Evaluation Summary of Total Organic Carbon (TOC) Removal Technologies and Concepts

TOC is removed in biological treatment processes with long solids retention time and high mixed liquor suspended solids (MLSS). Biological processes with these characteristics consume the organic carbon as food. The membrane biological reactor (MBR) process (identified as the Zenon treatment system on page 3-20 of the Alternatives Screening Analysis Report) provides controls to maximize these two operational parameters.

Some organic carbon compounds are very refractory and are resistant to biological degradation. Advanced oxidation processes utilize oxidants such as peroxide and ozone in combination with ultraviolet (UV) light to break apart refractory compounds. These processes are often used as a polishing process in combination with disinfection or are used for side stream treatment on a reject water stream from a membrane process.

When TOC is in small concentrations in water it is typically removed through adsorption onto granular activated carbon (GAC). This process is used extensively by AFCEE in their groundwater cleanup processes at MMR.

Finally, fine membranes such as reverse osmosis (RO) can be used as an additional polishing step to remove TOC to low levels.

These four processes (MBRs, advanced oxidation, GAC adsorption, and RO) are the main approaches to treat the emerging contaminants and produce a highly treated water that is suitable for well injection into Zone II areas.

Conceptual design of two treatment systems utilizing combinations of these flow processes were completed for costing and feasibility evaluations as identified below.

1. Treatment Type B including the following components:
    - Wastewater pretreatment for screenings and grit removal.
    - Membrane biological reactors (MBR) treatment configured in a Bardenpho configuration for organic carbon, nitrogen, and phosphorus removals.
    - Granular activated carbon adsorption (GAC) for final TOC removal.
    - Final disinfection.
2. Treatment Type C including the following components:
    - Wastewater pretreatment for screenings and grit removal.
    - Membrane biological reactors (MBR) treatment configured in a Bardenpho configuration for organic carbon, nitrogen, and phosphorus removals.
    - Reverse osmosis treatment of a portion of the flow to produce purified “product water” of approximately 67% of the total flow. This process also produces a reject water stream where all the organic carbon and inorganics are concentrated at approximately 22% of the flow.
    - Advanced oxidation of the reverse osmosis reject water to break apart the refractory organic carbon compounds that were not removed by the MBR and were concentrated in the reject water stream by reverse osmosis. Once the refractory carbon compounds are broken into

biodegradable compounds, the reject water is returned to the MBR for further biological treatment.

- GAC adsorption for approximately 33% of the total flow to produce a Type B product water. This Type B "bleed" stream is needed to avoid concentration of inorganic solids such as salts that would affect the biological process in the MBR.
- Combination of the Type B and reverse osmosis product waters for disinfection, reconditioning, and recharge.
- Possible segregation of the Type B and reverse osmosis product waters for separate infiltration: well infiltration for the reverse osmosis product water, and conventional sand bed or subsurface infiltration for the Type B product water.

Flow schematics of these two treatment types are illustrated on Figure 4-9 with the schematic for Treatment Type A.

Treatment performance of the treatment types is summarized below.

Table 4-6: Expected Treatment Performance from Alternative Treatment Types

Treatment Type	Total Nitrogen (mg/L)	Total Organic Carbon (mg/L)
Type A: SBR followed by Denitrification Filters	3	10 to 20
Type B: MBR followed by GAC Adsorption	2	<3
Type C: MBR followed by Reverse Osmosis and GAC Adsorption	1	<1

It is noted that the water purification industry is changing with the introduction and proven performance of new membrane types. Reverse osmosis membranes have been used for years for water purification and disinfection. Microfiltration and ultra-filtration membranes are two newer types that are used in MBRs. Nano-filtration membranes are also a newer type of membrane technology that is closer to reverse osmosis. The following table summarizes pore sizes of these membranes.

Table 4-7: Membrane Pore Sizes

Membrane Type	Typical Pore Size (micron)
Microfiltration	1.0
Ultrafiltration	0.05
Nanofiltration	0.005
Reverse Osmosis	<0.001

Selection of the membrane types for MBR and final polishing processes should remain flexible and would change over time as new membranes enter the market place. The membrane canisters should be selected during design with a perspective on future flexibility.

The layout for both the Type B and Type C treatment types would be similar. Membrane units (for the MBR process as well as final polishing membranes or reverse osmosis) and GAC adsorption units would be enclosed in a building. Figure 4-10 illustrates a layout for the Type B and C treatment systems.

Costs for these two treatment and recharge scenarios are summarized on Tables 1 and 2.

