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ENGINEERING ASSISTANCE IN UPDATING INFORMATION ON WATER SUPPLY AND REUSE SYSTEM COMPONENT COSTS

REVISED MAY 28, 2008

ST. JOHNS RIVER WATER MANAGEMENT DISTRICT

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Engineering Assistance in Updating Information on Water Supply and Reuse System Component Costs

District Project No. SK30712
Black & Veatch Project No. 146255.0100

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Executive Summary

The St. Johns River Water Management District (District) is required by Florida law to periodically update the District Water Supply Plan (DWSP). In order to facilitate the revisions to the DWSP, the District has directed the creation of a Conceptual Planning Level Costing Tool for approximate construction and operation and maintenance costs. The tool includes the water supply projects presented herein.

The Conceptual Planning Level Costing Tool consists of specific components within the water supply infrastructure and treatment process systems. Different water quality sources are used for costing the presented water treatment processes. Each component or system has a construction opinion of probable cost, and annual operation and maintenance cost. This report summarizes the data used in developing the Conceptual Planning Level Costing Tool. The results for each component and each water system are displayed in tables and graphs. These costs exclude land acquisition, permitting, taxes or engineering costs.

The cost of specific components within the water supply infrastructure (Part 1) listed herein is from the first quarter of 2007. The cost of water systems (Part 2) listed herein is from the third quarter of 2007.

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Acronyms and Abbreviations

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$/lin ft	dollar per linear foot
AASHTO	Association of State Highway and Transportation Officials
Actiflo	high-rate ballasted sand flocculation, process name by Siemens
ADF	average daily flow
AFD	adjustable frequency drive
ASR	aquifer storage recovery
AWWA	American Water Works Association
AWWARF	American Water Works Research Foundation
B&V	Black & Veatch Corporation
bls	below land surface
BOD	biochemical oxygen demand
BW-RO	brackish water reverse osmosis
C	Celsius
$CaCO_3$	calcium carbonate
CIP	clean in place
CPVC	chlorinated polyvinyl chloride
DBPP	disinfection by-product precursor
DI	ductile iron pipe
dia	diameter
DOC	dissolved organic carbon
DWSP	District Water Supply Plan
ED/EDR	Electrodialysis/Electrodialysis Reversal
EPA	U.S. Environmental Protection Agency
EPDM	ethylene propylene diene monomer, a type of rubber
EBCT	empty bed contact time
F	Fahrenheit
FAC	Florida Administrative Code
FDEP	Florida Department of Environmental Protection
FRP	fiberglass reinforced plastic
ft	foot
ft/s, fps	foot per second (velocity)
GAC	granular activated carbon
gal	gallon
gfd	gallons per square feet per day
gph	gallons per hour
gpm	gallons per minute
gpm/sf	gallons per minute per square foot
GOX	gaseous oxygen
HDD	horizontal directional drilling
HDPE	high density polyethylene
HDPE DR 11	high density polyethylene pipe with a dimension ratio of 11

hrs/day	hours per day
I&C	instrumentation and controls
IMS	integrated media support
kWh	kilowatt-hour
lb	pound
lb/d, ppd	pounds per day
LOX	liquid oxygen
LPHO	low pressure high output
max	maximum
MCL	maximum contaminant level
MDF	maximum daily flow
MDPC	maximum daily production capacity
MF	microfiltration
mg/mg	milligrams per milligram
Mgal	million gallons
mgd	million gallons per day
mg/L	milligrams per liter
MIT	mechanical integrate testing
mm	millimeter
MP	medium pressure
NA	not applicable
NF	nanofiltration
nm	nanometer
NPSH	net positive suction head
NTU	nephelometric turbidity unit
O_3	ozone
O&M	operation and maintenance
OPC	opinion of probable cost
OSHA	Occupational Safety and Health Administration
PAC	powdered activated carbon
PLC	programmable logic controller
ppd	pounds per day
psi	pounds per square inch
Pt-Co	Platinum-Cobalt Scale, used for color values
PVC	polyvinyl chloride
RFP	reinforced fiberglass polymer
RIB(s)	rapid infiltration basin(s)
RO	reverse osmosis
ROW	right of way
S	sulfur
SCADA	supervisory control and data acquisition
S/m	Siemens per meter (SI units for conductivity)
SpC	specific conductance
SOC	synthetic organic chemicals
sq ft	square foot

SW-RO	seawater reverse osmosis
TDS	total dissolved solids
TOC	total organic carbon
UF	ultrafiltration
ug/L	micrograms per liter
UV	ultraviolet
UVA	UV adsorption
UVT	UV transmittance
WERF	Water Environment Research Foundation
WRF	Water Reuse Federation
WTP	water treatment plant

Glossary of Terms

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Bathymetric – A survey of the ocean floor to show floor depths, similar to a topography study on the ground.

Construction OPC – Construction Opinion of Probable Cost, based on the data gathered for this report, this is the total project cost to be used for planning level budgets.

Greenfield – Site or plot of land never used for construction before, no existing buildings or pipes.

General Requirements – The cost of construction that cannot be counted on bid tabs, the overall cost to the contractor and client for construction services.

Maximum Daily Production Capacity – The maximum amount of treated water that can be produced or transported by an individual process or complete facility.

Thermography – This is the use of an infrared camera to check the electrical components for overheating, it was used for the O&M costs of the pumps.

Unit Process Flow – The maximum amount of raw water that can be treated in an individual process.

Yard Piping – All piping connecting together the different processes of a water treatment plant; piping within the water treatment plant site.

Introduction

The St. Johns River Water Management District (District) has developed this Conceptual Planning Level Costing Tool to aid in the pricing of projects identified in the District Water Supply Plan (DWSP). The tool includes opinions of construction and operation and maintenance (O&M) costs of different water supply projects. A water supply project includes water source, treatment, storage, and transmission.

The Conceptual Planning Level Costing Tool is divided into two parts; Part 1 is for components within the water supply infrastructure and Part 2 is for water systems. The opinion of probable cost presented in the tool uses 2007 prices and is based on Black & Veatch (B&V) conceptual designs. It excludes land acquisition, permitting, taxes, engineering, and any other non-construction costs.

The conceptual designs were developed and based on specific capacity and/or water source. Part 1 uses Lake Monroe near Sanford as a surface water source and Orange County as a groundwater source. Part 2 uses Lake Monroe as a brackish surface water source, Ocklawaha River as a fresh water source, and ocean water for desalination. The District provided design information for brackish groundwater. Appendix A contains summaries of the water quality characteristics. Where water quality data were incomplete, the District's equation relating total dissolved solids (TDS) to chlorides was used for the respective sources.

The Conceptual Planning Level Costing Tool outlines the basic assumptions and the items included in each opinion of cost (OPC). More explicit explanation about what the OPC entails is included in links (herein called Backgrounds). A comprehensive list of all backgrounds is included in Appendix B.

The tool contains 27 components and 15 water systems. It was prepared according to B&V standards for practice/design, District input, and Florida common practice. B&V sought manufacturers' input; the names of manufactures who provided input are listed in Appendix C.

Methods

The Conceptual Planning Level Costing Tool contains 27 components and 15 water systems. The opinion of probable cost (OPC) for each component (Part 1) is divided into installed equipment, building (if required), construction, and maintenance costs. The OPC for each water system (Part 2) is shown as construction costs and annual operation and maintenance costs.

Each OPC corresponds to the maximum amount of treated water, labeled as "unit process flow" for the components (Part 1) and "maximum daily production capacity" for the systems (Part 2). The capacities used are 0.5, 2, 5, 10, 25, and 40 million gallons per day (mgd).

The tool provides costs at the planning level, with an expected accuracy of plus or minus 35 percent. The costs for components (Part 1) are in first quarter 2007 dollars and the costs for water systems (Part 2) are in third-quarter 2007 dollars. The OPC includes all equipment and installation costs. Labor costs are included as part of installation, but are not broken down into number of days or hours.

Each OPC is based on greenfield (undeveloped) sites. Permitting, land acquisition, demolition, or extenuating circumstances (e.g., limited space) are excluded from the OPC.

Part 1 used Lake Monroe as a surface water source, near Sanford, and Orange County as a groundwater source. Part 2 used water qualities of Lake Monroe (brackish surface water source), Ocklawaha River (fresh water source), brackish groundwater, and ocean water. The water qualities are in Appendix A.

The Installed Equipment Cost in each table for the components (Part 1) includes equipment, mechanical, sitework, concrete work, and installation. Building cost is displayed separately if required. Buildings are basic brick and block structures with no styling; the cost includes excavation, site work, piping, lighting, doors, windows, and accessories. The electrical and instrumentation and controls (I&C) cost, also listed separately in components, is defined in section 1.1.21 Electrical and Instrument & Control. The OPC is the sum of the installed equipment costs, the building cost (except for chemical feed), electrical and I&C costs, and General Requirements.

The OPC in each table for the water systems (Part 2) includes installed equipment, electrical and I&C, buildings (as required), and General Requirements.

B&V standard practice for General Requirements is 8 percent of the opinion of construction cost. General Requirements cover the supervision, temporary facilities, temporary utilities, rental equipment, and miscellaneous costs associated with construction.

A Construction Markup should be added to each component or water system OPC. The recommended amount of markup is stated in Section 1.1.22 Construction Markup.

Part 1 includes maintenance costs, which consist of equipment maintenance and spare parts. Operation costs, such as labor, fuel, and power, were not included in Part 1.

Part 2 includes operation and maintenance (O&M) costs which consist of the costs of power used to operate the equipment, labor, spare parts, and maintenance tests. Operator hours are in compliance with FDEP 62-699, Treatment Plant Classification and Staffing. The following labor rates and energy consumption costs were assumed (Part 2):

Plant Operator: $50/hour, includes benefits
Plant Operator with Membranes: $60/hour, includes benefits
Maintenance, for conventional plants: $30/hour, includes benefits
Maintenance, for membrane plants: $40/hour, includes benefits
Energy: $0.08/kWh
Pump efficiency: 80%
Motor efficiency: 95%

Operation and maintenance costs for the pumps include emergency power supply, semiannual vibration analysis, semiannual thermography of electrical components, semiannual lubricant analysis, water operations permit compliance, and replacement of impellers and bearings.

The chemical costs used for the annual O&M in Part 2 are listed in Table 1 below. Chemical costs were not included for Part 1.

Table 1 Chemical Costs.

Chemicals	Cost per Drum/Tote/Bag, $/lb	Cost for Bulk, $/lb
Ammonia, 19%	$0.16	$0.10
Antiscalant	$2.50	$2.00
Carbon Dioxide	$0.06	$0.042
Caustic, 50%	$0.17	$0.10
Corrosion Inhibitor	$1.15	$0.70
Ferric Sulfate, 43%	$0.14	$0.08
Hydrofluosilicic Acid, 24%	$0.35	$0.20
Hydrated Lime	$0.22 (50 lb bags)	$0.095
Methanol	$4.19 (300 lb tote)	$2.66
Quicklime	$0.09 (50 lb bags)	$0.055
Polymer (liquid)	$1.50	$0.60
Potassium Permanganate	$2.20	$1.50
Powdered Activated Carbon	$0.80	$0.45
Sodium Bisulfite, 38%	$0.25	$0.15
Sodium Hypochlorite, 12.5%	$0.15	$0.09
Sulfuric Acid, 93%	$0.08	$0.05

Different utilization factors were used in determining the operating costs for Part 2. The utilization factor used, according to District preferences, is indicated in Table 2.

Table 2 Utilization Factors for Part 2.

	0.67 Utilization Factor	0.95 Utilization Factor
2.1 Wellfields	X	
2.2 ASR	*Note (1)*	
2.3 Booster Pump Station	X	
2.4 Residuals Disinfection for Trans. Systems	X	
2.5 Groundwater Treatment Plant	X	
2.6 Brackish Groundwater Treatment Plant	X	
2.7 Conventional Surface Water Treatment Plant		X
2.8.1 Brackish Surface WTP Potable Water		X
2.8.2 Brackish Surface WTP Reuse	X	
2.9 Seawater Desalination, Co-Located		X
2.10 Seawater Desalination		X
2.11.1 and 2.11.2 Upgrade Wastewater Plant		X
2.12 Reclaimed Water Storage Pond	NA	
2.13 RIBs	NA	
2.14 Surface Water Intake	X	
2.15 Injection Well	X	

NOTE: (1) *For the ASR, a utilization factor of 0.20 was used. It was assumed that the ASR pumps would operate in recharge mode for the majority of the time.*

Part 1

COMPONENT COSTS

FEBRUARY 2008

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1.1 Construction and Maintenance Costs

The construction and maintenance costs for Part 1 are listed in sections 1.1.1 to 1.6. For more information about the assumptions used, see the Methods section.

