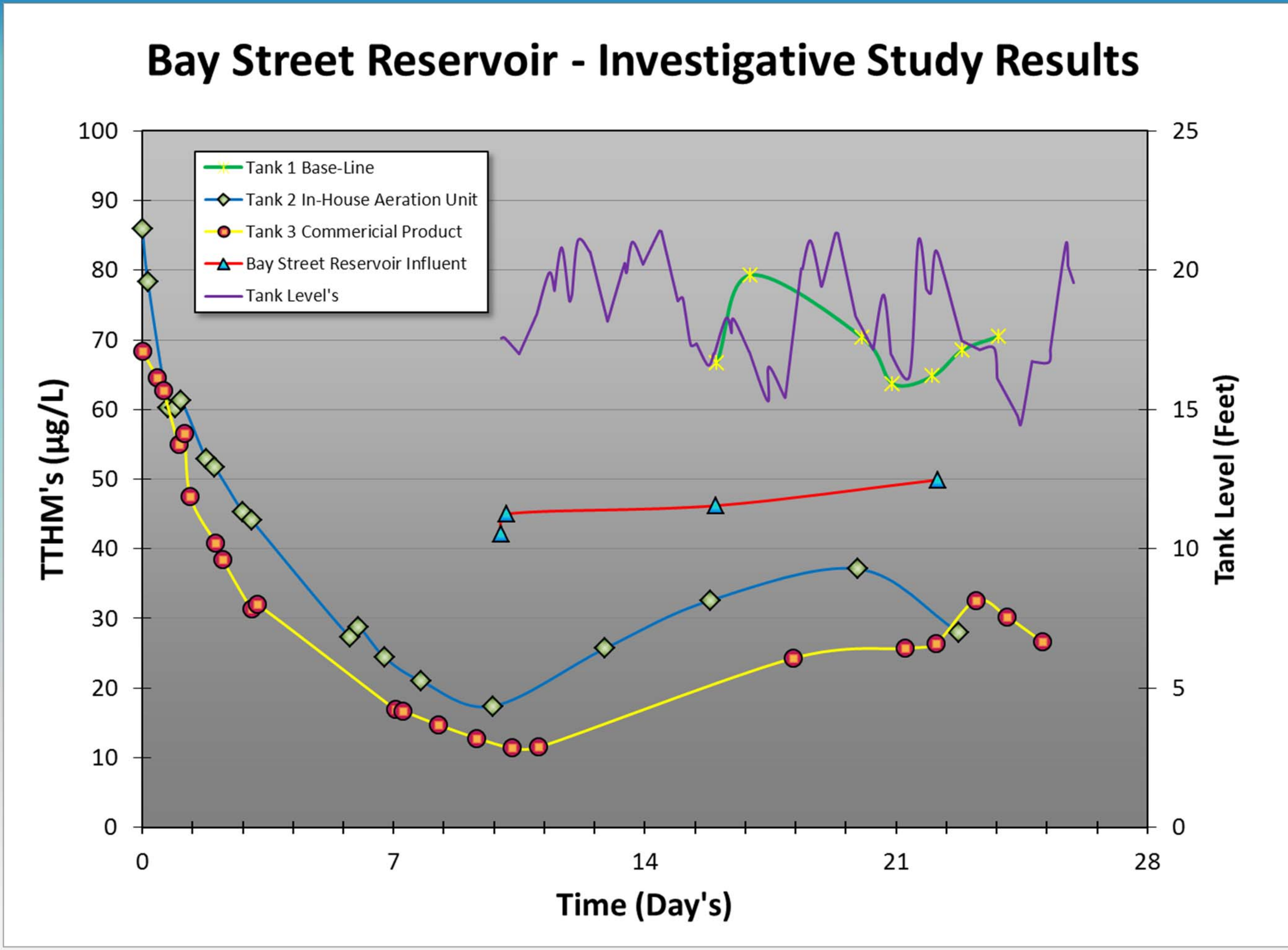
Commercially Available Product

Pros

- **Power Consumption**
- **ON/OFF Toggling**
- **Material Certification**
  - NSF/ANSI/FDA
- **Aesthetics**
- **Warranty**
- **Design**
  - Research and Development

Cons

- **Serviceability**
  - Accessibility
- **Noise Pollution**
- **Installation**



Bay Street Reservoir - Investigative Study Results
Tank 1 Base-Line
Tank 2 In-House Aeration Unit
Tank 3 Commericial Product
Bay Street Reservoir Influent
Tank Level's
TTHM's (µg/L)
Tank Level (Feet)
Time (Day's)
0
10
20
30
40
50
60
70
80
90
100
0
5
10
15
20
25
0
7
14
21
28

Conclusion

- It is possible to build an In-House aerator and obtain THM reduction
- The pros and cons of building an In-House unit must be carefully analyzed prior to installation
- Negotiating a trial period with mixing/aeration vendors can present its own challenges
- At minimum, water department staff will learn more about the process of removing THM's

Thank You

- Questions?

- Contact
  - Terry McKinney
    - City of Santa Cruz Water Department
    - Production Superintendent
    - tmckinney@cityofsantacruz.com

CITY OF SANTA CRUZ

WATER ADMINISTRATION
212 Locust Street, Suite A, Santa Cruz, CA 95060 • Ph: 831-420-5210

July 1, 2014

State of California Water Resources Control Board
Division of Water Rights
P.O. Box 2000
Sacramento CA 95812-2000

Attn: Barbara Evoy, Deputy Director for Water Rights

Subject: Order Approving Petition for Temporary Urgency Change (TUCP), License 9847 (Application 17913) City of Santa Cruz

Dear Ms. Evoy,

The State Water Board approved the City's TUCP on February 14, 2014. The Order allows a temporary, 180 day reduction in the downstream bypass/release from Newell Creek Reservoir from 1.0 cubic feet per second (cfs) to 0.2 cfs. The impact of the TUCP over the first four months has been to save 64 million gallons of storage in the reservoir. The TUCP is proving to be a significant benefit to the City's ability to manage the very real water shortage emergency we are facing.

Among the conditions of approval in the order are (1) reduce water demand by 20% of normal water use by instituting water rationing and promoting conservation; (2) monitor the effects of the amended release or bypass amount on fisheries resources and take all necessary steps to avoid harm to fish in Newell Creek; (3) submit a written report to the Deputy Director for Water Rights that summarizes all activities conducted to ensure compliance with the requirements of this Order, and the amount of water use reduction achieved. This report has been prepared to summarize our progress on these requirements.

Effect of Drought Response on Water Use

The City adopted and implemented a program by May 1, 2014, to meet with water reduction goals described in Stages 3 through 5 of the City Water Shortage Contingency Plan. On February 24, 2014, the City declared a Water Shortage Emergency in accordance with the Water Shortage Contingency Plan, which mandates 20% reduction in water use beginning May 1, 2014. Prior to that the City had been under continuous use reductions of 5% to 20%, since May 2013.

Reduction in use achieved for May 2014 was 18.3%, and as of June 20, 2014, 24%. While demand hardening due to our long standing pre-existing conservation programs makes new reductions in water use more difficult, the community is rising to the challenge.

The following sections detail just some of the many actions taken by the City to achieve the required use reduction.

1) is used to calculate these parameters and determine if the amount of carryover storage in Loch Lomond at the end of the year will be sufficient to meet essential health and safety needs in case the dry weather pattern continues into the following year, and ultimately, if even more aggressive use restrictions will be necessary. It also provides the data used to track use, as seen in the 2014 Water Production Targets (Attachments 2 and 2A). Attachment 3 is from the City website and states the goals for this year's program and Attachment 3A provides status of reduction achieved.

Implementation of Stage 3 Rationing

The City Water Department developed an action plan anticipating the activities that would be needed to successfully achieve the necessary reduction in water use. Attachment 4 describes these actions along with expected results, responsible staff, and status.

The City's strategy for dealing with water shortages of all levels involves the following four interrelated components:

A. Allocation system to establish reduction goals for different customer groups. Attachments 5 and 6 are the residential and business customer allotments developed for 2014.

B. Demand reduction measures. This element includes the actions necessary to declare a water emergency and provide the Water Department the authority to put rationing into effect and to fund the required activities. Attachments 7 and 8 are the City Council report for drought implementation and the City Council water emergency resolution.

C. Publicity and communications. The Water Department is conducting an aggressive and extensive public outreach and information program, making numerous mail outs, bill stuffers, and website information available in both English and Spanish. During the two months before rationing went into effect contact was made with all customer classes. The Rationing Communications Summary (Attachment 9) summarizes this effort, a good deal of which will be ongoing for the duration of rationing. Attachments 10 to 13 are examples of some information items distributed to customers.

D. Operating actions. The Water Department and other City Departments that use water in their normal operations have implemented a significant number of modified and new procedures to curtail their use. Attachment 14 details these actions.

Fiscal Impact

The required budget adjustment (Attachment 15) transferred $280,000 within the existing FY 2014 Water Department budget, and allocates an additional $420,000 for Stage 3 water rationing. Additional allocations for next fiscal year estimated to be $450,000, will be incorporated into the FY 2015 budget. Along with these additional costs of approximately $1,025,000, the lost revenue from decreased sales is expected to be around $1.1 million. Taken together, they have a material impact on the financial situation of the City and its Water Department, and unfortunately will require a significant rate increase in the near future.

Newell Creek Monitoring Results and Discussion

Monitoring of Newell Creek downstream of the reservoir began in early February 2014 and will continue as long as the TUCP remains in effect. By March 1, 2014, The City submitted to you a plan for compliance with Condition 2 of the TUCP Order, a copy of which is attached as

Attachment 16. This monitoring (Attachment 17) indicates that the reduced bypass flow has not changed passage conditions in critical riffles nor created any areas of hydrologic discontinuity.

Conclusion

The City is in compliance with the Order. We appreciate the assistance of the SWRCB to mitigate one of the impacts of the serious water shortage condition we are facing. As the dry season proceeds, we are seeing even lower flows in our local (and only) sources of municipal water supply. Absent material change to the prevailing hydrologic conditions, we anticipate needing to extend this order before its expiration on or about August 13, 2014. We will be in touch with you to coordinate that effort.

Please let us know if you have any questions or concerns. Again, we appreciate the opportunity to work in a collaborative manner to mitigate one of the impacts of this severe drought.

Sincerely,

for Terry Tompkins

Rosemary Menard
Water Director
City of Santa Cruz

Cc w/enc Martha Lennihan

CITY COUNCIL
AGENDA REPORT

DATE: 4/1/2014

AGENDA OF: 4/8/2014

DEPARTMENT: Water

SUBJECT: Budget for Implementation for Stage 3 Water Rationing – Budget Adjustment (WT)

Budget adjustment updated on 04/07/14.

RECOMMENDATION: Resolution amending the Water Department's FY 2014 Budget to authorize expenditures in the net amount of $419,656 to address the financial impact of implementing Stage 3 water rationing.

BACKGROUND: On February 25, 2014 the City Council adopted a resolution declaring a water shortage emergency and calling for at least a 25% reduction in normal water usage beginning May 1, 2014. The Water Department has been working diligently since then to identify and develop the various resources and systems needed to implement Stage 3 rationing effectively over the next seven months through October 2014.

The City has not had to implement such drastic water restrictions since 1990, but we are fortunate to have as a guide for this work the Water Shortage Contingency Plan approved by Council in 2009 which incorporates the lessons learned from those earlier restrictions.

DISCUSSION: We currently project needing additional resources in each of following sections of the Water Department to implement Stage 3 rationing. Note that all additional employees will be hired for no more than six months and costs include office or field equipment needed to support their work.

Costumer Service:
This section of the Water Department handles water account management and billing and will be the front line of communication with account holders about reduced water budgets and adjusted allocations. Anticipated resources needed are:

- Informational mailings to account holders regarding water rationing;
- Four (4) additional office employees to respond to increased customer communications and requests for adjusted allocations; and
- Two (2) additional field employees to respond, in the community, to customer requests about their service account and meter operations, and to help customer identify possible leaks.

Conservation:
The Conservation section will be the center of outreach into the community about rationing and ways to conserve to meet reduced water budgets. Anticipated resources needed are:

- Two (2) additional outreach employees to develop outreach materials, make presentations, staff information booths and events, and conduct customer water audits;
- Two (2) field employees to respond to water waste complaints, patrol to enforce water conservation ordinances, educate customers on drought restrictions, and issue violations when customers do not respond to education;
- Printed education and demonstration materials; and
- Conservation devices for free distribution.

Administration:
Anticipated resources needed in Water Administration are:

- One (1) additional coordinator position is needed to assist in the development and subsequent management of the violation appeals process modeled after the processed used for parking citation appeals;
- One (1) administrative employees to provide support to the violation appeals process as well as increased public communications efforts; and
- Critical public communications efforts including print and broadcast advertising.

Production:
As a result of reduced water flows, we expect to be treating water with higher turbidity. This has a significant impact on our water treatment system, requiring equipment changes, increased chemicals, and additional maintenance to ensure effective operations, including:

- Relocating and adding aerators and other treatment equipment;
- Increased costs for chemicals, electricity, and wastewater services; and
- One (1) additional plant mechanic to address increased maintenance needs caused by drought water conditions.

Distribution/Meter Shop:
We anticipate more calls to locate check and repairs water meters as customer focus more on their water usage.

- Two (2) additional meter technicians to conduct increased water meter reads, repairs and resolve meter problems in a more timely manner; and
- Accelerating the purchase of two trucks ($48,000), originally scheduled to be purchased in FY 2015, to take advantage of competitive pricing and provide staff with trucks needed for drought-related meter work.

The estimated total cost of these additional resources is $1,033,011; with $699,656 of that total needed in the Water Department's FY 2014 budget and $333,355 in FY 2015. We must caution that the factors on which these estimates are based are not fixed, but will be affected by changing drought conditions, human responses to necessary change, and other varying factors, that may make it necessary to return to Council with further adjustments.

The Department will cover a portion of the current FY 14 year costs by re-programing $280,000 in existing budget allocations for net cost of $419,656 in the current year. Drought planning has dominated much of the work in the Department during the last several months and work originally planned to be completed in FY 2014 was postponed allowing these budgeted amounts to be re-directed for drought related expenses. But additional allocation is still needed.

We also anticipate some revenue loss over the coming months as customers successfully conserve more water, and expect to use some of the current $2.4 million balance in the Water Rate Stabilization Fund to cover those lost revenues. We will return to Council at a later date to report on the specifics of that needed transfer.

Lastly, the Water Department would like to acknowledge the efforts of our other city department partners: Information Technology, Human Resources, Finance, and Public Works. Understanding the importance and timing of our efforts to implement a 25% reduction in water use, staff in these departments have shuffled their own priorities; worked long hours alongside Water Department staff; and have made a May 1st implementation date possible.

FISCAL IMPACT: The cost of implementing Stage 3 water rationing over the next seven months through October 2014 is currently projected to at $1,033,011; with $699,656 of that total needed in the Water Department's FY 2014 budget and $344,581 in FY 2015. In FY 2014, the $651,656 will be offset by reallocating existing resources for a net cost in FY 2014 of $419,656.

Council approval is requested of a budget adjustment that transfers $280,000 within the existing FY 2014 Water Department budget, and allocates an additional $419,656 for Stage 3 water rationing. Additional allocations for next fiscal year will be incorporated into the FY 2015 Recommended Budget.

Prepared by:	Submitted by:	Approved by:
Nicole Dennis	Rosemary Menard	Martín Bernal
Principal Management Analyst	Water Director	City Manager

ATTACHMENTS:
Budget Adjustment

City of Santa Cruz
BUDGET ADJUSTMENT REQUEST

○Council Approval .... Resolution No. ____________
○Successor Agency .... Resolution No. ____________
○Administrative Approval

○Current Fiscal Year
○Prior Fiscal Year

TO: FINANCE DIRECTOR
FROM: Water Department's FY 2

DATE:

ACCOUNT	REVENUE EDEN ACCOUNT TITLE	
	TOTAL REVENUE	0

City of Santa Cruz
BUDGET ADJUSTMENT REQUEST

TO: FINANCE DIRECTOR DATE:

FROM: Water Department's FY 2

ACCOUNT	EXPENDITURE EDEN ACCOUNT TITLE	
	see attached spreadsheet	
	TOTAL EXPENDITURE	0

NET: $ 0

Purpose:

Water Department's FY 2014 budget adjustments for implementation of Stage 3 Water Rationing

REQUESTED BY	DEPARTMENT HEAD APPROVAL	ACCOUNTING APPROVAL	FINANCE DIRECTOR APPROVAL	CITY MANAGER APPROVAL
Nicole B. Dennis (Digitally signed by Nicole B. Dennis)	Rosemary Menard (Digitally signed by Rosemary Menard)	Cheryl Fyfe (Digitally signed by Cheryl Fyfe)	Marcus Pimentel (Digitally signed by Marcus Pimentel)	
04/02/14	04/01/14	04/02/14	4/02/14	

Revised September 2012

Water Department
Drought Response CY 2014

Fund	Dept.	Division	New Drought Activity	Object	Description	Section Name	Total Expense	FY 2014 Budget Adjustment	FY 2015 Recommended Budget
711	70	90	7199	51122	Temporary	Administration	$ 69,720	34,860	34,860
711	70	90	7199	52199	Prof. & Tech Services	Administration	$ 42,500	42,500	-
711	70	90	7199	52261	Eqpmt, Bldg, Land Rentals	Administration	$ 1,260	1,260	-
711	70	90	7199	52960	Advertising	Administration	$ 22,850	8,000	14,850
711	70	90	7199	54203	Computer - non capital	Administration	$ 6,200	6,200	-
711	70	90	7199	54205	Telecommunications Equip	Administration	$ 400	400	-
711	70	90	7199	54990	Misc. supplies and services	Administration	$ 1,000	1,000	-
711	70	90	7199	57401	Office furniture equipment	Administration	$ 6,000	6,000	-
							$ 149,930	100,220	49,710
711	70	92	7199	51122	Temporary	Customer Svc	$ 115,750	57,875	57,875
711	70	92	7199	52199	Prof. & Tech Services	Customer Svc	$ 6,500	5,000	1,500
711	70	92	7199	52227	Fuel Charges	Customer Svc	$ 4,800	2,000	2,800
711	70	92	7199	52261	Eqpmt, Bldg, Land Rentals	Customer Svc	$ 2,500	1,000	1,500
711	70	92	7199	52972	Printing Outside	Customer Svc	$ 9,011	6,011	3,000
711	70	92	7199	53101	Postage	Customer Svc	$ 3,500	3,000	500
711	70	92	7199	53118	Uniforms	Customer Svc	$ 280	280	-
711	70	92	7199	54203	Computer - non capital	Customer Svc	$ 6,000	6,000	-
711	70	92	7199	54205	Telecommunications Equip	Customer Svc	$ 800	800	-
711	70	92	7199	57401	Office furniture equipment	Customer Svc	$ 12,000	12,000	-
							$ 161,141	93,966	67,175
711	70	93	7199	51122	Temporary	Conservation	$ 88,000	38,000	50,000
711	70	93	7199	52199	Prof. & Tech Services	Conservation	$ 50,000	50,000	
711	70	93	7199	52227	Fuel Charges	Conservation	$ 4,800	2,000	2,800
711	70	93	7199	52261	Eqpmt, Bldg, Land Rentals	Conservation	$ 1,000	1,000	-
711	70	93	7199	52972	Printing Outside	Conservation	$ 10,000	6,000	4,000
711	70	93	7199	53101	Postage	Conservation	$ 5,000	3,000	2,000
711	70	93	7199	53114	Program Operating supplies	Conservation	$ 85,000	25,410	59,590
711	70	93	7199	54203	Computer - non capital	Conservation	$ 3,600	3,600	-
711	70	93	7199	54205	Telecommunications Equip	Conservation	$ 600	600	-
711	70	93	7199	57401	Office furniture equipment	Conservation	$ 6,000	6,000	-
							$ 254,000	135,610	118,390
711	70	95	7199	51122	Temporary	Production	$ 31,320	15,660	15,660

Water Department
Drought Response CY 2014

Fund	Dept.	Division	New Drought Activity	Object	Description	Section Name	Total Expense	FY 2014 Budget Adjustment	FY 2015 Recommended Budget
711	70	95	7199	52201	Water, sewer and refuse	Production	$ 19,000	19,000	
711	70	95	7199	52227	Fuel Charges	Production	$ 4,800	2,000	2,800
711	70	95	7199	53103	Chemicals	Production	$ 80,000	35,000	45,000
711	70	95	7199	53118	Uniforms	Production	$ 350	350	-
711	70	95	7199	53311	Electricity	Production	$ 16,000	7,000	9,000
711	70	95	7199	57990	Other capital outlay	Production	$ 218,330	218,330	-
							$ 369,800	297,340	72,460
711	70	96	7199	53103	Chemicals	Lab	$ 5,000	2,000	3,000
							$ 5,000	2,000	3,000
711	70	97	7199	51122	Temporary	Distr./Meter Shop	$ 39,640	19,820	19,820
711	70	97	7199	52227	Fuel Charges	Distr./Meter Shop	$ 4,800	2,000	2,800
711	70	97	7199	53118	Uniforms	Distr./Meter Shop	$ 700	700	-
711	70	97	7118	57402	Vehicle Equipment	Distr./Meter Shop	$ 48,000	48,000	
							$ 93,140	70,520	22,620
						Total	$ 1,033,011	699,656	333,355
711	70	90	7101	57203	Building Remodeling	Administration	$ (120,000)	(120,000)	-
711	70	90	7101	57401	Office furniture equipment	Administration	$ (30,000)	(30,000)	-
711	70	93	7104	52199	Prof. & Tech Services	Conservation	$ (120,000)	(120,000)	-
711	70	96	7107	52199	Prof. & Tech Services	Lab	$ (10,000)	(10,000)	-
							$ (280,000)	(280,000)	-
						Grand Total	$ 753,011	419,656	333,355

CITY OF SANTA CRUZ

TTHM

Stage 2 Quarterly Disinfection Byproducts Compliance Report

Begin STAGE 2 compliance October 1, 2012

Monitoring Results and Locational Running Annual Averages (LRAA)

ug/L or ppb

City of Santa Cruz Water Department
System No. CA4410010

Report Date:

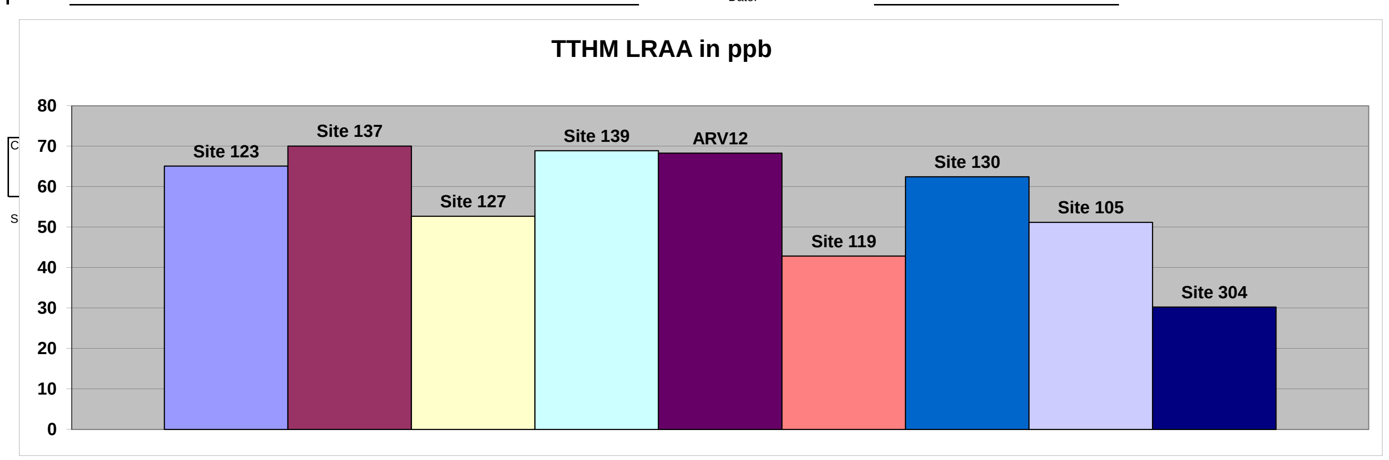
	Site 123			Site 137			Site 127			Site 139			Site ARV12			Site 119			Site 134			Site 105			Site 304			
Date	Ponderosa Dr	LRAA	OEL	Tanner Heights	LRAA	OEL	Swift & Modesto St	LRAA	OEL	Coast Rd	LRAA	OEL	Branciforte Dr	LRAA	OEL	Morrissey & Marnell	LRAA	OEL	Thurber and Winkle	LRAA	OEL	Gross Rd	LRAA	OEL	GHWTP Finished Water	Date Sampled	Basins Online	LRAA
6/14/2000							49.5			57.5						40.1			55.1						43.8	6/14/2000		
9/28/2000							54.9			79.0						45.0			67.6						43.3	9/28/2000		
12/26/2000							36.6			58.1															26.7	12/26/2000		
3/28/2001							40.9	45.5		58.6	63.3					36.3			40.4						29.8	3/28/2001		35.9
6/22/2001							64.2	49.2		84.6	70.1					54.7			73.3						48.4	6/21/2001		37.1
9/21/2001							42.8	46.1		64.9	66.6					39.5			59.4						36.3	9/21/2001		35.3
11/1/2001							68.1	54.0		63.1	67.8					64.6	48.8		55.3	57.1					59.4	11/1/2001		43.5
3/12/2002							40.1	53.8		43.7	64.1					32.0	47.7		61.6	62.4					27.9	3/13/2002		43.0
7/16/2002							62.3	53.3		71.5	60.8					45.2	45.3		69.6	61.5					41.7	7/17/2002		41.3
10/29/2002							38.8	52.3		52.6	57.7					31.0	43.2		45.8	58.1		19.8						43.0
4/17/2003							40.2	45.4		45.5	53.3					35.0	35.8								28.9	4/17/2003		32.8
7/8/2003							47.3	47.2		59.1	57.2					42.0	38.3					62.1			38.2	7/9/2003		36.3
3/19/2004							39.0	41.3		66.7	56.0					34.7	35.7								28.4	3/19/2004		31.8
5/14/2004							46.8	43.3		65.4	59.2					42.8	38.6			#DIV/0!					38.2	5/14/2004		33.4
8/27/2004							66.3	49.9		84.6	69.0					55.9	43.9			#DIV/0!					49.9	8/27/2004		38.7
2/10/2005							28.9	45.3		50.8	66.9					24.3	39.4			#DIV/0!					22.9	2/11/2005		34.9
5/27/2005							40.5	45.6		65.8	66.7					35.5	39.6			#DIV/0!					32.2	5/27/2005		35.8
8/26/2005							48.1	46.0		64.3	66.4					46.8	40.6			#DIV/0!					41.9	8/26/2005		36.7
5/18/2006							40.3	39.5		52.6	58.4					33.1	34.9			#DIV/0!					29.7	5/18/2006		31.7
8/10/2006							46.0	43.7		63.7	61.6					40.3	38.9			#DIV/0!					41.7	8/10/2006		36.4
11/16/2006							54.7	47.3		60.6	60.3					44.3	41.1			#DIV/0!					38.2	11/16/2006		37.9
2/26/2007							42.1	45.8		54.3	57.8					41.4	39.8			#DIV/0!					34.1	2/26/2007		35.9
5/24/2007							41.0	46.0		55.0	58.4					32.9	39.7			#DIV/0!								38.0
8/9/2007							51.4	47.3		60.5	57.6					44.4	40.8			#DIV/0!					44.4	8/9/2007		38.9
11/2/2007							53.7	47.1		59.1	57.2					42.4	40.3			#DIV/0!								39.3
2/20/2008							28.4	43.6		33.5	52.0					24.1	36.0			#DIV/0!					20.8	2/20/2008		32.6
5/22/2008							61.6	48.8		71.7	56.2					46.9	39.5			#DIV/0!					39.0	5/22/2008		34.7
8/21/2008	84.9			70.0			50.3	48.5		66.8	57.8		70.9			44.9	39.6			#DIV/0!		67.9						29.9
11/20/2008							46.8	46.8		59.1	57.8					37.4	38.3			#DIV/0!					34.8	11/20/2008		31.5
2/19/2009	70.0			70.1			42.2	50.2		59.8	64.4		50.6			35.9	41.3			#DIV/0!		44.4			30.7	2/19/2009		34.8
5/21/2009	59.2			63.0			44.1	45.9		66.8	63.1		53.6			45.1	40.8			#DIV/0!		50.8			31.8	5/21/2009		32.4
8/20/2009	74.0			60.3			51.3	46.1		65.8	62.9		64.0			40.2	39.7			#DIV/0!		40.3			37.3	8/20/2009		33.7
11/19/2009	57.1			67.0			45.6	45.8		61.8	63.6		53.5	55.4		35.6	39.2			#DIV/0!		47.7	45.8	46.6	27.8	11/19/2009		31.9
2/11/2010	62.1	63.1	63.8	57.0	61.8	60.3	31.0	43.0	39.7	47.8	60.6	61.9	50.6	55.4	54.7	25.7	36.7	31.8		#DIV/0!	0.0	33.3	43.0	38.7	21.2	2/11/2010	2	29.5
5/13/2010	45.6	59.7	52.6	48.9	58.3	55.4	33.1	40.3	35.7	43.8	54.8	58.4	41.8	52.5	46.9	26.9	32.1	28.8		#DIV/0!	0.0	36.4	39.4	38.5	23.1	5/13/2010	3	27.4
8/20/2010	59.1	56.0	56.5	63.2	59.0	58.1	47.0	39.2	39.5	61.2	53.7	55.7	55.9	50.4	51.0	36.1	31.1	31.2		#DIV/0!	0.0	43.0	40.1	38.9	33.2	8/20/2010	3	26.3
11/18/2010	67.3	58.5	59.8	65.0	58.5	60.5	42.6	38.4	41.3	48.1	50.2	52.2	62.8	52.8	55.8	37.8	31.6	34.7		#DIV/0!	0.0	13.4	31.5	26.6	33.5	11/15/2010	2	27.8
2/17/2011	49.0	55.3	56.1	50.2	56.8	57.2	45.8	42.1	45.3	50.0	50.8	51.4	48.5	52.2	53.9	49.8	37.7	43.4		#DIV/0!	0.0	49.8	35.7	39.0	24.7	2/14/2011	3	28.6
5/19/2011	48.3	55.9	53.2	67.2	61.4	62.4	67.8	50.8	56.0	54.3	53.4	52.0	60.1	56.8	57.9	45.2	42.2	44.5		#DIV/0!	0.0	32.3	34.6	32.0	30.9	5/16/2011	2	30.6
8/18/2011	64.0	57.2	56.3	74.2	64.2	66.5	57.9	53.5	57.4	66.5	54.7	53.4	69.7	60.3	62.0	46.3	44.8	46.9		#DIV/0!	0.0	44.5	35.0	42.8	36.8	8/15/2011	3	31.5
11/17/2011	60.1	55.4	58.1	70.9	65.6	70.8	35.3	51.7	49.1	51.7	55.6	54.8	50.0	57.1	57.5	28.1	42.4	36.9		#DIV/0!	0.0	37.3	41.0	37.9	28.1	11/14/2011	2	30.1
2/16/2012	56.0	57.1	59.0	60.5	68.2	66.5	42.7	50.9	44.7	55.6	57.0	56.1	53.6	58.4	56.7	35.0	38.7	36.1		#DIV/0!	0.0	44.9	39.8	42.9	32.3	2/13/2012	3	32.0
5/17/2012	68.6	62.2	63.3	68.8	68.6	67.3	48.7	46.2	43.9	55.6	57.4	56.8	67.1	60.1	59.5	39.1	37.1	35.3		#DIV/0!	0.0	45.9	43.2	43.5	30.0	5/14/2012	3	31.8
8/23/2012	71.5	64.1	66.9	72.3	68.1	68.5	55.8	45.6	50.8	69.9	58.2	57.7	72.1	60.7	66.2	43.1	36.3	40.1		#DIV/0!	0.0	57.1	46.3	51.3	35.8	8/20/2012	2	31.6
***Start of Stage 2 DBP Monitoring**																												
11/15/2012	78.1			51			40			57			61			32						44			29	11/13/2012	3	
2/21/2013	51.6			51			37			46			49			29						37			24	2/19/2013	3	
5/23/2013	75.0		69.9	67		59	54		46	54		53	59		57	45		38	69			54		47	36	5/20/2013	3	
8/15/2013	76	70	69.7	81	63	70	59	47	52	76	58	63	80	62	67	48	39	43	71			58	48	52	42	8/12/2013	3	33
11/21/2013	60	66	67.8	69	67	72	52	50	54	65	60	65	58	61	64	50	43	48	53	64	61	54	51	55	34	11/18/2013	3	34
2/20/2014	65	69	66.7	70	72	73	50	54	53	82	69	76	73	67	71	35	45	42	70	66	66	48	53	52	34	2/18/2014	3	36
5/12/2014	59	65	60.9	60	70	65	50	53	51	53	69	63	63	68	64	38	43	40	56	62	59	45	51	48	11	5/12/2014	2	30

Compliance: Locational Running Annual Average Limit < 80 ug/L

Compliance? Yes Yes No (Comment Below)

Date:

Site No.	Location
123	Ponderosa Dr
137	Tanner Heights
127	Swift & Modesto St
139	Coast Rd
ARV12	Branciforte Dr
119	Morrissey & Marnell
134	Thurber and Winkle (Replaced Stn 130 in May of 2013)
105	Gross Rd
304	GHWTP Finished Water



HAA5

Stage 2 Quarterly Disinfection Byproducts Compliance Report

Begin STAGE 2 compliance October 1, 2012

Monitoring Results and Locational Running Annual Averages (LRAA)

ug/L or ppb

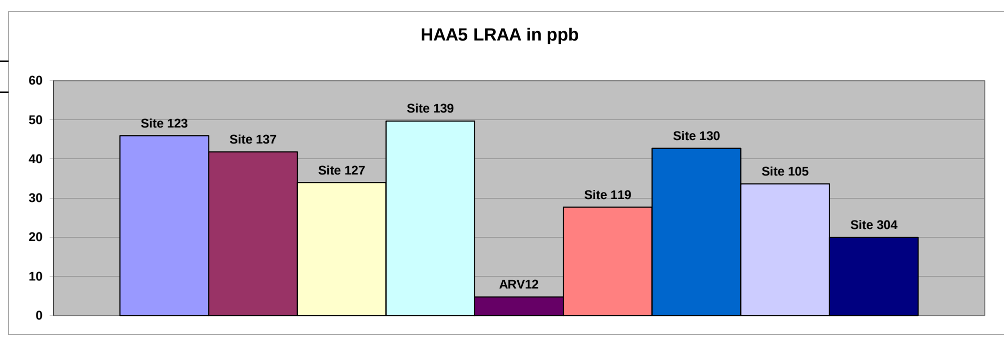
City of Santa Cruz Water Department
System No. CA4410010

Report Date:

	Site 123			Site 137			Site 127			Site 139			Site ARV12			Site 119			Site 134			Site 105			Site 304			LRAA
Date	Ponderosa Dr	LRAA	OEL	Tanner Heights	LRAA	OEL	Swift & Modesto St	LRAA	OEL	Coast Rd	LRAA	OEL	Branciforte Dr	LRAA	OEL	Morrissey & Marnell	LRAA	OEL	Thurber and Winkle	LRAA	OEL	Gross Rd	LRAA	OEL	GHWTP Finished Water	Date Sampled	Basins Online	
5/14/2004							43.4			58.0						39.4			57.6									
8/27/2004							31.0			19.1						35.3			31.0									
11/24/2004							39.3			37.7						31.3			52.8									
2/10/2005							17.7	32.9		16.8	32.9					13.7	29.9		19.1	40.1								
5/5/2005							20.4	27.1		20.9	23.6					21.4	25.4		20.5	30.9								
5/18/2006							23.5	25.2		27.0	25.6					19.3	21.4		31.6	31.0								
8/10/2006							17.9	19.9		18.1	20.7					15.4	17.5		14.3	21.4								
11/16/2006							42.3	26.0		20.3	21.6					38.4	23.6		41.0	26.9								
2/26/2007							33.0	29.2		39.0	26.1					34.0	26.8		37.1	31.0								
11/2/2007							41.2	33.6		46.6	31.0					31.9	29.9		35.8	32.1								
2/21/2008							23.3	35.0		30.5	34.1					20.0	31.1		21.2	33.8								
5/22/2008							24.8	30.6		40.9	39.3					23.0	27.2		34.5	32.2					19.1	5/22/2008		
8/21/2008	44.3			26.2			28.3	29.4		33.7	37.9		18.1			22.8	24.4		36.3	32.0		35.2						
11/20/2008							33.5	27.5		24.2	32.3					27.2	23.3		29.3	30.3					23.0	11/20/2008		
2/19/2009	63.0			37.3			51.0	34.4		55.0	38.5		3.5			40.0	28.3		49.0	37.3		53.0			32.0	2/19/2009		
5/21/2009	48.6			21.6			30.0	35.7		25.6	34.6		1.7			26.0	29.0		26.9	35.4		31.1			21.1	5/21/2009		
8/20/2009	34.5			13.7			25.3	35.0		19.6	31.1		0.0			20.8	28.5		24.3	32.4		13.8			17.6	8/20/2009		23.4
11/19/2009	24.5	42.7	33.0	12.0	21.2	14.8	21.4	31.9	24.5	26.2	31.6	24.4	0.0	1.3	0.4	19.2	26.5	27.6	21.0	30.3	23.3	24.8	30.7	23.6	16.2	11/19/2009		21.7
2/11/2010	63.1	42.7	46.3	36.2	20.9	24.5	37.0	28.4	30.2	52.0	30.9	37.5	0.0	0.4	0.0	28.0	23.5	25.5	35.0	26.8	28.8	35.0	26.2	27.2	24.0	2/11/2010	2	19.7
5/13/2010	23.6	36.4	33.7	32.4	23.6	28.3	26.2	27.5	27.7	34.4	33.1	36.8	3.9	1.0	2.0	20.4	22.1	23.6	24.7	26.3	26.4	26.3	25.0	28.1	16.8	5/13/2010	3	18.7
8/20/2010	26.1	34.3	34.7	31.9	28.1	33.1	29.7	28.6	30.7	26.0	34.7	34.6	2.7	1.7	2.3	22.8	22.6	22.7	28.6	27.3	29.2	28.0	28.5	29.3	20.6	8/20/2010	3	19.4
11/18/2010	39.3	38.0	32.1	33.7	33.6	32.9	34.8	31.9	31.4	35.1	36.9	32.7	3.9	2.6	3.6	30.7	25.5	23.9	34.0	30.6	30.3	1.7	22.8	14.4	21.2	11/15/2010	2	20.7
2/17/2011	40.1	32.3	36.4	36.6	33.7	34.7	44.0	33.7	38.1	36.4	33.0	33.5	6.6	4.3	5.0	52.6	31.6	27.8	57.3	36.2	44.3	52.6	27.2	33.7	24.7	2/14/2011	3	20.8
5/11/2011	40.1	36.4	39.9	44.2	36.6	39.7	71.1	44.9	55.3	42.9	35.1	39.3	22.7	9.0	14.0	43.7	37.5	33.0	61.9	45.5	53.8	22.3	26.2	24.7	24.7	5/11/2011	2	22.8
8/11/2011	30.5	37.5	35.3	31.3	36.5	35.9	32.0	45.5	44.8	29.7	36.0	34.7	20.2	13.4	17.4	16.4	35.9	35.2	21.7	43.7	40.7	13.3	22.5	25.4	13.3	8/11/2011	3	21.0
11/1/2011	39.8	37.6	37.6	42.1	38.6	39.9	27.6	43.7	39.6	38.7	36.9	37.5	6.8	14.1	14.1	21.4	33.5	35.1	24.8	41.4	33.3	30.6	29.7	24.2	21.5	11/11/2011	2	21.1
2/16/2012	44.0	38.6	39.6	41.7	39.8	39.2	38.8	42.4	34.3	44.3	38.9	39.3	12.8	15.6	13.2	34.3	29.0	31.8	36.8	36.3	30.0	41.6	27.0	31.8	26.4	2/13/2012	3	21.5
5/17/2012	35.5	37.5	38.7	23.0	34.5	32.5	30.5	32.2	31.9	34.5	36.8	38.0	18.0	14.5	13.9	24.2	24.1	27.7	30.8	28.5	30.8	23.7	27.3	29.9	20.6	5/14/2012	3	20.5
8/23/2012	21.5	35.2	30.6	27.3	33.5	29.8	24.8	30.4	29.7	35.2	38.2	37.3	11.0	12.2	13.2	23.0	25.7	26.1	24.0	29.1	28.9	26.4	30.6	29.5	24.7	8/20/2012	2	23.3
																Start of Stage 2 Compliance Monitoring												
11/15/2012	26			20			22			30			8			18						24			17	11/13/2012	3	
2/21/2013	38			30			32			36			16			25						29			17	2/19/2013	3	
5/23/2013	47		39	34		29	29		28	31		32	9		10	23		22	37			34		30	18	5/20/2013	3	
8/15/2013	44	39	43	41	31	36	32	29	31	46	36	40	4	9	8	23	22	23	41			30	29	31	16	8/12/2013	3	16.8
11/21/2013	51	45	48	35	35	36	41	34	36	51	41	45	2	7	4	45	29	34	46		42	48	35	40	22	11/18/2013	3	18.1
2/20/2014	62	51	55	67	44	53	39	35	38	82	52	65	9	6	6	28	30	31	62	46	53	40	38	40	31	2/18/2014	3	21.6
5/12/2014	27	46	42	24	42	38	24	34	32	20	50	43	ND	5	#VALUE!	15	28	26	22	43	38	16	34	30	11	5/12/2014	2	20.0

Compliance: Locational Running Annual Average Limit < 60 ug/L

In Compliance? Yes Yes No ______ (Comment Below)



Site No.	Location
123	Ponderosa Dr
137	Tanner Heights
127	Swift & Modesto St
139	Coast Rd
ARV12	Branciforte Dr
119	Morrissey & Marnell
130	Winkle & Sequoia Dr
105	Gross Rd
304	GHWTP Finished Water

Comment:

Signature:

The SCWD has operated and maintained the north coast supply (NCS) system since the 1880s. It consists of three small diversion dams and a natural spring, and 16 miles of transmission pipelines ranging in size from 10 to 22 inches, including both buried and unburied pipe. The system relies entirely on rainfall runoff and emergent groundwater to furnish up to 25 percent of SCWD’s overall water production. Over half of the 16 miles of pipeline is over 50 years old and traverses woodland, riparian forest, wetland, and grassland habitats, with approximately 50 trestles and stream crossings. As such visibility of the pipeline is restricted over much of its length, making it difficult to inspect for and detect leaks.