Table 1
Summary of Cost Comparison for
MBR and GAC Treatment, and Wellinjection Recharge at Rt 151 Corridor

	Scenario 3B (MMR[4] Site)	
Cost Component	Expanded High Priority Nitrogen Mitigation Area (5)	Addl. Costs for Upper Watershed Areas
Capital Costs		
Collection System	*$210,000,000*	*$115,000,000*
Collection and Minor PS & FM	$170,000,000	$110,000,000
Major PS and FM	$42,000,000	$4,800,000
Treatment Site and Systems	*$51,000,000*	*$16,000,000*
Site Development	$8,900,000	$3,000,000
WW Treatment Systems	$38,000,000	$13,000,000
Sludge Management System	$3,600,000	$250,000
Recharge System	*$8,000,000*	*$1,500,000*
Pump Station and Injection Well System	$2,900,000	$910,000
Treated Water Force Main to Injection Wells	$4,600,000	$540,000
Backup 0.5 mgd Infiltaration Bed System at MMR or FCC Site & FM	$530,000	$0
Total Construction Costs	**$269,000,000**	**$133,000,000**
Contingency (25%)	$67,000,000	$33,000,000
Fiscal, Legal and Engineering (25%)	$67,000,000	$33,000,000
Total Capital Costs	**$400,000,000**	**$200,000,000**

	Scenario 3B (MMR[4] Site)	
Cost Component	Expanded High Priority Nitrogen Mitigation Area (5)	Addl. Costs for Upper Watershed Areas
O&M Costs		
Electrical Costs		
Collection System Lift Stations	$210,000	$100,000
Treatment Site	$310,000	$160,000
WWTF operations & repairs	$2,700,000	$1,200,000
Collection system operations & repairs	$1,500,000	$560,000
Sludge Disposal	$300,000	$160,000
Treated Water Recharge System	$130,000	$34,000
Marine Water Quality Monitoring Allowance	$100,000	$100,000
Total O&M Costs per year	$5,300,000	$2,300,000
Discount Rate of 5% (P/A for 5% and 20 yr = 12.4622)		
Present Worth of O&M Costs	**$66,000,000**	**$29,000,000**
Total Present Worth Costs	**$470,000,000**	**$230,000,000**

Notes:

1. All costs are rounded to two significant digits except total construction costs which are rounded to three to reduce rounding error
2. All cost are referenced to July 2009 costs
3. Costs do not include potential costs for property purchase or easements
4. Massachusetts Military Reservation
5. This area is the original A-F area that extended to Inner Harbor and the Mashpee border

Table 2
Summary of Cost Comparison for
MBR, RO and GAC Treatment, and Well Injection Recharge at Rt 151 Corridor

	Scenario 3C (MMR[4] Site)	
Cost Component	Expanded High Priority Nitrogen Mitigation Area (5)	Addl. Costs for Upper Watershed Areas
Capital Costs		
Collection System	*$210,000,000*	*$111,000,000*
Collection and Minor PS & FM	$170,000,000	$107,000,000
Major PS and FM	$37,000,000	$4,800,000
Treatment Site and Systems	*$54,000,000*	*$17,000,000*
Site Development	$8,900,000	$3,100,000
WW Treatment Systems	$41,000,000	$13,000,000
Sludge Management System	$3,600,000	$600,000
Recharge System	*$8,000,000*	*$1,500,000*
Pump Station and Injection Well System	$2,900,000	$910,000
Treated Water Force Main to Injection Wells	$4,600,000	$540,000
Backup 0.5 mgd Infiltaration Bed System at FCC or MMR Site & FM	$530,000	$0
Total Construction Costs	**$272,000,000**	**$131,000,000**
Contingency (25%)	$68,000,000	$33,000,000
Fiscal, Legal and Engineering (25%)	$68,000,000	$33,000,000
Total Capital Costs	**$410,000,000**	**$200,000,000**

	Scenario 3C (MMR[4] Site)	
Cost Component	Expanded High Priority Nitrogen Mitigation Area (5)	Addl. Costs for Upper Watershed Areas
O&M Costs		
Electrical Costs		
Collection System Lift Stations	$210,000	$100,000
Treatment Site	$1,600,000	$900,000
WWTF operations & repairs	$2,500,000	$1,200,000
Collection system operations & repairs	$1,500,000	$620,000
Sludge Disposal	$300,000	$160,000
Treated Water Recharge System	$130,000	$36,000
Marine Water Quality Monitoring Allowance	$100,000	$100,000
Total O&M Costs per year	$6,300,000	$3,100,000
Discount Rate of 5% (P/A for 5% and 20 yr = 12.4622)		
Present Worth of O&M Costs	**$79,000,000**	**$39,000,000**
Total Present Worth Costs	**$490,000,000**	**$240,000,000**

General Notes:

1. All costs are rounded to two significant digits except total construction costs which are rounded to three to reduce rounding error
2. All cost are referenced to July 2009 costs
3. Costs do not include potential costs for property purchase or easements
4. Massachusetts Military Reservation
5. This area is the original A-F area that extended to Inner Harbor and the Mashpee border