1.1.1 Raw Water Pumping System

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Raw water pumping consists of two systems: groundwater pumping and surface water pumping. More information about the two pumping systems is included in Appendix B-1.1.1: Raw Water Pumping Background.

1.1.1.1 Groundwater Pumping System

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The groundwater pumping system consists of one vertical turbine pump that will be exposed to the elements (no pumphouse). Figure B-1.1.1.a in Appendix B-1.1.1, shows a typical groundwater pump setup. The costs include the following:

- Valving
- Vertical turbine pump and motor
- Totalizing flowmeter
- Equipment base
- Pipe supports
- Water pressure gauge
- Cone strainer
- Finishes (paint, corrosion protection)
- Fencing
- Earthwork and sitework
- Local electrical and I&C
- General Requirements

Pumping flows of 2, 3, 5, 6.5, and 10 mgd were considered. These costs do not include drilling. The costs assume one pump for each stated pumping capacity. The opinion of probable cost for a groundwater pumping system is presented in Table 1.1.1.1 and Figure 1.1.1.1. Maintenance costs include the equipment maintenance and spare parts for the pumps.

Table 1.1.1.1 Groundwater Raw Pumping—Construction OPC and Maintenance.

Pumping Capacity, mgd	Pumping Capacity, cfs	Installed Equipment Cost	Electrical and I&C	Construction OPC	Maintenance $/year
2	3.1	$66,000	$14,000	$86,000	$790
3	4.6	$90,000	$19,000	$118,000	$1,200
5	7.7	$161,000	$34,000	$211,000	$2,200
6.5	10.1	$187,000	$39,000	$245,000	$2,600
10	15.5	$244,000	$51,000	$319,000	$3,300

NOTES: (1) *General Requirements (8%) has been added to the Construction OPC, as explained in Methods.* ***(2)*** *It is recommended that a Construction Markup (Part 1.1.22) be added to all prices.*

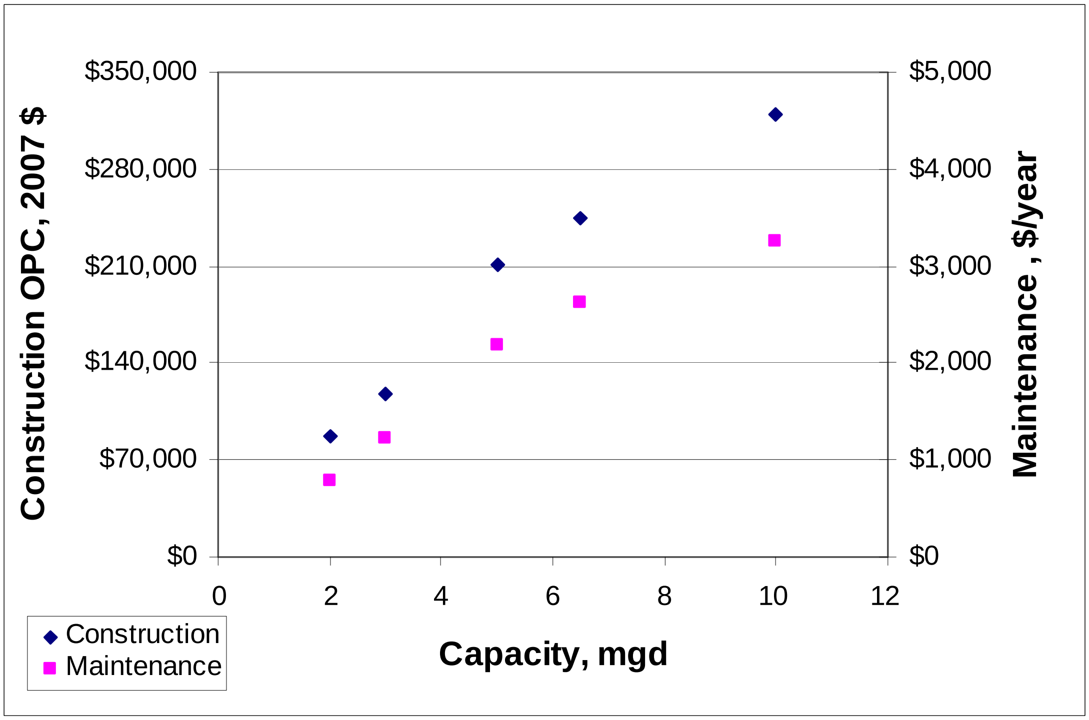

Figure 1.1.1.1 Groundwater Pumping—Construction OPC and Maintenance.

1.1.1.2 Surface Water Pumping System

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The surface water pumping system for the 2 and 5 mgd cases consists of a triplex installation with two permanent duty pumps and one standby pump. The system for the 10, 25, and 40 mgd is a quadruplex installation with three permanent duty pumps and one standby pump. Figure B-1.1.1.b and Figure B-1.1.1.c in Appendix B-1.1.1, show the two systems.

Surface water pumping costs include the following:

- Discharge riser/header piping
- Suction riser/header piping
- Valving
- Vertical turbine pumps and motors
- Fine intake screens
- Water pressure gauge
- Fencing
- Flowmeters
- Air backwash system
- Pump station building
- Local electrical and I&C
- General Requirements

The costs are shown in Table 1.1.1.2 and on Figure 1.1.1.2. The cost of the pump station building is included in the Installed Equipment Costs. The maintenance costs include the equipment maintenance and spare parts.

Table 1.1.1.2 Surface Water Pumping—Construction OPC and Maintenance.

Pumping Capacity mgd	Pumping Capacity cfs	Installed Equipment Cost	Electrical and I&C	Construction OPC	Maintenance $/year
2	3.1	$2,380,000	$500,000	$3,110,000	$4,600
5	7.7	$2,920,000	$613,000	$3,810,000	$8,100
10	15.5	$4,620,000	$971,000	$6,040,000	$14,800
25	38.7	$5,900,000	$1,240,000	$7,710,000	$16,500
40	61.9	$6,540,000	$1,370,000	$8,540,000	$19,100

NOTES:* *(1) *General Requirements (8%) has been added to the Construction OPC, as explained in Methods.* ***(2)*** *It is recommended that a Construction Markup (Part 1.1.22) be added to all prices.*

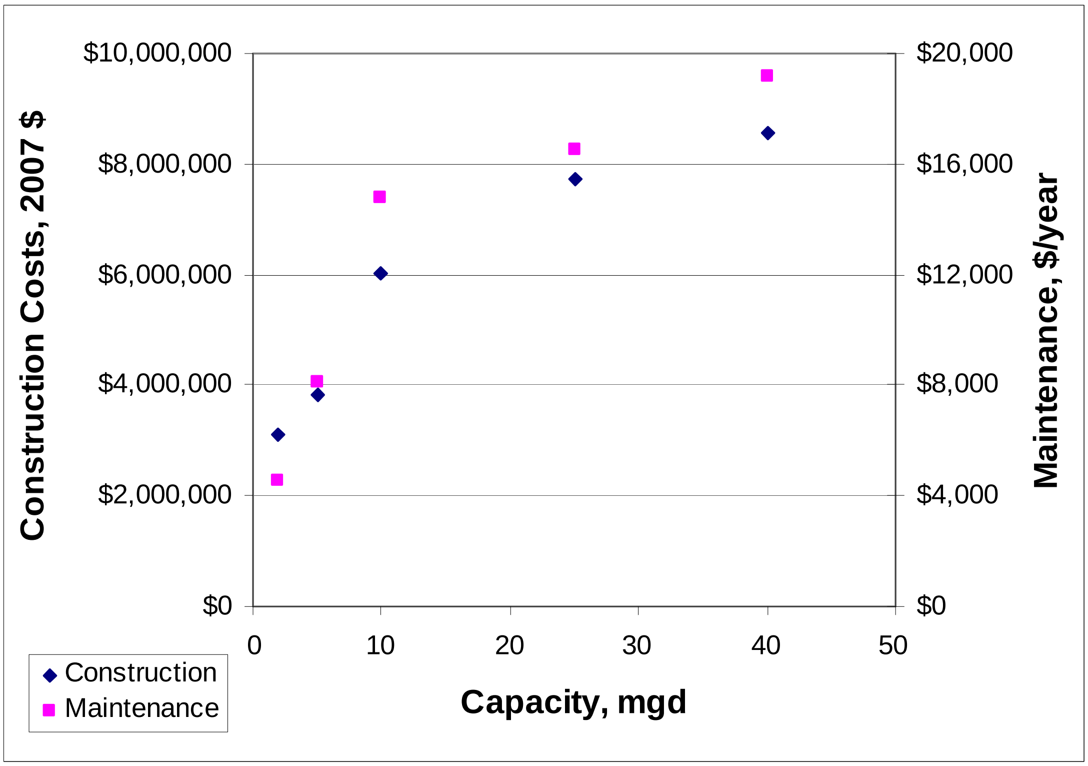

Figure 1.1.1.2 Surface Water Pumping—Construction OPC and Maintenance.

1.1.2 High-Rate Flocculation/Clarification

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The high-rate ballasted sand flocculation (Actiflo) process was used. Because of the corrosive nature of the water, stainless steel was used exclusively for all piping. Additional information on the high-rate flocculation/clarification process is presented in Appendix B-1.1.2: High-Rate Flocculation/Clarification Background.

The Actiflo system is proprietary and costs are based on quotes supplied by the system supplier, Kruger. The equipment costs include the following:

- Mixers
- Hydrocyclones
- Mechanical scraper
- Motors
- Solids pumps
- Startup services
- Concrete basin
- General Requirements

The system was designed to meet minimum redundancy requirements with multiple hydrocyclones and solids pumps, and includes two settling basins. A summary of the design and the probable cost of the process is listed in Table 1.1.2 and on Figure 1.1.2. The maintenance cost consists of equipment maintenance and spare parts.

Table 1.1.2 Actiflo—Construction OPC and Maintenance.

Unit Process Flow, mgd	Installed Equipment Cost	Concrete Basins	Electrical and I&C	Construction OPC	Maintenance $/year
0.5	$920,000	$2,000	$190,000	$1,200,000	$13,400
2	$1,000,000	$7,000	$210,000	$1,320,000	$15,200
5	$1,300,000	$160,000	$270,000	$1,870,000	$18,800
10	$1,700,000	$230,000	$360,000	$2,470,000	$24,000
25	$2,900,000	$390,000	$610,000	$4,210,000	$42,000
40	$4,100,000	$520,000	$860,000	$5,920,000	$60,000

NOTES:* *(1) *For the 0.5 and 2 mgd plants, a package Actiflo unit was considered.* ***(2)*** *General Requirements (8%) has been added to the Construction OPC, as explained in Methods.* ***(3)*** *It is recommended that a Construction Markup (Part 1.1.22) be added to all prices.*

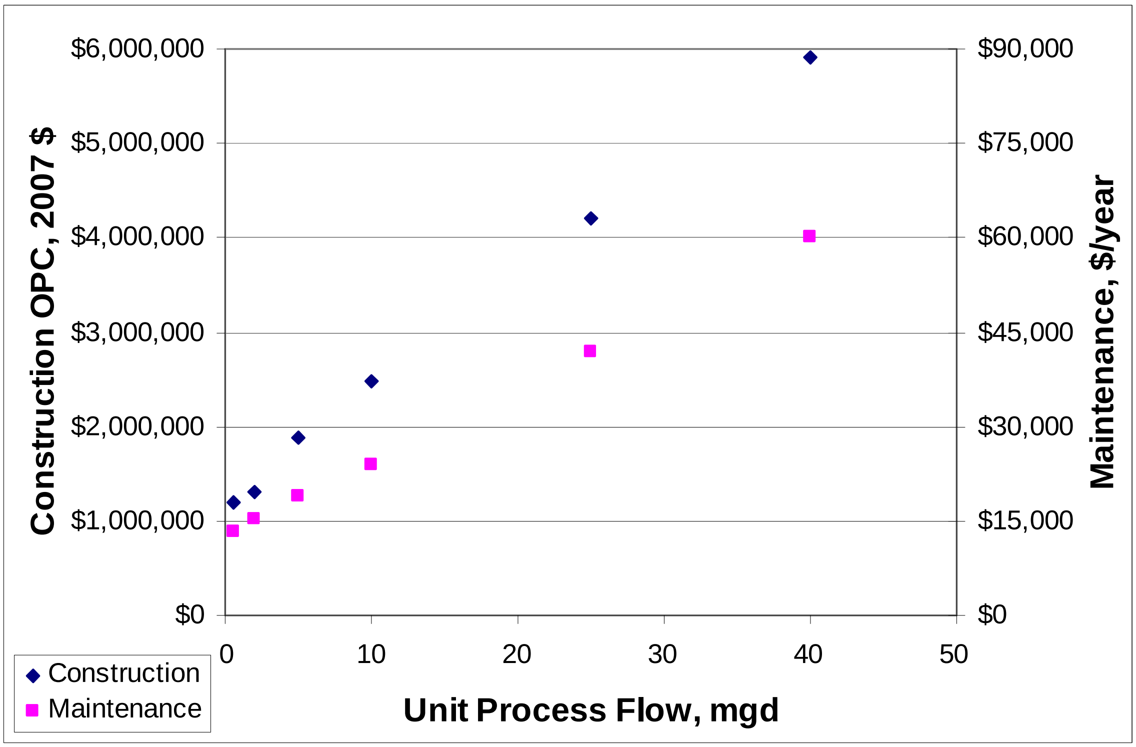

Figure 1.1.2 Actiflo—Construction OPC and Maintenance.