Likewise, maintaining the ROW to facilitate inspection is difficult because much of the pipeline is in sensitive habitats which limit the ability to effectively manage vegetative cover, consequently leaks ranging in size from a few gallons per minute to 500 gpm have been known to go undetected for weeks to months. A few examples include leaks that occurred in the early 2000s, near Lombardi Creek, 200 gpm, c. 5 months, Sandy Flat 500 gpm, c. 6 months, Little Baldwin Creek, 250 gpm, c. 6 months to one year. On average 3 major leaks per year occur in the NCS and have led to a historic loss rate of 15% to 20% compared to the average 5% to 6% for rest of the City's system.

To address the unacceptable loss rate, the City, beginning in 2005, initiated a NCS rehabilitation project intended to repair or replace all the facilities that make up the system over a period of 10 to 20 years. To date about 3.5 miles of pipeline has been replaced and the loss rate reduced to 8% to 10%. Nevertheless, the complexity of the project has seen the expected completion date extended to 25 to 30 years.

Upgrading the metering system on the NCS to give real time customer usage will reduce water loss by providing the City the data needed to audit the system and detect leaks on a timely basis by allowing comparison of production from each source and customer use to the amount of water arriving at the City's treatment plant. Currently, having only monthly meter readings for the amount of water withdrawn from the transmission pipeline to supply customer demand, it has been very difficult to determine if a sudden drop in production is due to customer usage or loss through a leak, requiring a time consuming and inefficient manual inspection of the pipelines.

Graham Hill Water Treatment Plant Technical Review

Final Alternatives Evaluation Report

August 13, 2010

Final Alternatives Evaluation Report

Graham Hill
Water Treatment Plant Technical Review

City of Santa Cruz

August 13, 2010

REGISTERED PROFESSIONAL ENGINEER
Richard G. Stratton
NO. 37261
EXP. 06-30-12
STATE OF CALIFORNIA

8-13-10

Prepared under the responsible charge of

Richard G. Stratton
C37261

HDR

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Walnut Creek, CA 94596

Contents

Figures

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Appendices

Appendix A: TM 2 – Review of Existing Background Information
Appendix B: Jar Test Results and Conclusions
Appendix C: Screening Summary of Process Alternatives Memo and Table of Screened Alternatives
Appendix D: Conceptual Capital and O&M Cost Tables

Introduction

The Santa Cruz Water Department (SCWD) desires to evaluate and select treatment process improvements that will enable the Graham Hill Water Treatment Plant (GHWTP) to effectively and efficiently achieve reliable plant capacity of 22 MGD while continuing to provide safe, aesthetically pleasing water that meets or exceeds current and impending regulatory requirements.

The purpose of this study is to review previous process upgrade evaluations for the GHWTP, develop additional process alternatives that reflect recent new source water quality information and resulting implications to regulatory requirements, and perform a complete evaluation of alternatives for the selection of treatment process improvements at the GHWTP.

Treatment Process and Water Quality Goals

As defined within the TM 2 – Review of Existing Background Information (HDR, January 2010), the primary objectives of the SCWD for selecting a treatment process include:

- Restore reliable water treatment plant (WTP) treatment capacity of 22 MGD
- Achieving consistent compliance with water quality goals
- Economic feasibility to construct and operate.

The SCWD's treated water quality goals are as follows:

- Maintain water age less than 5 - 10 days, as needed to meet other distribution water quality goals
- Assimilable Organic Carbon (AOC) < 0.2 mg/L
- Total Organic Carbon (TOC) > 15% removal or as required to meet distribution system goals
- Total Trihalomethanes (TTHMs) < 80 ppb (at 5-10 days water age)
- Haloacetic Acids (HAA5) < 60 ppb (at 5-10 days water age)
- Chlorine residual (distribution system) 0.2 to 1.5 mg/L free chlorine
- Threshold Odor Number (TON) $\leq$ 2, 100 percent of time
- Chlorine:ammonia (Cl2:NH4) ratio of 4:1 to 5:1 (if chloramines implemented)

These water quality goals are in addition to all applicable state and federal regulations. TM 2 - Review of Existing Background Information is attached in Appendix A.

HDR

Alternatives Evaluation

The evaluation of process treatment alternatives combines the information gathered from both bench-top testing and desk-top analyses to complete initial screening, cost development, and weighted criteria matrix evaluation to establish the most viable option(s) for treatment improvements.

Jar Test Summary

Bench scale jar testing was performed to obtain accurate information about the disinfection byproduct (DBP) formation potential of the settled water at the GHWTP. The objectives of the jar testing included:

- Determine whether ferric chloride (ferric) or alum is more effective at reducing the formation of TTHMs and HAA5 for the current pre-sedimentation chlorination practice.
- Determine the reduction in TTHM and HAA5 formation for chlorinating after the flocculation/sedimentation process.
- Determine the benefits of pH variation on TTHM and HAA5 formation.
- Determine the effects of aerating the chlorinated settled water for volatilizing TTHM and HAA5.

In addition to the onsite jar testing, Kruger and Orica performed bench scale jar tests to determine the feasibility of the MIEX and ACTIFLO systems to reduce TOC and disinfection by-product (DBP) formation. Raw water from Newell Creek was sent out for ACTIFLO high rate clarification (Kruger) and MIEX (Orica) system testing. Following these results, Kruger performed onsite testing to simulate their ACTIFLO CARB system.

Key conclusions from the testing include:

- On molar basis, the purchasing cost for ferric chloride is slightly higher (~ 7%) than alum. In other words, the costs of purchasing one metal ion (Al or Fe) are very close between these two coagulants.
- Natural organic matter (NOM), TTHM and HAA5 levels in all source waters were reduced when the pH was lowered. Based on Cost Adjusted Concentration (coagulant concentration normalized by purchasing costs), alum performed slightly better at the more neutral pH levels but ferric chloride outperformed alum at pH 5.5 and 6.0.
- The results showed no significant benefits to switching from alum to ferric chloride. At equivalent metal ion doses, ferric will result in a higher sludge production (ton/day) than alum.
- Newell Creek TTHM formation was best controlled by pH and enhanced coagulation. TTHM formation was moderately reduced by switching to post chlorination (4.6 – 9.7% reduction).
- Newell Creek HAA5 formation was controlled best by enhanced coagulation and moderately by pH. Post chlorination was largely ineffective at controlling HAA5 formation for Newell Creek.

- River/Coast TTHM formation was controlled well by enhanced coagulation, pH and post chlorination.
- Post chlorination had the most significant effect on River/Coast water HAA5 formation (22.2 – 28.9% reduction). High ferric doses and pH were also effective at reducing HAA5 formation in River/Coast water. Note, post chlorination is not a viable solution by itself to meet DBP reduction goals as only marginal benefits were observed for reducing TTHM formation in both sources.
- The aeration test on settled water collected from the treatment plant resulted in no significant decreases in TTHM and HAA5 levels as aeration is only effective at volatilizing DBPs that have already formed. It is suspected there were sufficient amounts of NOM and chlorine present after the aeration test resulting in DBP formation during the simulated distribution system (SDS) testing phase. Fine bubble diffusers may be necessary to effectively aerate the channel upstream of the filters. Aeration would not be cost effective due to high capital and energy costs.
- The ACTIFLO high rate clarification system had comparable results to conventional enhanced coagulation as the organic removal mechanisms are similar. The ACTIFLO system has a much shorter detention time than conventional coagulation and thus would require a smaller footprint.
- ACTIFLO CARB testing resulted in TOC concentrations below 2.0 mg/L with moderate to high Powdered Activated Carbon (PAC) doses as low as 15 mg/L (5 mg/L). Note that the estimated actual PAC dose in the full scale system will be approximately one third of the PAC dose used in the jar testing. The estimated full scale PAC doses are shown in parentheses. The lowest TOC level recorded was 1.2 mg/L although it was achieved with a high ferric (30 mg/L) and PAC dose 50 mg/L (17 mg/L). PAC and coagulant doses in conjunction with the resulting sludge production should be analyzed on a larger scale to further determine the feasibility of this alternative. In summary, the ACTIFLO CARB system is a promising technology for reducing DBP precursors.
- The MIEX system was the most effective treatment at reducing ultraviolet absorbance at a wavelength of 254 nm (UVA) and dissolved organic carbon (DOC) levels. The MIEX treatment with coagulation (8 mg/L of ferric chloride at pH adjusted to 6.75) resulted in a 55 percent reduction in finished water TTHM levels and 74 percent in HAA5 levels compared to coagulation alone (21 mg/L of ferric chloride without additional pH adjustment). Using MIEX technology prior to coagulation significantly reduced the required amount of coagulant and disinfectant.
- Previous jar testing demonstrated that chloramination after a short period of free chlorine contact in the sedimentation basins would meet the City's DBP goals.

Conclusions from the jar testing were used in the development of alternatives for the screening and evaluation process. The Jar Test Final report is attached as Appendix B.

Methodology

The methodology applied as the basis for the process alternative evaluation includes:

Step 1: Alternatives Development.

Together with HDR, the SCWD generated thirteen additional treatment alternatives which were added to the ten existing alternatives from 2007 Water Quality and System Improvements Study (WQ&SIS) and the 2009 Basis of Design Report (BDR).

Step 2: Alternatives Screening.

A screening review was conducted on several candidate process alternatives to determine which will potentially meet the SCWD's treatment goals and merit further evaluation as potential treatment solutions. The alternatives screened include new alternatives as well as those previously evaluated in other studies. Twenty three alternatives were screened initially against the following criteria:

- Particle reduction capability
- Microbial reduction / inactivation
- Taste & odor
- Disinfectant by product (DBP) formation; DBP removal
- Disinfection contact time (CT) modifications
- Capital cost
- O&M cost
- Residuals management (required system modifications)
- Distribution system modifications
- Flexibility to address future WQ changes (source changes)

The project team used biweekly project meetings to discuss the screening for each alternative and to determine which alternatives warranted continued consideration, evaluation, and ranking. Nine alternatives were selected for evaluation. Table 1 summarizes the results of the initial screening. A detailed explanation of the screening process, criteria definitions, and results is attached in Appendix C: Screening Summary of Process Alternatives Technical Memo.

Table 1. Screening of Processes Alternatives for Graham Hill Water Treatment Plant Upgrade

No.	Alternative	Particle Reduct.	Microbial Reduct./ Inactivation	T&O	DBP (TOC)	CT Location	Relative $$ (Cap)	Relative $$ (O&M)	Residuals Mgt.	Flexibility (WQ changes)	Dist. Sys. Mods.	Comments
		Ineffective Effective Highly Eff.	Ineffective Effective Highly Eff.	Ineffective Moderately Effective Effective Highly Eff.	Ineffective Effective Highly Eff.	Pre-Cl2 FW Tank[1] Cl2 basin 2nd FW Tank	Moderate High Very High	Moderate High Very High	Increase Same Decrease (proportional to flow)	Low Moderate High	Increase Same Decrease	1. FW Tank modifications (for flow through operation) do not address CT required for flow to the Passatiempo PS.
Current WTP Process												
0	Rapid Mix(RM) + KMnO4 + PAC+ Cl2 + Flocculation(F)1 + Sedimentation(S) +Cl2 + Filtration + Cl2	Effective2	Effective	Moderately Effective3	Ineffective4	Pre-Cl2	Low	Moderate	Same	Low	Same	Aluminum Sulfate dosed at approx. 20 mg/L. Limited to 3.5 gpm/sf. Seasonal operational challenges: seek improved control. Excessive DBPs may form, unable to consistently meet Stage 2 DBP limits.
Alternatives from WQ&SI Study (Oct 2007) (See Table Note 1)												
1 ✗	PAC+ KMnO4 + RM/F/S +Filtration+ UV + RO + Cl2	Highly Eff.	Highly Eff.	Highly Eff.	Highly Eff.	FW tank mods	Very High	Very High	Increase	High	Decrease	Brine disposal.
2 ✗	MIEX + PAC+ KMnO4 + RM/F/S + GAC Filters + UV + CL2	Effective	Highly Eff.	Effective	Highly Eff.	FW tank mods	Very High	High	Increase2	High	Decrease	Brine disposal.
3 ✗	MIEX + PAC+ KMnO4 + RM/F/S + MF/UF + Cl2	Highly Eff.	Highly Eff.	Moderately Effective1	Highly Eff.	FW tank mods	Very High	High	Increase2	High	Decrease	Same T&O control as existing operations. Brine disposal required.
4A ✗	PAC+ KMnO4 + Enhanced Coagulation + RM/F/S + Filtration + UV + Cl2	Effective	Highly Eff.	Moderately Effective1	Effective2	FW tank mods	Moderate	High	Increase3	Moderate4	Same	Same T&O control as existing operations. Increased DBP precursor removal over current operations. Additional solids from enhanced coagulation. May need additional DBP control features if future raw water TOC levels increase.
4B ✗	PAC+ KMnO4 + Enhanced Coagulation + RM/F/S + GAC Filters + UV + Cl2	Effective	Highly Eff.	Effective	Effective1	FW tank mods	High	High	Increase2	Moderate3	Decrease	Increased DBP precursor removal over current operations. Additional solids from enhanced coagulation. May need additional DBP control if future raw water TOC levels increase.
5 ✗	PAC+ KMnO4 + Enhanced Coagulation + RM/F/S + MF/UF + Cl2	Highly Eff.	Highly Eff.	Moderately Effective1	Effective2	FW tank mods	Very High	Moderate	Increase3	Moderate4	Same	Same T&O control as existing operations. Increased DBP precursor removal over current operations. Additional solids from enhanced coagulation. May need additional DBP control if future raw water TOC levels increase.
6 ✗	PAC+ KMnO4 + RM/F/S + Filtration + UV + Chloramines	Effective	Highly Eff.	Moderately Effective1	Highly Eff.	Pre-Cl2, FW tank mods	Moderate	Moderate	Same	Moderate	Increase	Same T&O control as existing operations.
7 ✗	PAC+ KMnO4 + RM/F/S + MF/UF + Chloramines	Highly Eff.	Highly Eff.	Moderately Effective1	Highly Eff.	Pre-Cl2, FW tank mods	Very High	Moderate	Same	Moderate	Increase	Same T&O control as existing operations.
8 ✗	PAC+ KMnO4 + RM/F/S + O3 + GAC Filters + Chloramines	Effective	Highly Eff.	Highly Eff.	Highly Eff.	Ozone contactor	High	Moderate	Same	High	Increase	Potential bromate formation issues.
9 ✗	ClO2 + RM/F/S + GAC Filters + Chloramines	Effective	Effective	Effective	Highly Eff.	Pre-Cl2, FW tank mods	Moderate	Moderate	Same	High	Increase	
Proposed WTP Process from Basis of Design Report (April 2009) and WQ&SI Study (Oct 2007)												
10 ✓	PAC + KMnO4 + RM/F/S + MF/UF + GAC Filter Adsorbers + Cl2	Highly Eff.	Highly Eff.	Highly Eff.	Effective1	FW tank + Pass. PS upgrade	Very High	Very High	Increase	High2	Decrease	DBP control credited to GAC contactors based on 6 month replacement rate. May need to increase GAC replacement rate to every 3 months if future raw water TOC levels increase.
	*NOTE: For the purpose of this evaluation, Alternative 10 is assumed to replace GAC every 6 months, acting as a contactor, rather than a filter cap with 3 year replacement (as indicated in 2009 BDR).											
Additional Alternatives Proposed by HDR (Sept 2009)												
11 ✓	MIEX + PAC + KMnO4 + RM/F/S + Filtration (GAC cap) + Cl2	Effective	Effective	Effective1	Highly Eff.	FW tank + Pass. PS upgrade; 2nd FW tank	High	High	Same2	Moderate	Decrease	GAC cap provides additional T&O control. Brine disposal added. Coagulant dose may be reduced to maintain solids loading rate at design capacity (lb/d).
12 ✓	PAC + KMnO4 + RM/F/S (Enhanced Coagulation) + Cl2 Contact + Filtration	Effective	Effective	Moderately Effective1	Effective2	New Cl2 contact (3rd Sed basin)	Moderate	High	Increase3	Moderate	Same/Inc.	Same T&O control as existing process. Sed. basins modified to remediate clogging at elevated PAC dose. Increased DBP precursor removal over current operations. Jar Tests indicate that pH suppression and coagulant doses of 60 mg/L may be required to meet DBP treatment goals. Additional solids from enhanced coagulation.

No.	Alternative	Particle Reduct.	Microbial Reduct./ Inactivation	T&O	DBP (TOC)	CT Location	Relative $$ (Cap)	Relative $$ (O&M)	Residuals Mgt.	Flexibility (WQ changes)	Dist. Sys. Mods.	Comments
13 ✗	PAC + KMnO4 + RM/F/S + Filtration (GAC cap) + Cl2	Effective	Effective	Effective1	Ineffective2	New Cl2 contact (3rd Sed basin)	Moderate	Moderate	Same	Low3	Same	GAC cap provides additional T&O control. Increased DBP precursor removal over current operations due to pH suppression is not likely sufficient to meet DBP goals. May need additional DBP and Cryptosporidium control.
14 (7B) ✗	PAC + KMnO4 + RM/F + Ceramic Membranes1 + Chloramines	Highly Eff.	Highly Eff.	Moderately Effective2	Highly Eff.	FW tank + Pass. PS upgrade	Very High	Moderate	Same	Moderate	Increase	Clarification is not required upstream of ceramic membranes. Same T&O control as existing operations.
15 ✓	PAC + KMnO4 + RM/F (Enhanced Coagulation) + Ceramic Membranes1 + Cl2	Highly Eff.	Highly Eff.	Moderately Effective2	Effective3	Sed. basin 1&2 chlorine contact	Very High	Moderate	Increase4	Low5	Same	Clarification is not required upstream of ceramic mem. Same T&O control as existing operations. Jar Tests indicate that pH suppression and coagulant doses of 60 mg/L may be required to meet DBP treatment goals. Additional solids from enhanced coagulation. May need additional DBP control, T&O control.
16 ✗	PAC + KMnO4 + RM/F/S + aeration1 + MF/UF + Cl2	Highly Eff.	Highly Eff.	Moderately Effective2	Ineffective3	FW tank + Pass. PS upgrade	High	Moderate	Same	Low4	Same	Aeration for 2 minutes within converted filter basin is not sufficient contact time, per jar test results. Same T&O control as existing operations. No significant improvement over alt. w/o aeration. May need additional DBP control.
17 ✗	PAC + KMnO4 + RM/F/S + MF/UF + Ion Exchange + Cl2	Highly Eff.	Highly Eff.	Moderately Effective1	Highly Eff.	FW tank + Pass. PS upgrade	Very High	High	Same	Moderate	Same/Inc.	Same T&O control as existing operations. Sed basins modified to remediate clogging at elevated PAC dose.
18 ✗	PAC + KMnO4 + High Rate Clarification + Cl2 contact + Filtration	Effective	Effective	Moderately Effective 1	Effective2	New Cl2 contact (3rd Sed basin)	High	Moderate	Increase	Moderate	Same/Inc.	Same T&O control as existing operations. Assumes increased coagulant dose for organics removal.
19 ✗	PAC + KMnO4 + High Rate Clarification + Cl2 contact + Filtration + Chloramines	Effective	Effective	Moderately Effective1	Highly Effective	New Cl2 contact (3rd Sed basin)	High	Moderate	Increase	Moderate	Increase	Same T&O control as existing operations.
20 ✓	PAC + KMnO4 + High Rate Clarification (EC) + (space for O31)+ Filtration 2 + Cl2	Effective	Highly Eff.	Moderately Effective (initial) Highly Eff. (future)	Effective3	New Cl2 contact (3rd Sed basin)	Very High	Moderate	Increase	Moderate4	Same/Inc.	Potential bromate formation issues. Space left for ozone system to be added in future, if needed for T&O. Ozone replaces free chlorine. When ozone is added, filter modified with GAC cap. Filter enables biological activity for removal of oxidized organics. Assumes increased coagulant dose for organics removal. Jar Tests indicate that pH suppression and coagulant doses of 60 mg/L may be required to meet DBP treatment goals. Additional solids from enhanced coagulation.
21 ✓	PAC + KMnO4 + RM/F/S + ACTIFLO CARB + Cl2 Contact + Filtration	Effective	Effective	Effective1	Highly Eff. 2	New Cl2 contact (3rd Sed basin)	High	High	Same3	Moderate	Decrease	Recirculation of PAC in Actiflo CARB increases T&O removal. Recirculation of PAC removes TOC. Coagulant dose reduced. PAC dose increased to 5 mg/L (constant).
22 ✓	Ozone1 + RM/F/S (Enhanced Coagulation) + Filtration (GAC cap) + Cl2	Effective	Effective	Highly Effective	Effective2	Ozone Contactor	High	High	Increase3	Moderate	Same/Inc.	Potential bromate formation issues. Increased DBP precursor removal over current operations. Alum dose assumed at 50 mg/L, based on removal of organics by ozone of 15%. Additional solids from enhanced coagulation.
23 ✓	PAC + KMnO4 + RM/F/S +Cl2 contact + Filtration+ Chloramines	Effective	Effective	Moderately Effective1	Highly Eff. 2	New Cl2 contact (3rd Sed basin)	Moderate	Moderate	Same3	Moderate	Increase	Same T&O control as existing operations. TTHMs and HAAs are not formed with chloramines.

Additional Table Notes:

1. Alternatives 1,2,4, and 6 were not selected for further evaluation as they include UV disinfection which is not required for WTPs with Bin 1 classification (per the LT2 Rule). Alternative 3 was modified as Alternative 11-A without membrane filtration to minimize capital cost. Alternative 5 was modified into Alternative 15 using ceramic membranes in place of MF/UF to create additional space for chlorine contact in the sedimentation basin, as pre- sedimentation is not required for ceramic membranes. Alternative 7,8, and 9 were not selected for further evaluation because advanced treatment processes such as MF/UF, O3, and ClO2 are not likely required (due to Bin 1 classification) when chloramines are used as a secondary disinfectant. Chloramines is evaluated (paired with conventional treatment) in Alternative 22.
2. High Rate Clarification technologies evaluated: Actiflo, Trident adsorption clarifier.
3. Alternatives with "FW Tank" as the CT location require modifications to the existing clearwell and associated piping to achieve CT downstream of the filters. Modifications may include addition of a second FW tank to provide CT upstream of Passatiempo pump station. Alternatives including conversion of one sedimentation basin into chlorine contact clearwell are noted.
4. All alternatives with "Filtration" include necessary filter upgrades such as adding Filter to Waste and other piping and basin upgrade modifications.
5. ✗ = Alternative eliminated from further evaluation.
6. ✓ = Alternative carried through to Life Cycle Analysis.

Step 3: Comparative Cost Development.

Preliminary capital, operation and maintenance and present value costs were developed for nine alternatives. To maintain optimal cost comparison between the pre-existing alternatives and the new alternatives, costs from the previous reports were used whenever possible (after appropriate escalation) for the new cost development. Capital and O&M cost sheets are attached in Appendix D.

Step 4: Ranking Criteria Development and Initial Alternatives Evaluation - Workshop 1

The project team from the SCWD and HDR met for an initial workshop to establish criteria against which to rank each of the nine alternatives. Each criteria was associated with a numerical weight, based on relative importance to the overall project objectives. The nine alternatives were ranked based on the established evaluation matrix.

Step 5: Alternatives Selection – Workshop 2

A second workshop was conducted to review the outcome of the matrix ranking. The two highest ranked alternatives and two sub-alternatives were selected for pilot-scale testing and evaluation. The specific advantages and disadvantages and costs of the selected alternatives are described below.

Process Alternative Descriptions for Matrix Ranking

Figure 1 summarizes the ten alternatives (eight from the screening analysis plus two sub-alternatives) that were included in the evaluation ranking process. Each alternative is described in greater detail with an individual process flow schematic.

HDR

Alt. 11-A	MIEX (Basin #3)	PAC	KMnO4	RM/F/S (Basin #1&2)	Filtration (GAC cap)	Chlorine Contact (FW Tank piping; NEW FW tank, UV (Passatiempo)	
Alt. 11-B	KMnO4[2]	Ozone (exist. carbon contactors)	MIEX (Basin #3)	RM/F/S (Basin #1&2)	Filtration (GAC cap)	Chlorine Contact (2° disinfection)	
Alt. 12	PAC	KMnO4	Enhanced Coagulation	RM/F/S (Basin #2&3)	Chlorine Contact (Basin #1)	Filtration	
Alt. 15	PAC	KMnO4	Enhanced Coagulation	RM/F (no sed) (Basin #3)	Ceramic Membrane Filt. (Basin #2)	Chlorine Contact (Basin #1)	
Alt. 20	PAC	KMnO4	High Rate Clarification (Basin #3)	Chlorine Contact (Basin #1)	Filtration		
Alt. 21-A	KMnO4	PAC	Actiflo CARB (Basin #2&3)	Chlorine Contact (Basin #2&3)	Filtration		
Alt. 21-B	KMnO4[2]	Ozone (exist. carbon contactors)	PAC	Actiflo CARB (Basin #2&3)	Chlorine Contact (Basin #2&3)	Filtration	
Alt. 22	Ozone (exist. carbon contactors)	Enhanced Coagulation (50 mg/L)[3]	RM/F/S (Basin #1,2,3)	Filtration (GAC Cap)	Chlorination (2°disinfection)		
Alt. 23	PAC	KMnO4	RM/F/S (Basin #2&3)	Chlorine Contact (Basin #1)	Filtration	Chloramines	

Legend :
- ☐ (white) Exisitng Processes
- ■ (grey) New/Modified Processes

Notes:
1. This alternative needs additional chlorine contact time for the Passatiempo line or reduced flows (per the 2009 BDR report) in order to be a viable alternative.
2. Permanganate would not be used when ozone is being added.
3. Alum dose reduced due to additional removal of organics by ozone.

Figure 1. Summary of Screened Treatment Alternatives

Alternative 10: Membrane Filtration + GAC

Alternative 10 is the recommended treatment process from the Basis of Design Report (CDM, April 2009). The plant influent will be treated by the existing conventional pretreatment treatment process. Settled water will be vacuum pumped through submerged membrane filters (Microfiltration or Ultrafiltration). Two of the flocculation / sedimentation basins will be upgraded with plate settlers and variable speed flocculators to enable use of the third sedimentation basin for the membrane building. Downstream of membrane filtration, flow will enter Granular Activated Carbon (GAC) filter adsorbers. The existing filters will be restored and the existing granular media replaced with GAC.

The membranes will provide primary disinfection for *Cryptosporidium* and *Giradia* and may provide partial disinfection for virus. GAC is an adsorption medium that removes elements from a water stream by adsorbing to its porous surface. Depending on design criteria and replacement frequency, GAC can be used for the removal of dissolved organic compounds that are precursors to disinfection byproducts and/or taste and odor. For this alternative, the GAC replacement rate was modified to 6 months for DBP control from the 3 year replacement frequency described within the Basis of Design Report. For membrane filtration processes, the CDPH implements a policy requiring an additional disinfection (0.5 log removal of Giardia) beyond that provided by the membranes to provide a multiple barrier. This alternative does not address the means by which this additional CT will be achieved. Figure 2 presents the process schematic diagram for Alternative 10: Membrane Filtration + GAC filter adsorber.

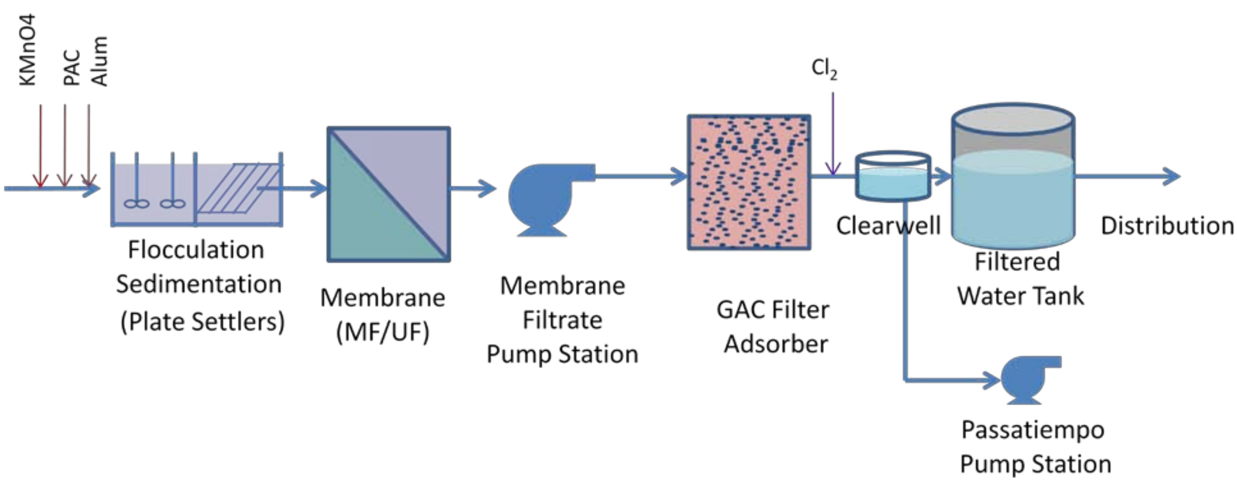


Figure 2. Alternative 10: Membrane Filtration + GAC Process Schematic

HDR

Alternative 11A: MIEX

MIEX is a proprietary advanced treatment process using magnetic ion exchange for the removal of organic material. The MIEX process contains small resin particles designed specifically for the adsorption removal of dissolved organic carbon (DOC). After mixing, the resin is settled in high rate clarifiers. The existing conventional treatment process will be used to treat the flow of water downstream of the MIEX process. Two of the flocculation / sedimentation basins will be upgraded with plate settlers and variable speed flocculators to enable use of the third sedimentation basin for the MIEX system.

The existing filters will be upgraded with a GAC filter cap for taste and odor control and a GAC replacement life of 3 years, which is common for T&O control uses. GAC capped filters would operate as biologically active filters. For disinfection contact time, a new baffled filtered water tank would be added in series upstream of the existing filtered water tank. Because the suction to the Passatiempo pump station is upstream of the existing filtered water tank, a 1 MGD UV system will be added for primary disinfection of that flow stream and free chlorine dosed for secondary disinfectant residual. Figure 3 presents the process schematic diagram for Alternative 11A: MIEX.

PAC would be dosed downstream of the MIEX system to avoid potential sticking to the resin as well as reduce the PAC dose due to removal of organics by MIEX. The MIEX resin is compatible with limited amounts of KMnO4, though the residual KMnO4 concentration should be monitored based on the following:

- Up to 0.1 mg/l average KMnO4 residual - no impact on resin
- Up to 0.2 mg/l average KMnO4 residual - minor impact on resin
- Up to 0.5 mg/l average KMnO4 residual - major impact on resin
- Up to 1mg/l KMnO4 residual for up to 24 hours - minor impact on resin

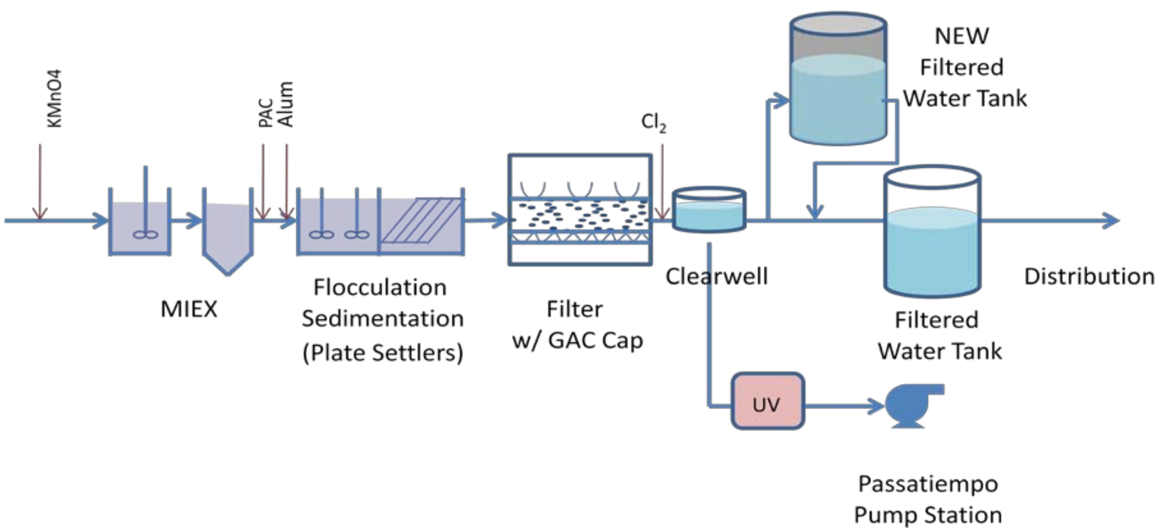


Figure 3. Alternative 11A: MIEX Process Schematic

HDR

Alternative 11B: Ozone + MIEX

Alternative 11B is similar to 11A in that MIEX is used for removal of organic material, followed by conventional pretreatment and filtration with a GAC cap. Permanganate would not be used when ozone is being added. Pre-ozonation is implemented upstream of MIEX, using side stream injection and the existing carbon contact basins as ozone contactors. Ozone is an effective treatment for control of taste and odor. Ozone will also achieve primary disinfection CT for *Cryptosporidium*, *Giardia*, and viruses. Downstream of ozone, MIEX is expected to remove a portion of the bromate formed. Biological filtration with a GAC cap removes the assimilable organic carbon (AOC) formed by ozonation. Figure 4 presents the process schematic diagram for Alternative 11B: Ozone + MIEX.

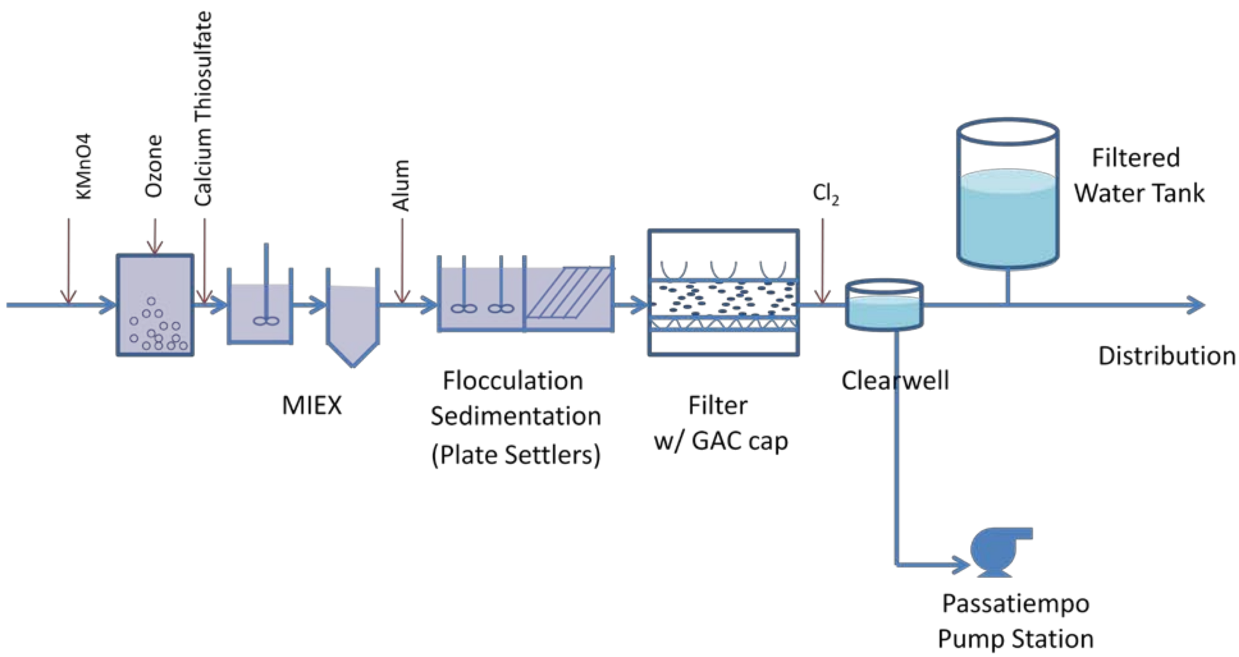


Figure 4. Alternative 11B: Ozone + MIEX Process Schematic

Alternative 12: Enhanced Coagulation

Enhanced coagulation is the practice of increasing the dose of coagulant beyond the level needed to optimize filtration in order to achieve supplemental removal of DBP precursor materials (organics). Based on results of jar testing (December 2009), a dose of 60 mg/L alum is assumed. In addition, pH will be suppressed by acid feed to approximately 6.5 for optimized organics removal. Two of the existing flocculation / sedimentation basins will be upgraded with plate settlers and variable speed flocculators to enable use of the third sedimentation basin for chlorine contact. Potassium permanganate and/or PAC will still be used for taste and odor control. A new caustic soda system will be used to adjust the pH of the finished water to approximately 7.5 units. Figure 5 presents the process schematic diagram for Alternative 12: Enhanced Coagulation.

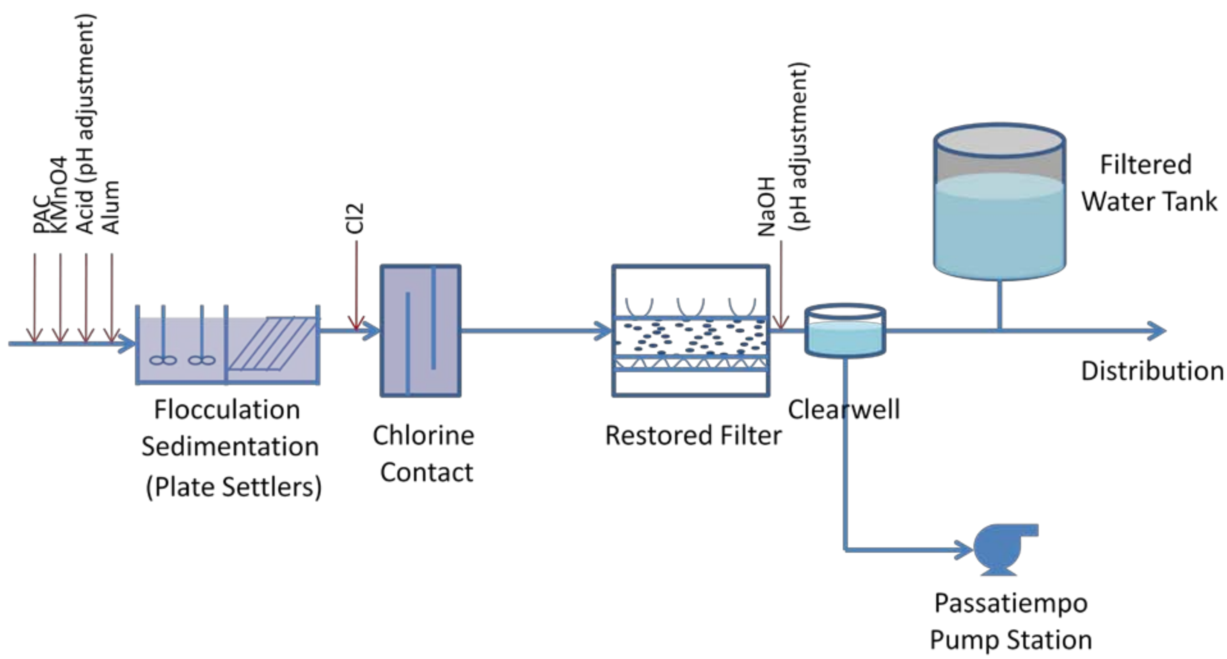


Figure 5. Alternative 12: Enhanced Coagulation Process Schematic

Alternative 15: Ceramic Membrane

Enhanced coagulation will be practiced with alum doses of approximately 60 mg/L (based on jar testing). pH will be suppressed by acid feed to approximately 6.5 for optimized organics removal. Potassium permanganate and/or PAC will still be used for taste and odor control. Flocculated water from two basins will be pumped through pressurized ceramic membrane filters. The membrane building will be constructed in the space of the third sedimentation basin, similar to Alternative 10. Ceramic membrane filters do not require settled water feed, thus the sedimentation portion of the two existing basins will be used as chlorine contact basins, downstream of membrane filtration.

Similar to Alternative 10, the membranes will provide primary disinfection for *Cryptosporidium* and *Giradia.* Some membranes also provide partial disinfection for virus. For membrane filtration processes, the CDPH requires an additional disinfection (0.5 log removal of Giardia) beyond that provided by the membranes. This additional CT for Giardia and any remaining CT for viruses will be achieved in the chlorine contact basin. A new caustic soda system will be used to adjust the pH of the finished water to approximately 7.0 units. Figure 6 presents the process schematic diagram for Alternative 15: Ceramic Membranes.

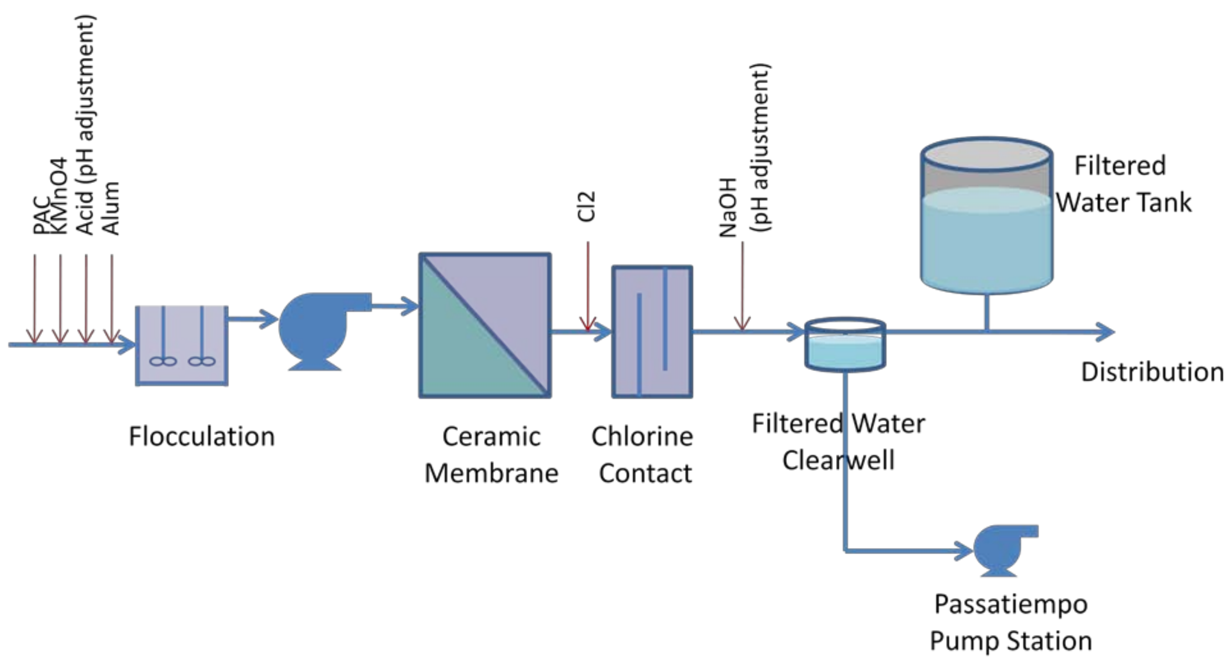


Figure 6. Alternative 15: Ceramic Membrane Process Schematic

Alternative 20: High Rate Clarification

Enhanced coagulation will be implemented for this alternative, as described in Alternative 12. pH will be suppressed by acid feed to approximately 6.5 for optimized organics removal. Two high rate clarifier units will be configured within one existing flocculation/sedimentation basin. One of the remaining two basins will be modified for chlorine contact. The third basin will be available for chemical system storage or other uses. Potassium permanganate and/or PAC will still be used for taste and odor control. A new caustic soda system will be used to adjust the pH of the finished water to approximately 7.0 units. Figure 7 presents the process schematic diagram for Alternative 20: High Rate Clarification.

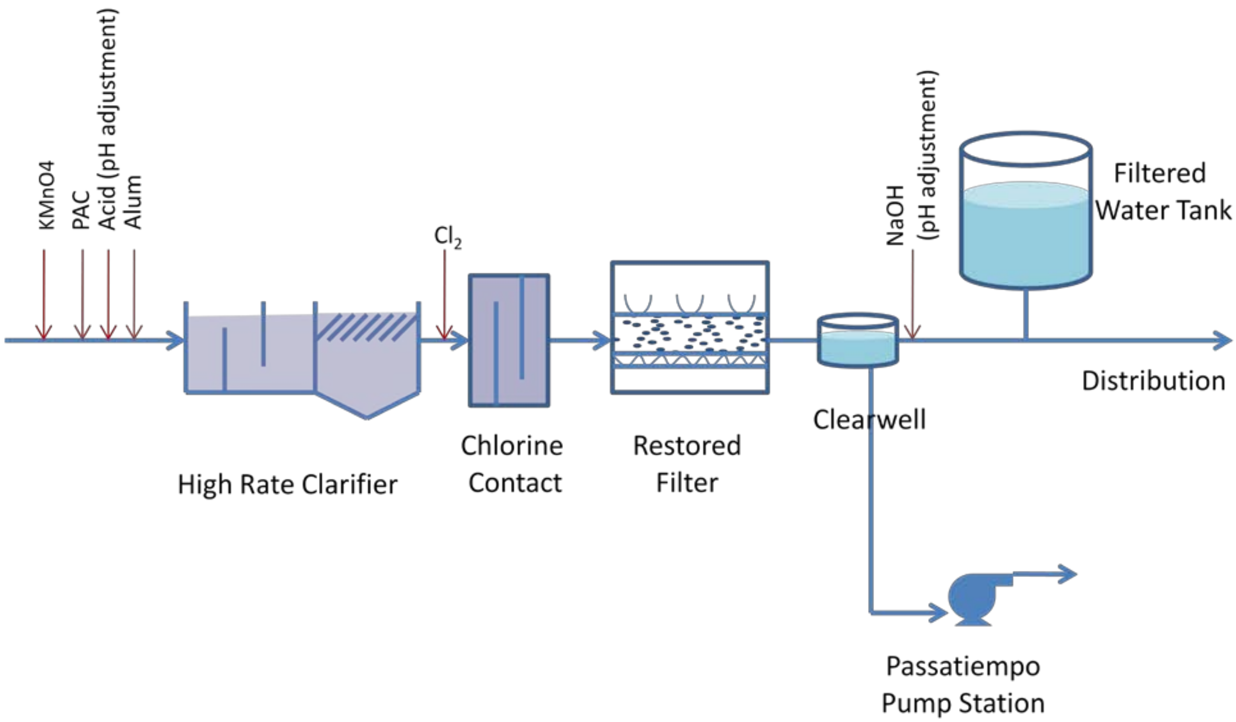


Figure 7. Alternative 20: High Rate Clarification Process Schematic

Alternative 21A: Actiflo CARB

Actiflo CARB combines the Actiflo clarification process with the continuous recirculation of PAC to enhance the removal (adsorption) of organic matter for increased NOM removal. PAC can also improve T&O control. Actiflo CARB will be implemented in place of conventional clarification. One Actiflo CARB unit will be configured within a portion of each of two sedimentation basins for a total of two Actiflo Carb units. The remaining space within each basin will be modified for chlorine contact. The third basin will be available for chemical system storage or other uses. High concentrations of PAC within Actiflo CARB's PAC contact chamber is expected to provide improved taste and odor control. During the infrequent elevated raw water turbidity episodes, the PAC feed rate will increase to compensate for higher wasting of sludge. Figure 8 presents the process schematic diagram for Alternative 21A: Actiflo CARB.

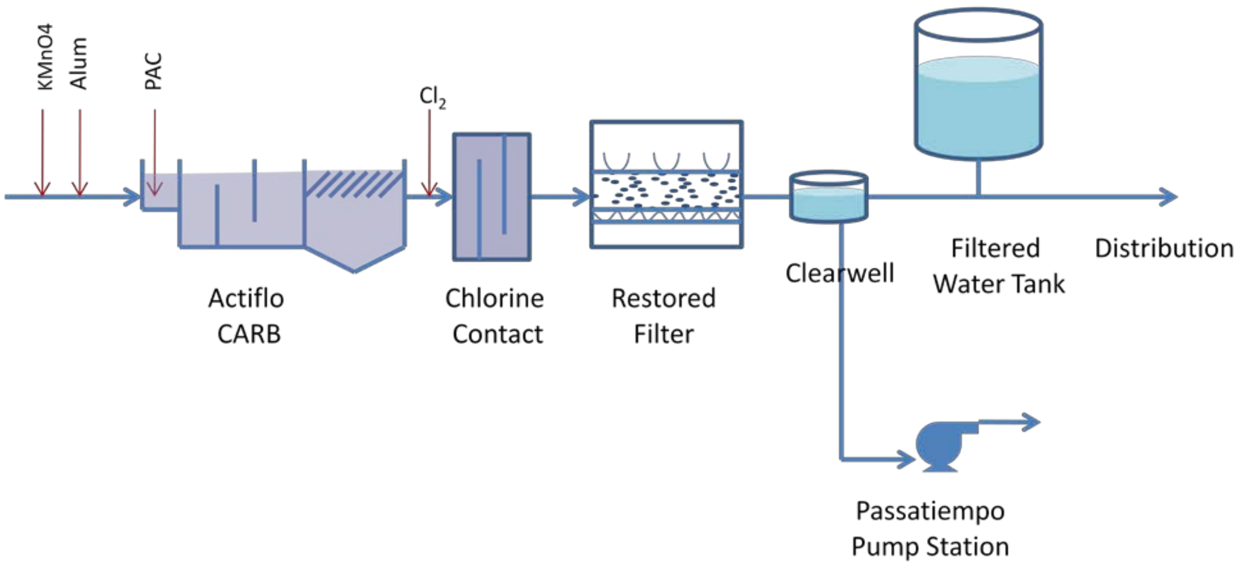


Figure 8. Alternative 21A: Actiflo CARB Process Schematic

Alternative 21B: Ozone + Actiflo CARB

Alternative 21B is similar to Alternative 21A in that the Actiflo CARB system is used for removal of organic precursor material for DBPs. Pre-ozonation will be implemented upstream of Actiflo CARB for additional control of taste and odor. The existing carbon contact basins will be modified for ozone contact in conjunction with side stream injection. Two sedimentation basins will be modified with each containing an Actiflo-CARB unit and chlorine contact basin for a total of two Actiflo CARB units and two chlorine contact basins. The third sedimentation basin will be available for locating the ozone system equipment or other uses. Due to upstream chlorine dose and residual, filtration will not be biological in this alternative. The Actiflo CARB units are expected to remove the assimilable organic carbon (AOC) formed by ozonation. This can be confirmed through pilot testing. As an option, an increased ozone dose could provide primary disinfection in place of chlorine for *Cryptosporidium*, *Giardia*, and viruses. Permanganate would not be used when ozone is being added. Figure 9 presents the process schematic diagram for Alternative 21B: Ozone + Actiflo CARB.

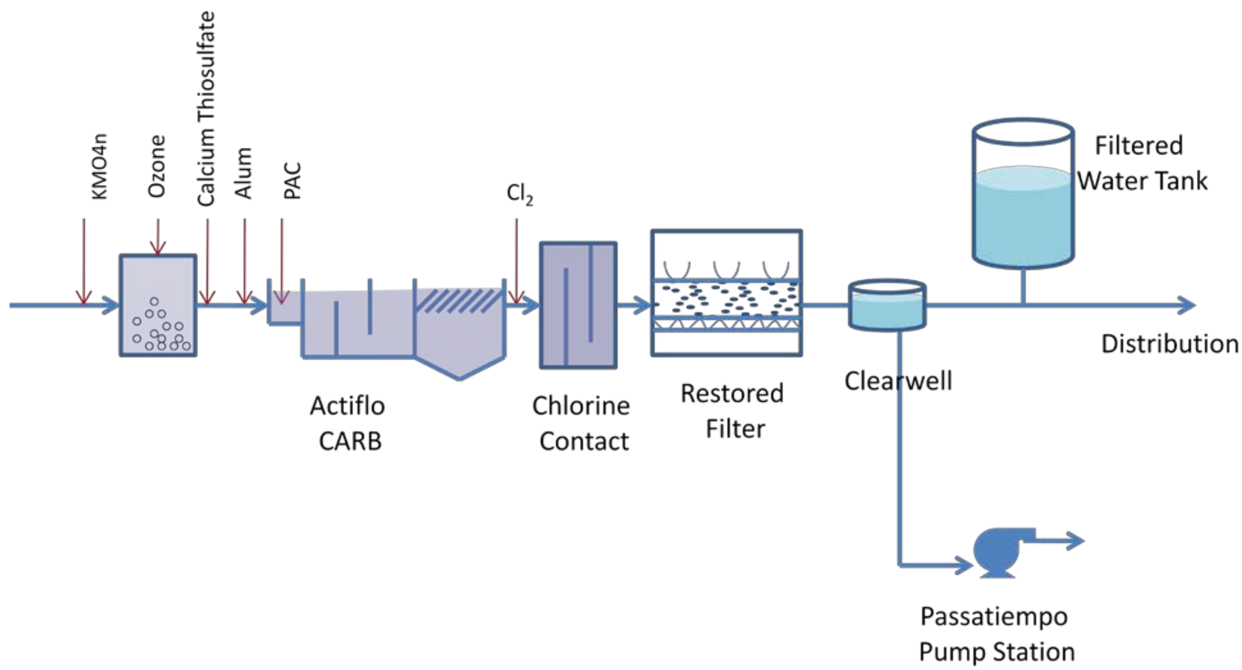


Figure 9. Alternative 21B: Ozone + Actiflo CARB Process Schematic

Alternative 22: Pre- Ozonation with Enhanced Coagulation

The plant influent will be treated by pre-ozonation for control of taste and odor. Permanganate would not be used when ozone is being added. Pre-ozonation will also provide primary disinfection for *Cryptosporidium*, *Giardia*, and viruses. Downstream of ozonation, calcium thiosulfate will quench any remaining unreacted ozone, and the flow will be treated by enhanced coagulation, as described in Alternative 12. pH will be suppressed by acid feed to approximately 6.5 for optimized organics removal. The existing flocculation / sedimentation basins will be upgraded with variable speed vertical flocculators. Although tube sellters may require replacement in conjunction with plant maintenance, the cost for replacement of existing tube settlers is not included for process evaluation because the operation of three sedimentation basins will continue. Biological filtration with a GAC cap removes the assimilable organic carbon (AOC) formed by ozonation. A new caustic soda system will be used to adjust the pH of the finished water to approximately 7.0 units. Figure 10 presents the process schematic diagram for Alternative 22: Pre-ozonation.

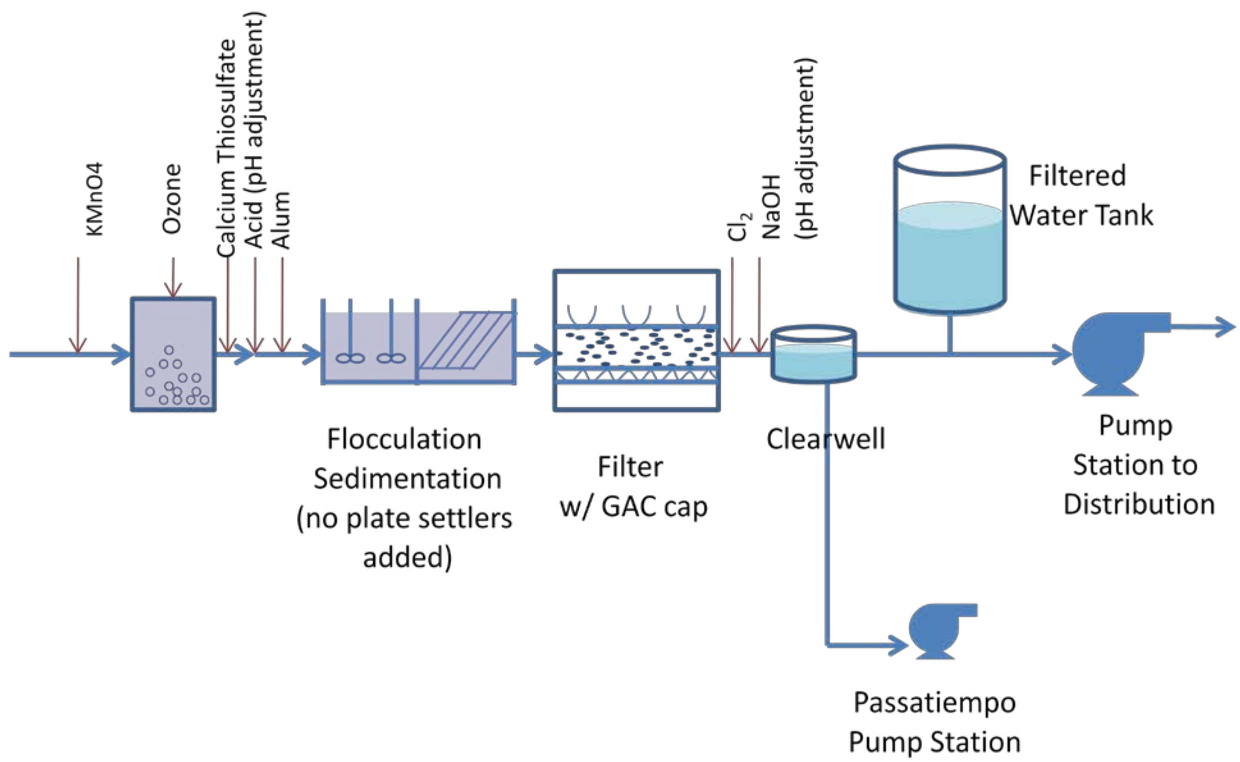


Figure 10. Alternative 22: Pre-Ozonation Process Schematic

Alternative 23: Chloramination

The plant influent will be treated by the existing conventional pretreatment treatment process.

Two of the flocculation / sedimentation basins will be upgraded with plate settlers and variable speed flocculators to enable use of the third sedimentation basin for primary disinfection chlorine contact. Ammonia will be added to the filtered water to form chloramines for secondary (residual) disinfection and DBP control. Figure 11 presents the process schematic diagram for Alternative 23: Chloramines.

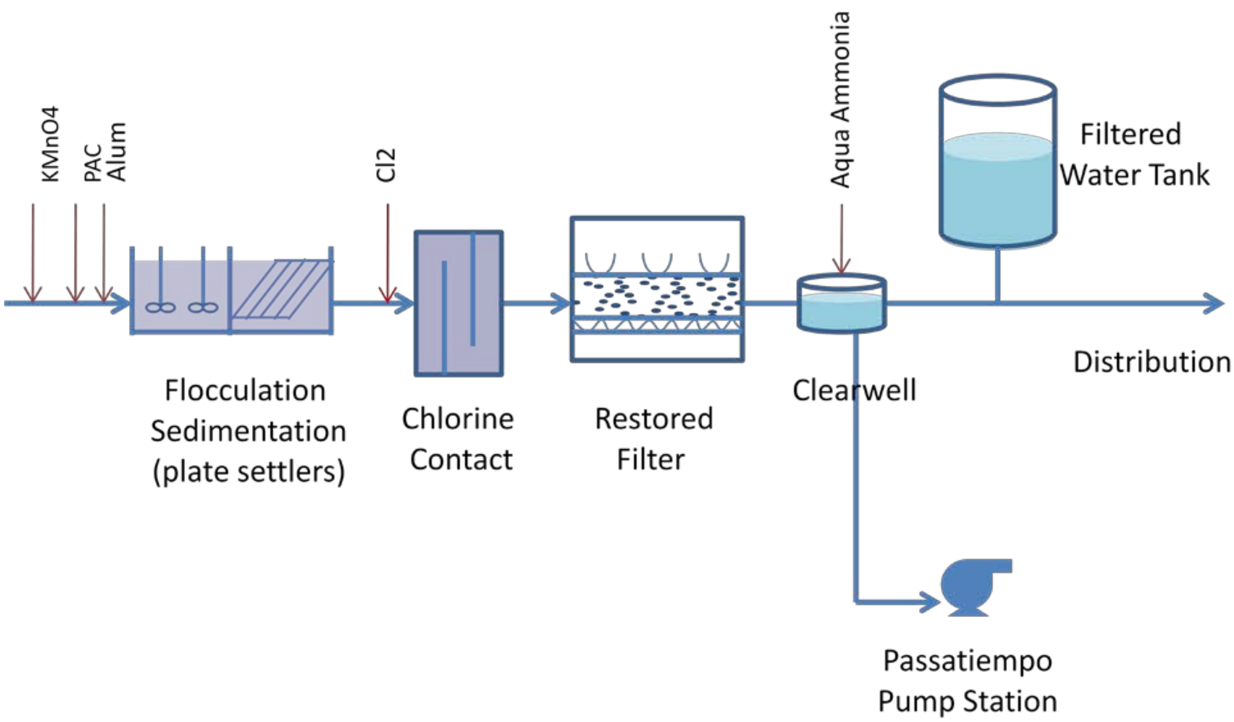


Figure 11. Alternative 23: Chloramines Process Schematic

Comparative Cost Summary

Figure 12 summarizes the conceptual level capital and operation and maintenance costs for each of the ten ranked alternatives. Detailed cost information for each alternative is attached in Appendix D. The conceptual level costs were generated for the purpose of alternatives comparison for process upgrades at the GHWTP. Construction costs were estimated and prorates were applied to develop the included conceptual level estimates. Where feasible, costs are based on and updated from the information contained within the following existing reports:

- Graham Hill Water Treatment Plant Regulatory and Production Reliability Improvements: Basis of Design Report, April 6, 2009. CDM.
- Water Quality and System Improvements Study, October 2007, CDM.
- Technical Memorandum 3A, Comparison of Treatment Process Alternatives of the Graham Hill Water Treatment Plant, November 10, 2004, CDM.

All costs were escalated to 2011 dollars, based on an approximate date for the mid point of construction.

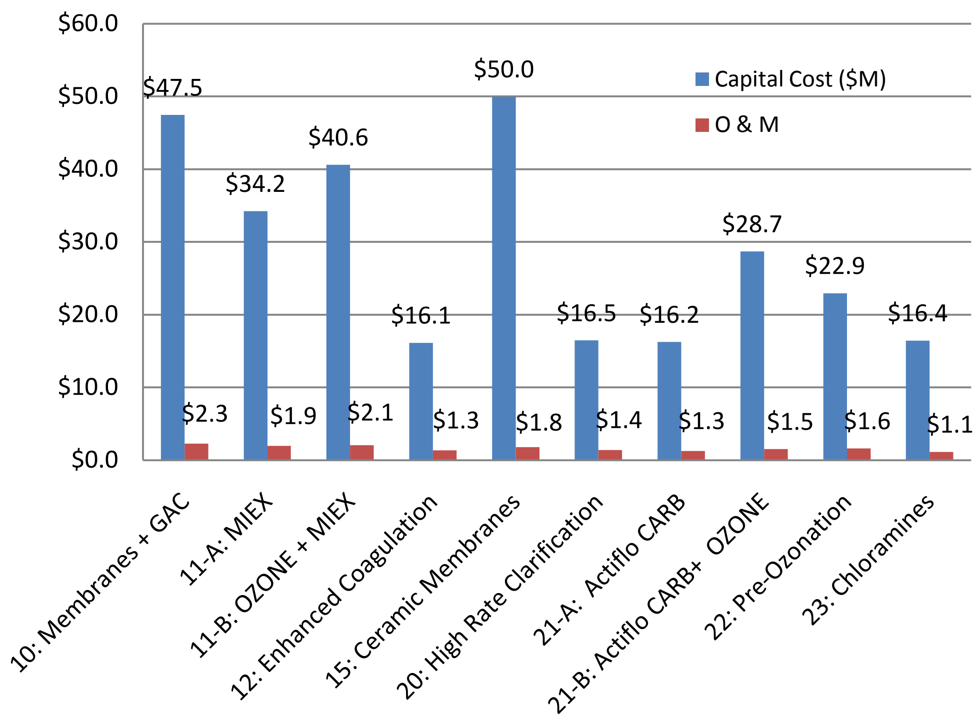


Figure 12. Capital and O&M Cost Summary of Screened Alternatives

Figure 13 presents the estimated 20 year present value (in 2011 dollars) for each of the ranked alternatives. The present values were calculated by adding the estimated capital cost to 20 times the estimated O&M cost. The 20 year period was selected for consistency with previously developed present value costs. Due to uncertainty regarding future residuals discharge limitations, the estimated costs for residuals management were not included in the comparative O&M costs.

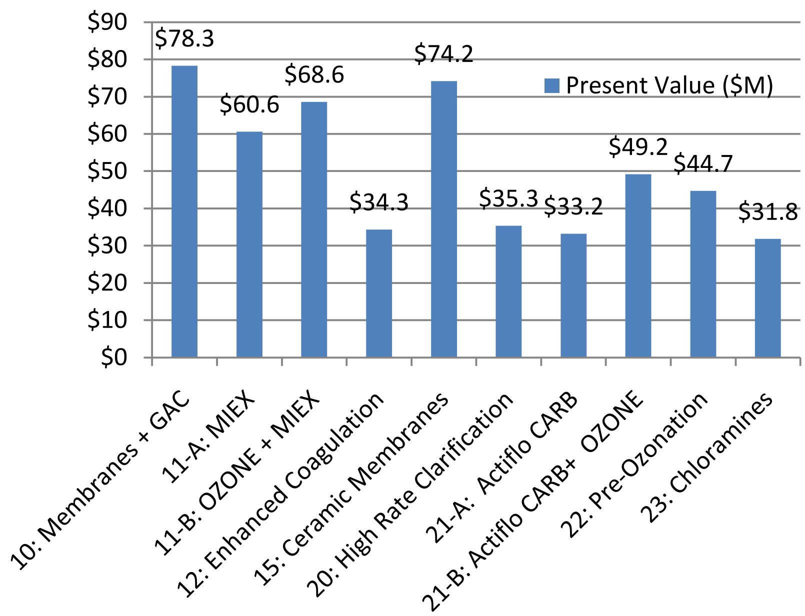


Figure 13. Present Value Cost Summary of Screened Alternatives

Alternatives Ranking – Evaluation Criteria

Table 2 presents the criteria and associated weights for ranking that were established during Workshop 1. Weights were assigned to each criteria based on the impact towards meeting project goals. Matrix rankings were calculated by summing the weighted scores for each evaluation criteria.

Table 2. Evaluation Ranking Criteria

#	Criteria Description	Weight
1	Disinfection Byproduct Control ▲ Ineffective – DBPs will likely violate water treatment and distribution system goals at design capacity. Process could be used together with other processes to meet WQ goals. ▲ Effective – DBP levels expected to comply with DBP water treatment goals. May require additional facilities for organics removal and/or residuals handling. May require operational modifications such as distribution system flushing. ▲ Highly Effective – DBPs levels expected to comply with DBP water treatment goals for current supply and future supply with potentially increased levels of organics.	20

#	Criteria Description	Weight
2	Taste & Odor Control ▲ Ineffective – does not meet T&O goals. ▲ Moderately Effective- same T&O control as current operations (KMnO4 and PAC). Experience seasonal operational T&O challenges. ▲ Effective – expected to meet T& O goals for current raw water blend. May not meet T&O goals for future demands beyond 19.5 MGD with greater portion of raw water from Newell Creek (Loch Lomond). ▲ Highly Effective – expected to meet T&O goals for current and future raw water blends.	13
3	Minimizing Solids Generation ▲ Decrease – WTP residuals production in proportion to flow will decrease. ▲ Same – WTP residuals production in proportion to flow will remain the same as current plant operations. ▲ Increase – WTP residuals production in proportion to flow will increase.	10
4	Ability to Treat High Turbidity ▲ Ineffective – Unable to consistently meet finished water quality turbidity goals during high source water turbidity episodes. ▲ Effective – Able to consistently meet finished water quality turbidity goals during high source water turbidity episodes. ▲ Highly Effective – Able to consistently exceed finished water quality turbidity goals during high source water turbidity episodes.	5
5	Microbial Reduction / Inactivation ▲ Ineffective – partially achieves reduction/ inactivation of microbials. ▲ Effective - achieves typical reduction/inactivation of microbials. ▲ Highly Effective - achieves substantial reduction/inactivation of microbials	17
6	Process Redundancy ▲ Low – Least overall process redundancy ▲ Moderate – Moderate overall process redundancy ▲ High – Greatest overall process redundancy	10
7	Minimizing Long Term Maintenance ▲ Low - Maximum foreseeable long term maintenance needs ▲ Moderate – Moderate foreseeable long term maintenance needsHigh – Minimum foreseeable long term maintenance needs	5
8	Ability to Construct in Phases ▲ Low – Lowest flexibility (relative to other alternatives) for phased delivery and associated cost savings ▲ Moderate – Moderate flexibility (relative to other alternatives) for phased delivery ▲ High – Highest flexibility (relative to other alternatives) for phased delivery	8
9	Plant Efficiency – Water Use (% of raw water treated and delivered) ▲ Low – Lowest relative overall water recovery ▲ Moderate - Median relative overall water recovery ▲ High – Highest relative overall water recovery	5
10	Annual O&M Cost ▲ Ranking based on O&M cost relative to the O&M cost range of the alternatives ▲ Weighted score = [(O&M Alternative X – O&M low) / (O&M high – O&M low)] * (7 / 100)	7
Total		100

Alternatives Ranking – Evaluation Matrix

Table 3 summarizes the ranking results for each alternative at the GHWTP against the evaluation criteria and scores described in Table 2. The highest three ranked alternatives are:

1. Alternative 21-B: Ozone + Actiflo CARB,
2. Alternative 21-A: Actiflo CARB, and
3. Alternative 11-B: Ozone + MIEX.

Table 3. Scoring Matrix Process Alternatives at the Graham Hill Water Treatment Plant

Alternative	Description	Capital Cost (2011 dollars) ($M)	Annual O&M Cost (2011 dollars) ($M/yr)	Present Value Cost (2011 dollars) ($M)	DBP Control	T&O Control	Minimizing Solids Generation	Ability to Handle High Turbidity	MRI (crypto/giardia)	Process Redundancy	Minimizing Long Term Maintenance	Ability to Construct in Phases	Plant Efficiency- water use	TOTAL
100	WEIGHT	0	7	0	020	13	10	5	17	10	5	8	5	100
RANGES	LOW	16	1.1	31.2	Ineffective	Less Eff.	Increase 1	Ineffective 1	Ineffective 1	Low 1	Low 1	Low 1	Low 1	
					Effective	Increase Eff.	Same 3	Effective 3	Effective 3	Moderate 3	Moderate 3	Moderate 3	Moderate 3	
	HIGH	56.9	2.3	80	Highly Eff.	Highly Eff.	Decrease 5	Highly Eff. 5	Highly Eff. 5	High 5	High 5	High 5	High 5	
21-B	Actiflo CARB + OZONE	$28.7	$1.5	$49.2	4	5	4.5	5	4	5	3	3	4	1
	Weighted score	0.000	0.046	0.000	0.160	0.130	0.090	0.050	0.136	0.100	0.030	0.048	0.040	0.8301
21-A	Actiflo CARB	$18.3	$1.3	$35.3	4	4	4	5	2	5	4	3	4	2
	Weighted score	0.000	0.061	0.000	0.160	0.104	0.080	0.050	0.068	0.100	0.040	0.048	0.040	0.7513
11-B	OZONE + MIEX	$40.6	$2.1	$68.6	4.5	5	5	2	4	2	2	3	4.5	3
	Weighted score	0.000	0.014	0.000	0.180	0.130	0.100	0.020	0.136	0.040	0.020	0.048	0.045	0.7330
15	Ceramic Membranes	$50.0	$1.8	$74.2	4	4	3	5	5	4	1.5	2	2	4
	Weighted score	0.000	0.030	0.000	0.160	0.104	0.060	0.050	0.170	0.080	0.015	0.032	0.020	0.7213
22	Pre-Ozonation	$22.9	$1.6	$44.7	3	5	2	3.5	4	3	2	4	3	5
	Weighted score	0.000	0.041	0.000	0.120	0.130	0.040	0.035	0.136	0.060	0.020	0.064	0.030	0.6758
10	Membranes + GAC	$47.5	$2.3	$78.3	4	4	3	4	5	4	1	2	2	6
	Weighted score	0.000	0.002	0.000	0.160	0.104	0.060	0.040	0.170	0.080	0.010	0.032	0.020	0.6778
11-A	MIEX	$34.2	$1.9	$60.6	4.5	3	5	2	2.5	2	3	3	4.5	7
	Weighted score	0.000	0.021	0.000	0.180	0.078	0.100	0.020	0.085	0.040	0.030	0.048	0.045	0.6470
23	Chloramines	$16.4	$1.1	$31.8	5	1	3	2	2.5	3	1.5	5	1	8
	Weighted score	0.000	0.068	0.000	0.200	0.026	0.060	0.020	0.085	0.060	0.015	0.080	0.010	0.6243
20	High Rate Clarification	$16.5	$1.4	$35.3	2	2	1	5	2.5	4	3.5	3	2.5	9
	Weighted score	0.000	0.053	0.000	0.080	0.052	0.020	0.050	0.085	0.080	0.035	0.048	0.025	0.5281
12	Enhanced Coagulation	$16.1	$1.3	$34.3	2	2	1	3	2.5	3	2.5	5	2.5	10
	Weighted score	0.000	0.056	0.000	0.080	0.052	0.020	0.030	0.085	0.060	0.025	0.080	0.025	0.5130

Alternative Ranking Conclusions

The resulting rank and associated present value cost of each alternative were discussed further by the SCWD and HDR during the project workshop 2 on April 22, 2010. Table 4 summarizes the conclusions from the ranking process and identifies the alternatives selected for further consideration.

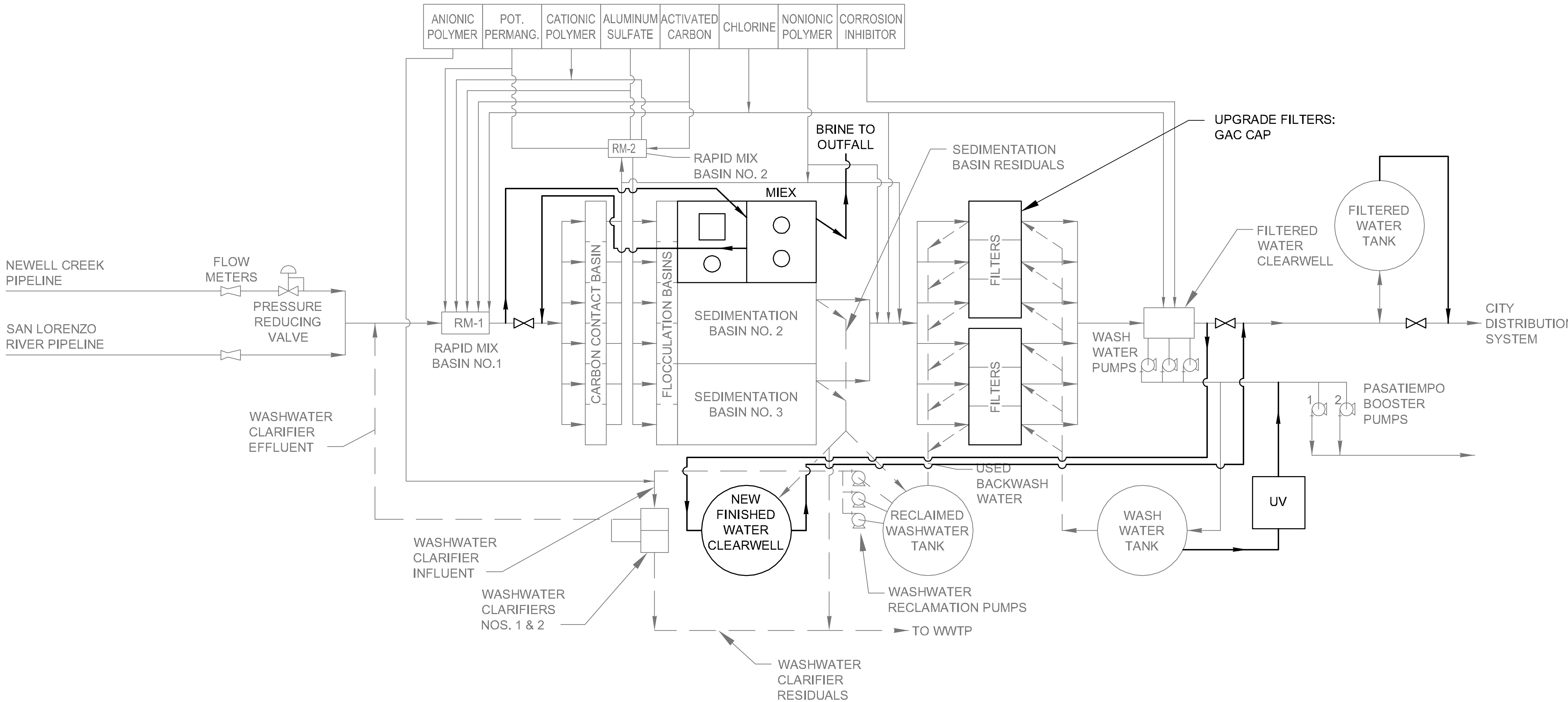
Table 4. Basis for Further Consideration of Alternatives

Rank	Consider Further?	Comment
6	N	Alt. 10: Membranes and GAC. This alternative has the highest total present worth values and ranks low (6th out of 10) on the selection criteria.
10	N	Alt. 12: Enhanced Coagulation. This alternative is not consistently reliable to meet regulatory goals for removal of organic precursors to disinfection byproducts. The SCWD has fed alum up to 70 mg/L during winter flows, but found it difficult to achieve 50 percent TOC removal. At times the TOC of the Newell Creek supply could be as high as 4 to 7 mg/L. Achieving only 50 percent removal would not allow the plant to meet the treated water TOC goal of less than 2.0 mg/L, as established during the bench jar testing. The elevated coagulant doses required for enhanced coagulation would increase the solids production rate proportional to flow, resulting in solids production rates greater than the permitted discharge.
4	N	Alt. 15: Ceramic Membranes. This alternative has a high cost and relies on enhanced coagulation, which is not reliable as described for Alternative 12.
9	N	Alt. 20: High Rate Clarification. This alternative relies on enhanced coagulation, which is not reliable as described for Alternative 12.
5	N	Alt. 22: Pre-Ozonation. This alternative relies on enhanced coagulation, which is not reliable as described for Alternative 12.
8	N	Alt. 23: Chloramination. This alternative requires public notification. The distribution system has 10-20% dead ends and would require significantly more frequent flushing, even during drought years when the desalination plant would be operating. Public perception is a concern when flushing during drought periods. O&M costs would increase for extra lab analyses and flushing. Chloramination would also limit the SCWD's ability to share water with other adjacent water systems such as Soquel, Scotts Valley, and San Lorenzo Valley.
7	Y	Alt. 11A: MIEX. The configuration of the MIEX system requires the footprint of one complete sedimentation basin. This alternative is selected for further consideration and piloting conjunction with Alternative 11B which ranked third in the evaluation.
3	Y	Alt. 11B: MIEX with Pre-ozonation. For this alternative, pre-ozone contactors would be installed in two of the carbon contactors with side-stream eductor ozone feed system.
2	Y	Alt. 21A: Actiflo CARB. This alternative assumes that the Actiflo CARB process could operate without pre-settling all of the time. During unusual high turbidity events, the PAC removal efficiency of TOC would be reduced. The cost-effectiveness of acidifying the raw water to improve TOC removal with a lower coagulant dose will be investigated. Each Actiflo CARB unit would be configured in a separate sedimentation basin for increased chlorine contact time downstream of the units. The third unused basin would be available for storage of new chemical systems or other components.
1	Y	Alt. 21B: Actiflo Carb with Pre-ozonation. For this alternative, pre-ozone contactors would be installed in two carbon contactors with side-stream eductor ozone feed system. A GAC cap would not be needed in the filters, allowing for chlorine contact upstream of filtration. Any assimilable organic carbon (AOC) produced by ozonation should be sufficiently removed in the Actiflo Carb units. This will be confirmed by pilot testing.