1.1.3 Chemical Feed and Storage

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Includes Part 1.1.10 Chlorine Disinfection System and Part 1.1.11Chloramines Disinfection System.

Based on the water quality information from Lake Monroe in Appendix A, the following chemical feed systems were considered for each plant size:

- Ammonia
- Antiscalant
- Caustic
- Ferric sulfate
- Hydrofluosilicic acid (fluoride)
- Coagulant polymer
- Powdered activated carbon (PAC)
- Sodium hypochlorite
- Sulfuric acid

Each chemical system is described in more detail, with typical arrangements, in Appendix B-1.1.3.a Chemical Feed System Background. Although the chemicals are the same for the various plant sizes, the system components and layouts vary slightly. Control of the chemical feeders is proportional to plant flow. Allowances were made to include a standby pump for each feed system. A complete list of assumptions and methods for determining sizing and equipment requirements for chemical feed systems is included in Appendix B-1.1.3.b Chemical Feed Basis and Assumptions Background.

For all processes (except for fluoride), the costs do not include day tanks. Chemical costs were not included in the OPC. The opinion of probable cost for each system includes the following:

- Storage tanks/totes
- Transfer pump (if required)
- Metering pump
- Air compressor (if required)
- Piping
- Valves
- Injector
- Scale (if required)
- Gas detectors (if required)
- Local electrical and I&C
- Yard piping from chemical storage to feed point
- General Requirements

Construction OPCs are listed on Tables 1.1.3.a-f., and include the installed equipment cost and the electrical and I&C; a chemical building cost is not included. Typical building costs for various chemical building sizes are presented in Table 1.1.3.g. The maintenance costs include replacement parts and do not include chemical costs or electric power consumption.

Table 1.1.3.a 0.5 mgd Chemical Feed—Construction OPC and Maintenance.

Chemical Feed System	Installed Equipment Cost	Electrical and I&C	Construction OPC	Maintenance $/yr
Ammonia	$54,000	$12,000	$70,000	$1,200
Antiscalant	$29,000	$6,000	$40,000	$700
Caustic	$130,000	$27,200	$169,000	$3,000
Ferric Sulfate	$89,000	$18,600	$116,000	$2,000
Hydrofluosilicic Acid	$29,000	$6,100	$38,000	$700
Polymer	$54,000	$11,400	$71,000	$1,300
PAC	$106,000	$22,200	$138,000	$2,400
Sodium Hypochlorite	$121,000	$25,400	$158,000	$2,800
Sulfuric Acid	$159,000	$33,400	$208,000	$3,600

***NOTES: (1)** It is recommended that a Construction Markup (Part 1.1.22) be added to all prices. **(2)** General Requirements (8%) has been added to the Construction OPC, as explained in* Methods.

Table 1.1.3.b 2 mgd Chemical Feed—Construction OPC and Maintenance.

Chemical Feed System	Installed Equipment Cost	Electrical and I&C	Construction OPC	Maintenance $/yr
Ammonia	$55,000	$11,000	$71,000	$1,100
Antiscalant	$29,000	$6,200	$38,000	$600
Caustic	$213,000	$45,000	$280,000	$4,300
Ferric Sulfate	$140,000	$29,000	$180,000	$2,800
Hydrofluosilicic Acid	$41,000	$8,500	$53,000	$900
Polymer	$56,000	$12,000	$73,000	$1,200
PAC	$477,000	$100,000	$630,000	$9,600
Sodium Hypochlorite	$156,000	$33,000	$204,000	$3,200
Sulfuric Acid	$219,000	$46,000	$290,000	$4,400

***NOTES: (1)** It is recommended that a Construction Markup (Part 1.1.22) be added to all prices. **(2)** General Requirements (8%) has been added to the Construction OPC, as explained in* Methods.

Table 1.1.3.c 5 mgd Chemical Feed—Construction OPC and Maintenance.

Chemical Feed System	Installed Equipment Cost	Electrical and I&C	Construction OPC	Maintenance $/yr
Ammonia	$56,000	$12,000	$73,000	$1,200
Antiscalant	$31,000	$6,400	$40,000	$700
Caustic	$270,000	$56,000	$350,000	$5,400
Ferric Sulfate	$220,000	$46,000	$280,000	$4,400
Hydrofluosilicic Acid	$41,000	$8,700	$54,000	$900
Polymer	$58,000	$12,000	$76,000	$1,200
PAC	$480,000	$100,000	$630,000	$9,600
Sodium Hypochlorite	$170,000	$36,000	$220,000	$3,400
Sulfuric Acid	$220,000	$46,000	$290,000	$4,400

NOTES: (1) *It is recommended that a* Construction Markup *(Part 1.1.22) be added to all prices.* ***(2)*** *General Requirements (8%) has been added to the Construction OPC, as explained in* Methods.

Table 1.1.3.d 10 mgd Chemical Feed—Construction OPC and Maintenance.

Chemical Feed System	Installed Equipment Cost	Electrical and I&C	Construction OPC	Maintenance $/yr
Ammonia	$110,000	$24,000	$150,000	$2,100
Antiscalant	$32,000	$6,800	$42,000	$600
Caustic	$501,000	$105,000	$650,000	$9,100
Ferric Sulfate	$370,000	$77,000	$480,000	$6,700
Hydrofluosilicic Acid	$63,000	$13,000	$83,000	$1,200
Polymer	$62,000	$13,000	$81,000	$1,200
PAC	$560,000	$120,000	$730,000	$10,100
Sodium Hypochlorite	$198,000	$42,000	$260,000	$3,600
Sulfuric Acid	$251,000	$53,000	$330,000	$4,600

NOTES: (1) *It is recommended that a* Construction Markup *(Part 1.1.22) be added to all prices.* ***(2)*** *General Requirements (8%) has been added to the Construction OPC, as explained in* Methods.

Table 1.1.3.e 25 mgd Chemical Feed—Construction OPC and Maintenance.

Chemical Feed System	Installed Equipment Cost	Electrical and I&C	Construction OPC	Maintenance $/yr
Ammonia	$150,000	$31,000	$195,000	$2,400
Antiscalant	$35,000	$7,400	$46,000	$600
Caustic	$906,000	$190,000	$1,180,000	$14,500
Ferric Sulfate	$880,000	$190,000	$1,150,000	$14,100
Hydrofluosilicic Acid	$84,000	$18,000	$110,000	$1,400
Polymer	$71,000	$15,000	$93,000	$1,200
PAC	$1,180,000	$250,000	$1,540,000	$19,000
Sodium Hypochlorite	$230,000	$49,000	$310,000	$3,800
Sulfuric Acid	$350,000	$74,000	$460,000	$5,700

***NOTES: (1)** It is recommended that a Construction Markup (Part 1.1.22) be added to all prices. **(2)** General Requirements (8%) has been added to the Construction OPC, as explained in* Methods.

Table 1.1.3.f 40 mgd Chemical Feed—Construction OPC and Maintenance.

Chemical Feed System	Installed Equipment Cost	Electrical and I&C	Construction OPC	Maintenance $/yr
Ammonia	$150,000	$32,000	$201,000	$2,400
Antiscalant	$57,000	$12,000	$74,000	$900
Caustic	$1,350,000	$280,000	$1,760,000	$20,300
Ferric Sulfate	$1,290,000	$270,000	$1,680,000	$19,4000
Hydrofluosilicic Acid	$88,000	$19,000	$116,000	$1,400
Polymer	$78,000	$16,000	$101,000	$1,200
PAC	$1,970,000	$415,000	$2,580,000	$29,700
Sodium Hypochlorite	$300,000	$63,000	$390,000	$4,500
Sulfuric Acid	$480,000	$100,000	$620,000	$7,200

***NOTES: (1)** It is recommended that a Construction Markup (Part 1.1.22) be added to all prices. **(2)** General Requirements (8%) has been added to the Construction OPC, as explained in* Methods.

Table 1.1.3.g Construction OPC for Typical Chemical Buildings.

Length, ft	Width, ft	Height, ft	Construction OPC
20	20	20	$170,000
40	20	20	$288,000
60	30	20	$504,000
80	50	20	$760,000
100	60	30	$1,200,000
120	80	30	$1,770,000
150	100	30	$2,400,000

NOTES: (1) *It is recommended that a* Construction Markup *(Part 1.1.22) be added to all prices.* ***(2)*** *General Requirements (8%) has been added to the Construction OPC, as explained in* Methods.

1.1.4 Deep Bed Filters

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The deep bed filters are equipped with dual media consisting of anthracite and sand. The filter loading rate was assumed to be 6 gpm/sf. Filter design information is presented in Appendix B-1.1.4: Deep Bed Filters Background. The probable costs of the filters include the following:

- Concrete basins
- Troughs
- Backwash pumps
- Integrated media support cap underdrain
- Surface wash equipment
- Backwash air compressor and header
- Local electrical and I&C
- Filter building
- General Requirements

The maintenance cost consists of maintenance for pumps, equipment maintenance, and spare parts. A summary of the probable cost is listed in Table 1.1.4 and on Figure 1.1.4.

Table 1.1.4 Deep Bed Filter—Construction OPC and Maintenance.

Unit Process Flow, mgd	Installed Equipment Cost	Electrical and I&C	Construction OPC	Maintenance $/year
0.5	$650,000	$136,000	$849,000	$2,100
2	$1,140,000	$238,000	$1,480,000	$2,800
5	$2,280,000	$478,000	$2,980,000	$6,900
10	$3,780,000	$793,000	$4,940,000	$8,300
25	$6,790,000	$1,430,000	$8,870,000	$11,600
40	$9,400,000	$1,970,000	$12,280,000	$15,200

NOTES: (1) *General Requirements (8%) has been added to the Construction OPC, as explained in Methods.* ***(2)*** *It is recommended that a Construction Markup (Part 1.1.22) be added to all prices.*

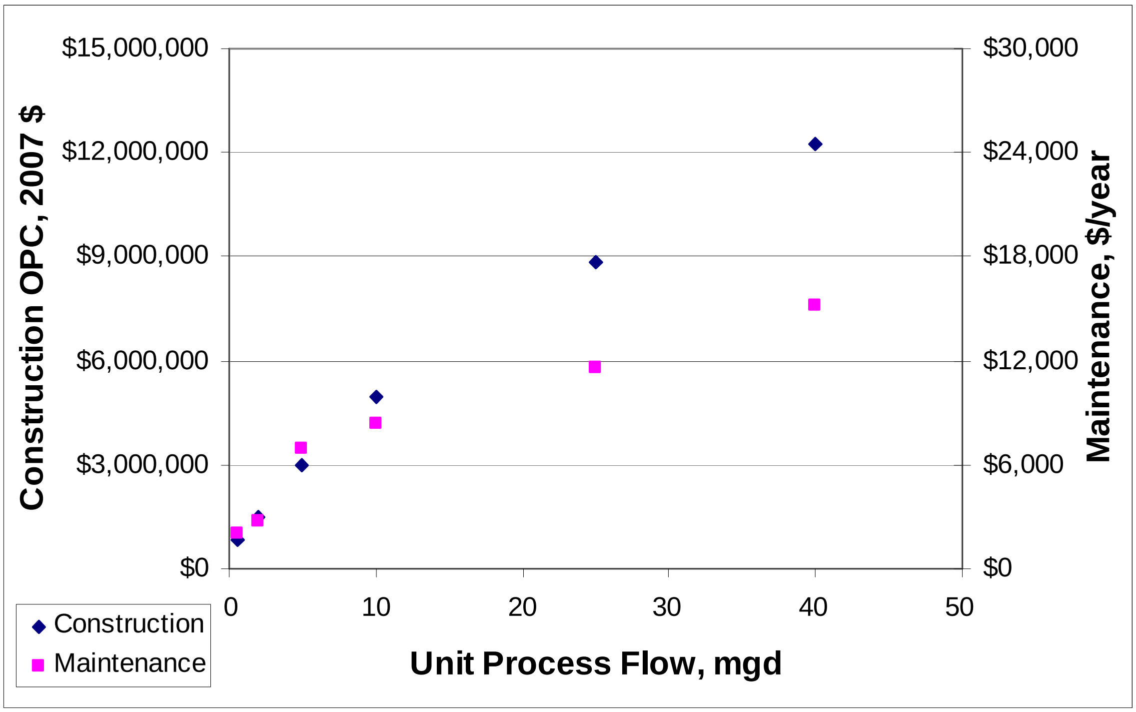

Figure 1.1.4 Deep Bed Filter—Construction OPC and Maintenance.