The four treatment alternatives selected for further evaluation include the use of Actiflo CARB or MIEX with or without pre-ozonation. Figures 14, 16, 18, and 20 present detailed flow schematics and Figures 15, 17, 19, and 21 depict conceptual site plans for each selected alternative. Table 5 summarizes the key advantages and disadvantages of each alternative. Based on the results of the bench scale testing conducted within this study, a revised TOC water quality goal of <2.0 mg/L, or as required to meet distribution system goals, is recommended for process alternatives using free chlorine as a secondary disinfectant, which include the four recommended for further evaluation. Verification of the TOC goal is recommended during pilot testing.

Table 5. Advantages & Disadvantages of Selected Alternatives

Advantages	Disadvantages
Actiflo CARB	
▲ Highly effective removal of organic precursor material to DBPs ▲ Most space – saving alternative. Leaves third sedimentation basin space available for future components/storage. ▲ Increased taste and odor control due to recirculated PAC.	▲ Installation experience: Currently one installation in US, though many in Europe. ▲ Increased PAC dose. ▲ During high turbidity episodes (>10 ntu), reduced effectiveness for organics removal and increased PAC use.
Ozone + Actiflo CARB	
▲ All of the advantages of Actiflo CARB alternative ▲ Superior control of taste and odor. ▲ Potential further reduction (~ 10%) of coagulant dose	▲ All of the disadvantages of Actiflo CARB alternative
MIEX	
▲ Highly effective removal of organic precursor material to DBPs ▲ Reduced coagulant dose resulting in reduced proportional solids production ▲	▲ Requires addition of new FW clearwell to meet CT. ▲ Disposal of residual brine (additional impact to WWTP) ▲ MIEX resign is proprietary
Ozone + MIEX	
▲ All of the advantages of MIEX alternative ▲ Superior control of taste and odor. ▲ Potential further reduction (~ 10%) of coagulant dose ▲ Removal of some bromate (if ozone is upstream of MIEX). ▲ New FW clearwell not required, CT achieved through ozone.	▲ Disposal of residual brine (additional impact to WWTP) ▲ MIEX resin is proprietary



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Alternative 11A: MIEX
Proposed Flow Schematic

City of Santa Cruz Graham Hill Water Treatment Plant
Alternatives Evaluation

HDR

DATE 8/13/10

FIGURE Figure 14

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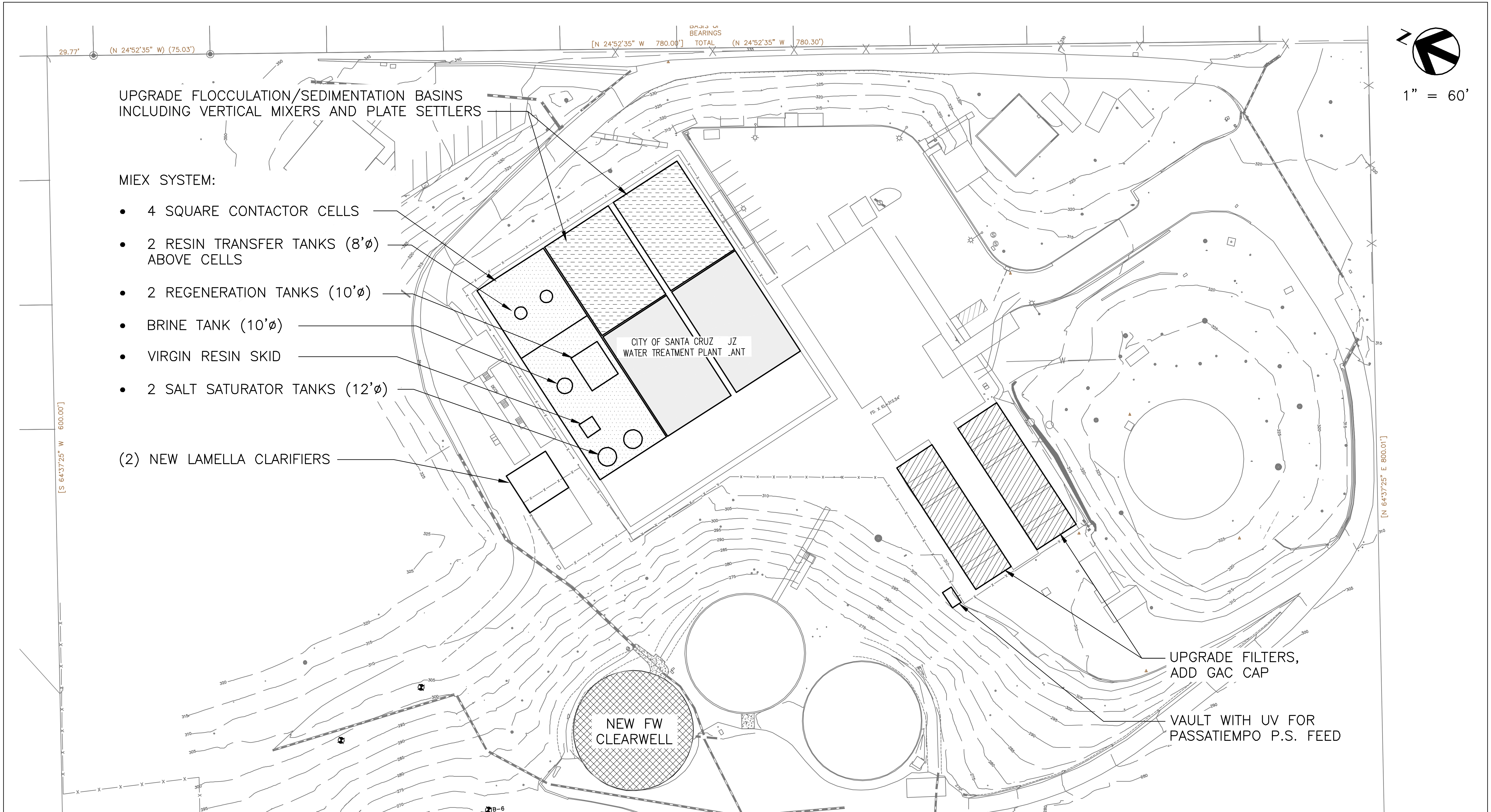

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HDR

Alternative 11A: MIEX
Proposed Site Layout

City of Santa Cruz Graham Hill Water Treatment Plant
Alternatives Evaluation

DATE 8/13/10

FIGURE Figure 15

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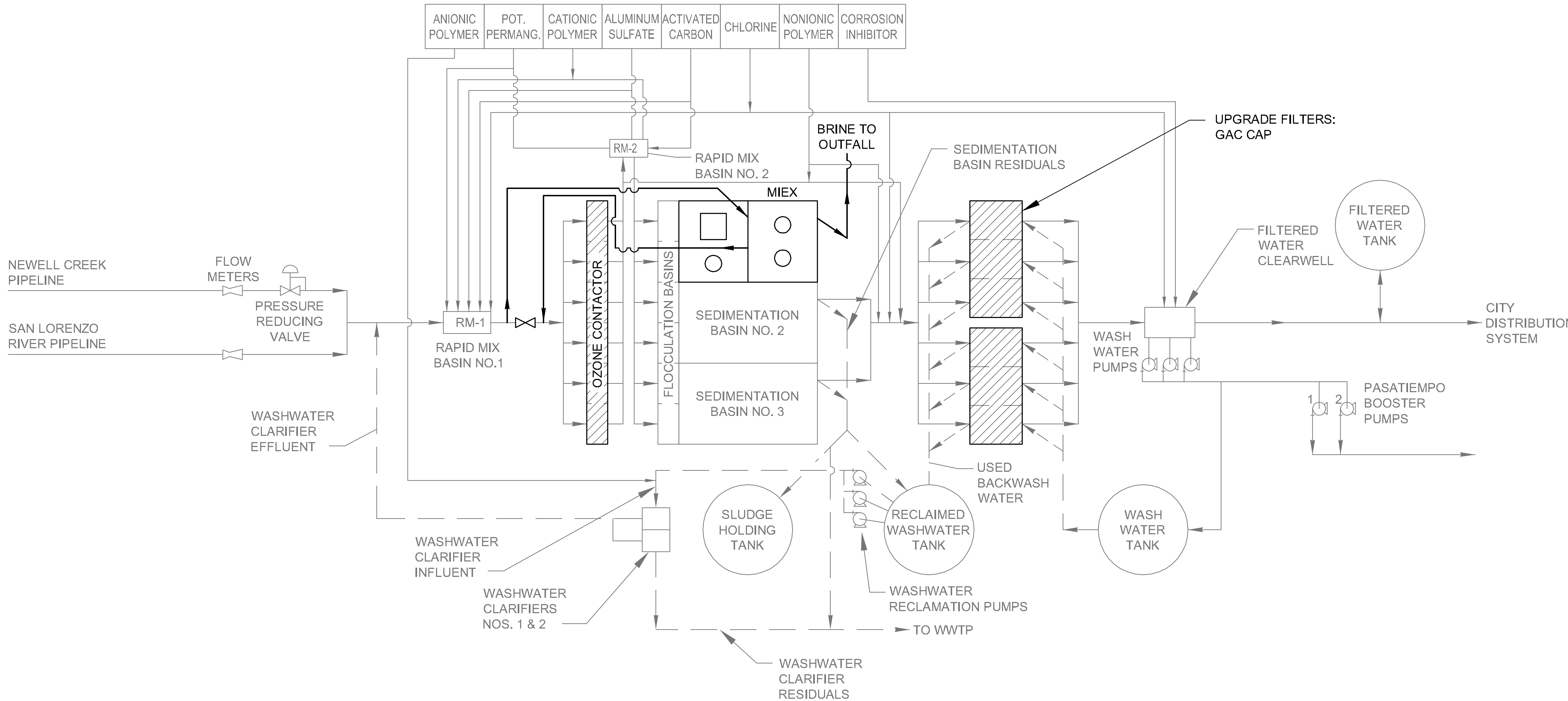

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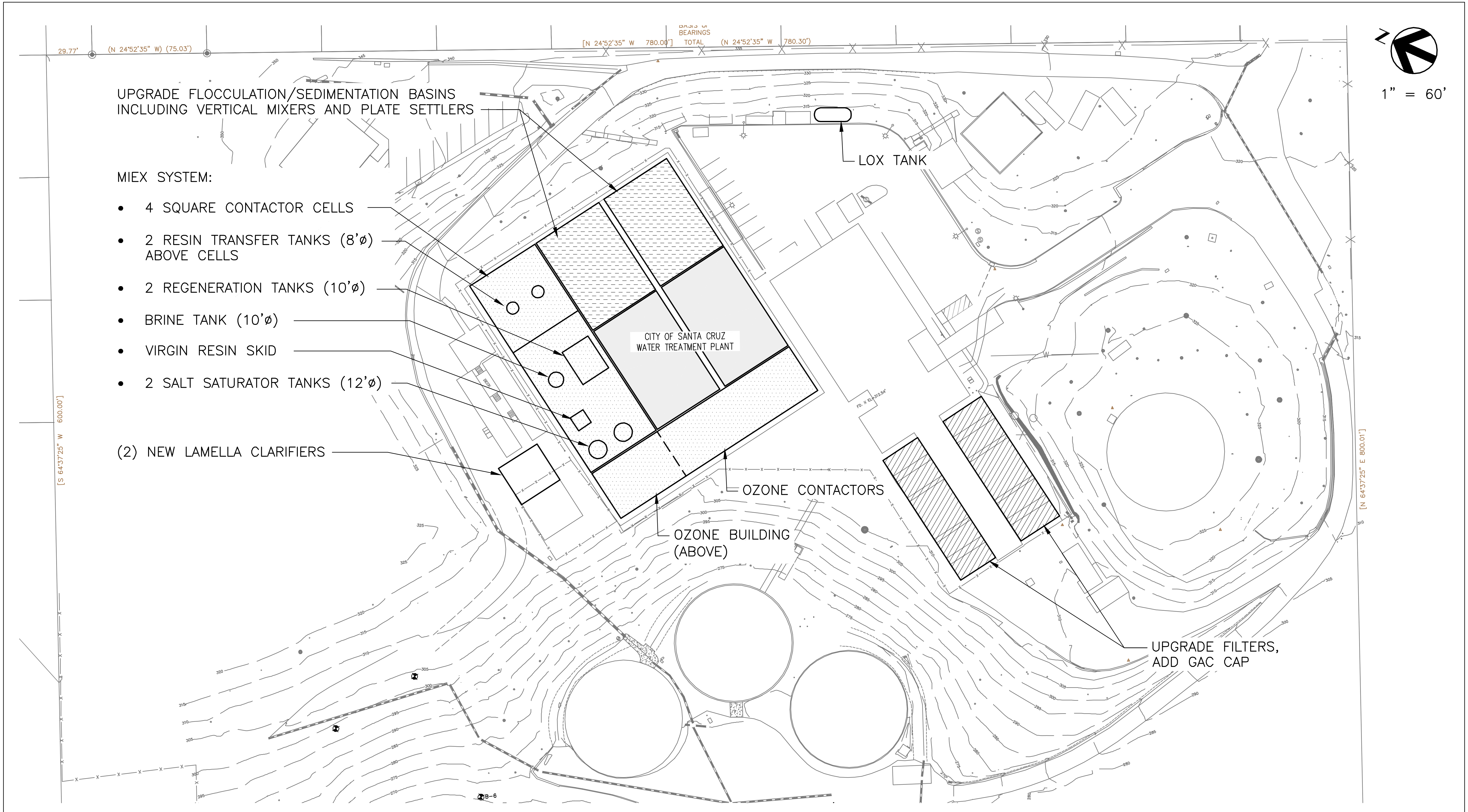
Alternative 11B: Ozone and MIEX
Proposed Flow Schematic

City of Santa Cruz Graham Hill Water Treatment Plant
Alternatives Evaluation

DATE 8/13/10

FIGURE Figure 16



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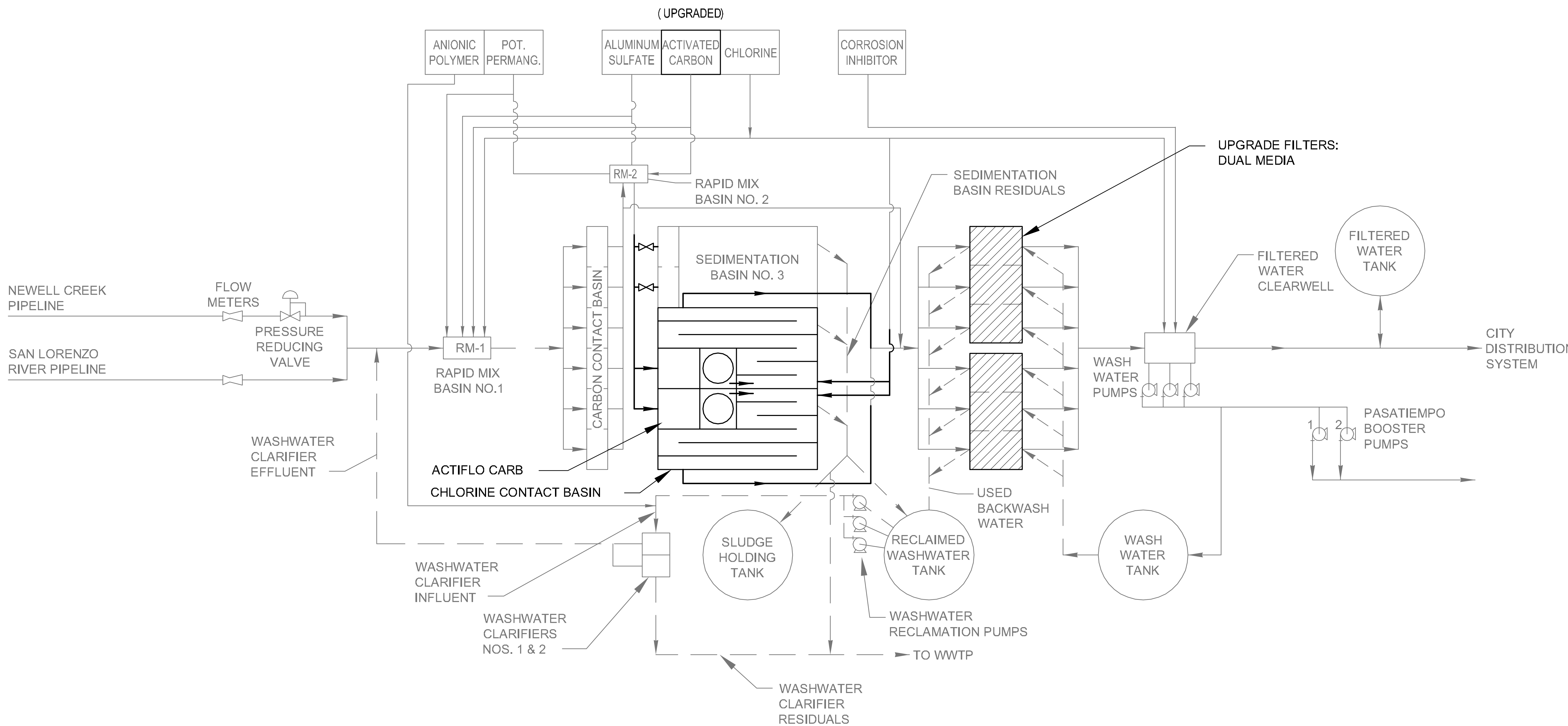
Alternative 11B: Ozone and MIEX
Proposed Site Layout

City of Santa Cruz Graham Hill Water Treatment Plant
Alternatives Evaluation

DATE 8/13/10

FIGURE Figure 17



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Alternative 21A: ACTIFLO CARB
Proposed Flow Schematic

City of Santa Cruz Graham Hill Water Treatment Plant
Alternatives Evaluation

DATE 8/13/10

FIGURE Figure 18

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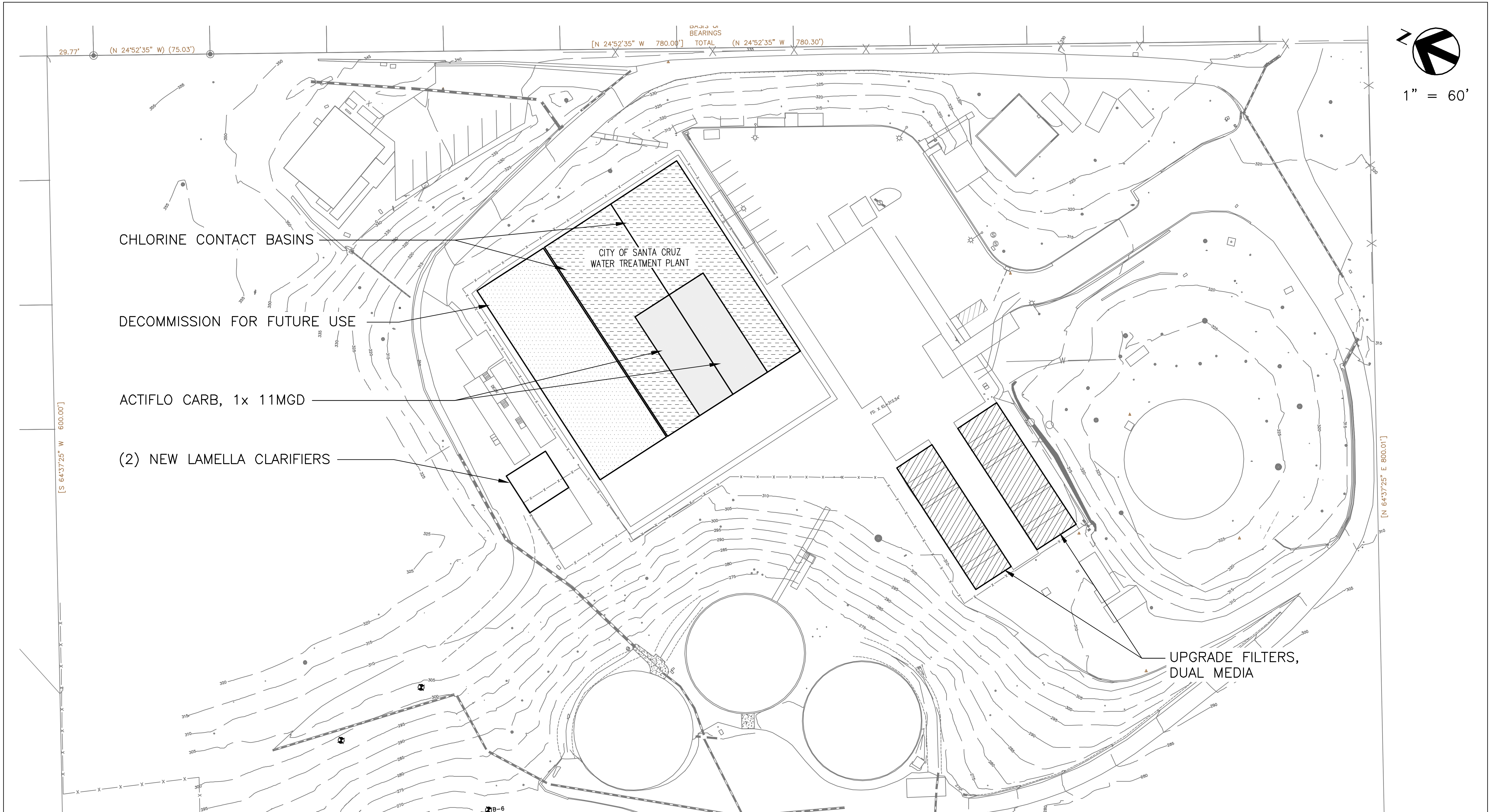

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Alternative 21A: ACTIFLO CARB
Proposed Site Layout

City of Santa Cruz Graham Hill Water Treatment Plant
Alternatives Evaluation

HDR

DATE 8/13/10

FIGURE Figure 19

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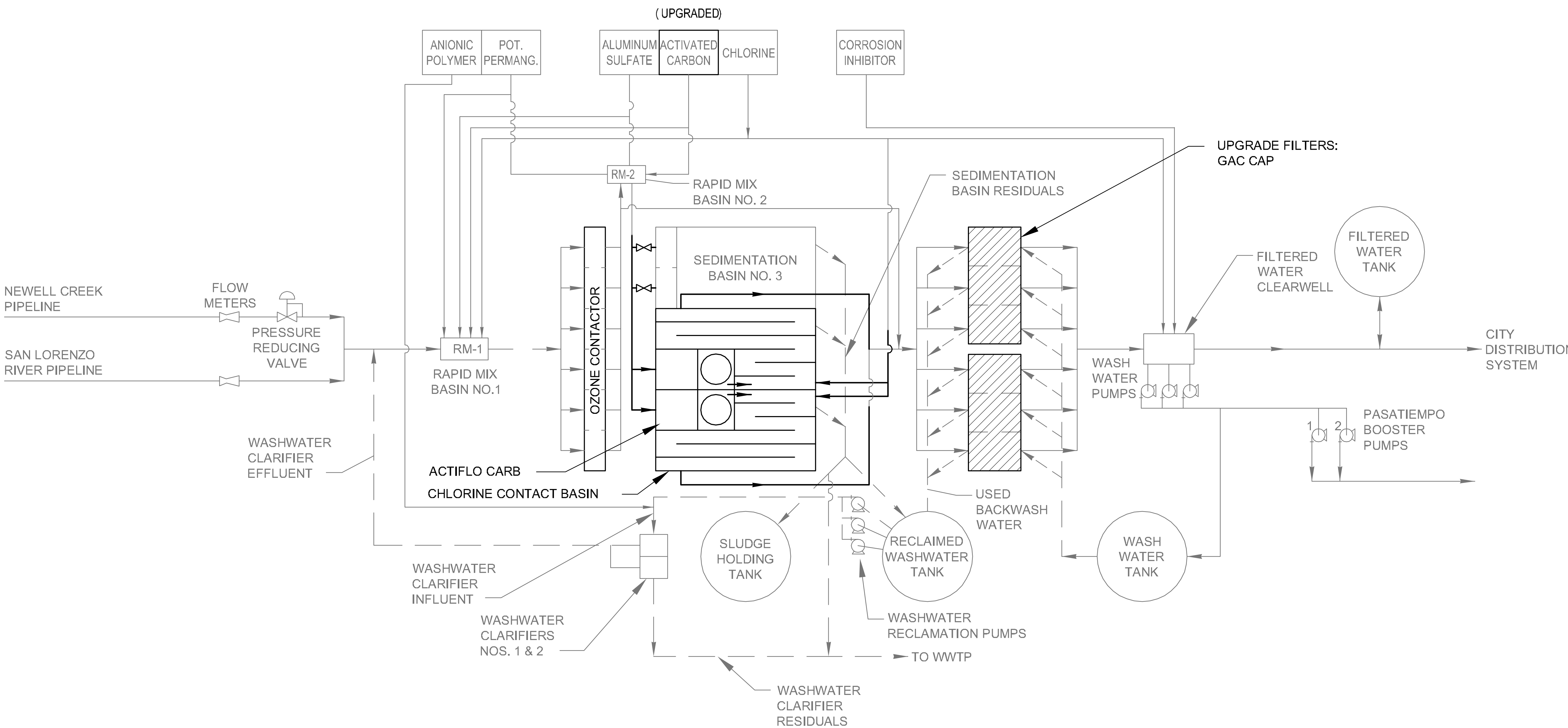

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Alternative 21B: Ozone and ACTIFLO CARB Proposed Flow Schematic

City of Santa Cruz Graham Hill Water Treatment Plant
Alternatives Evaluation

DATE 8/13/10

FIGURE Figure 20

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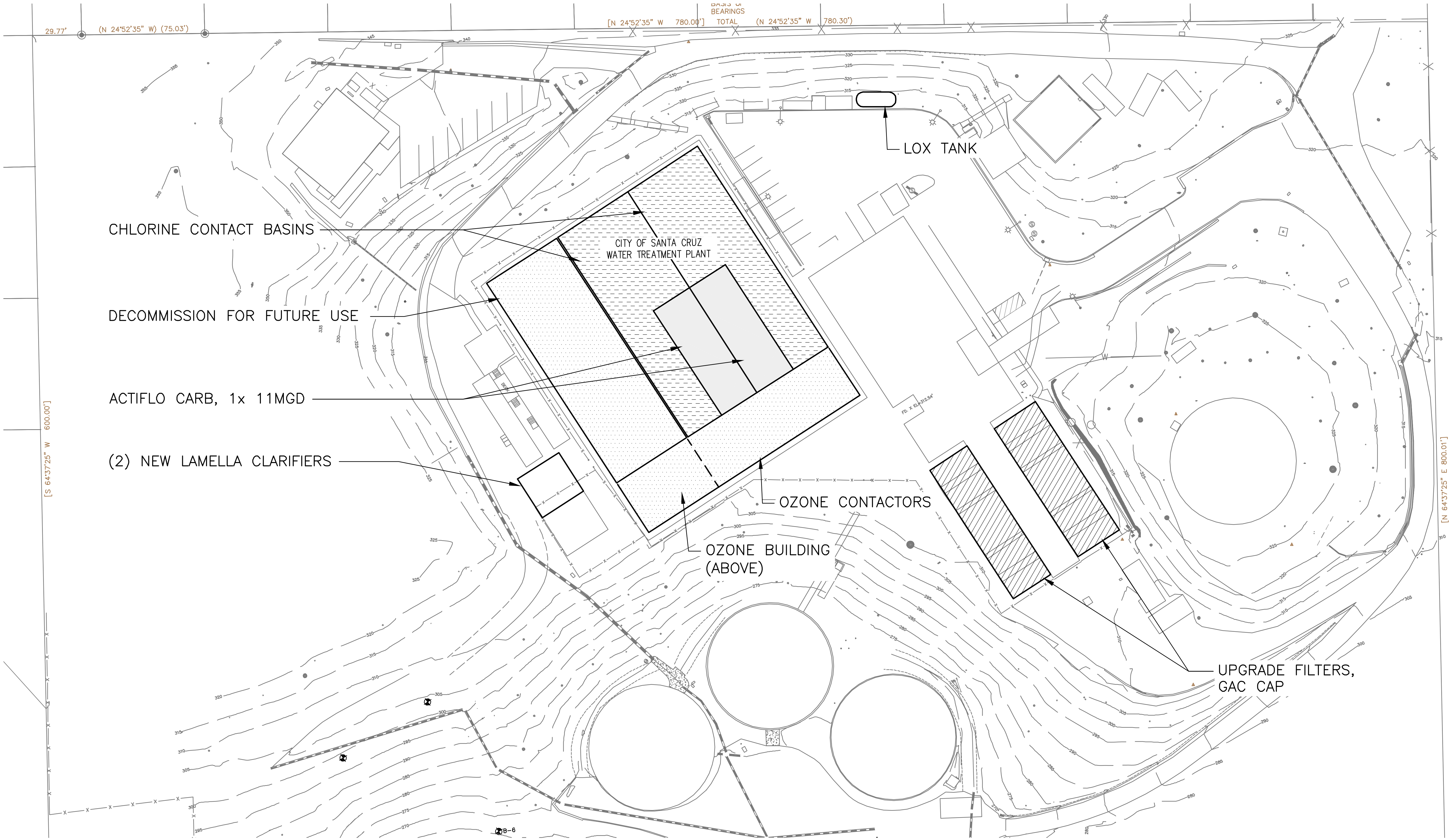

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Alternative 21B: Ozone and ACTIFLO CARB Proposed Site Layout

City of Santa Cruz Graham Hill Water Treatment Plant
Alternatives Evaluation

DATE 8/13/10

FIGURE Figure 21

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Solids Handling

The solids handling evaluation is based on the assumptions for current plant capacities shown in Table 6 below, which was obtained from previous reports and also documented in Appendix A:

Table 6. Plant Flow Data

Plant Flow Criteria	Value	Unit
Current Max Day Plant Operating Capacity	17.5	mgd
Current Max Day Demand	17	mgd
Current Average Daily Demand	10	mgd
Current Max Month Demand	13	mgd
Max day: Average Daily Demand ratio	1.7	
Max month: Average Daily Demand ratio	1.3	
Future Max Day Plant Operating Capacity	20.5	mgd
Future Max Day Demand	19.5	mgd
Future Average Daily Demand	11.5	mgd
Future Max Month Demand	15	mgd
Current average annual alum dose	26	mg/L
Current average annual PAC dose	3.5	mg/L

Based on the assumptions above, max month sludge production quantities were estimated for each Alternative, and are shown in Table 7 below.

Table 7. Solids Quantity Projections.

Alternative		Alum dose, mg/L	PAC dose, mg/L	Current Flow - Sludge Production/ Current Production, ratio	Current Max Month Flow - Sludge Production lb/day	Future Flow - Sludge Production/ Current Production, ratio	Future Max Month Flow - Sludge Production lb/day	Future Brine, gpd annual avg
	Current Operation	26	3.5	1.00	1820	1.17	2132	
21-B	OZONE + Actiflo CARB	36	10	1.34	2439	1.57	2857	
21-A	Actiflo CARB	40	10	1.45	2639	1.70	3091	
11-B	OZONE + MIEX (alum dose 62%)	16	3.5	0.73	1329	0.86	1556	6,150
15	Ceramic Membranes	60	5	1.90	3458	2.23	4051	
22	Pre-Ozonation	50	0	1.49	2712	1.75	3177	
10	Membranes + GAC	26	3.5	1.00	1820	1.17	2132	
11-A	MIEX (alum dose 62%)	18	3.5	0.78	1420	0.91	1663	6,150
23	Chloramines	26	3.5	1.00	1820	1.17	2132	
20	High Rate Clarification	60	3.5	1.90	3458	2.23	4051	
12	Enhanced Coagulation	60	3.5	1.90	3458	2.23	4051	

Alternatives

There are three alternatives that were considered for residuals handling. They are described below.

Alternative 1

This alternative is to continue to discharge the solids to the sewer as GHWTP is currently operating. The estimated solids production in Table 7 above shows that the future solids quantities for most alternatives exceed the current local limit of 2,085 lb/day with no limit on TDS. For this Alternative, the limit would need to be renegotiated. The local limits are currently being re-evaluated by another consultant, so potential resolution and costs associated with this alternative can't be reached until the local limits study has been completed. There is initial indication that the local limits for GHWTP can be increased and will not have a TDS limit imposed.

Alternative 2

This alternative is to discharge the solids to the Santa Cruz County Graham Hill Road Sewer, where greater pipeline capacity is available. The connection to this sewer already exists due to prior negotiations between the City of Sana Cruz and Santa Cruz County in exchange for an easement. In recent discussions with the Santa Cruz County Engineering Manager, the County is researching the request for information as to the potential requirements, limits, and costs associated with discharging to this sewer. The engineering manager indicated that the 8-inch diameter sewer has additional capacity and was optimistic that an arrangement could be made to accommodate GHWTP solids. For this Alternative, the limit would need to be renegotiated. There has been no indication of the costs associated with this option.

Alternative 3

This alternative would require that solids handling facilities be required on the GHWTP site. For this Alternative, the limit may require renegotiation depending on the type and capacity of solids handling facilities implemented at the WTP. This was not evaluated further due to the site constraints and indication that Alternatives 1 and 2 would be more cost-effective solutions.

Cost

To be determined once more information is obtained on the feasibility of Alternatives 1 and 2.

Preferred Alternative

To be determined once more information is obtained on the feasibility of Alternatives 1 and 2.

HDR

Project Cost Summary

Tables 8-15 summarize the estimated WTP process improvement project costs and O&M costs for each of the four selected alternatives as defined within this Alternatives Evaluation Study. Additional improvements to the GHWTP were recommended within Section 2 of the 2009 Basis of Design Report. Some of the Basis of Design Report recommended improvements are superseded by the treatment processes described in this report. Other improvements are still recommended. Table 16 presents an updated list of treatment plant improvements from the Basis of Design Report, and defines whether each improvement is currently included in, superseded by, or still recommended in addition to the selected alternatives of the current Alternatives Evaluation.

Table 8. Estimated Capital Cost for MIEX Alternative: MIEX + PAC + KMnO4 + RM/F/S + Filtration (GAC cap) + Cl2

Improvement Description		Base Cost (May 2011)
MIEX System		$5,950,000[1]
Sed Basin Mods for MIEX (add baffle wall(s), mount agitators (6))		$170,000
Plate Settlers & Basin Modifications (decommission 1 for MIEX use)		$3,670,000[2]
GAC CAP and Filter Restoration		$1,840,000[2]
Filtered Water Tank Piping Improvements (flow through)		$420,000
New 1 MG FW clear well; piping		$2,050,000[3]
UV system for Passatiempo Pump Station		$309,000[1]
New Lamella Clarifiers, No. 3 & 4		$690,000[2]
Subtotal New Facilities		$15,099,000
Electrical System Improvements	15%	$2,260,000
Control System Improvements	10%	$1,510,000
Site Modifications and Yard Piping	20%	$3,020,000
Unidentified Items	30%	$4,530,000
Subtotal		$26,419,000
Change Order Allowance	5%	$1,320,000
Subtotal - Construction Costs		$27,739,000
Preliminary and Final Design Fees	18%	$4,990,000
Resident Engineering, Inspection and Construction Support	12%	$3,330,000
Total Capital Cost		$36,059,000

Notes:

1. Assume upgrades equal half the cost for new chem feed system, as estimated in 2004 dollars, escalated to 2011.
2. March 2010 costs escalated to May 2011 with factor of 8.9% (assumes 4% annual increase). Assumes use of existing sedimentation basin No.1.
3. Cost from Table 5-1, BDR, April 2009. Prorates removed, escalated to 2011. Includes replacing paddle wheel flocculators with vertical turbine mixers, addition of plate settlers, concrete restoration.
4. CT achieved in new 1 MG FW tank.
5. Prorates applied from TM-3A Comparison of Treatment Process Alternatives (Nov '04).
6. Brine is assumed to be discharged to sewer.

HDR

Table 9. Estimated Annual O&M Cost for MIEX Alternative: MIEX + PAC + KMnO4 + RM/F/S + Filtration (GAC cap) + Cl2

	$/yr	$/1000-gal
Power	$120,000	$0.02[1]
Chemicals	$430,000	$0.07[2]
MIEX system -(salt, power, resin)	$700,800	$0.12
GAC Replacement	$120,000	$0.02[3]
Labor	$390,000	$0.07[4]
Misc.	$180,000	$0.03[4]
Residuals Disposal	$170,000	$0.03[4]
Total O&M Costs	$2,110,800	$0.36

Notes:
1. Assumes BDR 2009 power costs, replacing membranes with conventional filters, escalated to 2011 (factor 11.354%).
2. Assumed BDR chemical costs less membrane cleaning chemical cost.
3. Assumes replacement of GAC every 3 years. GAC replacement costs do not include labor.
4. Assumes BDR 2009 O&M cost, escalated to 2011.

Table 10. Estimated Capital Cost for Ozone + MIEX Alternative: Ozone + MIEX + PAC + KMnO4 + RM/F/S + Filtration (GAC cap) + Cl2

Improvement Description		Base Cost (May 2011)
Ozone System		$4,500,000[1]
LOX System		$520,000
Calcium Thiosulfate System		$390,000[1]
MIEX System		$5,950,000[2]
Sed Basin Mods for MIEX (add baffle wall(s), mount agitators (6))		$130,000
Plate Settlers & Basin Modifications (decommission 1 for MIEX use)		$3,670,000[3]
Filter Restoration + GAC cap		$1,840,000[3]
New Lamella Clarifiers, No. 3 & 4		$690,000[3]
Subtotal New Facilities		$17,000,000
Electrical System Improvements	15%	$2,550,000
Control System Improvements	10%	$1,700,000
Site Modifications and Yard Piping	20%	$3,400,000
Unidentified Items	30%	$5,100,000
Subtotal		$29,750,000
Change Order Allowance	5%	$1,490,000
Subtotal - Construction Costs		$31,240,000
Preliminary and Final Design Fees	18%	$5,620,000
Resident Engineering, Inspection and Construction Support	12%	$3,750,000
Total Capital Cost		$40,610,000

Notes:
1. Cost escalated from Nov 2004 TM-3A Comparison of Treatment Process Alternatives to 2011 (for comparison with 2009 BDR costs).
2. March 2010 costs escalated to May 2011 with factor of 8.9% (assumes 4% annual increase).
   Assumes use of Sed portion of existing basin (separated out into contact zone and settler zone).
3. Cost from Table 5-1, BDR, April 2009. Prorates removed, escalated to 2011.
4. Prorates applied from TM-3A Comparison of Treatment Process Alternatives (Nov '04).
5. Brine is assumed to be discharged to sewer.

Table 11. Estimated O&M Cost for Ozone + MIEX Alternative: Ozone + MIEX + PAC + KMnO4 + RM/F/S + Filtration (GAC cap) + Cl2

	$/yr	$/1000-gal
Power	$220,000	$0.04[1]
Chemicals	$450,000	$0.08[2]
MIEX system -(salt, power, resin)	$700,800	$0.12
GAC Replacement	$120,000	$0.02[3]
Labor	$390,000	$0.07[4]
Misc.	$180,000	$0.03[4]
Residuals Disposal	$170,000	$0.03[4]
Total O&M Costs	$2,230,800	$0.38

Notes:
1. Assumes BDR 2009 power costs, replacing membranes with conventional filters, adding ozone, escalated to 2011 (factor 11.354%).
2. Chemical costs based on 2009 BDR, less membrane cleaning chemical cost. Coagulant cost Increased by 33%. LOX added. Escalated to 2011.
3. Assumes replacement of GAC every 3 years. GAC replacement costs do not include labor.
4. Assumes BDR 2009 O&M cost, escalated to 2011.

Table 12. Estimated Capital Cost for Actiflo CARB Alternative: KMnO4 + PAC + Actiflo CARB + Cl2 + Filtration

Improvement Description		Base Cost (May 2011)
Alum system upgrades (increased capacity)		$190,000[1]
PAC system improvements		$190,000[1]
Actiflo CARB System		$3,680,000
Filter Restoration		$1,840,000[2]
Sed basin modifications (for Actiflo-Carb Retrofit), walls, concrete rehab		$735,000[3]
Chlorine contact modifications (in sed basin 2), walls, concrete rehab		$730,000[4]
New Lamella Clarifiers, No. 3 & 4		$690,000[2]
Subtotal New Facilities		$7,485,000
Electrical System Improvements	15%	$1,270,000
Control System Improvements	10%	$850,000
Site Modifications and Yard Piping	20%	$1,700,000
Unidentified Items	30%	$2,540,000
Subtotal		$13,845,000
Change Order Allowance	5%	$740,000
Subtotal - Construction Costs		$14,585,000
Preliminary and Final Design Fees	18%	$2,800,000
Resident Engineering, Inspection and Construction Support	12%	$1,870,000
Total Capital Cost		$19,255,000

Notes:
1. Assume upgrades equal half the cost for new chem feed system as estimated in 2004 dollars, escalated to 2011.
2. Cost from Table 5-1, BDR, April 2009. Prorates removed, escalated to 2011.
3. Basin modifications include addition of wall (s), concrete rehabilitation (1 basin), metal work.
4. Basin modifications include addition of baffle wall (s) ONLY downstream of Actiflo CARB. Piping not included.
5. Prorates used from TM-3A Comparison of Treatment Process Alternatives (Nov '04)
6. Assume Actiflo CARB is direct feed.

Table 13. Estimated O&M Cost for Actiflo CARB Alternative: KMnO4 + PAC + Actiflo CARB + Cl2 + Filtration

	$/yr	$/1000-gal
Power	$180,000	$0.03[1]
Chemicals	$500,000	$0.09[2]
Labor	$390,000	$0.07[3]
Misc.	$180,000	$0.03[3]
Residuals Disposal	$170,000	$0.03[3]
Total O&M Costs	$1,420,000	$0.24

Notes:
1. Assumes BDR 2009 power costs, replacing membranes with conventional filters, escalated to 2011 (factor 11.354%).
2. Chemical costs based on 2009 BDR. Coagulant cost Increased by 33%. Escalated to 2011.
3. Assumes BDR 2009 O&M cost, escalated to 2011.

Table 14. Estimated Capital Cost for Ozone + Actiflo CARB Alternative: KMnO4 + Ozone + PAC + Actiflo CARB + Cl2 + Filtration

Improvement Description		Base Cost (May 2011)
Ozone System		$4,500,000
LOX System		$520,000
Calcium Thiosulfate System		$390,000[1]
PAC system improvements		$190,000[1]
Actiflo CARB System		$3,110,000
Filter Restoration + GAC cap		$1,840,000[2]
Sed basin modifications (for Actiflo-Carb Retrofit), walls, concrete rehab		$735,000[3]
Chlorine contact modifications (in sed basin 2), walls, concrete rehab		$730,000[4]
New Lamella Clarifiers, No. 3 & 4		$690,000[2]
Subtotal New Facilities		$11,975,000
Electrical System Improvements	15%	$1,800,000
Control System Improvements	10%	$1,200,000
Site Modifications and Yard Piping	20%	$2,400,000
Unidentified Items	30%	$3,590,000
Subtotal		$21,695,000
Change Order Allowance	5%	$1,050,000
Subtotal - Construction Costs		$22,745,000
Preliminary and Final Design Fees	18%	$3,960,000
Resident Engineering, Inspection and Construction Support	12%	$2,640,000
Total Capital Cost		$29,345,000

Notes:
1. Assume upgrades equal half the cost for new chem feed system as estimated in 2004 dollars, escalated to 2011.
2. Cost from Table 5-1, BDR, April 2009. Prorates removed, escalated to 2011.
3. Basin modifications include addition of wall (s), concrete rehabilitation (1 basin), metal work.
4. Basin modifications include addition of baffle wall (s) ONLY downstream of Actiflo CARB. piping not included.
5. Prorates used from TM-3A Comparison of Treatment Process Alternatives (Nov '04)

Table 15. Estimated O&M Cost for Ozone + Actiflo CARB Alternative: KMnO4 + Ozone + PAC + Actiflo CARB + Cl2 + Filtration

	$/yr	$/1000-gal
Power	$290,000	$0.05[1]
Chemicals	$650,000	$0.11[2]
GAC Replacement	$120,000	$0.02[3]
Labor	$390,000	$0.07[4]
Misc.	$180,000	$0.03[4]
Residuals Disposal	$170,000	$0.03[4]
Total O&M Costs	$1,800,000	$0.31

Notes:
1. Assumes BDR 2009 power costs, replacing membranes with conventional filters, escalated to 2011 (factor 11.354%).
2. Chemical costs based on 2009 BDR, less membrane cleaning chemical cost. Coagulant cost Increased by 33%. LOX added. Escalated to 2011.
3. Assumes replacement of GAC every 3 years. GAC replacement costs do not include labor.
4. Assumes BDR 2009 O&M cost, escalated to 2011.

Table 16. Treatment Plant Improvements (Based on Section 2 of Basis of Design Report, 2009)

Improvement	Recommended? Included? Superseded?	Estimated Construction Cost Added to Total Project
Membrane Filtration System	S	-
Granular Activated Carbon (GAC) Adsorbers: Convert the existing granular media filters to GAC adsorbers to remove taste and odor compounds and organic DBP precursors to meet the THM and HAA goals.	S	-
Filtered Water Tank: Modify filtered water tank piping for flow-through operation.	R,I	Incl.
Onsite Hypochlorite System: Add an onsite sodium hypochlorite generation system. SCWD is currently replacing their existing gas chlorine system with a bulk sodium hypochlorite system. The bulk sodium hypochlorite system will be retained as a backup to the onsite generation system.	R	560,000[2]
Chemical Systems: Add new chemical systems for membrane cleaning and improvements to existing chemical systems.	S	-
Washwater Clarification: Expand the washwater clarification system to address the higher volume of used washwater that will result from the membranes. The expanded system will process sedimentation basin solids and backwash water (from the membranes and GAC contactors) to improve the recovery of water from the waste streams and minimize water lost through discharges to the sanitary sewer.	R,I	Incl.
Flocculation/Sedimentation Basins: Replace paddle wheel flocculators with variable speed vertical turbine mixers. The variable speed drives will allow operators to optimize flocculation by varying the mixing energy in each stage during seasonal and sudden changes in raw water flow and/or quality. Add plate settlers to improve settling at high flows. Modify the concrete wall and settled water channel for membranes.	R,I	Incl.
Site Improvements and Yard Piping: Improve access by trucks, add a chemical loading station, and implement yard piping improvements.	S	-
Electrical: Implement electrical improvements consistent with the new equipment.	R,I	Incl.
Controls: Replace existing FactoryLink software with Wonderware and upgrade plant control system for new and modified equipment.	R (partial incl.)	portions of 2,300,000[1,3]
New Membrane Building: The new membrane building will be designed according to the applicable codes and will accommodate solar panel equipment.	S	-

Improvement	Recommended? Included? Superseded?	Estimated Construction Cost Added to Total Project
Provisions for Future Facilities: Provide space for future facilities: ultraviolet light (UV) disinfection, ozone, aqua ammonia, and solids dewatering.	S	-
Solar Panels: Add solar panels to the new membrane and chemical buildings; may be implemented under a separate design/build contract.	R (for operations building.)	1,000,000[1]

Notes:
1. Costs are from Table 5-1 of the Basis of Design Report (CDM, April 2009).
2. Cost of $304,087 is from Appendix C of the Basis of Design Report (CDM, April 2009). Prorates added, as shown in Tables 6-13.
3. Based on Tables 6-13, a prorate of 10% has been added to preliminary construction cost estimates to account for controls improvements. The prorate does not include replacement of controls software.

Phasing Plan for Selected Alternatives

Each of the selected alternatives may be constructed and / or implemented in phases. Phased implementation often minimizes the initial capital expense of a project by constructing project components as they are needed in order to meet the regulatory, treatment, or other goals of the project. A proposed phasing plan for each alternative is as follows:

Actiflo CARB Alternative

Phase 1:

- Conversion of sedimentation basin(s) to Actiflo CARB system and chlorine contact basins.
- Improvements to PAC system (feed and storage).

Phase 2:

- Filtered water tank flow through piping for use in achieving CT, potentially reducing the chlorine dose in chlorine contact basins. Implementation following regulatory confirmation of use of distribution system downstream of Passatiempo pump station for partial CT.

Phase 3:

- Improvements to Alum system (feed and storage) based on new average alum dose.

Phase 4:

- Filter Restoration as required for improved operation and minimized maintenance.

Phase 5:

- Improvements to residuals system as required to meet existing and future discharge requirements.

Ozone + Actiflo CARB Alternative

Phase 1:

- Conversion of sedimentation basin(s) to Actiflo CARB system and chlorine contact basins.
- Improvements to PAC system (feed and storage).

Phase 2:

- Filtered water tank flow through piping for use in achieving CT, potentially reducing the chlorine dose in chlorine contact basins. Implementation following regulatory confirmation of use of distribution system downstream of Passatiempo pump station for partial CT.

Phase 3:

- Improvements to Alum system (feed and storage) based on full scale operational data of new average alum dose.

Phase 4:

- Filter Restoration with GAC cap for removal of AOC and improved filter operation.

Phase 5:

- Improvements to residuals system as required to meet existing and future discharge requirements.

Phase 6:

- Ozone system as required for superior supplemental T&O control, based on the full scale operational data of the anticipated inherent T&O control provided by the Actiflo CARB system.
- LOX system
- Calcium Thiosulfate system

MIEX Alternative

Phase 1:

- Modifications to sedimentation basins (addition of plate settlers, vertical flocculators).
- MIEX system (interim chlorine dose point upstream of flocculation/sedimentation basins to meet CT through basins and filters).

Phase 2:

- Filter restoration with GAC cap as required for improved control of taste and odor and improved operation.
- New finished water clearwell tank for chlorine contact downstream of GAC filter caps.
- Filtered water tank flow through piping for use in achieving CT, potentially reducing the chlorine.
- UV system for Passatiempo pump station.

Phase 3:

- Improvements to residuals system as required to meet existing and future discharge requirements.

Ozone + MIEX Alternative

Phase 1:

- Modifications to sedimentation basins (addition of plate settlers, vertical flocculators).
- MIEX system (interim chlorine dose point upstream of flocculation/sedimentation basins to meet CT through basins and filters).

Phase 2:

- Ozone system as required for superior supplemental T&O control, based on the full scale operational data of the anticipated inherent T&O control provided by the Actiflo CARB system.
- LOX system
- Calcium Thiosulfate system
- Filter restoration with GAC cap for removal of AOC and improved filter operation.
- Filtered water tank flow through piping for use in achieving CT, potentially reducing the chlorine.

Phase 3:

- Improvements to residuals system as required to meet existing and future discharge requirements.

Project Schedule

Figure 22 presents the preliminary schedule for the Graham Hill Water Treatment Plant Improvements project. The schedule incorporates the following critical project elements:

- Pilot testing phase
- Design phase
- Construction phase (phases of construction will vary depending on treatment process)
- Regulatory timeline

The Stage 2 D/DBPR requires that the GHWTP begin Stage 2 compliance monitoring (for the Locational Running Annual Average for TTHMs and HAA5) by October 1, 2012, but indicates that states may grant up to two years extension for water systems requiring capital improvements. Thus, HDR recommends that the SCWD pursue an extension with the California DPH.

Recommended Next Step - Pilot Testing

To complete this project and ensure regulatory compliance as near to the regulatory deadlines as possible, HDR recommends that the City initiate the Pilot Test Phase of the project for the four selected alternatives. To capture the most difficult water quality, the testing should ideally be performed during the late summer/early fall when algal blooms and lake turnover can occur. The second most difficult period would be during the winter after a rainy period when turbidity levels can be elevated in the lake. HDR recommends a minimum test duration of four to six weeks during each of the two test periods. The pilot test schedule is included in Figure 22. Objectives of the pilot testing would be to verify the operating cost assumptions for the processes, verify performance to meet water quality goals, determine the benefits of ozonation, and to allow operators to become familiar with the proposed processes.

Proposed Piloting of Selected Alternatives

Pilot Testing for selection of a treatment process typically consists of the following activities:

- Develop the Pilot Test Protocol – A test plan is a document that defines all of the major elements of the testing. An outline of a typical pilot test plan is presented below.
- Establish piloting contracts with vendors
- Construct the pilot testing plant facility (site configuration, source water supply, treated water discharge, residuals stream, power, tankage, data connection)
- Conduct testing per the test plan
- Decommission facility
- Analyze data; develop test report and make recommendations
- Coordination with vendors before, during, and after testing

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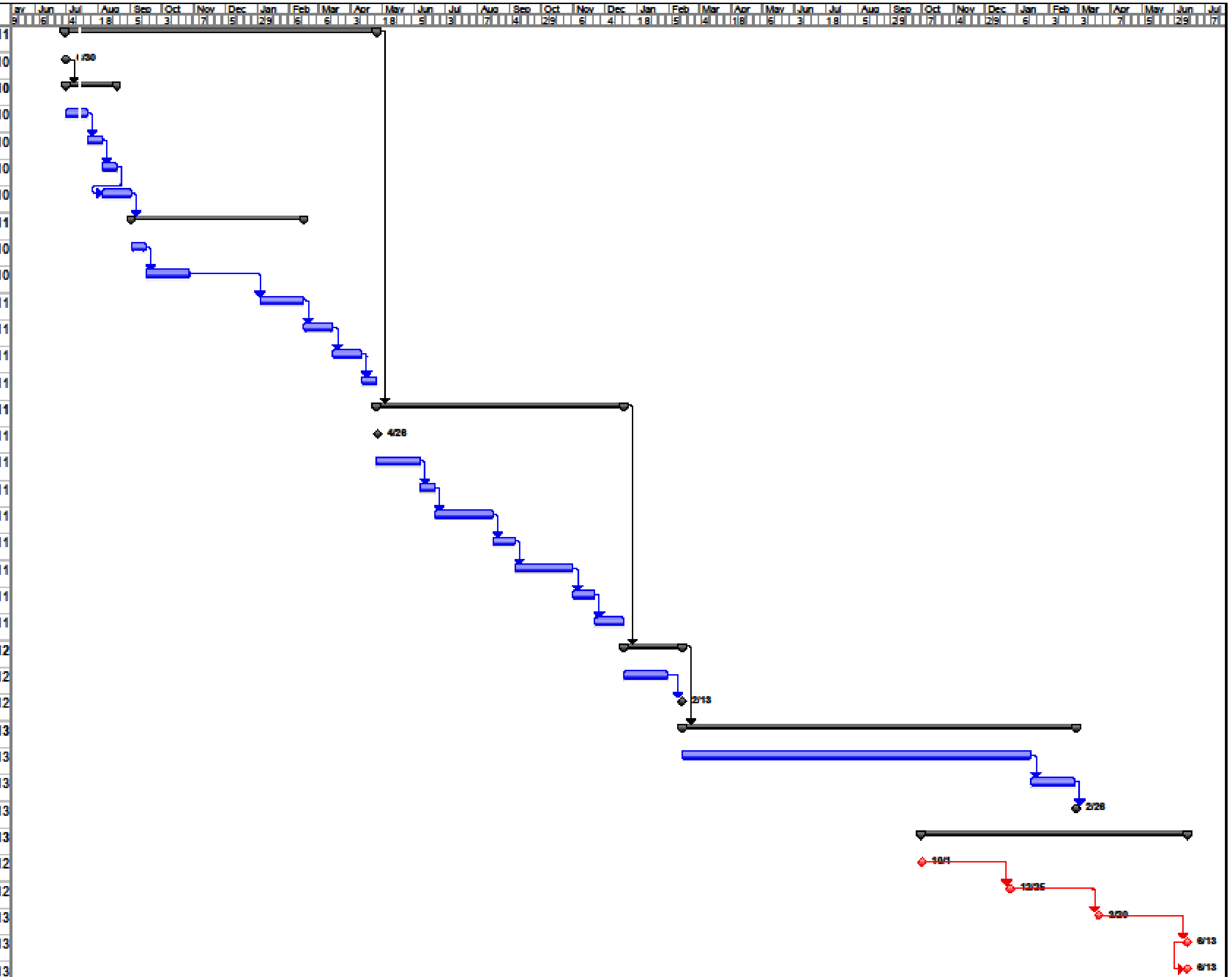
Test Plan Overview

A Pilot Test Protocol for the GHWTP Improvements Project would include the following elements:

- Pilot Test Program
  - Test objectives
  - Process descriptions
  - Pilot unit specifications
  - Program schedule
- Pilot Test Conditions and Standard Procedures
  - Operating Conditions
  - Responsibilities
    - Vendor responsibilities
    - Owner responsibilities
  - Standard sampling methods
  - Data handling protocol
- Pilot Test Plan
  - Phase 1 Testing: September/October (4-6 weeks)
    - Phase 1A Testing: MIEX & Actiflo CARB direct feed
    - Phase 1B Testing: MIEX & Actiflo CARB with pre-ozonation
    - Phase 1C Testing: MIEX & Actiflo CARB with intermediate ozonation
    - Filtration with GAC cap
  - Phase 2 Testing: January (4-6 weeks)
    - Phase 2A Testing: MIEX & Actiflo CARB direct feed
    - Phase 2B Testing: MIEX & Actiflo CARB with pre-ozonation
    - Phase 2C Testing: MIEX & Actiflo CARB with intermediate ozonation
    - Filtration with GAC cap
  - High turbidity event simulation
  - Data Requirements for each test phase
  - QA/QC verifications (daily, biweekly checking of pump flow rates, dosages, in-line analyzer verification, cleaning, recalibration)

ID	Task Name	Duration	Start	Finish
1	**Pilot Testing Phase**	**214 days**	**Wed 6/30/10**	**Mon 4/25/11**
2	Consultant NTP - Pilot Coordination	1 day	Wed 6/30/10	Wed 6/30/10
3	**Pilot Test Plan**	**35 days**	**Thu 7/1/10**	**Wed 8/18/10**
4	Draft Pilot Test Plan and Protocol	15 days	Thu 7/1/10	Wed 7/21/10
5	Test Plan Review	10 days	Thu 7/22/10	Wed 8/4/10
6	Final Pilot Test Plan & Protocol	10 days	Thu 8/5/10	Wed 8/18/10
7	Vendor Contracts Coordination	20 days	Thu 8/5/10	Wed 9/1/10
8	**Pilot Testing**	**118 days**	**Thu 9/2/10**	**Mon 2/14/11**
9	Pliot Plant Set Up	10 days	Thu 9/2/10	Wed 9/15/10
10	Phase 1 Pilot	30 days	Thu 9/16/10	/ed 10/27/10
11	Phase 2 Pilot	30 days	Tue 1/4/11	Mon 2/14/11
12	Draft Pilot Report	20 days	Tue 2/15/11	Mon 3/14/11
13	Report Review	20 days	Tue 3/15/11	Mon 4/11/11
14	Final Report	10 days	Tue 4/12/11	Mon 4/25/11
15	**Design Phase**	**170 days**	**Tue 4/26/11**	**lon 12/19/11**
16	Consultant NTP - Design	1 day	Tue 4/26/11	Tue 4/26/11
17	Basis of Design Report	30 days	Tue 4/26/11	Mon 6/6/11
18	BOD Review	10 days	Tue 6/7/11	Mon 6/20/11
19	50 % Design Submittal	40 days	Tue 6/21/11	Mon 8/15/11
20	50% Review	15 days	Tue 8/16/11	Mon 9/5/11
21	90% Design	40 days	Tue 9/6/11	ion 10/31/11
22	90% Review	15 days	Tue 11/1/11	ion 11/21/11
23	100% Design	20 days	Tue 11/22/11	ion 12/19/11
24	**Bid Phase**	**40 days**	**Tue 12/20/11**	**Mon 2/13/12**
25	Bidding Period	30 days	Tue 12/20/11	Mon 1/30/12
26	Contract Award	10 days	Tue 1/31/12	Mon 2/13/12
27	**Construction Phase**	**271 days**	**Tue 2/14/12**	**Tue 2/26/13**
28	Construction Period	240 days	Tue 2/14/12	Mon 1/14/13
29	Testing and Commissioning	30 days	Tue 1/15/13	Mon 2/25/13
30	WTP Online	1 day	Tue 2/26/13	Tue 2/26/13
31	**Regulatory Schedule**	**184 days**	**Mon 10/1/12**	**Thu 6/13/13**
32	Stage 2 DBP Rule Monitoring Begins	1 day	Mon 10/1/12	Mon 10/1/12
33	Quarterly Sample 2	1 day	Tue 12/25/12	Tue 12/25/12
34	Quarterly Sample 3	1 day	Wed 3/20/13	Wed 3/20/13
35	Quarterly Sample 4	1 day	Thu 6/13/13	Thu 6/13/13
36	LRAA COMPLIANCE	1 day	Thu 6/13/13	Thu 6/13/13



Project: Project Phasing Schedule
Date: Wed 7/14/10

Task | Split | Progress | Milestone | Summary | Project Summary | External Tasks | External Milestone | Deadline

Page 1

Figure 22. Graham Hill Water Treatment Plant Improvements Project Schedule

Appendices

Appendix A: TM 2 – Review of Existing Background Information
Appendix B: Jar Test Results and Conclusions
Appendix C: Screening Summary of Process Alternatives Memo and Table of Screened Alternatives
Appendix D: Conceptual Capital and O&M Cost Tables

Appendix A

TM 2 – Review of Existing Background Information
(HDR, July 20, 2010)

TM 2 – REVIEW OF EXISTING BACKGROUND INFORMATION

City of Santa Cruz Graham Hill Water Treatment Plant Technical Review ***July 20, 2010***

Reviewed by: Amy Miller, P.E.

Prepared by: Richard Stratton, P.E.

Introduction

The purpose of this technical memorandum (TM) is to summarize HDR's review of the reports, Technical Memorandums, and data provided by the City regarding the Graham Hill Water Treatment Plant (GHWTP). The items described as part of the review include:

- Raw water quality data for each of the water sources.
- Existing regulatory requirements including operating permit requirements.
- Treatment goals and operating assumptions.
- Existing treatment plant capacity and unit process limitations.
- Existing treatment challenges and concerns.
- Proposed expansion/improvements alternatives

Documents reviewed include:

- GHWTP Regulatory Basis of Design Report, April 6, 2009
- GHWTP Basis of Design Report Residuals Handling Selection Technical Memorandum, December 18, 2008
- GHWTP Basis of Design Report Membrane Selection Technical Memorandum, October 30, 2008
- Summary Report Water Quality and System Improvements Study , October 2007
- Technical Memorandum 3A Comparison of Treatment Process Alternatives for the Graham Hill Water Treatment Plant, November 2004
- Technical Memorandum 1 Evaluation of Treatment Process Alternatives for the Graham Hill Water Treatment Plant, October 2004
- Water Treatment Alternatives Study, 1991
- Appendix B-TM2 System and Service Reliability goals, December 2002

Raw Water Sources and Quality

The three primary water sources to the GHWTP include the San Lorenzo River, coastal creeks and Newell Creek (Loch Lomond Reservoir). A description of each water source follows:

San Lorenzo River

The San Lorenzo River turbidity is normally less than 5 NTU and total organic carbon (TOC) levels are normally around 2 mg/L. During storm events, turbidity can increase to near 1000 NTU and TOC can rise to above 7 mg/L. Bromide levels typically average about 0.2 mg/L. This source becomes unusable during the winter when flows are high and large quantizes of sand are present. Although turbidities from the San Lorenzo River waters do go over 1000 NTU, is not treated when turbidity is 10 NTU or greater. The Tait Diversion is typically in operation when river turbidity is below 10 NTU.

Newell Creek (Loch Lomond Reservoir)

Water withdrawn from Loch Lomond Reservoir normally has turbidities less than 2 NTU and an average TOC of around 4 mg/L. Bromide concentrations average about 0.1 mg/L. The reservoir is deep and stratifies most summers leading to elevated TOC. During the summer, heavy algae blooms occur in the reservoir. The algae blooms include blue-green algae that introduce taste and odor compounds such as geosmin and MIB into the water supply. During annual turnover of the reservoir in late fall, water quality sometimes worsens and at those times, the plant minimizes the use of this source. Water quality challenges during this time include those related to elevated manganese and iron.

Coast Sources (Laguna Creek, Liddell Spring, and Majors Creek)

The Coast Sources are high quality streams with less than 1 NTU turbidity and average TOC of about 1 mg/L. Turbidity and TOC levels can increase significantly during runoff events. Bromide is not present in theses sources.

The use of the sources varies throughout the year depending on rainfall events, reservoir turnover or other factors that may effect their water quality. The current annual average split of water supplied from each source is shown below. This split can change depending on whether it is a wet or dry year and water quality conditions from each source.

Newell Creek (NC)	15 percent
San Lorenzo River (SLR)	50 percent
Coast Sources (CS)	35 percent

In the future as demands increase, the Newell Creek water source deliveries will be increased to meet these demands as the SLR and CS supplies are now fully utilized.

A summary of the water usage split between the various sources is presented in Appendix A. The blended raw water quality that entered the plant for 2007, 2008, and 2009 (though August) is presented in Appendix B.

The blended raw water entering the plant typically has turbidity in the range of 0.5 to 11 NTU and TOC levels in the range 1.5 to 3 mg/L with values as high as 5 mg/L occasionally observed. Some other constituent besides TOC, such as bromides, may be causing the elevated DBP levels. Treatment alternatives developed for the GHWTP within the 2007 Water Quality and System Improvements Study (WQ&SIS) assumed the GHWTP would be placed in EPA Bin 3, based on anticipated Cryptosporidium detection. However, actual results from the LT2 sampling indicate the plant will be in Bin 1.

Regulatory Requirements

- The GHWTP operates under California Department of Public Health Operating Permit No 02-92-020, and was issued on December 21, 1992. The System No. is 44-10010. In addition to the normal State of California and EPA water quality regulations, the May 29, 2007 CDPH Inspection Report indicates the following: The plant is designed to treat a maximum flow of 24 MGD. Nominal filtration rates at a flow of 24 MGD are 3.9 gpm/sf with six filters in service, 4.7 gpm/sf with one filter out of service for backwashing, and 5.8 gpm/sf with only four filters in service. However, the operations plan indicates that the filters are to be operated at a rate of 3 gpm/sf or lower whenever possible. The range of filter loading rates at which the plant is operated complies with the operating criteria specified in Section 64660 of Title 22. Section 64660 sets a maximum filtration rate of 6.0 gpm/sf for conventional treatment plants with dual media filters under gravity flow.

Essentially no CT credit given after filters because the existing clearwell is very small and the pumps to the Pasatiempo system pump directly from the clearwell prior to the water entering the filtered water tank and the rest of the distribution system. In addition, the finished water tank is a currently branch design. Dedicated inlet and oulet piping and some baffling would be required for CT credit at the tank.

Additional issues pertaining to regulatory compliance include:

- Initially it was though that the blended raw water source would fall under Bin 3 for *Cryptosporidium*, however, testing now indicates that the source will fall under Bin 1.
- IDSE monitoring results have documented THM levels above 80 ppb at a limited number locations in the distribution system.
- Jar testing simulating GHWTP's current conventional treatment scheme showed that although chlorinating after treatment did reduce DBP formation by 10 to 15 percent, it would not prevent DBP levels from exceeding MCLs in the distribution system. Further testing using ferric chloride and a lower pH is warranted to determine if delayed chlorination would allow for continued use of free chlorine.

Treatment goals and operating assumptions

The City would like to achieve a reliable plant capacity of 22 mgd to ensure the ability to meet demands of 19.5 mgd. Up to 2.5 mgd of capacity should be available for backwash, plant water and other uses that do not enter the distribution system. In addition to complying with all state and federal water quality regulations, stated water quality goals for the distribution system are as follows:

- Water age less than 5 – 10 days, as needed to meet other distribution water quality goals
- Assimilable Organic Carbon < 0.2 mg/L
- THMs < 80 ppb*
- HAAs < 60 ppb*
- Chlorine 0.2 to 1.5 mg/L
- Threshold Odor Number ≤ 2 100 percent of the time
- Cl2:NH4 ratio in range of 4:1 to 5:1 (if chloramines implemented)

* These values reflect all distribution samples, and these are set at the MCL to provide a buffer for meeting the Locational Running Annual Average (LRAAs) in the distribution system.

Existing treatment plant capacity and unit process limitations

The GHWTP is a conventional treatment plant that was commissioned in 1960 as a 12 mgd plant and has undergone expansions and improvements over the last 40 years to increase the capacity to a nominal 24 mgd capacity. A brief description of the most significant limitations of the existing unit processes are presented below.

Plant Rated Capacity – The existing plant was constructed with a design capacity of 24 mgd, however, the plant's treatment capacity has been diminished by EPA and State regulations; other redundancy issues; and residuals handling limitations. A letter from CDPH dated June 13, 1998 requires the GHWTP to continuously provide 1-Log of additional disinfection for Giardia and Viruses (i.e., 4 Logs and 5-Logs respectively) in accordance with the California Surface Water Treatment Rule.

Rapid Mix (1 and 2), Carbon Contactors and Flocculators, Sedimentation Basins – These unit processes are functioning reasonably well but require improvements to increase their efficiency, prevent short circuiting, and replace aging equipment.

Dual-Media Filters – The existing filters have several deficiencies including:

- Lack of filter-to-waste piping
- Restricted filtration rate
- Shallow filter boxes
- Lack of air scour
- Small clearwell

Finished Water Tank – The existing tank was constructed in 1960, it's condition is unknown, and may have a limited remaining useful life. The Pasatiempo pumps draw water upstream of the Finished Water Tank and hence the plant does not receive credit for its use as chlorine contact basin for primary disinfection. The Finished Water Tank can be bypassed at the Tee. One side of the tee leads to the tank, with a 36" valve, and the other leads to the distribution system. The valve has not been operated in a while and it's condition is not known.

Residuals Handling System – The existing plant collects sedimentation solids and filter backwash waste in the Reclaimed Washwater Tank and then thickens these solids in a plate settler/thickener. The clarified water is returned to the head of the plant and the thickened solids are discharged to the sewer. The plate settler/thickener is currently overloaded and sewer capacity to convey residuals is limited.

A summary of the existing design criteria for the GHWTP after the 1986 improvements is presented in Table 1. These criteria are based on review of the 1959 and 1986 plant as-built drawings and Appendix B from the WQ&SIS.

Table 1 – Existing GHWTP Design Criteria

Item	Units	Value (at current capacity)	Typical Text Book Design Value
Design Flow (maximum day)	mgd	18	
Rapid Mix 1:			
Dimensions	LxWxD (ft)	5x5x4	
Volume	gal	750	
Detention time at design flow	seconds	4	
Motor size	hp	10	
G*t		5400	1000 - 2000
Carbon Contactors:			
Number	ea	6 (2 per sed basin)	
Dimensions	LxWxD (ft)	24.25x24.25x20.5	
Volume each	gal	90,000	
Mixer type		vertical	
Motor size	hp	10	
Detention time at design flow	minutes	43	10 to 40
Rapid Mix 2:			
Dimensions	LxWxD (ft)	6.75x6.75x7	
Volume	gal	2,400	
Detention time at design flow	sec	20	
Motor size	hp	10	
G*t		17,000	1000 - 2000
Flocculation Basins:			
Number	ea	3 (1 per sed basin)	
Stages, each	ea	2	3
Dimensions	LxWxD (ft)	19x50x21.5	
Volume, each	gal	153,000	
Detention time (total at design flow)	minutes	36	30 to 40
Flocculator type		Paddle wheels, 8 per basin	
Motor size: Stage 1 Stage 2	 hp hp	 7.5 7.5	
Sedimentation Basins			
Number	ea	3	
Dimensions	LxWxD avg (ft)	129.5x50x18	
Volume each	gal	872,000	

Item	Units	Value (at current capacity)	Typical Text Book Design Value
Detention time at design flow	minutes	209	
Tube settler area, each	sf	2,677	
Tube settler loading rate at design flow	gpm/sf	1.6 gpm/sf	2.5 gpm/sf
Sludge collector type		Travelling vacuum collector	
Settled Water Channels			
Channels in each Sed Basin			
Number	ea	3 (1 per basin)	
Dimensions	LxWxD avg (ft)	125x3x3.4	
Volume, each	gal	9,500	
Detention time (avg)	minutes	1.2	
Common Channel			
Number	ea	1	
Dimensions	LxWxD avg (ft)	127x6x6	
Volume	gal	34,000	
Detention time (avg)	minutes	1.5	
Filters			
Number	ea	6 (pairs)	
Dimensions (each single pair)	LxWxD (ft)	27x13.5x10	
Media type - depth	inches	Anthracite – 21 Sand – 9 Gravel - 12	
L/D		900	>1,000
Filter area, each (single/pair)	sf	364/728	
Filter loading rate at design flow, one filter out of service	gpm/sf	3.4	5 to 6
Filter loading rate at design flow, all filters in service	gpm/sf	2.9	
Available filter headloss (total)	ft	10	
Available filter headloss (for solids removal)	ft	6	8 to 10

Item	Units	Value (at current capacity)	Typical Text Book Design Value
Clearwell dimensions	LxWxD (ft)	24x18x6	
Volume	gal	19,000	
Filter Backwash System			
Washwater tank volume	gal	496,000	
Backwash rate	gpm/sf	34.3	
Backwash volume	gal	180,000	
UBWV	gal/sf	175	<150
Filtered Water Tank			
Dimensions	Diameter x H (ft)	74.5x30	
Volume	gal	990,000	
Residuals Handling System			
Reclaimed Washwater Holding Tank			
Dimensions	Diameter x H (ft)	74.5x22.5	
Volume	gal	744,000	
Sludge Holding Tank			
Dimensions	Diameter x H (ft)	74.5x22.5	
Volume	gal	744,000	
Plate settler unit			
Number	ea	2	
Capacity, each	gpm	300	
Discharge pipeline diameter	inches	4	
Allowed discharge to sewer	lb/day	2,085	

Existing Treatment Challenges and Concerns

Regulatory

- Initial Distribution System Evaluation (IDSE) testing and monitoring is now complete, giving the City a better understanding of trihalomethanes (THMs) and haloacetic acids (HAAs) levels. Locational Running Annual Averages (LRAAs) are below regulatory limits.
- In the past, samples were within 60% of the MCL for THMs and HAAs but are now 85% of the MCL.

Source Water and System Demands

- Future water demands are lower than anticipated. Growth rates projected in the 1998 Water Demand Investigation have not been realized. Due to several factors, water demands have decreased significantly over the past decade. If current water demands started to grow at the rate projected in the Integrated Water Plan (IWP), the “2030” demand would be reached somewhere between 2045 and 2065; meaning that it is not likely that the "2030" demand of 19.5 MGD will be reached during the life of the planned upgrades. It may also be that the City will never see the demands that were originally forecast.

- Peak day demand continues in a downward trend due to conservation and water pricing.
- Fish and Game Regulations might impact the City's ability to use the coastal sources the way they are currently used. This will likely impact the quantity of water the City gets from the coastal streams. Less water from coastal streams will result increased water supply from Newell Creek. Because TOC levels are higher for Newell Creek, the resulting TOC levels for raw water coming into the plant may increase. The amount and timing of fish releases has not yet been negotiated.

Treatment Plant

- The structural integrity of all concrete structures at the plant is a concern, particularly the sedimentation basins, filters and filter gallery. There are cracks in the walls of all of these areas, and the integrity of the rebar in these areas is also a concern. This will have to be looked at and evaluated prior to any modifications to any of these structures.
- Multiple raw water sources with different water qualities make it difficult to operate without upsetting the filters.
- The plant has difficulty dealing with flow changes of more than 2 mgd.
- To meet disinfection CT requirements for Giardia inactivation, the plant currently adds chlorine at RM # 2 and uses the flocculation and sedimentation basins to achieve CT. The existing clearwell is too small to get sufficient contact time. The existing filtered water tank does not qualify for CT credit because the Pasatiempo pumps draw water from the clearwell upstream of the tank and it is not a flow through tank.
- The EPA and state regulations have limited the treatment design capacity.
- Combined filtered effluent NTU. History shown even minor filter upsets have the potential to elevate effluent NTU, which is why operators must be careful when changing the raw water blend. The last event of this type was 5/25/2000. Few if any filter upsets have occurred over the last 4 to 5 years.
- Lack of filter to waste capabilities to reduce the likelihood of NTU problems and health risk to customers.
- Filter, Inlet drain, and effluent valves need replacement.
- Filter Underdrain problems (Sand in Clearwell and holes in underdrain).
- No air scour in filters; resulting in high washwater use.
- Capacity on the existing Washwater Clarification System is limited.
- Chemical Dosing Systems clog and have poor operation at high and low flows. The systems were also constructed with improper materials (electrical conduit pipe).
- Unequal flow split between basins.
- Lack of redundancy to allow the treatment plant to be taken off line for proper maintenance. Only portions of the treatment plant would have to be taken out of service if independent, parallel processes were in place.
- Enhanced coagulation will result in increased solids production which may exceed current operating limits. A revision of the operating limits or additional solids handling facilities would be required to operate this way.
- To reduce taste and odor, the plant currently adds permanganate and PAC. The 1986 plant modifications allow for the addition of permanganate and PAC in the first stage contactors, but both are not typically used at this location. Permanganate is fed at Rapid Mixer No. 1 at a concentration between .9 and 1.0 mg/L and a small dose, 5-6 ppm, of PAC is fed at Rapid Mixer

No. 2 in order to quench the excess permanganate preventing any possibility of pink water formation. In a high odor event, the feeding of permanganate is stopped, and the PAC feed is moved to Rapid Mixer No. 1, raising the feed rate to 8-10 ppm. Chlorine and coagulant are added at the second flash mixer prior to the second stage flocculators. This approach is sufficient for low to moderate T&O events, but not for heavy events that occur with algal blooms in Loch Lomond reservoir. PAC carryover interferes with the chlorination upstream of the sedimentation basins.

Distribution System

- Bay Street Reservoir (BSR) is now reduced in volume; it has gone from 35 MG to 6 MG with an expansion to 12 MG. This has had an effect on water age issues.
- BSR now carries chlorine residual; it did not in the past. System has gone from unwritten policy of 3 days emergency storage to the greater of 0.5 Max Day Demand (MDD) emergency or fire storage.
- Looking into a departmental Tank Master Plan to look at all water storage tanks in the distribution system to evaluate storage volumes based on new emergency storage policy and identify reliability improvements needed.
- The City has started a tank maintenance program with the potential to add mixing systems in the water storage tanks.
- The distribution system has many dead-end lines that would require a high frequency of flushing in the event Chloramination was implemented.

Site Constraints

- The existing site is filled with treatment processes and does not have space for additional facilities except in the northwest portion of the site. This area would be difficult to access without constructing a new road and would require significant grading to create enough space for equipment or tanks.
- Another potential limitation is that the slopes in this area may be unstable and subject to landslide failure.

Residuals Handling Issues

- The existing residuals handling system is currently operating near its capacity due to the hydraulic capacity of the existing plate settler clarifiers, the hydraulic limitations of the 4-inch discharge line, and the solids loading limit of 2,085 lb/day to the City WWTP. The plant currently produces approximately 1,500 lbs/day of solids.
- Sludge collectors in the basins clog and there are problems with the control panels.
- Sludge Holding Tank operation is problematic because it does not have a drain on bottom or a slopped bottom and the side seeps at the 10 foot elevation.
- As the plant production increases, the existing system will not be able to keep up with residual loadings. Also, any changes in the proposed treatment processes that increase chemical dosages or increase residuals volumes will exacerbate the problem.
- Increased carbon use will increase solids production.
- The future cost of solids disposal by the current method is unpredictable.
- Increases in solids production will require an amendment to the current wastewater discharge permit.

- The City is currently developing local limits that could impact the ability of the GHWTP to discharge residuals to the WWTP. Variance requests will likely be required if any changes from current loadings are requested.
- An alternative conveyance path that uses a dual 8-inch siphon constructed by the County needs to be evaluated as way to avoid overflow problems the City has in the 6-inch sewer in Ocean Street.

Proposed Expansion/Improvements Alternatives

The City and CDM evaluated nine (9) treatment process alternatives for upgrading the GHWTP. The alternatives included processes such as MIEX, membranes, UV disinfection, enhanced coagulation, GAC absorbers, chloramine disinfection, chlorine dioxide disinfection, ozonation, and reverse osmosis. The current recommended scope of improvements to the GHWTP includes:

- Addition of a Submerged Membrane Filtration System
- Addition of a Membrane Building
- Conversion of existing media filters to Granular Activated Carbon Adsorbers
- Filtered Water Tank Modifications
- Onsite Hypochlorite System Addition
- Chemical System Additions and Modifications
- Expansion of the Washwater Clarification System
- Flocculation/Sedimentation Basins Improvements and Modifications
- Site and Yard Piping Improvements
- Electrical Improvements (in progress)
- Plant Control System Upgrade and Modifications (in progress)
- Addition of Solar Panels on new membrane building

The total capital cost of this alternative has risen to $50 million. The City anticipated a much lower budget for the total cost of needed improvements when the decision to pursue the full project was made. Without dropping other planned project, the City cannot afford this now. At the time of the evaluation, the City agreed that the future was with membranes rather than filters. The City knew a lot less about them then and thought they would be much easier to maintain and operate; this may not be the case today. Also, it was thought that the membranes would allow use of the San Lorenzo River for extended periods of time during and after a rain event. In reality, only an additional 70 MG (1.5% of annual supply) may be able to be obtained using membranes to treat higher turbidity water. Thus, the City desires to reevaluate the previous alternatives and any new alternatives, such as high rate clarification with upgraded filters that might provide a “best value" solution in light of more recent information.