1.1.5 Lime Softening System

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The lime softening system is considered to be storage and feed facilities. It is not included in the Part 1.3 Chemical Feed and Storage because it would be used only when it is desired to reduce calcium and magnesium hardness. Groundwater information from Orange County, Florida, was the basis of design. The mixing basins were sized to treat 100 percent of the flow. Additional information about lime softening, including figures representing chemical schematics, is presented in Appendix B-1.1.5: Lime Softening Background.

The opinion of probable cost includes the following:

- Lime silos (5, 10, 25, 40 mgd)
- Lime hopper (0.5, 2 mgd)
- Volumetric screw feeder
- Lime slurry tank (0.5, 2 mgd)
- Piping and hose
- Pumps
- Valves
- Mixers
- Air compressor
- Lime building (0.5, 2 mgd)
- Lime slaker (5, 10, 25, 40 mgd)
- Steel basins
- Local electrical and I&C equipment
- General Requirements

The 0.5 and 2 mgd plants both use hydrated lime; larger plants will use quicklime. Maintenance consists of equipment maintenance costs. Costs do not include operation, labor or chemicals.

Table 1.1.5 Lime Softening System—Construction OPC and Maintenance.

Unit Process Flow, mgd	Installed Equipment Costs	Steel Basin	Electrical and I&C	Construction OPC[1]	Maintenance $/yr
0.5	$97,000	$393,000	$20,000	$760,000	$3,000
2	$220,000	$684,000	$47,000	$1,260,000	$4,400
5	$470,000	$1,120,000	$98,000	$1,820,000	$7,100
10	$504,000	$2,520,000	$106,000	$3,380,000	$7,600
25	$580,000	$3,640,000	$122,000	$4,690,000	$8,700
40	$1,060,000	$4,910,000	$223,000	$6,700,000	$16,000

NOTES:* (1)** *A lime feed building is required for the 0.5 mgd and the 2 mgd flows. The building costs $191,000 and $217,000, respectively. For other flows the space under the lime silo is utilized.* ***(2) *General Requirements (8%) has been added to the Construction OPC, as explained in Methods.* ***(3)*** *It is recommended that a Construction Markup (Part 1.1.22) be added to all prices.*

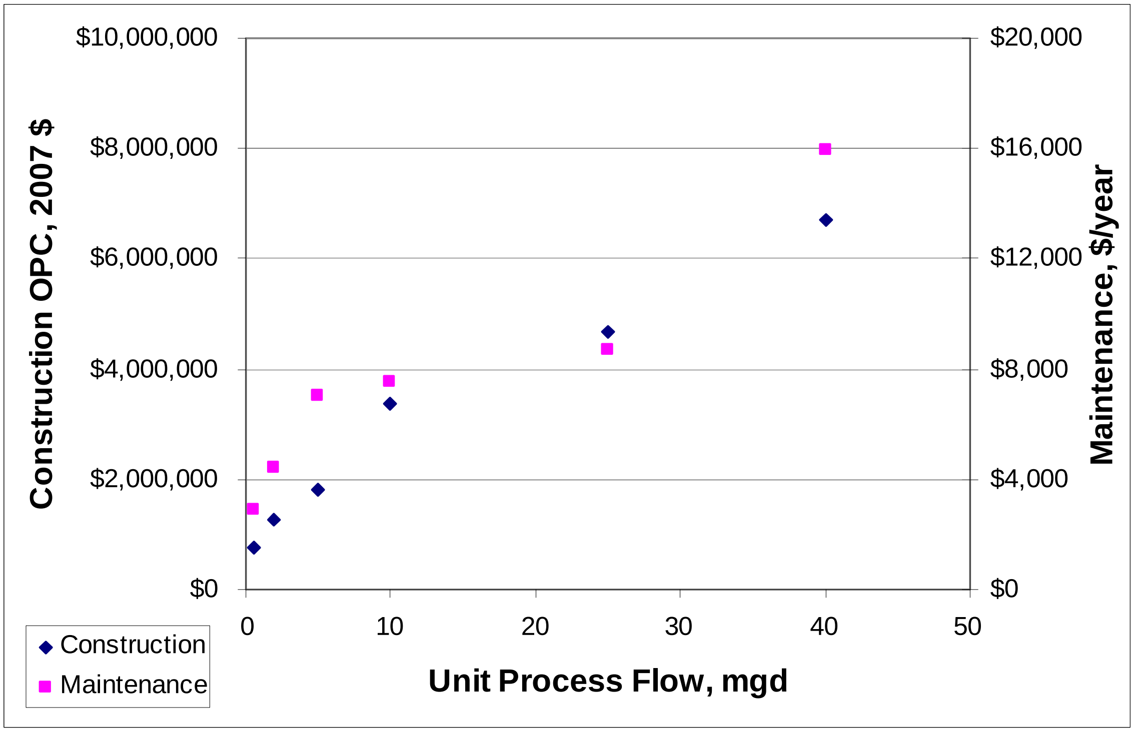

Figure 1.1.5 Lime Softening System—Construction OPC and Maintenance.

1.1.6 Residuals Handling

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Residuals handling consists of sludge holding, thickening, or dewatering typically provided at a water treatment plant. More information, including a table summarizing the method of residuals handling provided for each size of plant, is included in the Appendix B-1.1.6: Residuals Handling Background.

The costs include the following:

- Gravity thickeners
- Paved drying beds (where applicable)
- Belt filter press (where applicable)
- Centrifuge (where applicable)
- Polymer
- Building costs (if applicable)
- Local electrical and I&C
- General Requirements

The construction OPC is presented in Table 1.1.6 and on Figure 1.1.6. The maintenance is for equipment. Maintenance does not include polymer chemical costs or labor.

Table 1.1.6 Residuals Handling—Construction OPC and Maintenance.

Unit Process Flow, mgd	Installed Equipment Costs	Electrical and I&C	Construction OPC	Maintenance $/year
0.5	$540,000	$81,000	$670,000	$7,800
2	$2,650,000	$400,000	$3,290,000	$36,900
5	$4,310,000	$650,000	$5,350,000	$41,300
10	$6,840,000	$1,030,000	$8,490,000	$61,900
25	$8,970,000	$1,350,000	$11,140,000	$83,200
40	$11,580,000	$1,740,000	$14,380,000	$107,900

NOTES: (1) *Dewatering consists of paved drying beds for 0.5 and 2 mgd flows. Gravity thickeners were used for all but the 0.5 mgd flow. A belt filter press was used for the 5 mgd flow and centrifuges for the 10, 25, and 50 mgd flows.* ***(2)*** *General Requirements (8%) has been added to the Construction OPC, as explained in Methods.* ***(3)*** *It is recommended that a Construction Markup (Part 1.1.22) be added to all prices.*

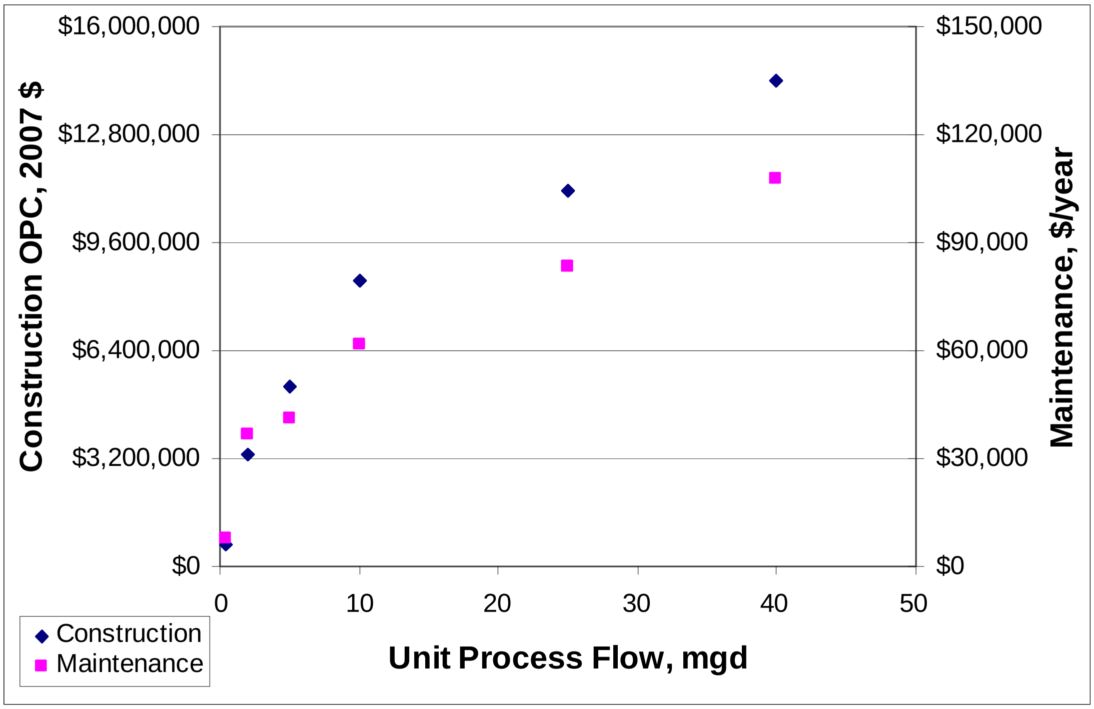

Figure 1.1.6 Residuals Handling—Construction OPC and Maintenance.

1.1.7 Membrane Feed and Pumping

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Membrane costs shown in parts 1.1.8 Membrane Softening, Seawater Reverse Osmosis, Brackish Water Reverse Osmosis, and Microfiltration/Ultrafiltration include all feed and pumping equipment required.

1.1.8 Membrane Treatment System

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The following membrane technologies are included in this tool:

- Nanofiltration (NF) for membrane softening and low TDS applications.
- Seawater reverse osmosis (SW-RO) for desalination of seawater.
- Brackish water reverse osmosis (BW-RO) for desalination of low TDS concentration brackish waters.
- Microfiltration and ultrafiltration (MF/UF) for surface water treatment or pretreatment for RO.

Background information and more information on the design of the membrane systems is presented in Appendix B-1.1.8: Membrane Treatment Systems Background.

For each membrane system construction cost, the scope is the following:

- Installed membrane process equipment with membrane elements and vessels.
- Directly associated pumps and motors.
- Local programmable logic controller (PLC).
- Chemical clean-in-place (CIP) equipment (not related Part 1.1.3 Chemical Feed and Storage).
- Membrane cleaning system (Part 1.1.8.5).
- Feedwater cartridge filters (prescreening for MF/UF).
- Building.
- Local electrical and I&C.
- General Requirements.

The following items are not included in this portion of the cost:

- Pretreatment or post-treatment.
- Other items included elsewhere in the report (such as chemical feed systems or yard piping).

Maintenance costs for the membrane system cover membrane replacement and routine maintenance. Ongoing operating chemicals, such as pretreatment acid and antiscalant, are not included, but are listed in Part 1.1.3, Chemical Feed and Storage. Labor and electricity are not included.

1.1.8.1 Cartridge Filters

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Cartridge filters are included in the probable costs of the membrane system. The NF and RO membranes have a cartridge filter rated at 5 microns. Cartridge filters were not used for the MF/UF membrane.

1.1.8.2 Membrane Skids

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Back to Membrane Treatment System (1.1.8)

The probable cost shown for membrane systems includes the cost of skids. The different skid set-ups are described as follows:

- NF and RO: a dedicated feed pump for each treatment train followed by a rack of horizontally mounted pressure vessels.
- MF/UF: feed pumps (for an encased system) or filtrate pumps (for a submerged system) arranged on common headers; flow to (or from) each train is automatically controlled with valves.
    - Encased membrane system: elements mounted in pressure vessels which in turn are mounted on a rack.
    - Submerged membrane system: elements mounted in basins.
    - Encased and submerged systems have different hydraulic profiles, but experience indicates that, for budgetary purposes, their costs are identical.

1.1.8.3 Membrane Softening (Nanofiltration)

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Back to Membrane Treatment System (1.1.8)

NF probable costs are listed in Table 1.1.8.3 and on Figure 1.1.8.3. The Membrane Treatment System, Part 1.1.8, details what the costs include. Figures for the different layouts are included in Appendix B-1.1.8: Membrane Treatment Systems Background. These costs assume a source water with a TDS concentration of 1500 milligrams per liter (mg/L) and the same assumptions are used for the BW-RO. The difference between the NF and the BW-RO is the installed and operating pressure, highlighted in the maintenance costs. The assumed recovery was 85 percent and the bypass was 15 percent.