Appendix A – Water Source Usage

Water Production (Million Gallons)
Source

							GHWTP Total	Percent of GHWTP Total				
	Coastal Sources	SLR	Tait Wells	Newell Creek	Beltz Wells	Total	Total minus Beltz	Coastal Sources	SLR	Tait Wells	Newell Creek	Total %
1/1/2003	146.91	108.30	0.00	12.17	0.00	267.38	267.38	54.94%	40.50%	0.00%	4.55%	100.00%
2/1/2003	124.81	94.80	3.41	26.83	0.00	249.85	249.85	49.95%	37.94%	1.36%	10.74%	100.00%
3/1/2003	119.71	117.16	0.00	38.88	0.00	275.75	275.75	43.41%	42.49%	0.00%	14.10%	100.00%
4/1/2003	139.80	119.31	0.00	34.98	0.00	294.09	294.09	47.54%	40.57%	0.00%	11.89%	100.00%
5/1/2003	144.37	166.56	2.14	27.52	2.32	342.91	340.59	42.39%	48.90%	0.63%	8.08%	100.00%
6/1/2003	106.92	200.64	0.08	68.92	21.35	397.91	376.56	28.39%	53.28%	0.02%	18.30%	100.00%
7/1/2003	100.18	218.94	1.08	124.64	26.16	471.00	444.84	22.52%	49.22%	0.24%	28.02%	100.00%
8/1/2003	86.81	229.55	0.88	115.32	23.40	455.96	432.56	20.07%	53.07%	0.20%	26.66%	100.00%
9/1/2003	84.11	220.70	0.00	89.29	23.00	417.10	394.10	21.34%	56.00%	0.00%	22.66%	100.00%
10/1/2003	74.15	231.40	0.00	82.33	19.99	407.87	387.88	19.12%	59.66%	0.00%	21.23%	100.00%
11/1/2003	76.12	149.23	7.09	43.09	9.90	285.43	275.53	27.63%	54.16%	2.57%	15.64%	100.00%
12/1/2003	93.07	61.30	16.37	84.49	3.54	258.77	255.23	36.47%	24.02%	6.41%	33.10%	100.00%
Yearly Total	**1,296.96**	**1,917.89**	**31.05**	**748.46**	**129.66**	**4,124.02**	**3,994.36**					
1/1/2004	132.61	89.20		17.94	0.00	239.74	239.74	55.31%	37.21%	0.00%	7.48%	100.00%
2/1/2004	131.71	41.73		60.82	4.28	238.54	234.26	56.22%	17.82%	0.00%	25.96%	100.00%
3/1/2004	166.41	126.56		6.61	2.22	301.80	299.58	55.55%	42.25%	0.00%	2.21%	100.00%
4/1/2004	128.99	200.78		8.95	1.81	340.52	338.71	38.08%	59.28%	0.00%	2.64%	100.00%
5/1/2004	123.43	233.20		50.27	12.60	419.50	406.90	30.33%	57.31%	0.00%	12.35%	100.00%
6/1/2004	108.64	221.97		81.52	13.15	425.27	412.13	26.36%	53.86%	0.00%	19.78%	100.00%
7/1/2004	88.33	233.13		73.72	28.56	423.74	395.18	22.35%	58.99%	0.00%	18.66%	100.00%
8/1/2004	92.84	225.91		91.48	22.28	432.51	410.24	22.63%	55.07%	0.00%	22.30%	100.00%
9/1/2004	76.04	225.38		97.53	18.16	417.11	398.95	19.06%	56.49%	0.00%	24.45%	100.00%
10/1/2004	87.63	154.29		83.60	20.49	345.99	325.51	26.92%	47.40%	0.00%	25.68%	100.00%
11/1/2004	80.86	139.17		33.29	0.01	253.33	253.32	31.92%	54.94%	0.00%	13.14%	100.00%
12/1/2004	97.95	93.04		46.93	0.08	237.99	237.91	41.17%	39.11%	0.00%	19.72%	100.00%
Yearly Total	**1,315.44**	**1,984.36**	**0.00**	**652.63**	**123.62**	**4,076.04**	**3,952.43**					
1/1/2005	119.761	35.363		92.387	0.113	247.62	247.51	48.39%	14.29%	0.00%	37.33%	100.00%
2/1/2005	120.388	46.533		56.593	0.096	223.61	223.51	53.86%	20.82%	0.00%	25.32%	100.00%
3/1/2005	86.767	19.501		111.351	0.392	218.01	217.62	39.87%	8.96%	0.00%	51.17%	100.00%
4/1/2005	160.051	98.545		21.318	0.162	280.08	279.91	57.18%	35.21%	0.00%	7.62%	100.00%
5/1/2005	176.112	131.373		6.62	0	314.11	314.11	56.07%	41.82%	0.00%	2.11%	100.00%
6/1/2005	138.446	135		78.16	6.867	358.47	351.61	39.38%	38.40%	0.00%	22.23%	100.00%
7/1/2005	158.125	223.372		24.562	25.874	431.93	406.06	38.94%	55.01%	0.00%	6.05%	100.00%
8/1/2005	122.277	220.913		36.553	25.969	405.71	379.74	32.20%	58.17%	0.00%	9.63%	100.00%
9/1/2005	108.775	209.659		24.694	22.848	365.98	343.13	31.70%	61.10%	0.00%	7.20%	100.00%
10/1/2005	94.983	219.798		40.824	2.297	357.90	355.61	26.71%	61.81%	0.00%	11.48%	100.00%
11/1/2005	86.525	173.959		12.175	0.1	272.76	272.66	31.73%	63.80%	0.00%	4.47%	100.00%
12/1/2005	114.965	59.326		78.565	0.14	253.00	252.86	45.47%	23.46%	0.00%	31.07%	100.00%
Yearly Total	**1,487.18**	**1,573.34**	**0.00**	**583.80**	**84.86**	**3,729.18**	**3,644.32**					
1/1/2006	160.23	41.69		48.50	0.00	250.42	250.42	63.98%	16.65%	0.00%	19.37%	100.00%
2/1/2006	141.00	76.00		18.44	0.00	235.43	235.43	59.89%	32.28%	0.00%	7.83%	100.00%
3/1/2006	162.19	1.00		107.39	0.76	271.34	270.58	59.94%	0.37%	0.00%	39.69%	100.00%
4/1/2006	139.95	31.94		91.81	0.55	264.24	263.69	53.07%	12.11%	0.00%	34.82%	100.00%
5/1/2006	176.31	111.00		27.05	13.94	328.30	314.36	56.09%	35.31%	0.00%	8.60%	100.00%
6/1/2006	168.97	187.06		34.38	6.18	396.58	390.41	43.28%	47.91%	0.00%	8.81%	100.00%
7/1/2006	158.48	229.63		24.96	24.07	437.14	413.07	38.37%	55.59%	0.00%	6.04%	100.00%
8/1/2006	133.27	228.51		27.55	23.06	412.40	389.33	34.23%	58.69%	0.00%	7.08%	100.00%
9/1/2006	108.08	212.22		25.60	24.89	370.79	345.90	31.25%	61.35%	0.00%	7.40%	100.00%
10/1/2006	82.31	224.22		13.30	18.75	338.58	319.83	25.74%	70.11%	0.00%	4.16%	100.00%
11/1/2006	87.08	145.57		22.93	6.27	261.85	255.58	34.07%	56.96%	0.00%	8.97%	100.00%
12/1/2006	85.97	121.36		25.40	0.00	232.73	232.72	36.94%	52.15%	0.00%	10.91%	100.00%
Yearly Total	**1,603.83**	**1,610.20**	**0.00**	**467.31**	**118.48**	**3,799.82**	**3,681.33**					
1/1/2007	69.549	176.56		7.22	0	253.33	253.33	27.45%	69.70%	0.00%	2.85%	100.00%
2/1/2007	95.271	95.768		30.164	3.219	224.42	221.20	43.07%	43.29%	0.00%	13.64%	100.00%
3/1/2007	111.635	152.875		6.954	0	271.46	271.46	41.12%	56.32%	0.00%	2.56%	100.00%
4/1/2007	68.446	207.364		18.021	0	293.83	293.83	23.29%	70.57%	0.00%	6.13%	100.00%
5/1/2007	75.178	231.623		29.009	19.925	355.74	335.81	22.39%	68.97%	0.00%	8.64%	100.00%
6/1/2007	76.431	226.01		59.567	26.088	388.10	362.01	21.11%	62.43%	0.00%	16.45%	100.00%
7/1/2007	78.927	235.091		74.299	26.495	414.81	388.32	20.33%	60.54%	0.00%	19.13%	100.00%

8/1/2007	66.172	231.399		100.858	21.187	419.62	398.43	16.61%	58.08%	0.00%	25.31%	100.00%
9/1/2007	55	210.998		57.933	14.961	338.89	323.93	16.98%	65.14%	0.00%	17.88%	100.00%
10/1/2007	38.889	175.243		79.305	20.442	313.88	293.44	13.25%	59.72%	0.00%	27.03%	100.00%
11/1/2007	49.175	184.419		5.409	23.478	262.48	239.00	20.58%	77.16%	0.00%	2.26%	100.00%
12/1/2007	63.978	134.209		19.08	23.14	240.41	217.27	29.45%	61.77%	0.00%	8.78%	100.00%
Yearly Total	**848.65**	**2,261.56**	**0.00**	**487.82**	**178.94**	**3,776.96**	**3,598.03**					
1/1/2008	101.807	90		42	0	233.81	233.81	43.54%	38.49%	0.00%	17.96%	100.00%
2/1/2008	132.715	58		27	0	217.72	217.72	60.96%	26.64%	0.00%	12.40%	100.00%
3/1/2008	115.461	143		1	0	259.46	259.46	44.50%	55.11%	0.00%	0.39%	100.00%
4/1/2008	68.65	218.71		19	0	306.36	306.36	22.41%	71.39%	0.00%	6.20%	100.00%
5/1/2008	79.972	228.273		21	22.74	351.99	329.25	24.29%	69.33%	0.00%	6.38%	100.00%
6/1/2008	54.041	225		68	23.613	370.65	347.04	15.57%	64.83%	0.00%	19.59%	100.00%
7/1/2008	56.063	231		61	25.432	373.50	348.06	16.11%	66.37%	0.00%	17.53%	100.00%
8/1/2008	51.833	235.788		60	24.107	371.73	347.62	14.91%	67.83%	0.00%	17.26%	100.00%
9/1/2008	0	0		0	0	0.00	0.00					
10/1/2008	0	0		0	0	0.00	0.00					
11/1/2008	0	0		0	0	0.00	0.00					
12/1/2008	0	0		0	0	0.00	0.00					
Yearly Total	**660.54**	**1,429.77**	**0.00**	**299.00**	**95.89**	**2,485.21**	**2,389.31**					

Incomplete

SLR Production Includes Tait Well Production

2008 is Incomplete

Appendix B – Blended Raw Water Quality

Summary of Blended Raw Water Constituents Recorded for Graham Hill WTP

Constituent	2009			2008			2007		
	Minimum	Maximum	Average	Minimum	Maximum	Average	Minimum	Maximum	Average
Alkalinity (mg/L as $CaCO_3$)	86	138	125	85	149	124	114	138	127
Color (CU)	8	28	14	7	32	17	10	28	16
Conductivity (umhos/cm)	270	425	386	240	425	375	360	460	403
Corr (ratio)	-0.376	0.361	-0.002	-0.587	0.191	-0.120	-0.580	-0.092	-0.267
E. coli (MPN/100mL)	10	122	54	1	733	67	10	158	42
Hardness (mg/L as CaCO3)	100	175	162	104	178	159	148	168	160
Odor (TON)	4	12	7	4	12	8	6	17	11
pH	7.4	8.0	7.7	7.2	7.9	7.6	7.2	7.7	7.5
Total Coliform (MPN/100mL)	435	12,033	2,039	29	5,794	1,205	97	2,143	724
Temperature (degrees C)	8.7	18.8	14.8	8.6	19.1	14.2	9.7	15.2	12.8
TOC (mg/L)	1.4	3.1	1.8	1.2	3.1	1.8	1.3	1.8	1.5
Turbidity (NTU)	0.5	4.5	1.3	0.5	10.7	1.4	0.2	4.4	1.2

Appendix B

Jar Test Results and Conclusions
(HDR, July, 2010)

JAR TEST RESULTS AND CONCLUSIONS

City of Santa Cruz
Graham Hill Water Treatment Plant ***July 2010***

Reviewed by: Rich Stratton, P.E. and Amy Miller, P.E.
Prepared by: Brad Leidecker, P.E.

This Technical Memorandum (TM) summarizes the bench scale jar testing results and provides conclusions based on the effectiveness of the each test parameter.

Background

The Graham Hill Water Treatment Plant (GHWTP) relies on source water from Newell Creek (Loch Lomond Reservoir) and River/Coast sources. Going forward the plant will increasingly depend on the Newell Creek source as the raw water blend shifts. Historical testing of disinfection by-products (DBPs) has come within 80 percent of the maximum contaminant level (MCL) and the City wants to ensure its continued compliance following implementation of Stage 2 of the DBP Rule. The amended EPA rule increases compliance monitoring requirements for two groups of DBPs, trihalomethanes (TTHM) and haloacetic acids (HAA5).

The Newell Creek source is expected to increase the disinfection byproduct (DBP) levels due to a higher total organic carbon (TOC) concentration and seasonal challenges involving stratification, low dissolved oxygen concentrations, and blue-green algae blooms.

Objectives

Bench scale jar testing was performed at the City of Santa Cruz's Graham Hill Water Treatment Plant (GHWTP) to accomplish the following objectives:

- Determine whether ferric chloride (ferric) or alum is more effective at reducing the formation of total trihalomethanes (TTHM) and haloacetic acids (HAA5) for the current pre-sedimentation chlorination practice.
- Determine the reduction in TTHM and HAA5 formation for chlorinating after the flocculation/sedimentation process.
- Determine the benefits of pH variation on TTHM and HAA5 formation.
- Determine the effects of aerating the chlorinated settled water for volatilizing TTHMs and HAA5.

In addition to the onsite jar testing, Kruger and Orica performed bench scale jar tests to determine the feasibility of the ACTIFLO and MIEX systems to reduce TOC and DBP formation. Raw water from Newell Creek was sent out for ACTIFLO high rate clarification (Kruger) and MIEX (Orica) system testing. Following these results, Kruger performed onsite testing to simulate their ACTIFLO CARB system.

Summary of Methods

Representative samples of Newell Creek and River/Coast water were collected at the plant to perform bench scale jar testing using the EPA Enhanced Coagulation and Enhanced Precipitative Softening Guidance Manual as a primary reference. Each water source went through a series of test runs varying the following parameters: pH (5.5, 6.0, 6.5, 7.0), pre and post sedimentation chlorination, and coagulant type (alum and ferric chloride). The full testing parameters and results are included in the Appendix.

Testing mimicked normal plant operation to the extent possible. Each sample was taken from the Flash Mix#2 sample point and contained potassium permanganate and PAC. A coagulant aid polymer was added with the coagulant. Mixing energies and durations for the gang stirrers were based on calculations used in previous jar testing studies.

Increased water temperatures were experienced during the testing due to the ambient temperature in the lab. Therefore, it is expected the DBP formation rates increased during the lab phase. The collected samples were stored in the filter gallery at the GHWTP at temperatures representative of the distribution system. Data was collected for each unique testing jar including turbidity, UV Absorbance at UV 254 nm (UVA), pH, temperature, chlorine residual, TTHM (day 7) and HAA5 (day 7) levels . These results are discussed below and the full tabulated figures are listed in the Appendix.

A ferric chloride baseline test was performed to determine the optimum coagulant dose for Newell Creek. Each of 12 jars was dosed between 0 and 24 mg/L as ferric chloride in increments of 2 mg/L. Turbidity and UV254 tests were conducted and the optimal dose was selected by the lowest turbidity.

An aeration test was performed on settled plant water (blended source water) to determine whether aeration was an effective means of decreasing the DBP levels in solution. The duration of aeration was determined from the approximate average detention time in the channel upstream of the filters.

At the Orica facility, personnel performed MIEX jar testing, conventional jar testing, and combined jar testing using Newell Creek raw water. The MIEX jar testing utilized only MIEX resin to determine the optimal resin regeneration rate. The conventional jar testing was performed as a control to determine the additional benefits of using MIEX resin and the reduction in coagulant. The combined treatment consisted of MIEX resin treated water followed by conventional coagulation.

Similarly, Kruger performed bench scale jar testing to simulate the ACTIFLO high rate clarification process consisting of micro-sand, polymer, specific mixing characteristics and coagulant. All testing was done using Newell Creek raw water.

Kruger also performed on site testing of their ACTIFLO CARB system which utilizes a PAC slurry that is recycled for increased efficiency. The two-day visit tested both alum and ferric as coagulants and a wide range of PAC doses. Source water was an equal blend of Newell Creek and San Lorenzo River.

Results

Jar tests are approximations of the results that can be expected at full scale. Thus, the jar test results should only be compared to each other on a relative basis and are not considered to be indicative of the full scale removal efficiency. The results will be used as a starting point to estimate full scale results. The testing methods were followed closely and consistently each time a jar test was conducted in order to limit error introduced by variability in testing procedure.

Coagulant Comparison

Alum and ferric chloride were used throughout the jar testing to evaluate any significant benefits to switching coagulants. The plant currently uses alum as a primary coagulant and has no provisions for storing or dosing ferric at this time. Table 1 summarizes the metal ion equivalent doses and comparative costs, based on current chemical costs to the City's WTP and WWTP. Ferric has approximately twice the metal ion molarity of alum. For example, a 10 mg/L dose of ferric (as $FeCl_3$) is equivalent to 18.3 mg/L of alum and a 10 mg/L dose of alum is equivalent to 5.5 mg/L of ferric. Although ferric chloride costs significantly more than alum per dry ton, it is only 7 percent more on an equivalent dose basis.

Table 1: Summary of Coagulant Costs and Equivalent Doses.

	Alum (mg/L)			Ferric (mg/L)		
	10	20	30	10	20	30
Cost ($) / dry ton	$401.65			$788.09		
Molarity (mmol/L)	0.034	0.067	0.101	0.062	0.123	0.185
Cost Adjusted Molarity (mmol/L)	0.034	0.067	0.101	0.066	0.132	0.198
Cost ($) / Mgal	$16.72	$33.45	$50.17	$32.81	$65.62	$98.44
Equivalent Ferric Dose (mg/L)	5.5	10.9	16.4	--	--	--
Equivalent Alum Dose (mg/L)	--	--	--	18.3	36.7	55.0
Cost ($) / Mgal using equiv. dose	$17.90	$35.80	$53.69	$30.66	$61.32	$91.97
Cost ($) / Mgal % difference	+7.03%	+7.03%	+7.03%	-6.56%	-6.56%	-6.56%

Alum Ferric

Table 2 summarizes the theoretical sludge produced from the corresponding jar testing doses. Sludge production attributed to turbidity will vary by raw water conditions and was not evaluated. Based on an equivalent dose, if the plant were to switch from alum to ferric chloride they should expect a 38.5 percent increase in coagulant sludge production.

Table 2: Summary of Predicted Solids Residuals Attributed to Coagulant Addition.

	Alum (mg/L)			Ferric (mg/L)		
	10	20	30	10	20	30
Theoretical Pounds Dry Sludge/Pound Coagulant	0.26			0.66		
Pounds Dry Sludge / Mgal	21.7	43.4	65.1	55.0	110.1	165.1
Pounds Dry Sludge / Mgal for Equivalent Ferric Dose	30.0	60.0	90.1	--	--	--
Pounds Dry Sludge / Mgal for Equivalent Alum Dose	--	--	--	39.8	79.5	119.3
% difference	38.5%	38.5%	38.5%	-27.8%	-27.8%	-27.8%

Alum	Ferric

Figure 1 shows the percent removal of NOM (UV254) against the coagulant Cost Adjusted Concentration (CAC) for various doses and pH levels on Newell Creek water. At pH 6.5 and 7.0, alum outperformed ferric. However when the pH was lowered to 5.5 and 6.0, ferric was the dominant coagulant. Higher removal rates were observed with ferric due to the significantly higher doses. However, we would expect alum to have similar removal rates at equivalent doses. Overall, enhanced coagulation was effective at removing NOM from the Newell Creek source water.

Figure 1: UV254 Percent Removal for Newell Creek Water.

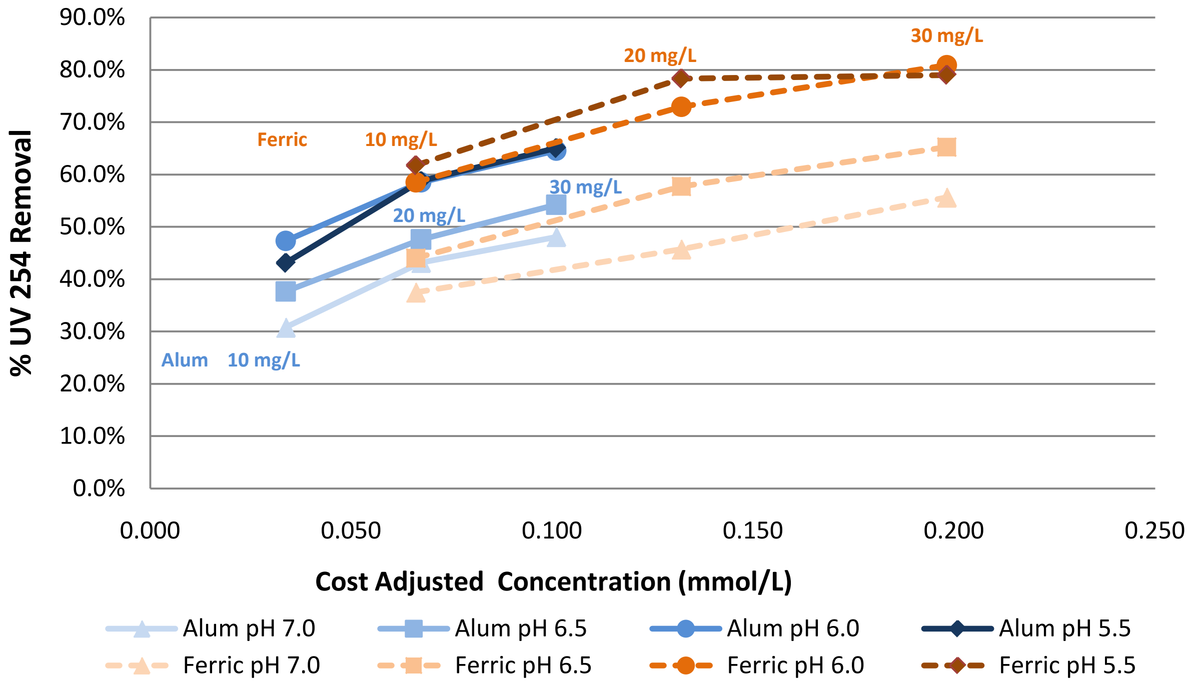
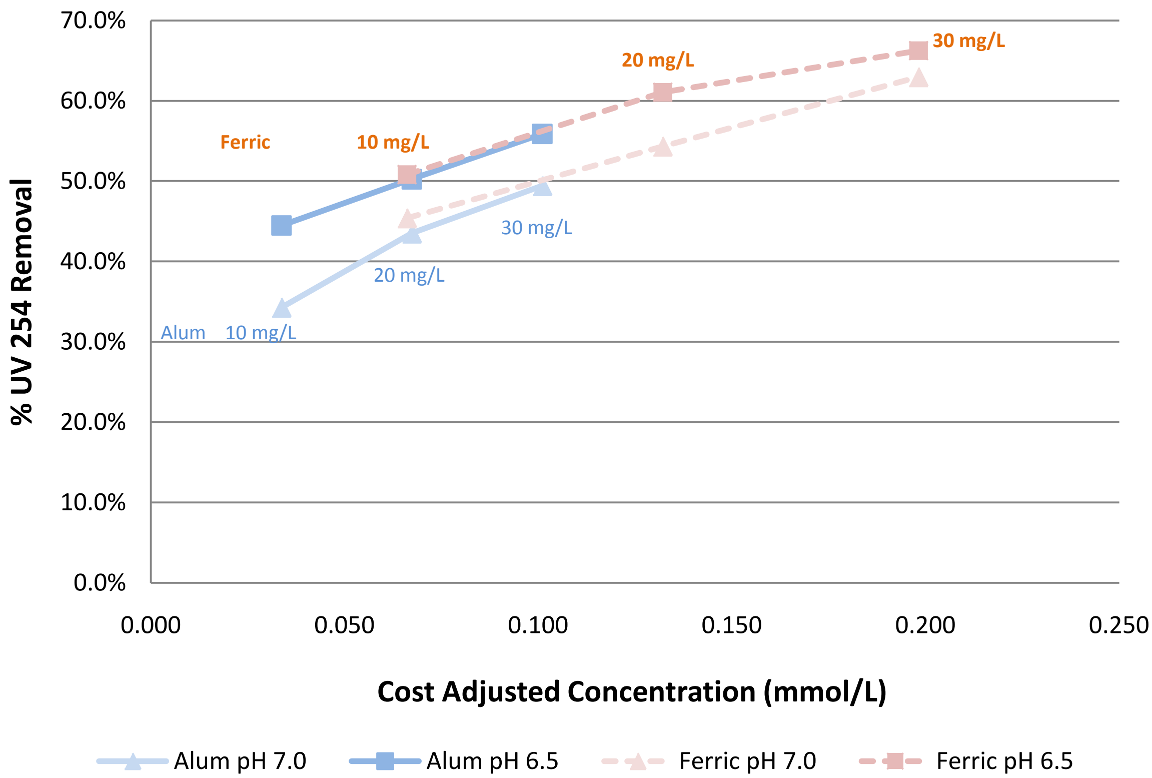


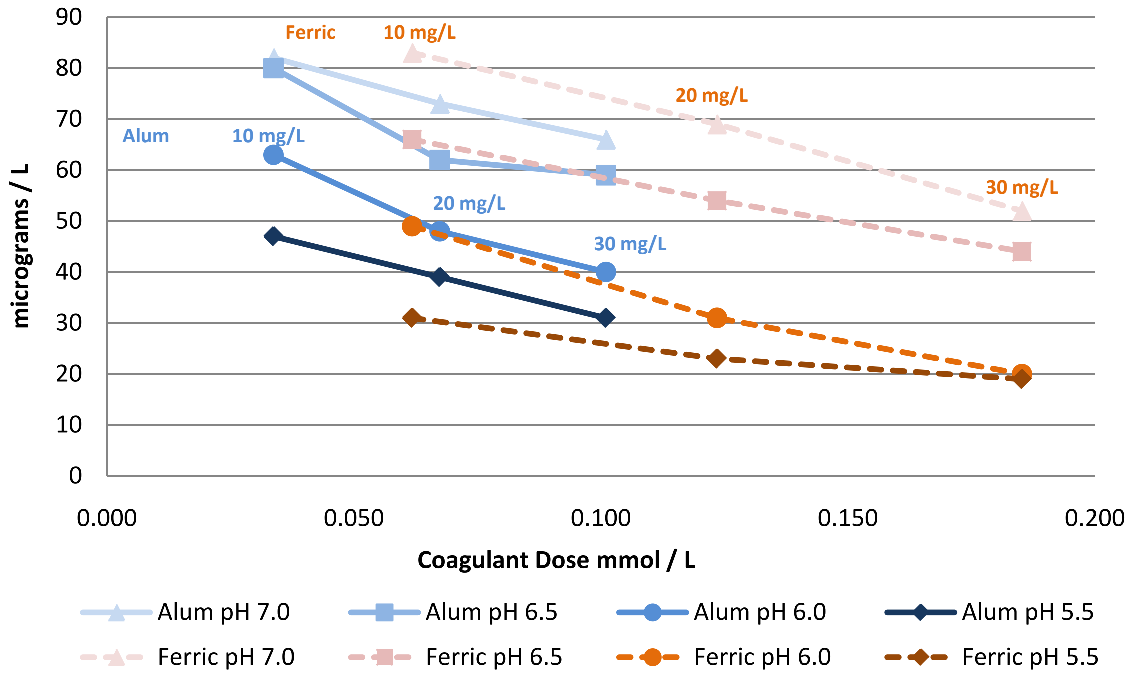
Figure 2 shows the percent removal of NOM (UV254) against the coagulant Cost Adjusted Concentration (CAC) for various doses and pH levels on River/Coast water. No significant differences between the coagulants were observed. Enhanced coagulation was effective at removing NOM from the River/Coast source water.

Figure 2: UV254 Percent Removal for River / Coast Water.



The TTHM results for Newell Creek are presented in Figure 3. Higher coagulant doses were more effective at reducing TTHM levels. Alum performed as good as or better than ferric at pH 6.5 and 7.0. Not until pH 5.5 did ferric show significant benefits. Both coagulants were more effective at reducing TTHM levels as the pH was lowered.

Figure 3: TTHM Results for Newell Creek Water.



The HAA5 results for Newell Creek are presented in Figure 4. The HAA5 levels trend downward with coagulant dose and pH. Neither coagulant significantly outperformed the other.

Figure 4: HAA5 Results for Newell Creek Water.

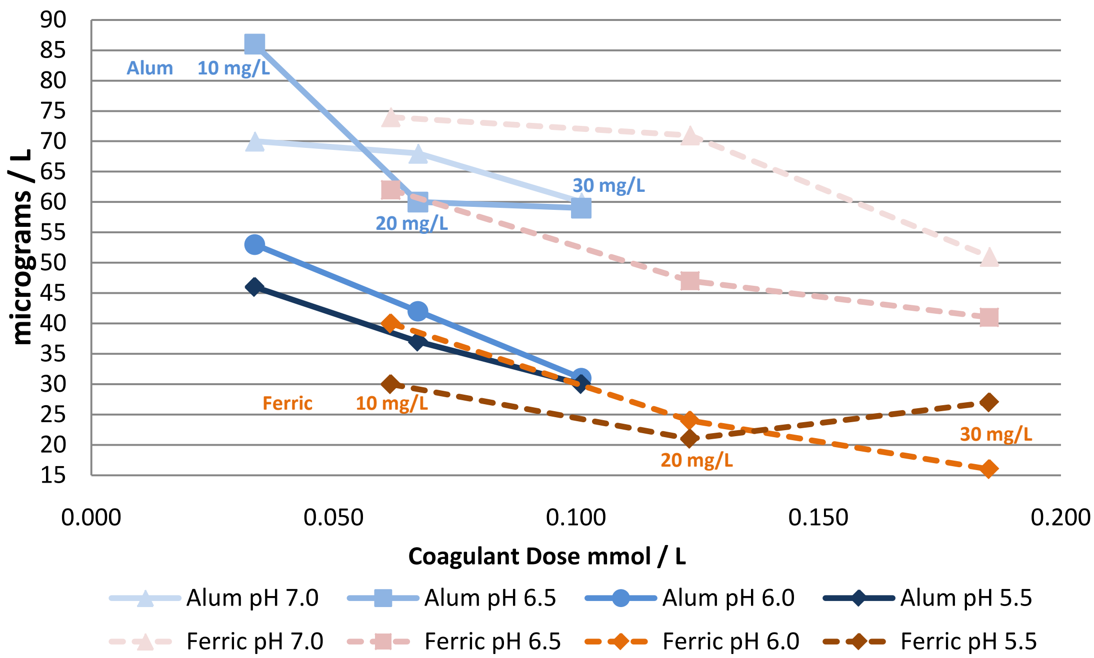
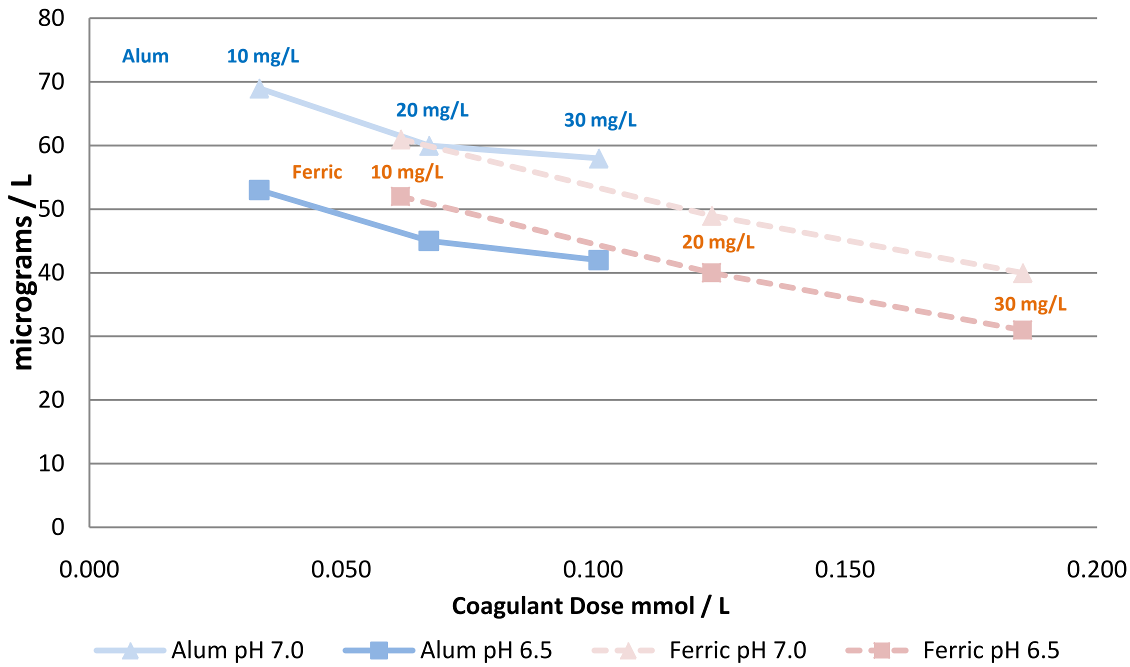


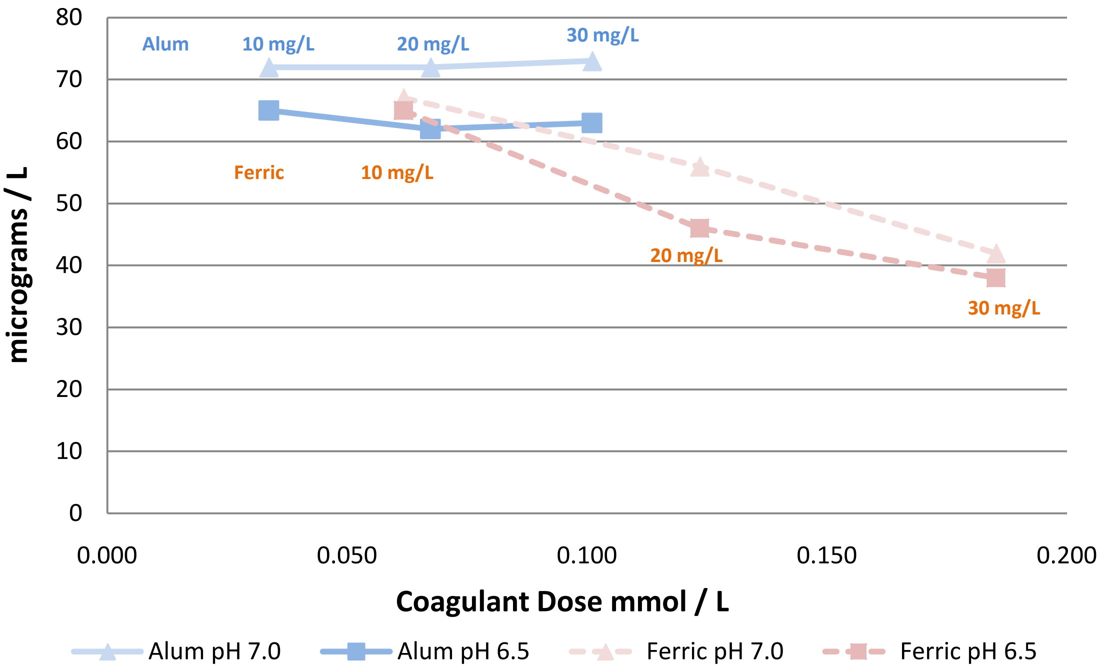
Figure 5 shows the TTHM levels for the River/Coast source water. Both coagulants had similar performance at pH 7.0 and alum dominated at pH 6.5. Enhanced coagulation was effective at reducing TTHM formation.

Figure 5: TTHM Results for River / Coast Water.



Reducing the HAA5 formation in the River/Coast source water (Figure 6) was less straight forward than the other parameters. Decreasing the pH to 6.5 resulted in a 10 percent reduction of HAA5 levels. Although both coagulants were effective at reducing NOM in this water source (see Figure 2), they had less success at reducing HAA5 formation. Increased doses of alum (up to 30 mg/L as alum) did not effectively reduce HAA5 formation however, high doses of ferric did (20 and 30 mg/L as $FeCl_3$). A higher dose of alum may have helped reduce the formation.

Figure 6: HAA5 Results for River / Coast Water.



Pre and Post Chlorination Comparison

The alternative of chlorinating after sedimentation instead of pre chlorinating provided mixed results. In all instances there was a measureable benefit to post chlorination. The percent reduction in TTHM and HAA5 levels is presented in Table 3. The Newell Creek water had marginal decreases in TTHM and HAA5 levels of up to 10 percent. Newell Creek TTHM levels using alum saw the greatest reduction. Post chlorination had the most dramatic impact on the River/Coast water where the reduction in TTHM and HAA5 levels was approximately 12 and 26 percent respectively.

Table 3: Percent Reduction in TTHM and HAA5 Levels for Post Chlorination Practice.

	Newell Creek			River / Coast		
	Alum	Ferric	Average	Alum	Ferric	Average
TTHMs	9.7%	4.6%	7.1%	14.3%	10.0%	12.1%
HAA5	2.0%	3.7%	2.9%	22.2%	28.9%	25.6%

TTHM and HAA5 levels for the River/Coast source are presented in Figures 7 and 8 below. These figures further illustrate the effectiveness of post chlorination on the River/Coast water source.

Figure 7: TTHM Results Comparing Pre and Post Chlorination for River / Coast Water.

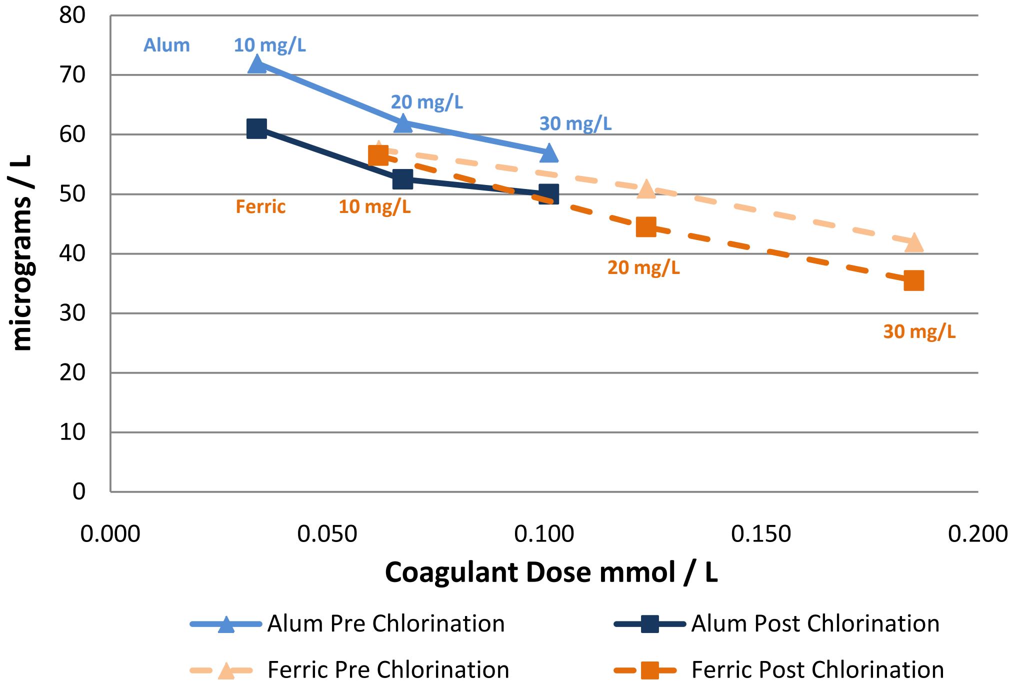
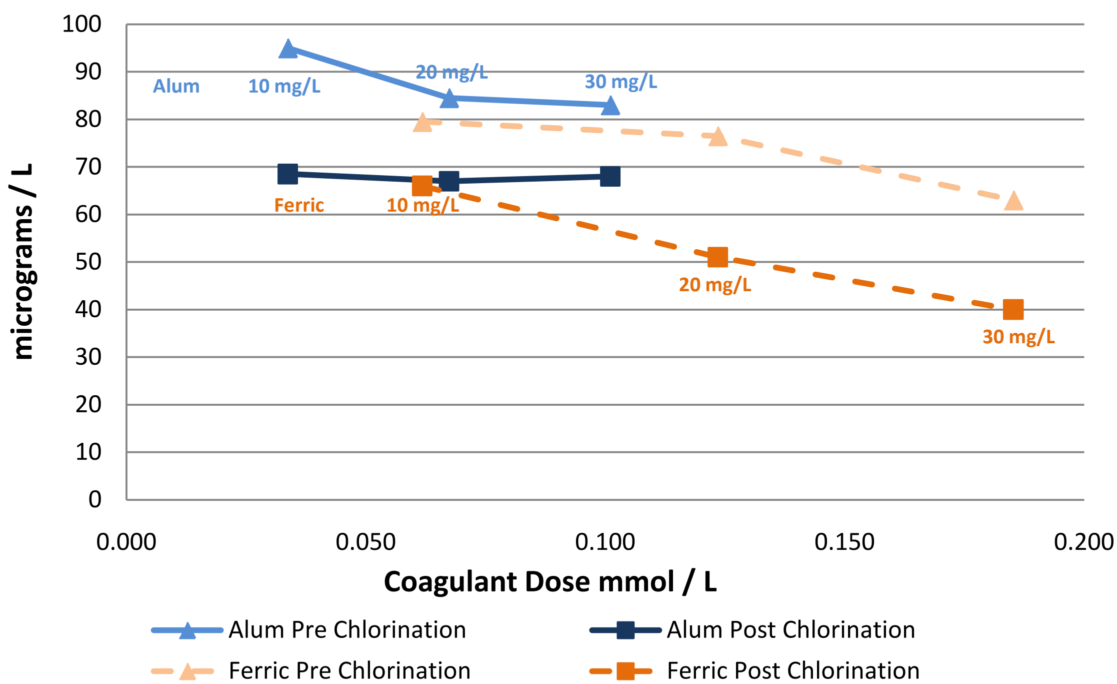


Figure 8: HAA5 Results Comparing Pre and Post Chlorination for River / Coast Water.