Table 1.1.8.3 Membrane Softening (Nanofiltration)—Construction OPC and Maintenance.

Unit Process Flow, mgd	Installed Equipment Cost	Building Cost	Electrical and I&C	Construction OPC	Maintenance $/year
0.5	$1,010,000	$395,000	$296,000	$1,840,000	$47,000
2	$3,040,000	$567,000	$758,000	$4,720,000	$146,000
5	$6,250,000	$868,000	$1,495,000	$9,310,000	$305,000
10	$10,650,000	$1,300,000	$2,510,000	$15,610,000	$570,000
25	$21,130,000	$3,570,000	$5,190,000	$32,270,000	$1,380,000
40	$29,910,000	$6,830,000	$7,720,000	$48,010,000	$2,250,000

***NOTES: (1)** General Requirements (8%) has been added to the Construction OPC, as explained in Methods. **(2)** It is recommended that a Construction Markup (Part 1.1.22) be added to all prices.*

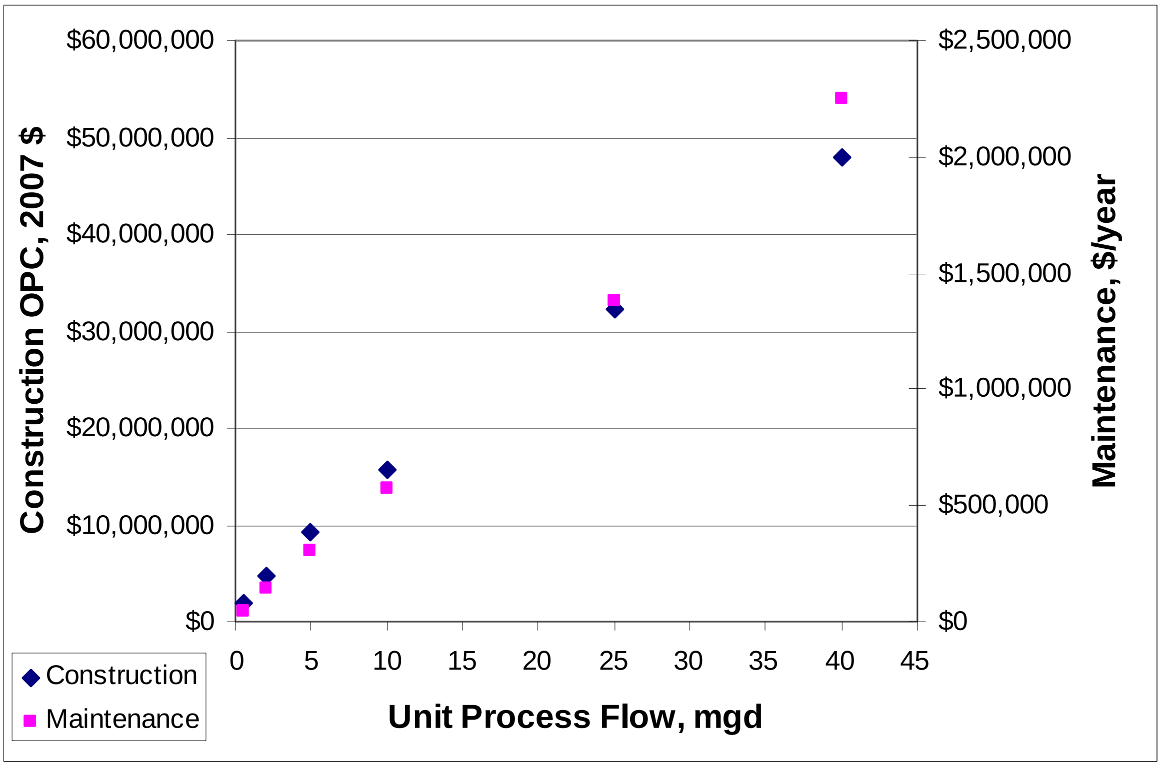

Figure 1.1.8.3 Membrane Softening (Nanofiltration) —Construction OPC and Maintenance.

1.1.8.4.1 Seawater Reverse Osmosis Membranes

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Back to Membrane Treatment System (1.1.8)

The opinion of probable cost of the SW-RO membranes is presented in Table 1.1.8.4.1 and on Figure 1.1.8.4.1. The Membrane Treatment System, Part 1.1.8, details what the costs include. Figures of the different layouts are presented in Appendix B-1.1.8: Membrane Treatment Systems Background. A recovery of 45 percent and a bypass of zero percent was assumed.

Water quality information is provided in Appendix A. It was assumed that the raw water had a TDS of 32,000 mg/L and a finished water TDS of 400 mg/L.

Table 1.1.8.4.1 Seawater RO Membrane—Construction OPC and Maintenance.

Unit Process Flow, mgd	Installed Equipment Cost	Building Cost	Electrical and I&C	Construction OPC	Maintenance $/year
0.5	$3,890,000	$395,000	$899,000	$5,600,000	$78,000
2	$11,300,000	$567,000	$2,500,000	$15,600,000	$236,000
5	$23,000,000	$868,000	$5,010,000	$31,200,000	$488,000
10	$38,900,000	$1,300,000	$8,440,000	$52,500,000	$895,000
25	$77,400,000	$3,570,000	$17,000,000	$106,000,000	$2,090,000
40	$110,000,000	$6,830,000	$24,500,000	$153,000,000	$3,310,000

NOTES: (1) *General Requirements (8%) has been added to the Construction OPC, as explained in Methods.* ***(2)*** *It is recommended that a Construction Markup (Part 1.1.22) be added to all prices.*

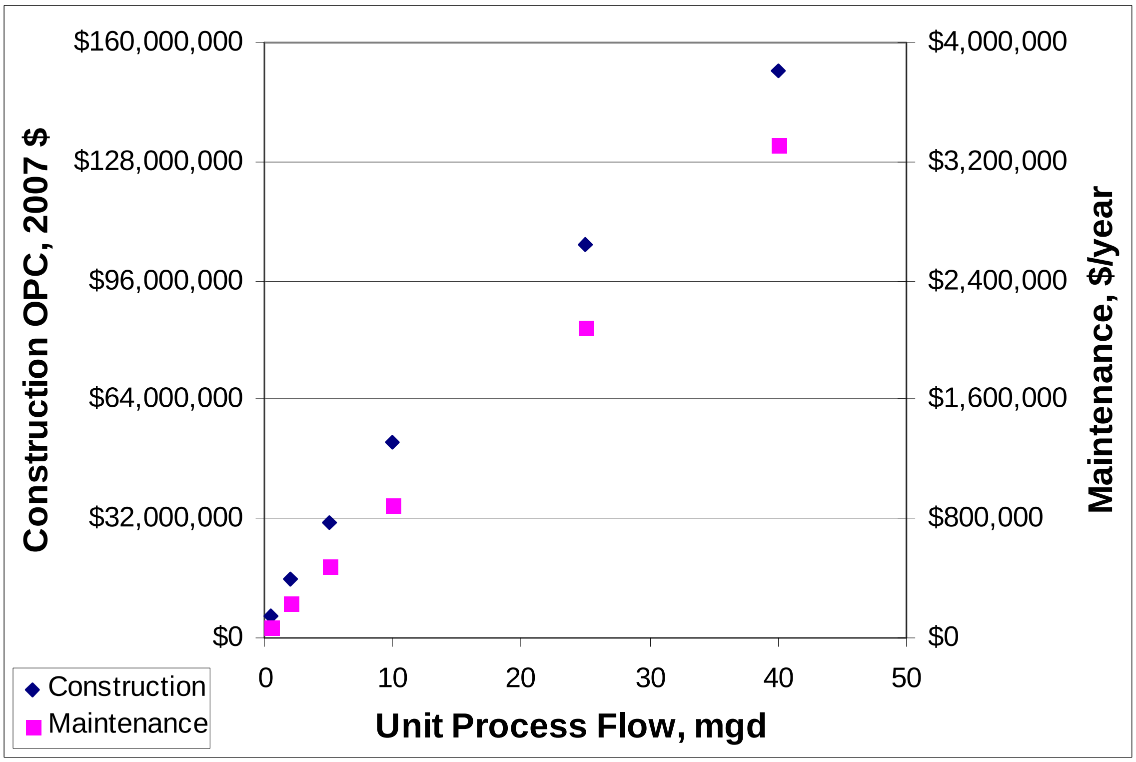

Figure 1.1.8.4.1 Seawater RO Membrane—Construction OPC and Maintenance.

1.1.8.4.2 Brackish Water Reverse Osmosis Membranes

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Back to Membrane Treatment System (1.1.8)

The probable costs of a BW-RO membrane system are presented in Tables 1.1.8.4.2.a-e. The Membrane Treatment System, Part 1.1.8, details what the costs include. The different feed water TDS concentrations considered were 750, 1,120, 1,500, 3,000, and 8,000 mg/L. There is no linear equation to adequately describe the relationship between the cost of membranes and the TDS concentration. Further explanation, as well as layouts for buildings of different sizes, are included in Appendix B-1.1.8: Membrane Treatment Systems Background.

Table 1.1.8.4.2.a BW-RO Membrane (750 mg/L TDS)—Construction OPC and Maintenance.

Unit Process Flow, mgd	Installed Equipment Cost	Building Cost	Electrical and I&C	Construction OPC	Maintenance $/year
0.5	$845,000	$395,000	$260,000	$1,620,000	$38,000
2	$2,200,000	$567,000	$580,000	$3,610,000	$118,000
5	$4,390,000	$868,000	$1,110,000	$6,880,000	$249,000
10	$7,610,000	$1,300,000	$1,870,000	$11,600,000	$467,000
25	$15,000,000	$3,570,000	$3,910,000	$24,300,000	$1,110,000
40	$21,290,000	$6,830,000	$5,910,000	$36,800,000	$1,790,000

***NOTES: (1)** Assumed recovery is 85%, assumed bypass is 46%. **(2)** General Requirements (8%) has been added to the Construction OPC, as explained in Methods. **(3)** It is recommended that a Construction Markup (Part 1.1.22) be added to all prices.*

Table 1.1.8.4.2.b BW-RO Membrane (1,120 mg/L TDS)—Construction OPC and Maintenance.

Unit Process Flow, mgd	Installed Equipment Cost	Building Cost	Electrical and I&C	Construction OPC	Maintenance $/year
0.5	$1,014,000	$395,000	$296,000	$1,840,000	$48,000
2	$2,704,000	$567,000	$687,000	$4,270,000	$149,000
5	$5,580,000	$868,000	$1,350,000	$8,420,000	$312,000
10	$9,630,000	$1,300,000	$2,300,000	$14,290,000	$582,000
25	$19,100,000	$3,570,000	$4,760,000	$29,620,000	$1,410,000
40	$27,040,000	$6,830,000	$7,110,000	$44,260,000	$2,290,000

***NOTES: (1)** Assumed recovery is 85%, assumed bypass is 26%. **(2)** General Requirements (8%) has been added to the Construction OPC, as explained in Methods. **(3)** It is recommended that a Construction Markup (Part 1.1.22) be added to all prices.*

Table 1.1.8.4.2.c BW-RO Membrane (1,500 mg/L TDS)—Construction OPC and Maintenance.

Unit Process Flow, mgd	Installed Equipment Cost	Building Cost	Electrical and I&C	Construction OPC	Maintenance $/year
0.5	$1,010,000	$395,000	$296,000	$1,840,000	$54,000
2	$3,040,000	$567,000	$758,000	$4,720,000	$165,000
5	$6,250,000	$868,000	$1,500,000	$9,310,000	$344,000
10	$10,700,000	$1,300,000	$2,510,000	$15,600,000	$644,000
25	$21,100,000	$3,570,000	$5,190,000	$32,300,000	$1,550,000
40	$29,900,000	$6,830,000	$7,720,000	$48,000,000	$2,520,000

NOTES: (1) *Assumed recovery is 85%, assumed bypass is 15%.* ***(2)*** *General Requirements (8%) has been added to the Construction OPC, as explained in* Methods*.* ***(3)*** *It is recommended that a* Construction Markup *(Part 1.1.22) be added to all prices.*

Table 1.1.8.4.2.d BW-RO Membrane (3,000 mg/L TDS)—Construction OPC and Maintenance.