Effects of pH

Lowering the pH improved the coagulation process and lowered NOM, TTHM and HAA5 levels across the board. The percent reduction from pH 7.0 in TTHM and HAA5 levels were averaged across all three coagulant doses and are shown in Table 4 below (see also Figures 3-6 above). Lowering the pH to 6.5 resulted in approximately a 14 and 22 percent reduction in TTHM levels for Newell Creek and River/Coast water respectively. At pH 6.5, HAA5 levels did not see as great of a reduction. The River/Coast water had approximately an 11 percent reduction in HAA5. The Newell Creek HAA5 levels using alum showed an increase in HAA5 levels due to one extreme point.

Note, the baseline (pH 7.0) for these results received a slight pH adjustment and therefore the percent reduction values should be more pronounced when considering the current treatment process as a baseline, which has no pH adjustment (typical raw water pH ranges from 7.2-7.7).

Table 4: Percent Reduction in TTHM and HAA5 Levels from pH 7.0.

		Newell Creek			River / Coast		
pH		Alum	Ferric	Average	Alum	Ferric	Average
6.5	TTHMs	9.4%	19.2%	14.3%	25.3%	18.5%	21.9%
	HAA5	-3.1%	23.2%	10.0%	12.4%	10.1%	11.3%
6.0	TTHMs	32.3%	52.5%	42.4%			
	HAA5	37.0%	60.3%	48.6%			
5.5	TTHMs	47.4%	64.3%	55.8%			
	HAA5	43.3%	59.0%	51.1%			

UVA and DBP Correlation

UVA is an indicator of NOM present in the water source and is generally correlated with DBP formation. TTHM and UVA values showed a strong positive linear correlation (+0.9) and are presented in Figure 9. The data provides further confidence in accurately estimating TTHM values based on a simple UV 254 test.

HAA5 and UVA values showed a moderate positive linear correlation (+0.5) and are presented in Figure 10. Estimating HAA5 values from UVA data will provide some benefit however the level of precision will not be as high as estimating TTHM values.

Figure 9: TTHM Results Plotted Against UVA Results

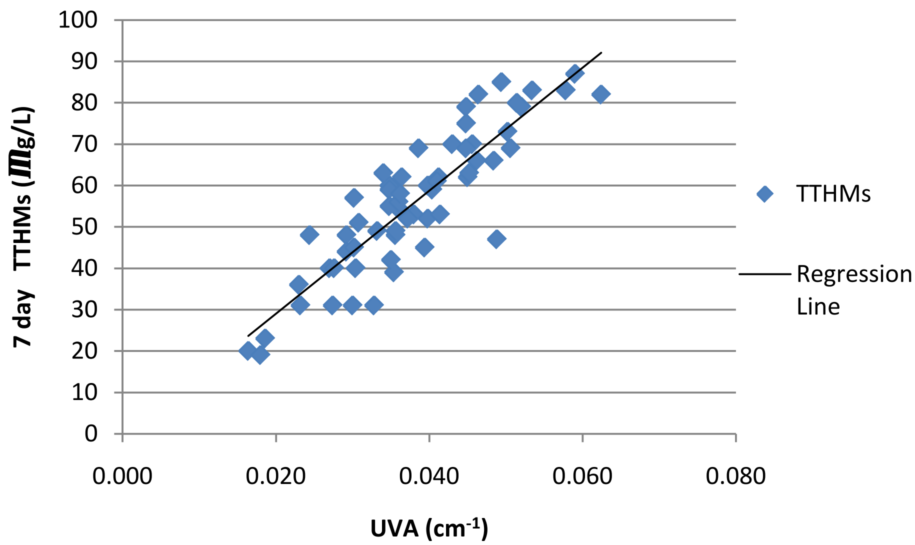
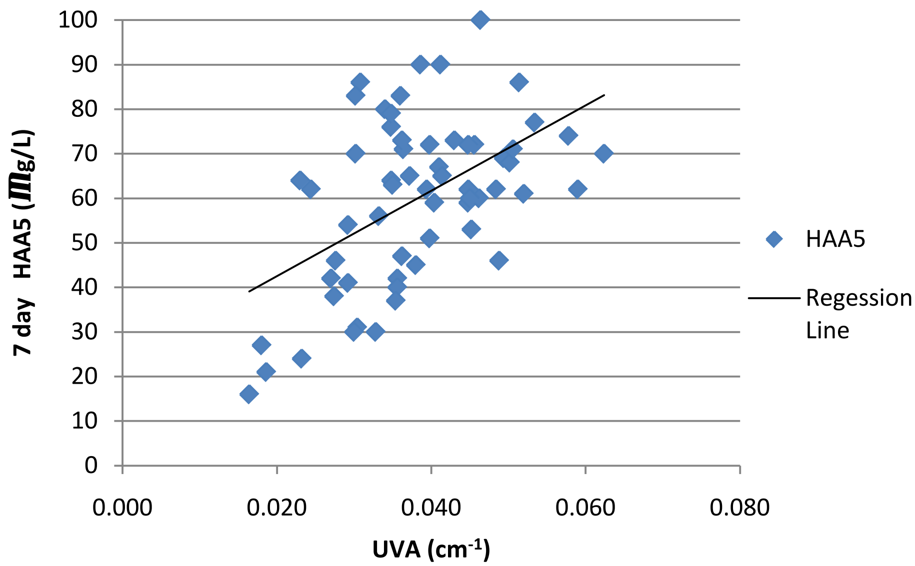


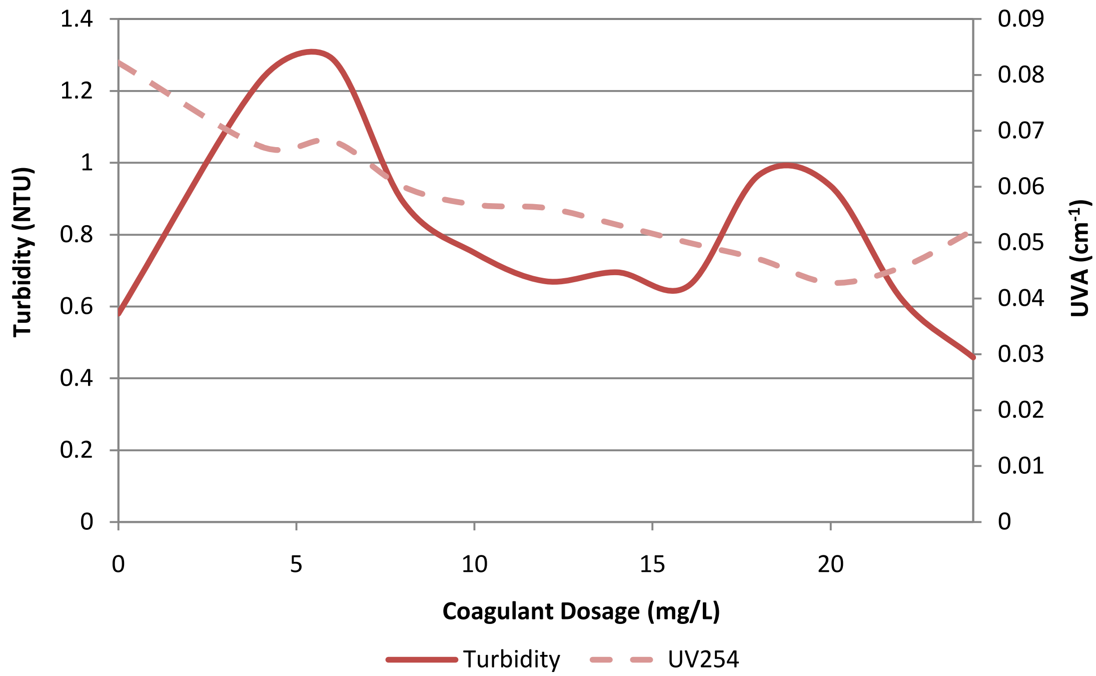
Figure 10: HAA5 Results Plotted Against UVA Results



Ferric Chloride Baseline Test

Turbidity and UVA levels are presented in Figure 11 below. Based on turbidity, the optimal ferric dose was approximately 16 mg/L. However, in most instances, minimizing turbidity is not the sole objective. Subsequent testing showed the levels of UVA and DBPs were further reduced with larger coagulant doses.

Figure 11: Turbidity and UVA Levels in Ferric Chloride Baseline Test for Newell Creek Water.



Aeration Test

The aeration test was ineffective at removing or volatizing DBPs as the TTHM and HAA5 levels from the aerated water did not significantly differ from the control. Complete results are included in the Appendix.

MIEX Testing

The results from the MIEX testing are presented in Tables 5 and 6. The MIEX treatment without coagulation resulted in a 73 percent reduction in UVA and 55 percent reduction in DOC. Adding coagulant after MIEX pre-treatment produced additional reduction in UVA and DOC. Suppressing the pH to 6.75, while maintaining the coagulant dose at 8 mg/L resulted in the largest UVA and DOC reduction (79 percent for UVA and 61 percent for DOC). The UVA levels achieved by combined treatment were 70 percent lower than those of coagulation alone.

Table 5: Summary of MIEX Resin Pre-Treatment Followed by Coagulation Test Results

	Raw Water	MIEX/Coagulation									
MIEX® Treatment Rate (BV)	-	1000 Bed Volumes									
Initial pH	8.18	8.26	8.26	8.26	8.26	8.26	8.26	7.48*	7.07*	**6.55***	6.11*
Ferric Chloride (mg/L)	0	0	4	8	12	16	20	8	8	**8**	8
Settled Turbidity (NTU)	0.68	0.63	0.48	0.41	0.38	0.4	0.4	0.52	0.44	**0.4**	0.39
Alkalinity (mg/L CaCO3)	180	160	160	160	160	160	160	140	120	**100**	60
Final pH	8.18	8.26	8.26	8.17	8.16	8.15	8.12	7.52	7.21	**6.75**	6.31
True Color (PCU)	7	0	0	0	0	0	0	0	0	**0**	0
UVA (cm-1)	0.092	0.025	0.022	0.021	0.026	0.021	0.025	0.02	0.019	**0.019**	0.017
UVA Removal (%)	-	73	76	77	72	77	73	78	79	**79**	82
DOC mg/L	3.9	1.76	1.87	1.74	1.72	1.67	1.65	1.64	1.65	**1.52**	1.43
DOC Removal (%)	-	55	52	55	56	57	58	58	58	**61**	63

*Data point is high due to analytical error, the pH data point is likely the minimum pH of the solution before coagulation.

DBP testing was performed on two samples to compare the benefits of the MIEX treatment system in addition to coagulation. The control sample was coagulated using a dose of 21 mg/L ferric chloride. The MIEX treated sample was followed up with an 8 mg/L ferric chloride dose and the pH was adjusted to 6.75. The MIEX treatment with coagulation resulted in a 55 percent reduction in TTHM levels and 74 percent in HAA5 levels compared to the control. Note, the chlorine residual of 0.06 mg/L in the control sample at day 14 approached the detection limit of the instrument. If the control sample used up all available chlorine, the DBP formation reaction would have ceased prematurely and lowered the potential DBP levels.

The MIEX system resulted in a 62 percent reduction in coagulant dose based on 21 mg/L ferric without MIEX treatment and 8 mg/L ferric with MIEX. The resulting lower DOC levels of the MIEX system lowered the chlorine demand and thus reduced the chlorine dose by 40 percent.

Table 6: Summary of MIEX Simulated Distribution System (SDS) DBP Formation Results

Treatment	DOC (mg/L)	14-Day SDS Method TTHM (mg/L)	14-Day SDS Method HAA5 (mg/L)
21 mg/L ferric chloride (control)	3.03	66.7	32
1000 BV MIEX and 8 mg/L ferric chloride at pH 6.75	1.52	30.2	8.4
% Reduction	50%	55%	74%

ACTIFLO High Rate Clarification Testing

The results from Kruger's ACTIFLO offsite testing are presented in Table 7. The optimal coagulant doses based on turbidity were selected for UVA and DOC testing. Conventional enhanced coagulation at lower coagulant doses outperformed ACTIFLO in terms of percent UVA reduction. DBP levels were not recorded due to a miscommunication between Kruger and the testing laboratory.

Table 7: Summary of ACTIFLO Test Results

	Raw Water	Alum (mg/L)						Ferric (mg/L)			
	-	10	20	30	40	50	60	20	40	60	80
Settled Turbidity (NTU)	0.40	1.70	1.60	1.30	0.70	1.80	1.00	1.40	0.80	0.50	0.25
Final pH	7.6	-	-	-	-	-	7.0	6.6	6.5	6.3	6.2
UVA (cm-1)	0.086	-	-	-	-	-	0.039	-	-	0.028	0.020
UVA Removal (%)	-	-	-	-	-	-	55	-	-	67	77
DOC mg/L	2.6	-	-	-	2.1	-	1.9	-	-	1.6	1.1
DOC Removal (%)	-	-	-	-	19	-	27	-	-	38	58

ACTIFLO CARB Jar Testing

Kruger's test results from onsite jar testing of the ACTIFLO CARB system are summarized in Table 8 below. Source water for the two day test was an equal blend of Newell Creek and San Lorenzo River water. Coagulant doses were selected based on turbidities from pre test results while the PAC dose was varied to characterize the effectiveness of PAC type and concentration. PAC doses used during ACTIFLO CARB jar testing are generally higher than typical used in the full scale process. All samples contained an anionic polymer dose of 0.30 mg/L and a micro sand concentration of 5 g/L.

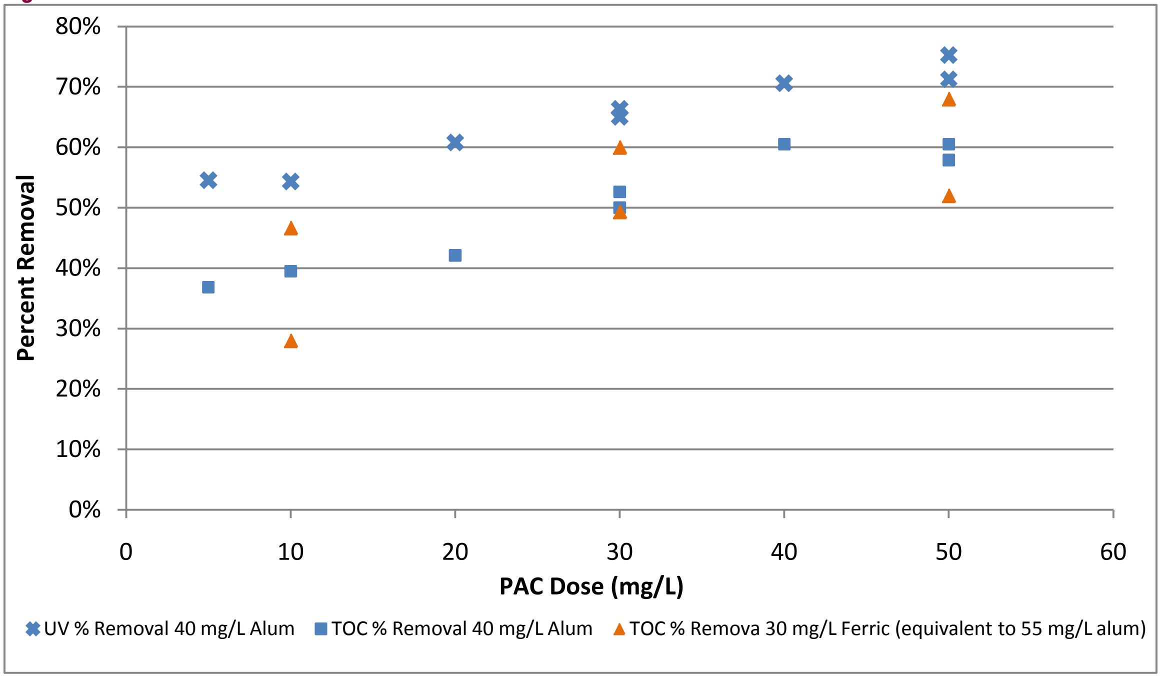
At an alum dose of 40 mg/L and a PAC dose of 30 mg/L and higher, the TOC levels dropped below 2 mg/L resulting in TOC removal rates as high as 61%. A ferric dose of 30 mg/L (metal ion equivalent dose of 55 mg/L alum) resulted in slightly better TOC removal and better DBP reduction.

Table 8: Summary of ACTIFLO CARB Test Results

		Alum 40 mg/L								Ferric 30 mg/L (equivalent to 55 mg/L alum)					
	PAC Type	PICAW						PICAC		PICAW					
	(mg/L)	5	10	20	30	40	50	30	50	10	30	50	10	30	50
pH		7.2	7.2	7.1	7.1	7.1	7.1	7.1	7.1	7.1	7.1	6.9	6.9	7.0	7.0
Turbidity	(NTU)	1.2	1.0	1.3	1.2	0.9	1.1	1.1	1.1	0.4	0.5	0.5	0.6	0.6	0.4
UVA	(cm-1)	.041	.041	.035	.030	.026	.026	.031	.022	-	-	-	-	-	-
UV % removal	-	55%	54%	61%	66%	71%	71%	65%	75%	-	-	-	-	-	-
TOC	(mg/L)	2.4	2.3	2.2	1.8	1.5	1.6	1.9	1.5	2.0	1.5	1.2	2.7	1.9	1.8
TOC % removal	-	37%	39%	42%	53%	61%	58%	50%	61%	47%	60%	68%	28%	49%	52%
DOC	(mg/L)	-	2.2	-	1.7	-	1.4	1.8	1.4	-	1.5	-	-	1.4	-
TTHM	(mg/L)	-	91	-	64	-	56	-	-	56	44	28	62	38	36
HAA5	(mg/L)	-	84	-	62	-	50	-	-	41	35	22	62	39	28

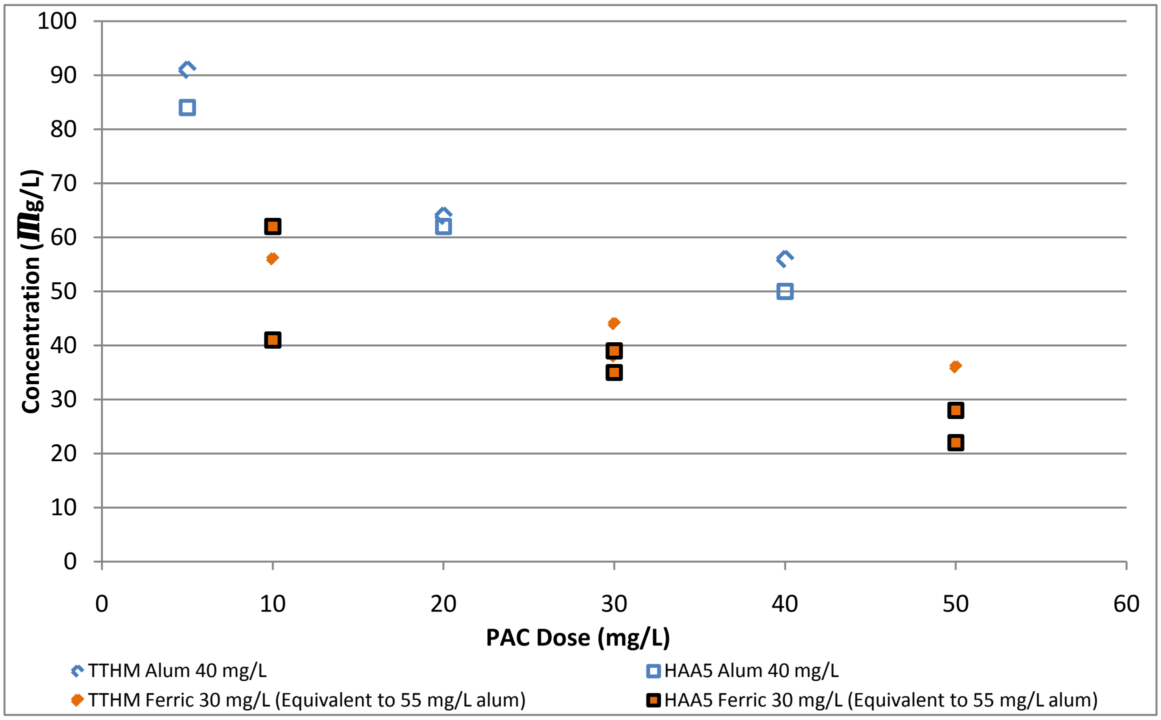
The UVA and TOC percent removal rates are presented in Figure 12. As expected, there is a strong correlation between PAC dose and percent removal. UVA removal reached 75% for the alum samples however data was not recorded for ferric.

Figure 12: ACTIFLO CARB Percent Removal UVA and TOC



DBP results from the 7-day SDS testing are presented in Figure 13. The 40 mg/L alum samples exceeded the TTHM and HAA5 MCLs at 10 mg/L PAC but were able stay below the MCL at higher doses. The 30 mg/L ferric samples had much better TTHM and HAA5 results while only exceeding the MCL in one instance (62 ppb HAA5 with 10 mg/L PAC). All SDS testing followed the initial jar testing parameters for temperature, 7-day incubation and free-chlorine dosage.

Figure 13: ACTIFLO CARB TTHM and HAA5 Levels at Day 7 of SDS Testing



Summary and Conclusions

NOM, TTHM and HAA5 levels in all source waters were reduced when the pH was lowered. Alum performed slightly better at the more neutral pH levels but ferric chloride outperformed alum at pH 5.5 and 6.0.

The results showed no significant benefits to switching from alum to ferric chloride. At equivalent metal ion doses, ferric will result in a higher sludge production than alum.

Newell Creek TTHM formation was best controlled by pH and enhanced coagulation. TTHM formation was moderately reduced by switching to post chlorination.

Newell Creek HAA5 formation was controlled best by enhanced coagulation and moderately by pH. Post chlorination was largely ineffective at controlling HAA5 formation for Newell Creek.

River/Coast TTHM formation was controlled well by enhanced coagulation, pH and post chlorination.

Post chlorination had the most significant effect on River/Coast water HAA5 formation. High ferric doses and pH were also effective at reducing HAA5 formation in River/Coast water.

The aeration test on settled water collected from the treatment plant resulted in no significant decreases in TTHM and HAA5 levels as aeration is only effective at volatilizing DBPs that have already formed. It is suspected there were sufficient amounts of NOM and chlorine present after the aeration test resulting in DBP formation during the simulated distribution system (SDS) testing phase. Fine bubble diffusers may be necessary to effectively aerate the channel upstream of the filters. Aeration would not be cost effective due to high capital and energy costs.

The ACTIFLO high rate clarification system had comparable results to conventional enhanced coagulation as the treatment mechanisms are similar. The ACTIFLO system has a much smaller detention time than conventional coagulation and thus would require a smaller footprint.

ACTIFLO CARB testing resulted in TOC concentrations below 2.0 mg/L with moderate to high PAC doses. The lowest TOC level recorded was 1.2 mg/L although it was achieved with a high ferric and PAC dose. PAC and coagulant doses in conjunction with the resulting sludge production should be analyzed on a larger scale to further determine the feasibility of this alternative. In summary, the ACTIFLO CARB system is a promising technology for reducing DBP precursors.

The MIEX system was the most effective treatment at reducing UVA and DOC levels. The MIEX treatment with coagulation resulted in a 55 percent reduction in finished water TTHM levels and 74 percent in HAA5 levels compared to coagulation alone. Using MIEX technology prior to coagulation significantly reduced the required amount of coagulant and disinfectant.

Table 9 compares the results from the optimal data set within each treatment process jar test. Results are considered optimal if they satisfy treatment goals for DBP reduction without providing more treatment than necessary.

Table 9: Optimal Sample Set for Each Treatment Process

	Enhanced Coagulation		**MIEX**	**MIEX[1]**	**ACTIFLO CARB**
Source	Newell Creek	River / Coast	Newell Creek	Newell Creek	50% Blend
UVA initial	0.082	0.078	0.092	0.092	0.087
UVA final	0.029	0.027	0.025	0.019	0.030
UVA % removal	65%	65%	73%	79%	66%
TOC /DOC final (mg/L)	-	-	1.76 (DOC)	1.52 (DOC)	1.8 (TOC)
TOC/DOC % removal			55%	61%	53%
pH	6.5	6.5	8.26	6.75	7.1
Coagulant (mg/L)	Fe = 30 (Al = 55)		Fe = 0	Fe = 8 (Al = 15)	Al = 40 (Fe = 21.8)
PAC (mg/L)	-	-	-	-	15 (full scale) 30 (jar test)
TTHM (ug/L)	44 (7 day)	31 (7 day)	-	30 (14 day)	64 (7 day)
HAA5 (ug/L)	41 (7 day)	38 (7 day)	-	8.4 (14 day)	62 (7 day)

[1] This sample set reduced pH further than optimal and included coagulation, which is not necessary for optimal results. It is included in this table for comparison of DBP data.

Appendix

Table A1: Full Results for UV254, TTHM, HAA5

			Newell Creek Source (LL Reservoir)							River / Coast Source						
pH			Control (neutral pH)	Alum (mg/L)			Ferric (mg/L)			Control (neutral pH)	Alum (mg/L)			Ferric (mg/L)		
			0	10	20	30	10	20	30	0	10	20	30	10	20	30
Cost Adjusted Concentration (CAC) mmol (Al^{3+} or Fe^{3+}) / L			0	0.034	0.067	0.101	0.062	0.123	0.185	0	0.034	0.067	0.101	0.062	0.123	0.185
Pre Chlorination	7.0	UVA (cm^{-1})	0.082	0.059	0.049	0.045	0.052	0.045	0.038	0.069	0.046	0.039	0.034	0.035	0.030	0.024
		TTHMs (mg/L)	--	87	85	79	79	75	53	110	82	69	63	59	57	48
		HAA5 (mg/L)	--	62	69	59	61	62	45	89	100	90	80	76	70	62
	6.5	UVA (cm^{-1})	0.087	0.053	0.043	0.036	0.046	0.035	0.029	0.071	0.041	0.035	0.031	0.036	0.030	0.023
		TTHMs (mg/L)	67[1]	83	70	62	70	60	48	--	62	55	51	56	45	36
		HAA5 (mg/L)	38[1]	77	73	71	72	64	54	--	90	79	86	83	83	64
Post Chlorination	7.0	UVA (cm^{-1})	0.093	0.062	0.050	0.046	0.058	0.051	0.040	0.069	0.045	0.040	0.036	0.041	0.033	0.027
		TTHMs (mg/L)	--	82	73	66	83	69	52	--	69	60	58	61	49	40
		HAA5 (mg/L)	--	70	68	60	74	71	51	--	72	72	73	67	56	42
	6.5	UVA (cm^{-1})	0.082	0.051	0.045	0.040	0.048	0.036	0.029	0.078	0.041	0.039	0.035	0.037	0.028	0.027
		TTHMs (mg/L)	--	80	62	59	66	54	44	--	53	45	42	52	40	31
		HAA5 (mg/L)	--	86	60	59	62	47	41	--	65	62	63	65	46	38
	6.0	UVA (cm^{-1})	0.086	0.045	0.036	0.030	0.036	0.023	0.016							
		TTHMs (mg/L)	41[1]	63	48	40	49	31	20							
		HAA5 (mg/L)	21[1]	53	42	31	40	24	16							
	5.5	UVA (cm^{-1})	0.086	0.049	0.035	0.030	0.033	0.019	0.018							
		TTHMs (mg/L)	--	47	39	31	31	23	19							
		HAA5 (mg/L)	--	46	37	30	30	21	27							

Notes:

1. At day 7, the chlorine residual was below detection levels (BDL) for these control samples. It is suspected the DBP formation was limited by the chlorine dose in these cases.

Table A2: Aeration Test Conditions

	Jar 1	Jar 2
Duration (min.)	2	0
Rate of Flow (scfm.)	0.035	0
TTHMs (mg/L)	25	27
HAA5 (mg/L)	41	39

Appendix C

Screening Summary of Process Alternatives Memo
and
Table of Screened Alternatives
(HDR, February, 2010)

SCREENING SUMMARY OF PROCESS ALTERNATIVES

City of Santa Cruz Graham Hill Water Treatment Plant Technical Review ***February 16, 2010***

Reviewed by: Richard Stratton, P.E.; Amy Miller, P.E.

Prepared by: Karen Pappas

This memo discusses the screening evaluation of treatment process alternatives for improvements to the Graham Hill WTP. The Santa Cruz Water District's (The City's) primary objectives for selecting a treatment process include:

- Increasing WTP capacity to 22 MGD
- Achieving consistent compliance with WQ goals
- Economic feasibility to construct and operate.

The goal of this screening step is to select specific alternatives that merit further evaluation as potential treatment solutions.

The City's treated water quality goals (in addition to all applicable state and federal regulations), as described in TM 2 – Review of Existing Background Information (January 2010), are as follows:

- Maintain 5 day or less water age throughout system.
- Assimilable Organic Carbon < 0.2 mg/L
- TTHMs < 80 ppb (at 5 days water age)
- HAA5 < 60 ppb (at 5 days water age)
- Chlorine residual (distribution system) 0.2 to 1.5 mg/L
- Threshold Odor Number < 2 100 percent of time
- Cl2:NH4 ratio of 4:1 to 5:1 (if chloramines implemented)

Technology Alternatives

Understanding that several processes can produce treated water meeting or exceeding regulatory requirements, the parameters most influencing process selection for the Graham Hill WTP improvements include:

- Disinfection byproducts (resulting from the use of chlorine as the primary and secondary disinfectant)
- Taste and odor (resulting from seasonal reservoir turn over and storm events).
- Site constraints (minimal available space)

- Existing process constraints

Two common approaches to reduce TTHM and HAA5 formation are 1) to remove or reduce the naturally occurring organic precursors that form disinfection byproducts (DBPs) when reacted with chlorine, or 2) to utilize an alternative disinfectant which minimizes the formation of DBPs, such as chloramines or chlorine dioxide.

Chlorine is the City's stated preference for secondary disinfectant.

Screening Evaluation

A screening review was conducted on several candidate process alternatives to determine which potentially meet the City's treatment goals and merit further evaluation. The alternatives screened include new alternatives as well as those previously evaluated in the Water Quality and System Improvements (October 2007) Study. Each alternative was screened based on parameters such as ability to meet water treatment goals, cost, residuals management, and operational flexibility. Table 1 briefly describes each of the process technologies included in the screening evaluation.

Table 1: Treatment Process Descriptions

Rapid Mix / Flocculation / Sedimentation (RM/F/S)	This pretreatment scheme is generally assumed to be the same as the current plant operational practices, except that coagulant type and dose and feed water pH are optimized for disinfection byproduct (DBP) precursor removal.
Enhanced Coagulation	Enhanced coagulation is the practice of increasing the dose of coagulant beyond the level needed to optimize filtration in order to achieve supplemental removal of DBP precursor materials (organics). Based on results of jar testing (December 2009), a dose of 60 mg/L alum is assumed. This elevated coagulant dosing will result in increased residual production.
MIEX	MIEX is a proprietary advanced treatment process using magnetic ion exchange for the removal of organics. The MIEX process contains small resin particles designed specifically for the adsorption removal of dissolved organic carbon (DOC). Bench tests (December 2009) indicate 50% removal of TOC.
Microfiltration / Ultrafiltration (MF/UF)	Membranes serve as a physical barrier against pathogens and some viruses. Membranes separate substances from feed water through sieving actions using various pore sizes and operating pressures.
Ceramic Membranes	Ceramic membranes also serve as a physical barrier against pathogens and some viruses (similar to MF/UF). Ceramic membranes do not require pre-clarified feed water and have

	an extended replacement life.
GAC • Filter Adsorber (TOC, T&O) • Filter Cap (T&O)	Granular activated carbon is an adsorption medium that removes elements from a water stream by adsorbing to its porous surface. Depending on design criteria and replacement frequency, GAC can be used for the removal of disinfection byproduct precursors and/or taste and odor. For Alternative 10 (Table 2), GAC replacement is assumed at 6 months for DBP control. In all other alternatives, GAC replacement life is assumed at 3 years, which is common for T&O control uses. GAC capped filters would operate as biologically active filters.
UV	UV disinfection is used for the inactivation of Cryptosporidium and Giardia cysts and oocysts. UV lamps project ultraviolet rays into the water stream. UV is absorbed by the DNA in the microorganisms and causes a disruption in the structure of these large molecules, making it impossible to for the microorganisms to replicate, and hence no infection is possible.
Ozone	Ozone is a disinfection alternative as well as a preoxidant for control of DBP precursors. Ozonation can control algae and associated T&O compounds, remove color, and oxidize iron and manganese. Ozone can be generated from air or oxygen and is mixed with water through use of bubble diffusers or other mixing technique.
High Rate Clarification (Actiflo)	Actiflo is a clarification process that uses ballasted mircorsand in a small footprint. It can be used with enhanced coagulation for TOC removal. Actiflo would replace the conventional floc/sed basins. Remaining available space in the sed basins would be used for chlorine contact and future ozonation.
High Rate Clarification (Trident)	Trident is a two stage high rate clarification technology. The first stage included coagulation, flocculation, and solids contact plate clarification technology. The second stage is an upflow adsorbption clarifier system for removal of the smaller floc particles. The Trident system is used with enhanced coagulation for organics removal.
Actiflo CARB	Actiflo CARB combines the Actiflo process with the recirculation of PAC to enhance the removal (adsorption) of organic matter for increased NOM removal. Actiflo CARB would be added downstream of conventional clarification so that PAC adsorption capacity is used by soluble organic mater rather than solids.
Ion Exchange	The process of ion exchange removes undesirable ions from raw water by exchanging them with desirable ions (stored in

	the ion exchange resin). After reaching the capacity for exchange, the resin is washed with a regeneration solution and used again. Ion exchange is typically used for water softening and removal of minerals from water. In this application, Ion exchange is used for TOC removal.

A summary description and results of the screening for Graham Hill WTP are shown in Table 2. The terms and rating factors used in the table are defined as follows:

Particle Reduction

- Ineffective – partially achieves required reduction for particles and turbidity. May violate treatment goals.
- Effective – particles and turbidity are removed to comply with treatment goals.
- Highly Effective – particles and turbidity are removed to well below treatment goals.

Microbial Reduction / Inactivation (MRI)

- Ineffective – partially achieves reduction/ inactivation of microbials.
- Effective - achieves typical reduction/inactivation of microbials.
- Highly Effective - achieves substantial reduction/inactivation of microbials.

Taste & Odor

- Ineffective – does not meet T&O goals.
- Moderately Effective- same T&O control as current operations (KMnO4 and PAC). Experience seasonal operational T&O challenges.
- Effective – expected to meet T& O goals for current raw water blend. May not meet T&O goals for future demands beyond 19.5 MGD with greater portion of raw water from Newell Creek (Loch Lomond).
- Highly Effective – expected to meet T&O goals for current and future raw water blends.

DBP Formation, Precursor Removal

- Ineffective – DBPs will likely violate water treatment and distribution system goals at design capacity. Process could be used together with other processes to meet WQ goals.
- Effective – DBP levels expected to comply with DBP water treatment goals. May require additional facilities for organics removal and/or residuals handling. May require operational modifications such as distribution system flushing.
- Highly Effective – DBPs levels expected to comply with DBP water treatment goals for current supply and future supply with potentially increased levels of organics.

Relative $$ (CAP)

- Moderate – Capital costs are comparable to a typical conventional plant.
- High - Capital costs are high compared to a typical conventional plant.

- Very High - Capital costs are high compared to a typical conventional plant.

Relative $$ (O&M)
- Moderate – O&M costs are comparable to a typical conventional plant.
- High - O&M costs are high compared to a typical conventional plant.
- Very High – O&M costs are very high compared to a typical conventional plant.

Residuals Management / System Modifications
- Decrease – WTP residuals system may NOT require modifications due to decreased solids production.
- Same – WTP residuals system may require SOME modifications for design capacity due to similar solids production as current operation.
- Increase – WTP residuals system will require MAJOR modifications due to increased solids production.

Distribution System Modifications
- Decrease – Distribution system maintenance will decrease.
- Same - Distribution system maintenance will remain the same.
- Increase – Modifications are required to distribution system and/or maintenance will increase.

Flexibility (future WQ changes when proportion of Newell Creek source water increases)
- Low – allows for little to no change in WQ to continue to meet treated WQ goals.
- Moderate – allows for moderate raw WQ changes while continuing to meet treated WQ goals.
- High – allows for greatest flexibility for changing raw WQ while continuing to meet treated WQ goals.

Screening Evaluation Conclusions

The general conclusions of the screening evaluation are as follows:

Disinfection Byproduct Control
- Membrane filtration + GAC (**Alternative 10**) is the proposed alternative in the Basis of Design Report (April 2009) and is recommended for further comparison against the new alternatives. TOC removal is achieved through conventional pretreatment and GAC filter adsorbers (contactors).
- MIEX alternatives (**11 A, B, and C**) are recommended for further evaluation due to the superior TOC removal capability of the MIEX system. The addition of plate settlers to two of the sedimentation basins would allow for the MIEX system to be configured within the third basin. Future ozone systems (for supplental T& O control) could be added upstream of MIEX or upstream of the filters. **Alternative 11-A** is a modificd

version of **Alternative 3** using modified existing filters (with GAC) in place of membranes to minimize capital cost and add a T&O control element.

- Enhanced coagulation alternatives (**12 and 20**) are recommended for further evaluation to determine whether the City's DBP reduction goals can be achieved and the associated costs for upgraded residuals handling. These alternatives are likely to be the least costly options. The addition of plate settlers to two of the sedimentation basins (**Alt 12**) would allow for use of the third basin for chlorine contact. The use of high rate clarification (**Alt 20**) creates available space within the sedimentation basins for use as chlorine contact and/or future ozone systems.
- Ceramic membrane filtration with enhanced coagulation (**Alternative 15**) is recommended for further evaluation. The third sedimentation basins would be decommissioned and converted to a membrane building. Ceramic membranes do not require settled water feed and thus a portion of sedminetation basins 1 and 2 could be used for chlorine contact. **Alternative 15** is a modified version of **Alternative 5** using ceramic membranes in place of MF/UF to create additional space for chlorine contact in the sedimentation basin.
- Ion Exchange **(Alternative 17**) is recommended for further evaluation due to its TOC removal capability.
- Actiflo **–** CARB (**Alternative 21**) is recommended for further evaluation due to its TOC removal capability and its small footprint. Recirculation of PAC within the Actiflo unit enables enhanced TOC removal and additional T&O control. The addition of plate settlers to two of the sedimentation basins would allow for configuration of the Actiflo-CARB system within the third basin. Additional space would also be available in the third basin for chlorine contact.

<u>Taste and Odor Control</u>

- PAC and KMnO4 are currently dosed at the plant to control T&O. Additional T&O control processes would improve ease of operation and consistency.
- GAC filter adsorber (**Alternative 10**) would provide improved T&) control over current process.
- GAC Filter Cap (**Alternatives 11-A, 11-B, 11-C,12, 20**) will provide improved T&O control over current process.
- Ozone - future (**Alternatives 11-B, 11-C, 20**) will provide additional T&O control (if needed) in future.
- PAC (recirculated for extended contact time) (**Alternative 21**) will provide additional T&O control over current process.