Unit Process Flow, mgd	Installed Equipment Cost	Building Cost	Electrical and I&C	Construction OPC	Maintenance $/year
0.5	$1,180,000	$395,000	$331,000	$2,060,000	$62,000
2	$3,380,000	$567,000	$829,000	$5,160,000	$189,000
5	$7,100,000	$868,000	$1,670,000	$10,400,000	$394,000
10	$12,000,000	$1,300,000	$2,790,000	$17,400,000	$736,000
25	$23,800,000	$3,570,000	$5,750,000	$35,800,000	$1,770,000
40	$33,800,000	$6,830,000	$8,530,000	$53,100,000	$2,860,000

NOTES: (1) *Assumed recovery is 85%, assumed bypass is 0%.* ***(2)*** *General Requirements (8%) has been added to the Construction OPC, as explained in* Methods*.* ***(3)*** *It is recommended that a* Construction Markup *(Part 1.1.22) be added to all prices.* ***(4)*** *The cost of the 3000 TDS and the 8000 TDS BW-RO membrane is the same as both systems have the same flows and 0% bypass. The difference in cost would be seen in operating costs as the operating pressures are not the same, however these operating costs are not included in Part 1; only maintenance costs are included. Another difference in cost would be seen in the size and scale of the pretreatment costs.*

Table 1.1.8.4.2.e BW-RO Membrane (8,000 mg/L TDS)—Construction OPC and Maintenance.

Unit Process Flow, mgd	Installed Equipment Cost	Building Cost	Electrical and I&C	Construction OPC	Maintenance $/year
0.5	$1,180,000	$395,000	$331,000	$2,060,000	$62,000
2	$3,380,000	$567,000	$829,000	$5,160,000	$189,000
5	$7,100,000	$868,000	$1,670,000	$10,400,000	$394,000
10	$12,000,000	$1,300,000	$2,790,000	$17,400,000	$736,000
25	$23,800,000	$3,570,000	$5,750,000	$35,800,000	$1,770,000
40	$33,800,000	$6,830,000	$8,530,000	$53,100,000	$2,860,000

NOTES: (1) *Assumed recovery is 75%, assumed bypass is 0%.* ***(2)*** *General Requirements (8%) has been added to the Construction OPC, as explained in Methods.* ***(3)*** *It is recommended that a Construction Markup (Part 1.1.22) be added to all prices.* ***(4)*** *The cost of the 3000 TDS and the 8000 TDS BW-RO membrane is the same as both systems have the same permeate flows and 0% bypass. The difference in cost would be seen in operating costs as the operating pressures are not the same, however operating costs are not included in Part 1; only maintenance costs are included. Another difference in cost would be seen in the size and scale of the pretreatment costs.*

1.1.8.5 Membrane Cleaning System

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A membrane cleaning system is included for each type of membrane in the Construction OPC.

For NF and RO this system would include the following:

- Chemical CIP solution tank
- Recirculation pump
- Cartridge filter
- Piping
- Valves
- Controls and instrumentation (for automation)

For MF/UF there would be a similar CIP system, as well as a backwash system using filtered water.

1.1.8.6 MF/UF Membrane Filtration System

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The opinion of probable cost for a MF/UF membrane filtration system is presented in Table 1.1.8.6 and on Figure 1.1.8.6. The system may be used for filtration of surface waters, either as the main treatment step for fresh surface water or as pretreatment for NF or RO. The costs are based on surface water treatment with a minimum recovery of 90 percent and zero percent bypass. The Membrane Treatment System, Part 1.1.8 includes an itemized list of the costs included. Figures of the typical layouts are presented in Appendix B-1.1.8: Membrane Treatment Systems Background. A package system was used for the 0.5 mgd flow.

Table 1.1.8.6 MF/UF Membrane—Construction OPC and Maintenance.

Unit Process Flow, mgd	Installed Equipment Cost	Building	Electrical and I&C	Construction OPC	Maintenance $/year
0.5	$2,130,000	$614,000	$577,000	$3,600,000	$48,300
2	$2,860,000	$1,270,000	$867,000	$5,400,000	$110,000
5	$3,970,000	$1,170,000	$1,080,000	$6,720,000	$236,000
10	$6,590,000	$1,350,000	$1,670,000	$10,400,000	$429,000
25	$16,500,000	$1,730,000	$3,820,000	$23,800,000	$1,040,000
40	$21,600,000	$7,310,000	$6,080,000	$37,800,000	$1,550,000

***NOTES: (1)** General Requirements (8%) has been added to the Construction OPC, as explained in Methods. **(2)** It is recommended that a Construction Markup (Part 1.1.22) be added to all prices.*

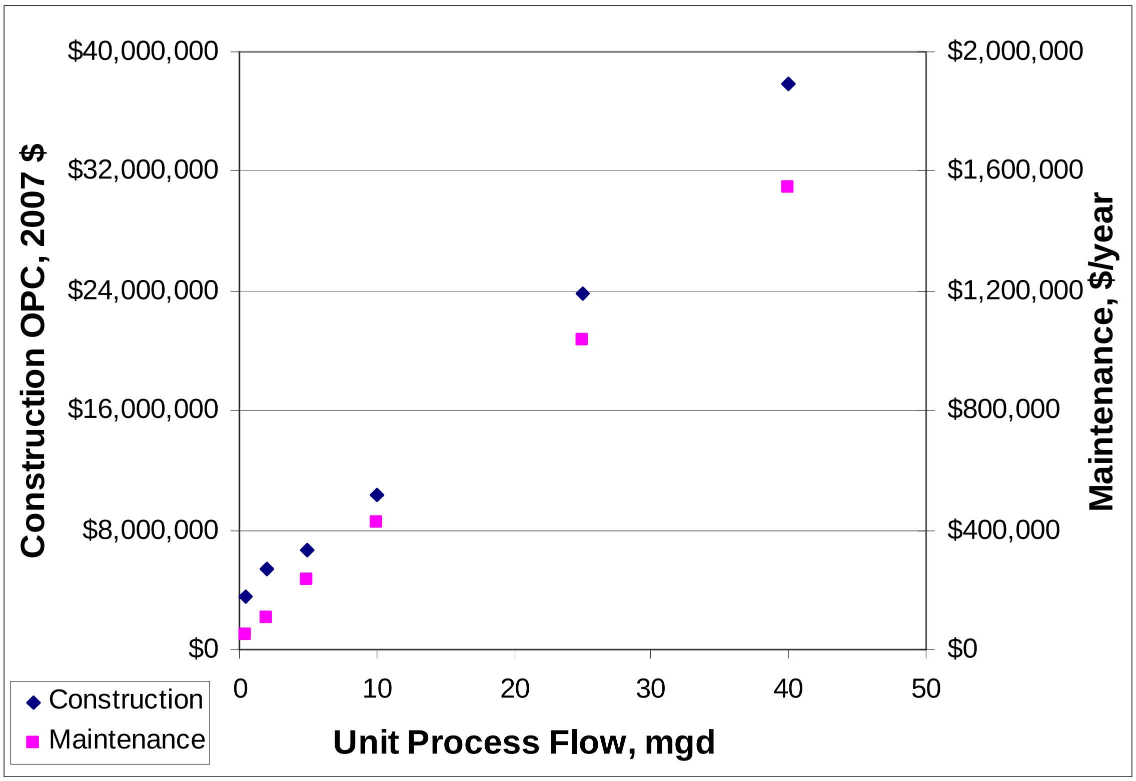

Figure 1.1.8.6 MF/UF Membrane—Construction OPC and Maintenance**.**

1.1.9 Aeration for Groundwater Systems

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For groundwater systems, the aerators are placed on top of a prestressed concrete circular tank. The tank is sized to store 10 percent of the stated capacity. Costs are for groundwater of a quality that requires conventional gravity aeration. Two types of aerators were considered: cascading and perforated tray as indicated on Figure B-1.1.9.a and Figure B-1.1.9.b, described in Appendix B-1.1.9: Aeration Background. The costs include the following:

- Aerator
- Prestressed concrete circular tank
- Reinforced concrete floor slab, 4 inches thick
- Self-supporting concrete dome
- Exterior painting
- Ladders (interior and exterior)
- Wall manhole
- Dome ventilator
- Dome hatch and fiberglass cover
- General Requirements

Maintenance costs are not usually considered for aeration, since they are insignificant for a conceptual planning level. The OPCs for different rates of flow are listed in Tables 1.1.9.a and 1.1.9.b. Figure 1.1.9 illustrates the costs for the two types of aerators.

Table 1.1.9.a Cascading Aerators—Construction OPC and Maintenance.

Capacity mgd	Capacity gpm	Aerator	Prestressed Tank	Construction OPC
0.94	650	$11,000	$470,000	$519,000
1.87	1,300	$13,000	$740,000	$813,000
2.74	1,900	$14,000	$955,000	$1,047,000
3.74	2,600	$16,000	$1,150,000	$1,259,000
5.47	3,800	$49,000	$1,560,000	$1,738,000
7.20	5,000	$30,000	$1,970,000	$2,160,000
9.22	6,400	$34,000	$2,410,000	$2,640,000
10.80	7,500	$38,000	$2,890,000	$3,162,000

NOTES: (1) *General Requirements (8%) has been added to the Construction OPC, as explained in Methods.* ***(2)*** *It is recommended that a Construction Markup (Part 1.1.22) be added to all prices*

Table 1.1.9.b Perforated Tray Aerators—Construction OPC and Maintenance.

Capacity mgd	Capacity gpm	Aerator	Prestressed Tank	Construction OPC
7.20	5,000	$42,000	$1,970,000	$2,170,000
14.40	10,000	$46,000	$3,600,000	$3,938,000
21.60	15,000	$54,000	$5,000,000	$5,458,000
28.80	20,000	$92,000	$7,200,000	$7,875,000

***NOTES: (1)** General Requirements (8%) has been added to the Construction OPC, as explained in Methods. **(2)** It is recommended that a Construction Markup (Part 1.1.22) be added to all prices*

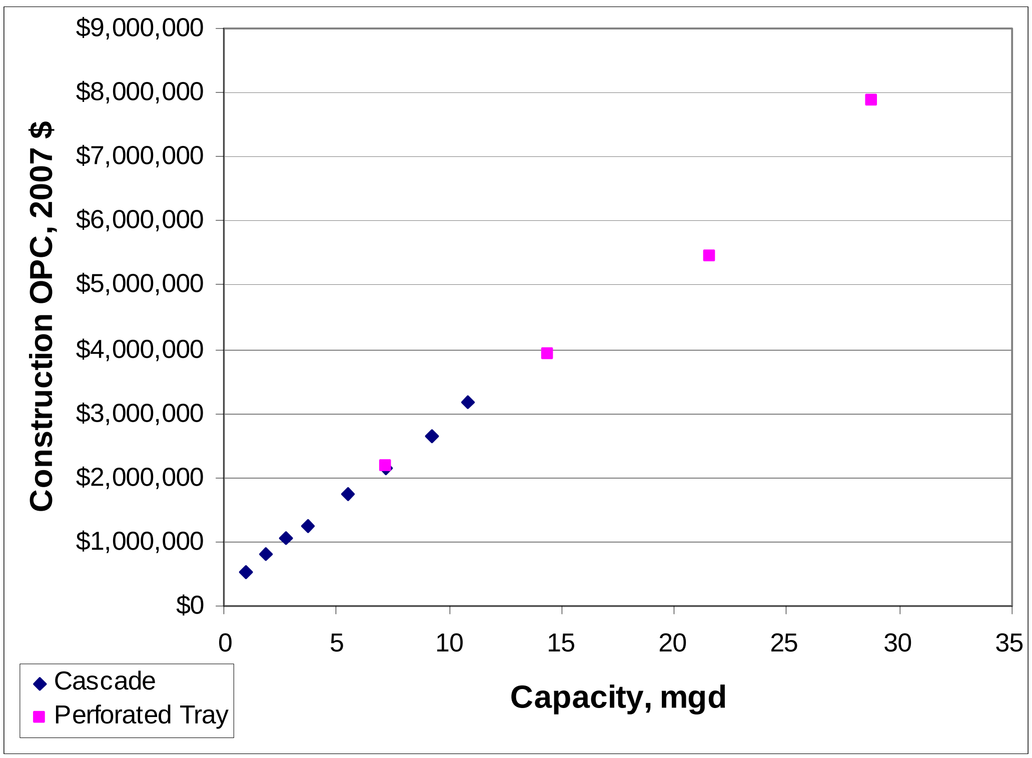

Figure 1.1.9 Aerator—Construction OPC and Maintenance**.**

1.1.10 Chlorine Disinfection System

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Chlorine disinfection is done with sodium hypochlorite. The description and costs of this component are presented in Part 1.1.3, Chemical Feed and Storage. The construction OPC is listed in Table 1.1.10 and presented graphically on Figure 1.1.10. A building cost is not included in the Construction OPC. The maintenance cost is for the chemical feed equipment and does not include the costs for chemicals.

Table 1.1.10 Chlorine Disinfection System—Construction OPC and Maintenance.