Disinfection (primary)

- Previously evaluated alternatives (**1,2,4,6**) that include UV will not be evaluated further as UV will not be required for cryptosporidium inactivation (per source water testing results indicating classification under Bin 1).

Disinfection (secondary)

- Previously evaluated alternatives with chloramines as a secondary disinfectant (**6,7,8,9**) were not selected for further evaluation based on the City's preference to maintain free chlorine in the distribution system. In addition, Alternatives 7,8, and 9 include advanced treatment processes such as MF/UF, O3, and ClO2 which are not likely required (due to Bin 1 classification) if chloramines are used as a secondary disinfectant. For comparison, **Alternative 22** does evaluate chloramines as a secondary disinfectant following conventional treatment.

Residuals Management

- The increase in residuals production associated with the screened alternatives was not a determining factor in warranting further evaluation. However, additional costs associated with increased residuals management will be assigned to such alternatives, as appropriate.

Table 2: Screening of Processes Alternatives for Graham Hill Water Treatment Plant Upgrade

No.	Alternative	Particle Red.	MRI (Crypto/ Giardia)	T&O	DBP (TOC)	CT Location	Relative $$ (Cap)	Relative $$ (O&M)	Residuals Management	Flexibility (WQ changes)	Dist. Sys. Mods.	Comments
		Ineffective Effective Highly Eff.	Ineffective Effective Highly Eff.	Ineffective Moderately Effective Effective Highly Eff.	Ineffective Effective Highly Eff.	Pre-Cl2 FW Tank[1] New CW 2nd FW Tank	Moderate High Very High	Moderate High Very High	Increase Same Decrease (proportional to flow)	Low Moderate High	Increase Same Decrease	1. FW Tank modifications (for flow through operation) do not address CT required for flow to the Passatiempo PS.
Current WTP Process												
0	Rapid Mix(RM) + KMnO4 + PAC+ Cl2 + Flocculation(F)[1] + Sedimentation(S) +Cl2 + Filtration + Cl2	Effective[2]	Effective	Moderately Effective[3]	Ineffective[4]	Pre-Cl2	Low	Moderate	Same	Low	Same	1. Aluminum Sulfate dosed at approx. 20 mg/L. 2. Limited to 3.5 gpm/sf. 3. Seasonal operational challenges: seek improved control. 4. Excessive DBPs may form, unable to consistently meet Stage 2 DBP limits.
Alternatives from WQ&SI Study (Oct 2007) (See Table Note 1)												
1 ✗	PAC+ KMnO4 + RM/F/S +Filtration+ UV + RO + Cl2	Highly Eff.	Highly Eff.	Highly Eff.	Highly Eff.	FW tank mods	Very High	Very High	Increase	High	Decrease	1. Brine disposal.
2 ✗	MIEX + PAC+ KMnO4 + RM/F/S + GAC Filters + UV + CL2	Effective	Highly Eff.	Effective	Highly Eff.	FW tank mods	Very High	High	Increase[2]	High	Decrease	1. Brine disposal.
3 ✗	MIEX + PAC+ KMnO4 + RM/F/S + MF/UF + Cl2	Highly Eff.	Highly Eff.	Moderately Effective[1]	Highly Eff.	FW tank mods	Very High	High	Increase[2]	High	Decrease	1. Same T&O control as existing operations. 2. Brine disposal required.
4A ✗	PAC+ KMnO4 + Enhanced Coagulation + RM/F/S + Filtration + UV + Cl2	Effective	Highly Eff.	Moderately Effective[1]	Effective[2]	FW tank mods	Moderate	High	Increase[3]	Moderate[4]	Same	1. Same T&O control as existing operations. 2. Increased DBP precursor removal over current operations. 3. Additional solids from enhanced coagulation. 4. May need additional DBP control features if future raw water TOC levels increase.
4B ✗	PAC+ KMnO4 + Enhanced Coagulation + RM/F/S + GAC Filters + UV + Cl2	Effective	Highly Eff.	Effective	Effective[1]	FW tank mods	High	High	Increase[2]	Moderate[3]	Decrease	1. Increased DBP precursor removal over current operations. 2. Additional solids from enhanced coagulation. 3. May need additional DBP control if future raw water TOC levels increase.
5 ✗	PAC+ KMnO4 + Enhanced Coagulation + RM/F/S + MF/UF + Cl2	Highly Eff.	Highly Eff.	Moderately Effective[1]	Effective[2]	FW tank mods	Very High	Moderate	Increase[3]	Moderate[4]	Same	1. Same T&O control as existing operations. 2. Increased DBP precursor removal over current operations. 3. Additional solids from enhanced coagulation. 4. May need additional DBP control if future raw water TOC levels increase.
6 ✗	PAC+ KMnO4 + RM/F/S + UV + Chloramines	Effective	Highly Eff.	Moderately Effective[1]	Highly Eff.	Pre-Cl2, FW tank mods	Moderate	Moderate	Same	Moderate	Increase	1. Same T&O control as existing operations.
7 ✗	PAC+ KMnO4 + RM/F/S + MF/UF + Chloramines	Highly Eff.	Highly Eff.	Moderately Effective[1]	Highly Eff.	Pre-Cl2, FW tank mods	Very High	Moderate	Same	Moderate	Increase	1. Same T&O control as existing operations.
8 ✗	PAC+ KMnO4 + RM/F/S + O3 + GAC Filters + Chloramines	Effective	Highly Eff.	Highly Eff.	Highly Eff.	Ozone contactor	High	Moderate	Same	High	Increase	1. Potential bromate formation issues.
9 ✗	ClO2 + RM/F/S + GAC Filters + Chloramines	Effective	Effective	Effective	Highly Eff.	Pre-Cl2, FW tank mods	Moderate	Moderate	Same	High	Increase	
Proposed WTP Process from Basis of Design Report (April 2009) and WQ&SI Study (Oct 2007)												
10 ✓	PAC + KMnO4 + RM/F/S + MF/UF + GAC Filter Adsorbers + Cl2 *NOTE: For the purpose of this evaluation, Alternative 10 is assumed to replace GAC every 6 months, acting as a contactor, rather than a filter cap with 3 year replacement (as indicated in 2009 BDR).	Highly Eff.	Highly Eff.	Highly Eff.	Effective[1]	FW tank + Pass. PS upgrade	High	Very High	Increase	High[2]	Decrease	1. DBP control credited to GAC contactors based on 6 month replacement rate. 2. May need to increase GAC replacement rate to every 3 months if future raw water TOC levels increase.
Additional Alternatives Proposed by HDR (Sept 2009)												
11 - A ✓	MIEX + PAC + KMnO4 + RM/F/S + Filtration (GAC cap) + Cl2	Effective	Effective	Effective[1]	Highly Eff.	FW tank + Pass. PS upgrade; 2nd FW tank	High	High	Same[2]	Moderate	Decrease	1. GAC cap provides additional T&O control. 2. Brine disposal added. Coagulant dose may be reduced to maintain solids loading rate at design capacity (lb/d).

Table 2: Screening of Processes Alternatives for Graham Hill Water Treatment Plant Upgrade

No.	Alternative	Particle Red.	MRI (Crypto/ Giardia)	T&O	DBP (TOC)	CT Location	Relative $$ (Cap)	Relative $$ (O&M)	Residuals Management	Flexibility (WQ changes)	Dist. Sys. Mods.	Comments
		Ineffective Effective Highly Eff.	Ineffective Effective Highly Eff.	Ineffective Moderately Effective Effective Highly Eff.	Ineffective Effective Highly Eff.	Pre-Cl2 FW Tank[1] New CW 2nd FW Tank	Moderate High Very High	Moderate High Very High	Increase Same Decrease (proportional to flow)	Low Moderate High	Increase Same Decrease	1. FW Tank modifications (for flow through operation) do not address CT required for flow to the Passatiempo PS.
12 ✓	PAC + KMnO4 + RM/F/S (Enhanced Coagulation) + Cl2 Contact + Filtration	Effective	Effective	Moderately Effective[1]	Effective[2]	New CW (3rd Sed basin)	Moderate	High	Increase[3]	Moderate	Same/Inc.	1. Same T&O control as existing process. Sed basins modified to remediate clogging at elevated PAC dose. 2. Increased DBP precursor removal over current operations. Jar Tests indicate that pH suppression and coagulant doses of 60 mg/L may be required to meet DBP treatment goals. 3. Additional solids from enhanced coagulation.
13 ✗	PAC + KMnO4 + RM/F/S + Filtration (GAC cap) + Cl2	Effective	Effective	Effective[1]	Ineffective[2]	3rd Sed. basin chlorine contact	Moderate	Moderate	Same	Low[3]	Same	1. GAC cap provides additional T&O control. 2. Increased DBP precursor removal over current operations due to pH suppression is not likely sufficient to meet DBP goals. 3. May need additional DBP and Cryptosporidium control.
14(7B) ✗	PAC + KMnO4 + RM/F + Ceramic Membranes[1] + Chloramines	Highly Eff.	Highly Eff.	Moderately Effective[2]	Highly Eff.	FW tank + Pass. PS upgrade	Very High	Moderate	Same	Moderate	Increase	1. Clarification is not required upstream of ceramic membranes. 2. Same T&O control as existing operations.
15 ✓	PAC + KMnO4 + RM/F (Enhanced Coagulation) + Ceramic Membranes[1] + Cl2	Highly Eff.	Highly Eff.	Moderately Effective[2]	Effective[3]	Sed. basin 1&2 chlorine contact	Very High	Moderate	Increase[4]	Low[5]	Same	1. Clarification is not required upstream of ceramic mem. 2. Same T&O control as existing operations. 3. Jar Tests indicate that pH suppression and coagulant doses of 60 mg/L may be required to meet DBP treatment goals. 4. Additional solids from enhanced coagulation. 5. May need additional DBP control, T&O control.
16 ✗	PAC + KMnO4 + RM/F/S + aeration[1] + MF/UF + Cl2	Highly Eff.	Highly Eff.	Moderately Effective[2]	Ineffective[3]	FW tank + Pass. PS upgrade	High	Moderate	Same	Low[4]	Same	1. Aeration for 2 minutes within converted filter basin is not sufficient contact time, per jar test results. 2. Same T&O control as existing operations. 3. No significant improvement over alt. w/o aeration. 4. May need additional DBP control.
17 ✓	PAC + KMnO4 + RM/F/S + MF/UF + Ion Exchange + Cl2	Highly Eff.	Highly Eff.	Moderately Effective[1]	Highly Eff.	FW tank + Pass. PS upgrade	Very High	High	Same	Moderate	Same/Inc.	1. Same T&O control as existing operations. Sed basins modified to remediate clogging at elevated PAC dose.
18 ✗	PAC + KMnO4 + High Rate Clarification + Cl2 contact + Filtration	Effective	Effective	Moderately Effective [1]	Effective[2]	New CW (3rd Sed basin)	High	Moderate	Increase	Moderate	Same/Inc.	1. Same T&O control as existing operations. 2. Assumes increased coagulant dose for organics removal.
19 ✗	PAC + KMnO4 + High Rate Clarification + Cl2 contact + Filtration + Chloramines	Effective	Effective	Moderately Effective[1]	Highly Effective	New CW (3rd Sed basin)	High	Moderate	Increase	Moderate	Increase	1. Same T&O control as existing operations.
20 ✓	PAC + KMnO4 + High Rate Clarification (EC) + (space for O_3[1])+ Filtration [2] + Cl2	Effective	Highly Eff.	Moderately Effective (initial) Highly Eff. (future)	Effective[3]	New CW (3rd Sed basin)	Very High	Moderate	Increase	Moderate[4]	Same/Inc.	1. Potential bromate formation issues. Space left for ozone system to be added in future, if needed for T&O. Ozone replaces free chlorine. 2. When ozone is added, filter modified with GAC cap. Filter enables biological activity for removal of oxidized organics. 3. Assumes increased coagulant dose for organics removal. Jar Tests indicate that pH suppression and coagulant doses of 60 mg/L may be required to meet DBP treatment goals. 4. Additional solids from enhanced coagulation.
21 ✓	PAC + KMnO4 + RM/F/S + ACTIFLO CARB + Cl2 Contact + Filtration	Effective	Effective	Effective[1]	Highly Eff. [2]	New CW (3rd Sed basin)	High	High	Same[3]	Moderate	Decrease	1. Recirculation of PAC in Actiflo CARB increases T&O removal. 2. Recirculation of PAC removes TOC. 3. Coagulant dose reduced. PAC dose increased to 5 mg/L (constant).

Table 2: Screening of Processes Alternatives for Graham Hill Water Treatment Plant Upgrade

No.	Alternative	Particle Red.	MRI (Crypto/ Giardia)	T&O	DBP (TOC)	CT Location	Relative $$ (Cap)	Relative $$ (O&M)	Residuals Management	Flexibility (WQ changes)	Dist. Sys. Mods.	Comments
		Ineffective Effective Highly Eff.	Ineffective Effective Highly Eff.	Ineffective Moderately Effective Effective Highly Eff.	Ineffective Effective Highly Eff.	Pre-Cl2 FW Tank[1] New CW 2nd FW Tank	Moderate High Very High	Moderate High Very High	Increase Same Decrease (proportional to flow)	Low Moderate High	Increase Same Decrease	1. FW Tank modifications (for flow through operation) do not address CT required for flow to the Passatiempo PS.
22 	Ozone[1] + RM/F/S (Enhanced Coagulation) + Filtration (GAC cap) + Cl2	Effective	Effective	Highly Effective	Effective[2]	Ozone Contactor (exist. carbon basins)	High	High	Increase[3]	Moderate	Same/Inc.	1. Potential bromate formation issues. 2. Increased DBP precursor removal over current operations. Alum dose assumed at 50 mg/L, based on removal of organics by ozone of 15%. 3. Additional solids from enhanced coagulation.
23 	PAC + KMnO4 + RM/F/S +Cl2 contact + Filtration+ Chloramines	Effective	Effective	Moderately Effective[1]	Highly Eff. [2]	New CW (3rd Sed basin)	Moderate	Moderate	Same[3]	Moderate	Increase	1. Same T&O control as existing operations. Sed basins modified to remediate clogging at elevated PAC dose.. 2. TTHMs and HAAs are not formed with chloramines.

Additional Table Notes:

1. Alternatives 1,2,4, and 6 were not selected for further evaluation as they include UV disinfection which is not required for WTPs with Bin 1 classification (per the LT2 Rule). Alternative 3 was modified as Alternative 11-A without membrane filtration to minimize capital cost. Alternative 5 was modified into Alternative 15 using ceramic membranes in place of MF/UF to create additional space for chlorine contact in the sedimentation basin, as pre- sedimentation is not required for ceramic membranes. Alternative 7,8, and 9 were not selected for further evaluation because advanced treatment processes such as MF/UF, O3, and ClO2 are not likely required (due to Bin 1 classification) when chloramines are used as a secondary disinfectant. Chloramines is evaluated (paired with conventional treatment) in Alternative 22.
2. High Rate Clarification technologies to be evaluated: Actiflo, Trident adsorption clarifier.
3. Assumes ozone would be dosed in a pipe diffuser.
4. Alternatives with "FW Tank" as the CT location require modifications to the existing CW and associated piping to achieve CT downstream of the filters. Modifications may include addition of a second FW tank to provide CT upstream of Passatiempo pump station. Alternatives including conversion of one sedimentation basin into chlorine contact clearwell are noted.
5. All alternatives with "Filtration" include necessary filter upgrades such as adding Filter to Waste and other piping and basin upgrade modifications.
6.  = Alternative eliminated from further evaluation.
7.  = Alternative carried through to Life Cycle Analysis.

Appendix D

Conceptual Capital and O&M Cost Tables

Process Alternative: Membranes + GAC

PAC + KMnO4 + RM/F/S + MF/UF + GAC + Cl2

Improvement Description		Base Cost		
Submerged Membrane Facility		$11,000,000		
Plate Settlers & Basin Modifications		$3,300,000		
New Washwater Clarifier / Thickeners and Transfer Pumps		$710,000		
GAC CAP and Filter Restoration		$1,650,000		
New Bulk Chemical Facilities		$910,000		
Filtered Water Tank Piping Improvements		$270,000		
New 1 MG FW clear well; assoc. piping		$2,050,000		
Subtotal New Facilities		**$17,840,000**		
Electrical System Improvements	15%	$2,680,000		
Control System Improvements	10%	$1,780,000		
Site Modifications and Yard Piping	20%	$3,570,000		
Unidentified Items	30%	$5,350,000		
Subtotal		$31,220,000		
Change Order Allowance	5%	$1,560,000		
Subtotal - Construction Costs		**$32,780,000**		
Preliminary and Final Design Fees	18%	$5,900,000		
Resident Engineering, Inspection and Construction Support	12%	$3,930,000		
Total		**$42,610,000**	11.354%	**$47,450,000**
		(Mar 2009)		(May 2011)

Notes:

1. Base Costs extracted from April 2009 BDR (using prorates from TM-3A Nov 2004)
2. Prorates used from TM-3A Comparison of Treatment Process Alterntatives, Nov '04)
3. CT for required 0.5 log Giardia (downstream of membranes) achieved in new FW tank.

Process Alternative: Membranes + GAC

PAC + KMnO4 + RM/F/S + MF/UF + GAC + Cl2

	$/yr	$/1000-gal	
Power	$220,000	$0.04	(1)
Chemicals	$480,000	$0.08	(1)
GAC Replacement	$700,000	$0.12	(2)
Membrane Replacement	$300,000	$0.05	(1)
Labor	$390,000	$0.07	(1)
Misc.	$180,000	$0.03	(1)
Total O&M Costs	$2,270,000	$0.39	

Notes:

(1) Costs from BDR, March 2009, excalated to May 2011.

(2) Revised to reflect GAC replacement at 6 month interval.

(3) Residuals disposal costs not included.

Process Alternative: MIEX

MIEX + PAC + KMnO4 + RM/F/S + Filtration (GAC cap) + Cl2

Improvement Description		**Base Cost (May 2011)**	
MIEX System		$5,950,000	(1)
Sed Basin Mods for MIEX (add baffle wall(s), mount agitators (6))		$170,000	
Plate Settlers & Basin Modifications (decommission 1 for MIEX use)		$3,670,000	(2)
GAC CAP and Filter Restoration		$1,840,000	(2)
Filtered Water Tank Piping Improvements (flow through)		$300,000	
New 1 MG FW clear well; piping		$2,050,000	(3)
UV system for Passatiempo Pump Station		$309,000	(1)
Subtotal New Facilities		**$14,289,000**	
Electrical System Improvements	15%	$2,140,000	
Control System Improvements	10%	$1,430,000	
Site Modifications and Yard Piping	20%	$2,860,000	
Unidentified Items	30%	$4,290,000	
Subtotal		$25,009,000	
Change Order Allowance	5%	$1,250,000	
Subtotal - Construction Costs		**$26,259,000**	
Preliminary and Final Design Fees	18%	$4,730,000	
Resident Engineering, Inspection and Construction Support	12%	$3,150,000	
Total Capital Cost		**$34,139,000**	

Notes:

1. March 2010 costs escalated to May 2011 with factor of 8.9% (assumes 4% annual increase).
   Assumes use of Sed portion of existing basin (separated out into contact zone and settler zone).
2. Cost from Table 5-1, BDR, April 2009. Prorates removed, escalated to 2011.
3. CT achieved in new 1 MG FW tank.
4. Prorates applied from TM-3A Comparison of Treatment Process Alterntatives (Nov '04).
5. Brine is assumed to be discharged to sewer.

Process Alternative: MIEX

MIEX + PAC + KMnO4 + RM/F/S + Filtration (GAC cap) + Cl2

	\$/yr	**\$/1000-gal**	
Power	\$120,000	\$0.02	(1)
Chemicals	\$430,000	\$0.07	(1)
MIEX system -(salt, power, resin)	\$700,800	\$0.12	
GAC Replacement	\$120,000	\$0.02	(2)
Labor	\$390,000	\$0.07	(1)
Misc.	\$180,000	\$0.03	(1)
Total O&M Costs	\$1,940,800	\$0.33	

Notes:

(1) Costs from BDR, March 2009, escalated to May 2011 (factor of 11.354%)

(2) Assumes replacement of GAC every 3 years.

(3) Residuals disposal costs not included.

Process Alternative: Ozone + MIEX

Ozone + MIEX + PAC + KMnO4 + RM/F/S + Filtration (GAC cap) + Cl2

Improvement Description		**Base Cost (May 2011)**	
Ozone System		$4,500,000	(1)
LOX System		$520,000	(1)
Calcium Thiosulfate System		$390,000	(1)
MIEX System		$5,950,000	(2)
Sed Basin Mods for MIEX (add baffle wall(s), mount agitators (6))		$130,000	
Plate Settlers & Basin Modifications (decommission 1 for MIEX use)		$3,670,000	(3)
Filter Restoration + GAC cap		$1,840,000	(3)
Subtotal New Facilities		**$17,000,000**	
Electrical System Improvements	15%	$2,550,000	
Control System Improvements	10%	$1,700,000	
Site Modifications and Yard Piping	20%	$3,400,000	
Unidentified Items	30%	$5,100,000	
Subtotal		$29,750,000	
Change Order Allowance	5%	$1,490,000	
Subtotal - Construction Costs		**$31,240,000**	
Preliminary and Final Design Fees	18%	$5,620,000	
Resident Engineering, Inspection and Construction Support	12%	$3,750,000	
Total Capital Cost		**$40,610,000**	

Notes:

1. Cost escalated from Nov 2004 TM-3A Comparison of Treatment Process Alterntatives to 2011 (for comparison with 2009 BDR costs).
2. March 2010 costs escalated to May 2011 with factor of 8.9% (assumes 4% annual increase). Assumes use of Sed portion of existing basin (separated out into contact zone and settler zone).
3. Cost from Table 5-1, BDR, April 2009. Prorates removed, escalated to 2011.
4. Prorates applied from TM-3A Comparison of Treatment Process Alterntatives (Nov '04).
5. Brine is assumed to be discharged to sewer.

Process Alternative: OZONE + MIEX
Ozone + MIEX + PAC + KMnO4 + RM/F/S + Filtration (GAC cap) + Cl2

	$/yr	$/1000-gal	
Power	$220,000	$0.04	(1)
Chemicals	$450,000	$0.08	(1)
MIEX system -(salt, power, resin)	$700,800	$0.12	
GAC Replacement	$120,000	$0.02	(2)
Labor	$390,000	$0.07	(1)
Misc.	$180,000	$0.03	(1)
Total O&M Costs	$2,060,800	$0.35	

Notes:
(1) Costs from BDR, March 2009, escalated to May 2011 (factor of 11.354%)
(2) Assumes replacement of GAC every 3 years.
(3) Residuals disposal costs not included.

Process Alternative: Enhanced Coagulation

PAC + KMnO4 + RM/F/S (60 mg/L alum) + Filtration + Cl2

Improvement Description		**Base Cost (May 2011)**	
Alum system upgrades (increased capacity)		$190,000	(1)
Acid feed system (pH depression)		$390,000	
Caustic Soda System (pH adjustment)		$390,000	(2)
Filter Restoration		$1,840,000	(3)
Plate Settlers & Basin Modifications (decommission 1 for Cl2 contact)		$3,670,000	(3)
Chlorine Contact Modifications (in 3rd sed basin)		$270,000	(4)
Subtotal New Facilities		**$6,750,000**	
Electrical System Improvements	15%	1010000	
Control System Improvements	10%	680000	
Site Modifications and Yard Piping	20%	1350000	
Unidentified Items	30%	2030000	
Subtotal		$11,820,000	
Change Order Allowance	5%	$590,000	
Subtotal - Construction Costs		**$12,410,000**	
Preliminary and Final Design Fees	18%	$2,230,000	
Resident Engineering, Inspection and Construction Support	12%	$1,490,000	
Total Capital Cost		**$16,130,000**	

Notes:

1. Assume upgrades equal half the cost for new chem feed system, as estimated in 2004 dollars, escalated to 2011.
2. Costs escalated from Nov 2004 TM-3A Comparison of Treatment Process Alterntatives to 2011 (for comparison with 2009 BDR costs).
3. Cost from Table 5-1, BDR, April 2009. Prorates removed, except excalation to 2011.
4. Modifications include addition of baffle wall. Inlet/outlet piping for flow re-routing not included.
5. Prorates Used from TM-3A Comparison of Treatment Process Alterntatives (Nov '04)
6. Chlorine contact time achieved downstream of 2 floc/sed basins.
7. Residuals Handling costs not included.

Process Alternative: Enhanced Coagulation

PAC + KMnO4 + RM/F/S (60 mg/L alum) + Filtration + Cl2

	$/yr	$/1000-gal	
Power	$120,000	$0.02	(1)
Chemicals	$650,000	$0.11	(2)
Labor	$390,000	$0.07	(3)
Misc.	$180,000	$0.03	(1)
Total O&M Costs	$1,340,000	$0.23	

(1) Assumes BDR 2009 power costs, replacing membranes with conventional filters,
filters, escalated to 2011 (factor 11.354%).

(2) Chemical costs based on 2009 BDR. Coagulant cost doubled. Escalated to 2011.

(3) Assumes BDR 2009 Labor cost, escalated to 2011.

(4) Residuals disposal costs not included.

Process Alternative: KCM w/ Enhanced Coagulation

PAC + KMnO4 + RM/F (60 mg/L alum) + Ceramic Membranes[1] + Cl2

Improvement Description		**Base Cost (May 2011)**	
Acid feed system (pH depression)		$390,000	
Caustic System (pH adjustment)		$390,000	(1)
Alum system upgrades (increased capacity)		$190,000	(2)
Ceramic Membrane		$16,770,000	(3)
Basin Modifications (decommission 1 for membrane building)		$2,120,000	(4)
New Washwater Clarifier / Thickeners and Transfer Pumps		$790,000	(4)
Chlorine Contact Modifications (Sed basin 1 or 2)		$270,000	
Subtotal New Facilities		**$20,920,000**	
Electrical System Improvements	15%	$3,140,000	
Control System Improvements	10%	$2,092,000	
Site Modifications and Yard Piping	20%	$4,184,000	
Unidentified Items	30%	$6,276,000	
Subtotal		$36,612,000	
Change Order Allowance	5%	$1,830,000	
Subtotal - Construction Costs		**$38,442,000**	
Preliminary and Final Design Fees	18%	$6,920,000	
Resident Engineering, Inspection and Construction Support	12%	$4,610,000	
Total Capital Cost		**$49,972,000**	

Notes:

1. Costs escalated from Nov 2004 TM-3A Comparison of Treatment Process Alterntatives to 2011 (for comparison with 2009 BDR costs).

2. Assume upgrades equal half of the cost for new chemical feed system as estimated in 2004 dollars, escalated to 2011.

3. Membrane system capacity = 20.5 MGD (summer), 15 MGD (winter)

4. Cost from Table 5-1, BDR, April 2009. Plate settler portion of basin modificatins omitted. Prorates remove, except escalation to 2011.

5. Prorates Used from TM-3A Comparison of Treatment Process Alterntatives (Nov '04).

6. Residuals Handling costs not included.

Process Alternative: KCM w/ Enhanced Coagulation

PAC + KMnO4 + RM/F (60 mg/L alum) + Ceramic Membranes[1] + Cl2

	$/yr	$/1000-gal	
Power	$210,000	$0.04	(1)
Chemicals	$700,000	$0.12	(2)
Membrane Replacement	$300,000	$0.05	(1)
Labor	$390,000	$0.07	(1)
Misc.	$180,000	$0.03	(1)
Total O&M Costs	$1,780,000	$0.30	

Notes:

(1) Costs from BDR, March 2009, excalated to May 2011.

(2) Chemical costs based on 2009 BDR. Coagulant cost doubled.

(3) Residuals disposal costs not included.

Process Alternative: High Rate Clarification

PAC + KMnO4 + High Rate Clarification (EC) + (space for O_3[1])+ Filtration (GAC cap)[2] + Cl2

			Base Cost (May 2011)		
Construction Cost Estimate		**A**	**B**	**C**	
Alum system upgrades (increased capacity)		$190,000	$190,000	$190,000	(1)
Acid feed system (pH depression)		$390,000	$390,000	$390,000	(2)
Caustic System (pH adjustment)		$390,000	$390,000	$390,000	(2)
A Trident HSC-15		$8,070,000	-	-	
B Contrafast		-	$1,560,000		
C ACTIFLO (2@11 MGD)		-	-	$2,720,000	
Sed basin modifications (for high rate clarifiers) ; walls and concrete rehab		$680,000	$620,000	$630,000	(3)
Sed basin modifications (for chlorine contact), walls and concrete rehab		$730,000	$730,000	$730,000	(3)
Filter Restoration		$1,840,000	$1,840,000	$1,840,000	
Subtotal New Facilities		**$12,290,000**	**$5,720,000**	**$6,890,000**	
Electrical System Improvements	15%	$1,840,000	$860,000	$1,030,000	
Control System Improvements	10%	$1,229,000	$572,000	$689,000	
Site Modifications and Yard Piping	20%	$2,458,000	$1,144,000	$1,378,000	
Unidentified Items	30%	$3,687,000	$1,716,000	$2,067,000	
Subtotal		$21,504,000	$10,012,000	$12,054,000	
Change Order Allowance	5%	$1,080,000	$500,000	$600,000	
Subtotal - Construction Costs		**$22,584,000**	**$10,512,000**	**$12,654,000**	
Preliminary and Final Design Fees	18%	$4,070,000	$1,890,000	$2,280,000	
Resident Engineering, Inspection and Construction Support	12%	$2,710,000	$1,260,000	$1,520,000	
Total Capital Cost		**$29,364,000**	**$13,662,000**	**$16,454,000**	

Notes:

1. Assume upgrades equal half the cost for new chem feed system, as estimated in 2004 dollars, escalated to 2011.
2. Costs for chemical feed system escalated from Nov 2004 TM-3A Comparison of Treatment Process Alterntatives to 2011 (for comparison with 2009 BDR costs).
3. Basin modifications include addition of baffle wall (s) and concrete rehabilitation, metal work. Inlet/outlet piping for flow re-routing not included.
4. Residuals handling costs not included.
5. Prorates Used from TM-3A Comparison of Treatment Alterntatives, CDM, Nov '04.

Process Alternative: High Rate Clarification

PAC + KMnO4 + High Rate Clarification (EC) + (space for O_3)+ Filtration + Cl2

	$/yr	$/1000-gal	
Power	$170,000	$0.03	(1)
Chemicals	$650,000	$0.11	(2)
Labor	$390,000	$0.07	(3)
Misc.	$180,000	$0.03	(1)
Total O&M Costs	$1,390,000	$0.24	

(1) Assumes BDR 2009 power costs, replacing membranes with conventional filters, escalated to 2011 (factor 11.354%).

(2) Chemical costs based on 2009 BDR. Coagulant cost doubled. Escalated to 2011.

(3) Assumes BDR 2009 Labor cost, escalated to 2011.

(4) Residuals disposal costs not included.

Process Alternative: ACTIFO CARB
KMnO4 + RM/F/S + ACTIFLO CARB (w/ PAC) + Filtration + Cl2

Improvement Description		**Base Cost (May 2011)**	
Alum system upgrades (increased capacity)		$190,000	(1)
PAC system improvements		$190,000	(1)
Actiflo CARB System		$3,680,000	
Filter Restoration		$1,840,000	(2)
Sed basin modifications (for Actiflo-Carb Retrofit), walls, concrete rehab		$735,000	(3)
Chlorine contact modifications (in sed basin 2), walls, concrete rehab		$730,000	(4)
Filtered Water Tank Piping Improvements (flow through)		$300,000	
Subtotal New Facilities		**$7,665,000**	
Electrical System Improvements	15%	$1,150,000	
Control System Improvements	10%	$770,000	
Site Modifications and Yard Piping	20%	$1,530,000	
Unidentified Items	30%	$2,300,000	
Subtotal		$13,415,000	
Change Order Allowance	5%	$670,000	
Subtotal - Construction Costs		**$14,085,000**	
Preliminary and Final Design Fees	18%	$2,540,000	
Resident Engineering, Inspection and Construction Support	12%	$1,690,000	
Total Capital Cost		**$18,315,000**	

Notes:

1. Assume upgrades equal half the cost for new chem feed system as estimated in 2004 dollars, escalated to 2011.
2. Cost from Table 5-1, BDR, April 2009. Prorates removed, escalated to 2011.
3. Basin modifications include addition of wall (s), concrete rehabilitation (1 basin), metal work.

4. Basin modifications include addition of baffle wall (s) ONLY downstream of Actiflo CARB. piping not included.
5. Prorates used from TM-3A Comparison of Treatment Process Alterntatives (Nov '04)
6. Residuals Handling cost not included.
7. Assume Actiflo CARB is direct feed.

Process Alternative: ACTIFO CARB
KMnO4 + ACTIFLO CARB (w/ PAC) + Filtration + Cl2

	$/yr	$/1000-gal	
Power	$180,000	$0.03	(1)
Chemicals	$500,000	$0.09	(2)
Labor	$390,000	$0.07	(3)
Misc.	$180,000	$0.03	(1)
Total O&M Costs	$1,250,000	$0.21	

(1) Assumes BDR 2009 power costs, replacing membranes with conventional filt

(2) Chemical costs based on 2009 BDR. Coagulant cost Increased by 33%.
Escalated to 2011.
(3) Assumes BDR 2009 Labor cost, escalated to 2011.
(4) Residuals disposal costs not included.

Process Alternative: Ozone + ACTIFO CARB
KMnO4 + Ozone + RM/F/S + ACTIFLO CARB (w/ PAC) + Filtration (GAC) + Cl2

Improvement Description		**Base Cost (May 2011)**	
Ozone System		$4,500,000	
LOX System		$520,000	
Calcium Thiosulfate System		$390,000	(1)
PAC system improvements		$190,000	(2)
Actiflo CARB System		$3,110,000	
Filter Restoration + GAC cap		$1,840,000	(3)
Sed basin modifications (for Actiflo-Carb Retrofit), walls, concrete rehab		$735,000	(4)
Subtotal New Facilities		**$11,285,000**	
Electrical System Improvements	15%	$1,690,000	
Control System Improvements	10%	$1,130,000	
Site Modifications and Yard Piping	20%	$2,260,000	
Unidentified Items	30%	$3,390,000	
Subtotal		$19,755,000	
Change Order Allowance	5%	$990,000	
Subtotal - Construction Costs		**$20,745,000**	
Preliminary and Final Design Fees	18%	$3,730,000	
Resident Engineering, Inspection and Construction Support	12%	$2,490,000	
Total Capital Cost		**$26,965,000**	

Notes:

1. Cost escalated from Nov 2004 TM-3A Comparison of Treatment Process Alterntatives to 2011 (for comparison with 2009 BDR costs).

2. Assume upgrades equal half the cost for new chem feed system as estimated in 2004 dollars, escalated to 2011.
3. Cost from Table 5-1, BDR, April 2009. Prorates removed, escalated to 2011.
4. Basin modifications include addition of wall (s), concrete rehabilitation (1 basin), metal work.
5. Prorates used from TM-3A Comparison of Treatment Process Alterntatives (Nov '04)
6. Residuals Handling cost not included.

Process Alternative: OZONE + ACTIFO CARB
KMnO4 + Ozone + RM/F/S + ACTIFLO CARB (w/ PAC) + Filtration (GAC CAP) + Cl2

	$/yr	$/1000-gal	
Power	$290,000	$0.05	(1)
Chemicals	$650,000	$0.11	(2)
GAC Replacement	$120,000	$0.02	(3)
Labor	$390,000	$0.07	(4)
Misc.	$180,000	$0.03	(5)
Total O&M Costs	$1,630,000	$0.28	

(1) Assumes BDR 2009 power costs, replacing membranes with conventional filters, escalated to 2011 (factor 11.354%).

(2) Chemical costs based on 2009 BDR. Coagulant cost Increased by 33%. Escalated to 2011.
(3) Assumes replacement of GAC every 3 years.
(4) Assumes BDR 2009 Labor cost, escalated to 2011.
(5) Residuals disposal costs not included.

Process Alternative: Chloramines
KMnO4 + RM/F/S + Filtration + Cl2 + Chloramines

Improvement Description		**Base Cost (May 2011)**	
Aqua Amonia Feed System		$390,000	(1)
Plate Settlers & Basin Modifications (decommission 1 for chlorine contact use)		$3,670,000	(2)
Chlorine Contact Modifications (in 3rd sed basin)		$270,000	(3)
Filter Restoration		$1,840,000	(2)
Distribution System Storage Tank Mixing System (5 reservoirs upgraded)		$710,000	
Subtotal New Facilities		**$6,880,000**	
Electrical System Improvements	15%	$1,030,000	
Control System Improvements	10%	$690,000	
Site Modifications and Yard Piping	20%	$1,380,000	
Unidentified Items	30%	$2,060,000	
Subtotal		$12,040,000	
Change Order Allowance	5%	$600,000	
Subtotal - Construction Costs		**$12,640,000**	
Preliminary and Final Design Fees	18%	$2,280,000	
Resident Engineering, Inspection and Construction Support	12%	$1,520,000	
Total Capital Cost		**$16,440,000**	

Notes:
1. Costs escalated from Nov 2004 Comparison of Treatment Process Alterntatives to 2011 (for comparison with 2009 BDR costs).
2. Cost from Table 5-1, BDR, April 2009. Prorates removed, excalated to 2011.
3. Modifications include addition of baffle wall. Inlet/outlet piping for flow re-routing not included.
4. Prorates Used from TM-3A Comparison of Treatment Process Alterntatives (Nov '04)

Process Alternative: Chloramines

KMnO4 + RM/F/S + Filtration + Cl2 + Chloramines

	$/yr	$/1000-gal	
Power	$120,000	$0.02	(1)
Chemicals	$440,000	$0.08	(2)
Labor	$390,000	$0.07	(3)
Misc.	$180,000	$0.03	(1)
Total O&M Costs	$1,130,000	$0.19	

(1) Assumes BDR 2009 power costs, replacing membranes with conventional filters, escalated to 2011 (factor 11.354%).

(2) Chemical costs based on 2009 BDR. Coagulant cost doubled. Escalated to 2011.

(3) Assumes BDR 2009 Labor cost, escalated to 2011.

(4) Residuals disposal costs not included.

Process Alternative: Pre-Ozonation

Ozone + RM/F/S (50 mg/L alum) + Filtration (GAC cap) + Cl2

Improvement Description		**Base Cost (May 2011)**	
Ozone System		$4,500,000	(1)
LOX System		$520,000	(1)
Alum system upgrades (increased capacity)		$190,000	(4)
Acid feed system (pH depression)		$390,000	
Caustic Soda System (pH adjustment)		$390,000	(1)
Calcium Thiosulfate System		$390,000	(1)
GAC CAP and Filter Restoration		$1,840,000	(2)
Floc/Sed Basin Modifications (concrete restoration, vertical shaft mixers		$1,390,000	(3)
Subtotal New Facilities		**$9,610,000**	
Electrical System Improvements	15%	1440000	
Control System Improvements	10%	960000	
Site Modifications and Yard Piping	20%	1920000	
Unidentified Items	30%	2880000	
Subtotal		$16,810,000	
Change Order Allowance	5%	$840,000	
Subtotal - Construction Costs		**$17,650,000**	
Preliminary and Final Design Fees	18%	$3,177,000	
Resident Engineering, Inspection and Construction Support	12%	$2,118,000	
Total Capital Cost		**$22,945,000**	

Notes:

1. Cost escalated from Nov 2004 TM-3A Comparison of Treatment Process Alterntatives to 2011 (for comparison with 2009 BDR costs)
2. Cost from Appendix C, (Basin Mods including concrete restoration, vertical mixers/gears only). BDR, April 2009. Prorates removed, except excalation to 2011.
3. Cost from Table 5-1, BDR, April 2009. Prorates removed, except excalation to 2011., Basin mods do NOT include plate settlers as in BDR
4. Assume upgrades equal half the cost for new chem feed system, as estimated in 2004 dollars, escalated to 2011
5. Modifications include addition of baffle wall. Inlet/outlet piping for flow re-routing not included
6. Prorates Used from TM-3A Comparison of Treatment Process Alterntatives (Nov '04)
7. Residuals Handling costs not included.

Process Alternative: Pre-Ozonation

Ozone + RM/F/S (50 mg/L alum) + Filtration (GAC cap) + Cl2

	$/yr	**$/1000-gal**	
Power	$240,000	$0.04	(1)
Chemicals	$670,000	$0.11	(2)
GAC Replacement	$120,000	$0.02	(3)
Labor	$390,000	$0.07	(4)
Misc.	$180,000	$0.03	(1)
Total O&M Costs	$1,600,000	$0.27	

(1) Assumes BDR 2009 power costs, replacing membranes with conventional filters, escalated to 2011 (factor 11.354%).

(2) Chemical costs based on 2009 BDR. Coagulant cost doubled. Escalated to 2011.

(3) Assumes replacement of GAC every 3 years.

(4) Assumes BDR 2009 Labor cost, escalated to 2011.

(5) Residuals disposal costs not included.

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