Unit Process Flow, mgd	Total Installed Equipment Cost	Electrical and I&C	Construction OPC	Maintenance $/yr
0.5	$121,000	$25,000	$158,000	$2,800
2	$156,000	$33,000	$204,000	$3,200
5	$170,000	$36,000	$222,000	$3,400
10	$198,000	$42,000	$259,000	$3,600
25	$235,000	$49,000	$307,000	$3,800
40	$299,000	$63,000	$391,000	$4,500

NOTES: (1) *General Requirements (8%) has been added to the Construction OPC, as explained in Methods.* ***(2)*** *It is recommended that a Construction Markup (Part 1.1.22) be added to all prices*

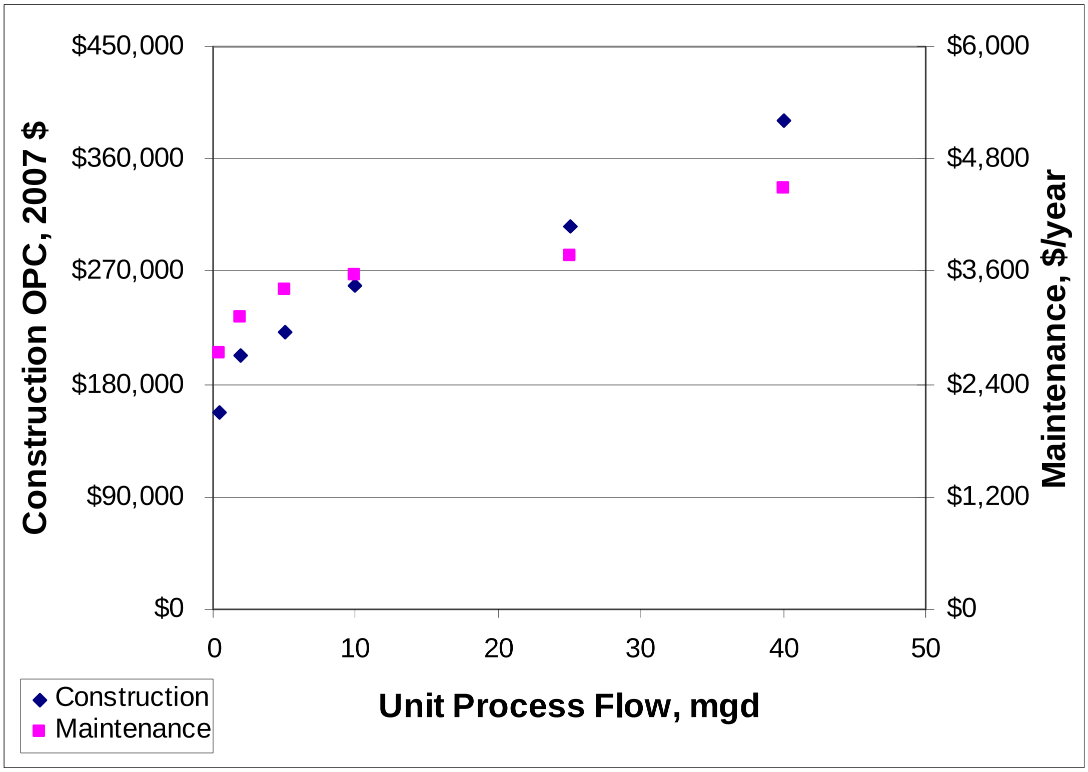

Figure 1.1.10 Chlorine Disinfection System—Construction OPC and Maintenance**.**

1.1.11 Chloramine Disinfection System

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Chloramine disinfection is done with sodium hypochlorite plus ammonia. The description and costs of this process are included in Part 1.1.3, Chemical Feed and Storage. The Construction OPC is presented in Table 1.1.11 and on Figure 1.1.11; a building cost is not included.

Table 1.1.11 Chloramines Disinfection System—Construction OPC and Maintenance.

Unit Process Flow, mgd	Total Installed Equipment Cost	Electrical and I&C	Construction OPC	Maintenance $/yr
0.5	$175,000	$37,000	$228,000	$4,000
2	$211,000	$44,000	$275,000	$4,300
5	$226,000	$47,000	$295,000	$4,600
10	$311,000	$65,000	$406,000	$5,600
25	$384,000	$81,000	$502,000	$6,200
40	$453,000	$95,000	$592,000	$6,800

NOTES: (1) *General Requirements (8%) has been added to the Construction OPC, as explained in Methods.* ***(2)*** *It is recommended that a Construction Markup (Part 1.1.22) be added to all prices.*

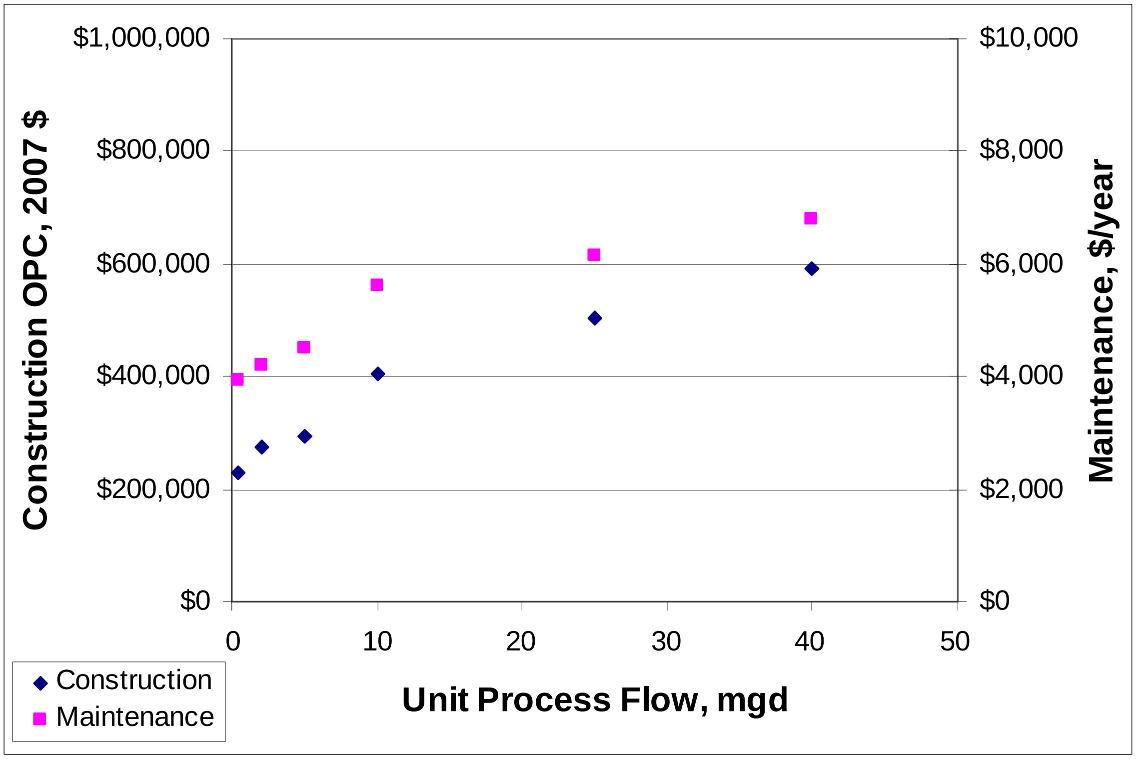

Figure 1.1.11 Chloramines Disinfection System—Construction System OPC and Maintenance.

1.1.12 UV Disinfection System

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More detailed information on UV disinfection is included in Appendix B-1.1.12: UV Disinfection Background. Table 1.1.12 and Figure 1.1.12 contain a summary of the probable costs for UV facilities, including redundancy for the UV system and the following:

- UV reactors
- Electrical equipment
- Flowmeters
- Valves
- UV building
- Electrical and I&C
- General Requirements

The opinion of probable cost does not include any processes/items included elsewhere in the report, such as chemical feed or yard piping. Maintenance cost is for the equipment.

Table 1.1.12 UV Disinfection System—Construction OPC and Maintenance.

Unit Process Flow, mgd	Installed Equipment Costs	Electrical and I&C	Construction OPC	Maintenance $/year
0.5	$380,000	$130,000	$550,000	$5,000
2	$1,000,000	$330,000	$1,440,000	$10,000
5	$1,700,000	$560,000	$2,440,000	$20,000
10	$2,100,000	$690,000	$3,020,000	$37,000
25	$2,600,000	$860,000	$3,730,000	$84,000
40	$2,900,000	$960,000	$4,170,000	$100,000

NOTES: ***(1)*** *General Requirements (8%) has been added to the Construction OPC, as explained in Methods.* ***(2)*** *It is recommended that a Construction Markup (Part 1.1.22) be added to all prices.*

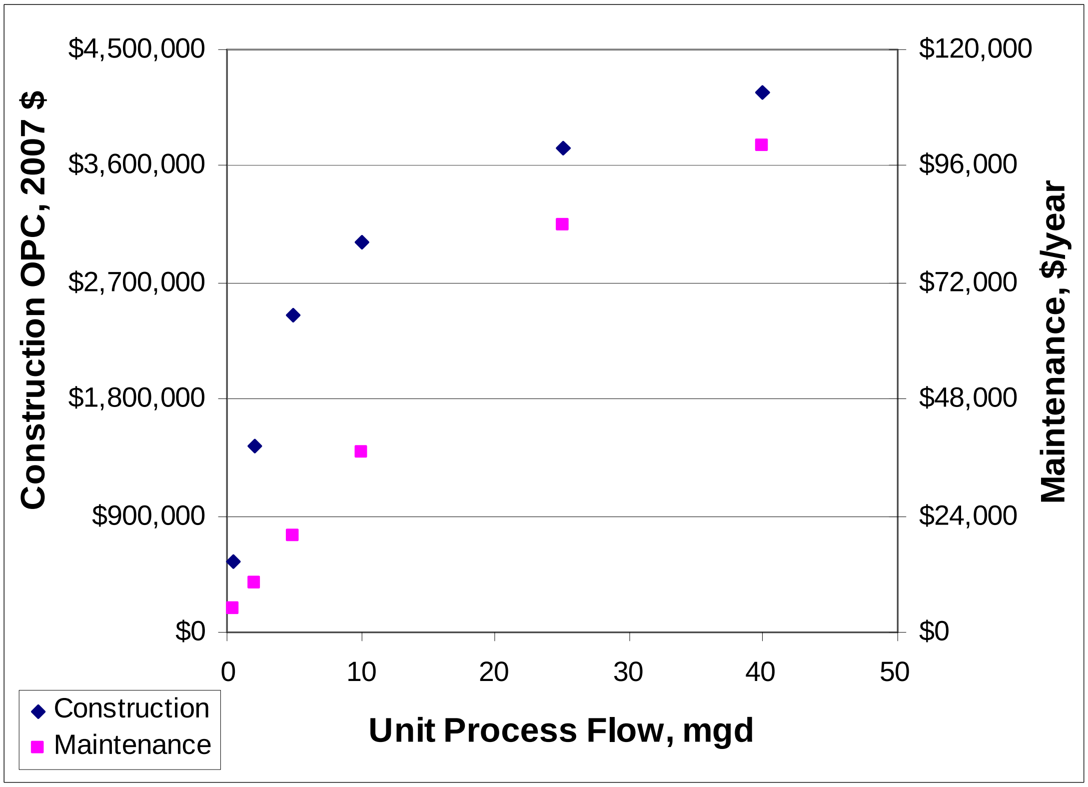

Figure 1.1.12 UV Disinfection System—Construction OPC and Maintenance.

1.1.13 Ozone Disinfection System

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Design criteria and assumptions about ozone (O_3) can be accessed in Appendix B-1.1.13: Ozone Disinfection Background. The opinion of probable cost was developed for an intermediate ozonation system located downstream from the pretreatment process (e.g., Actiflo) and upstream from filtration. The costs, listed in Table 1.1.13 and shown graphically on Figure 1.1.13, include the following:

- Liquid oxygen (LOX) storage tank
- LOX vaporizers
- Two ozone generators
- Dissolution system
- Ozone contactor
- Ozone off-gas destruction units
- Ozone building
- General Requirements

The opinion of maintenance cost does not include the purchase of LOX.

Table 1.1.13 Ozone Disinfection System—Construction OPC and Maintenance.

Unit Process Flow, mgd	Installed Equipment Costs	Electrical and I&C	Construction OPC	Maintenance $/year
0.5	$680,000	$140,000	$890,000	$9,300
2	$1,890,000	$400,000	$2,460,000	$26,000
5	$2,610,000	$550,000	$3,410,000	$36,000
10	$3,400,000	$710,000	$4,440,000	$46,500
25	$6,170,000	$1,300,000	$8,060,000	$85,800
40	$7,650,000	$1,610,000	$9,990,000	$108,000

***NOTES: (1)** General Requirements (8%) has been added to the Construction OPC, as explained in Methods. **(2)** It is recommended that a Construction Markup (Part 1.1.22) be added to all prices*

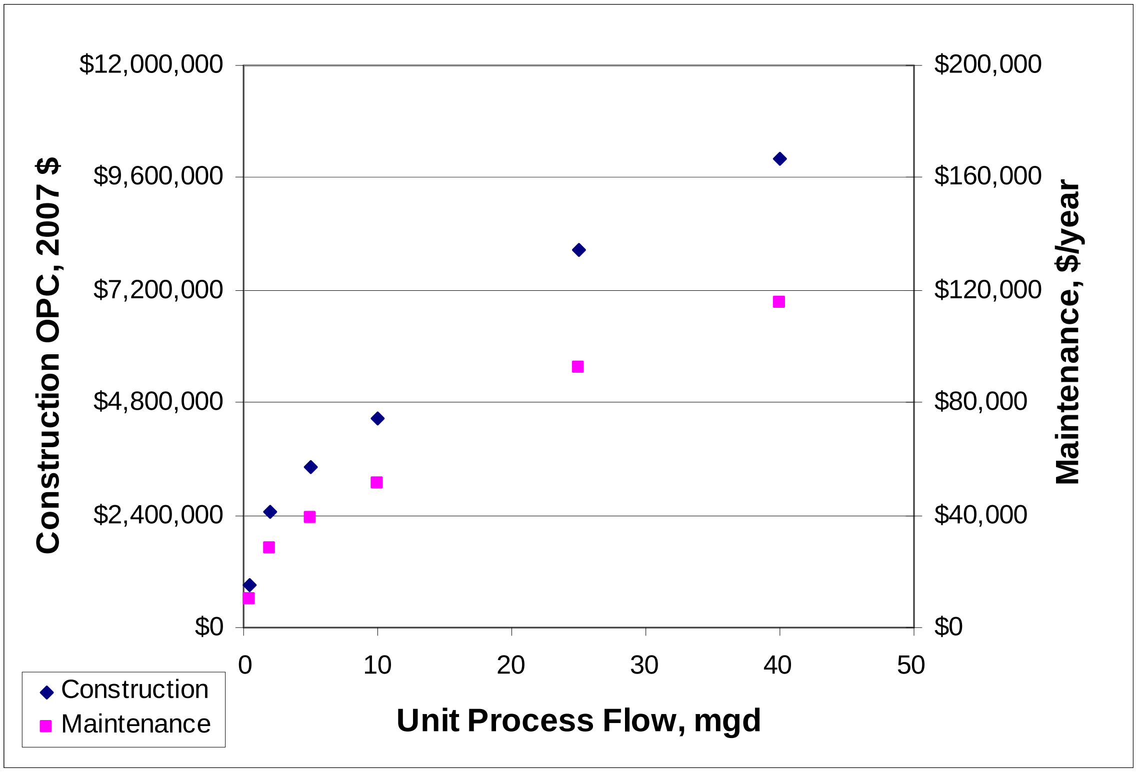

Figure 1.1.13 Ozone Disinfection System—Construction OPC and Maintenance.

1.1.14 Granular Activated Carbon (GAC) Filters

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More information describing the GAC filters is included in Appendix B-1.1.14: GAC Background. The minimum surface loading rate is 4 gpm/sf. The Construction OPC is presented in Table 1.1.14 and on Figure 1.1.14. The opinion of cost for GAC filters includes the following:

- Concrete basins
- Media
- Backwash system
- Piping/valving
- Filter building
- Local electrical and I&C
- General Requirements

The maintenance cost consists of two changes of the GAC each year and routine pump maintenance.

Table 1.1.14 GAC Filters—Construction OPC and Maintenance.

Unit Process Flow, mgd	Installed Equipment Cost	Electrical and I&C	Construction OPC	Maintenance $/year
0.5	$501,000	$105,000	$655,000	$93,000
2	$1,831,000	$384,000	$2,393,000	$371,000
5	$3,967,000	$833,000	$5,184,000	$928,000
10	$6,360,000	$1,336,000	$8,312,000	$1,850,000
25	$9,871,000	$2,073,000	$12,900,000	$4,600,000
40	$14,473,000	$3,039,000	$18,914,000	$7,350,000

NOTES: (1) *General Requirements (8%) has been added to the Construction OPC, as explained in Methods.* ***(2)*** *It is recommended that a Construction Markup (Part 1.1.22) be added to all prices.*

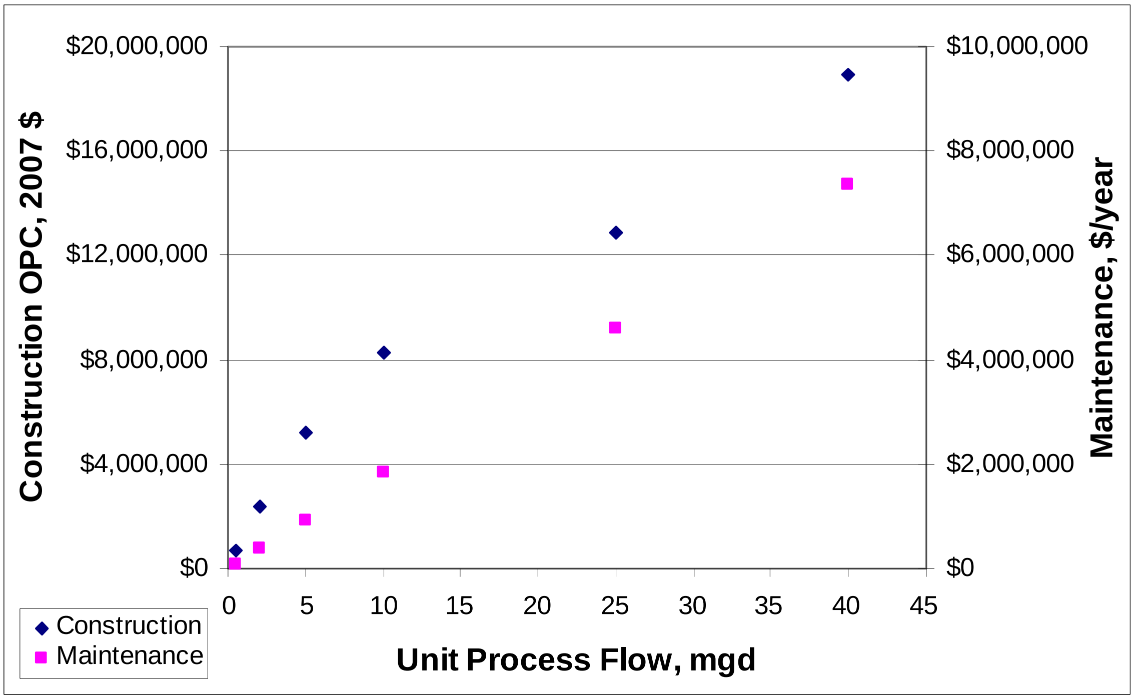

Figure 1.1.14 GAC Filters Construction OPC and Maintenance.

1.1.15 Transfer Pumping System

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The transfer pumping facility is designed as a triplex system for the 0.5, 2, and 5 mgd plants and as a quadruplex system for the 10, 25, and 40 mgd plants. Background information was deemed unnecessary. The triplex system consists of two continuous duty pumps and one standby unit, and the quadruplex system consists of three continuous duty pumps and one standby unit. The head was assumed to be 20 ft. The opinion of cost includes the following:

- Valving
- Concrete pad
- Horizontal split case pumps and motors
- Piping
- Local electrical and I&C
- General Requirements

The Construction OPC is presented in Table 1.1.15 and on Figure 1.1.15. The maintenance costs are for routine pump maintenance and testing.

Table 1.1.15 Transfer Pumping System—Construction OPC and Maintenance.

Pumping Capacity, mgd	Installed Equipment Cost	Electrical and I&C	Construction OPC	Maintenance $/year
0.5	$49,000	$10,000	$64,000	$1,500
2	$64,000	$13,000	$84,000	$1,900
5	$174,000	$37,000	$230,000	$5,200
10	$344,000	$72,000	$450,000	$10,300
25	$629,000	$132,000	$820,000	$18,900
40	$845,000	$177,000	$1,100,000	$25,400

NOTES:* *(1) *General Requirements (8%) has been added to the Construction OPC, as explained in Methods.* ***(2)*** *It is recommended that a Construction Markup (Part 1.1.22) be added to all prices.*

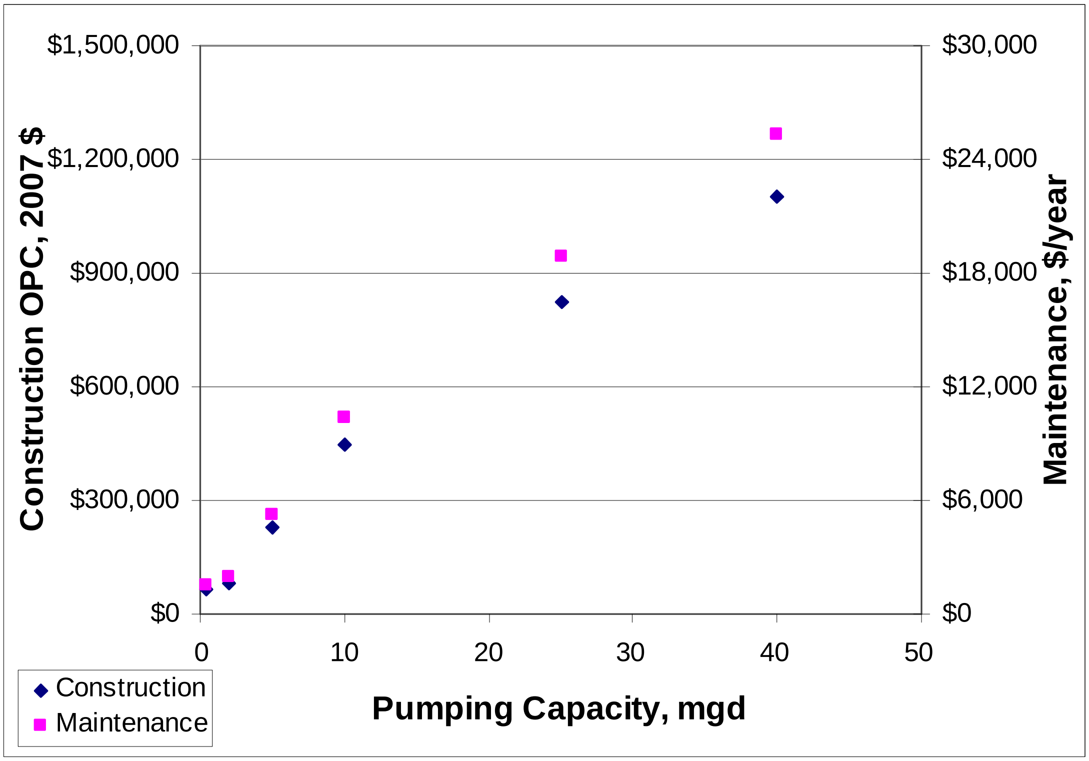

Figure 1.1.15 Transfer Pumping System Construction OPC and Maintenance.

1.1.16 High Service Pumping System

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The high service pump is housed in a pump station. The 0.5, 2, and 5 mgd systems are triplex systems consisting of three pumps (two duty and one standby). The 10, 25, and 40 mgd quadruplex systems consist of a total of four pumps (three duty and one standby). The systems and their layouts are described in more detail in Appendix B-1.1.16: High Service Pumping Background. The opinion of cost includes the following:

- Pump building
- Hydropneumatic tank (including an air compressor; for 0.5, 2, and 5 mgd plants)
- AFD (including training, field testing, spare parts, conduit and wire, PLC, and programming; for 10, 25, and 40 mgd plants)
- Valves
- Piping
- Fencing
- Standby pump
- Local electrical and I&C
- General Requirements

The Construction OPC is in Table 1.1.16 and on Figure 1.1.16. The maintenance costs are for routine pump maintenance and testing.

Table 1.1.16 High Service Pumping System—Construction OPC and Maintenance.

Pumping Capacity, mgd	Installed Equipment Cost	Electrical and I&C	Construction OPC	Maintenance $/year
0.5	$347,000	$73,000	$453,000	$720
2	$535,000	$112,000	$700,000	$4,960
5	$761,000	$160,000	$994,000	$8,870
10	$1,460,000	$307,000	$1,910,000	$22,600
25	$4,480,000	$940,000	$5,850,000	$55,700
40	$6,120,000	$1,290,000	$8,000,000	$66,100

NOTES: (1) *General Requirements (8%) has been added to the Construction OPC, as explained in Methods.* ***(2)*** *It is recommended that a Construction Markup (Part 1.1.22) be added to all prices.*

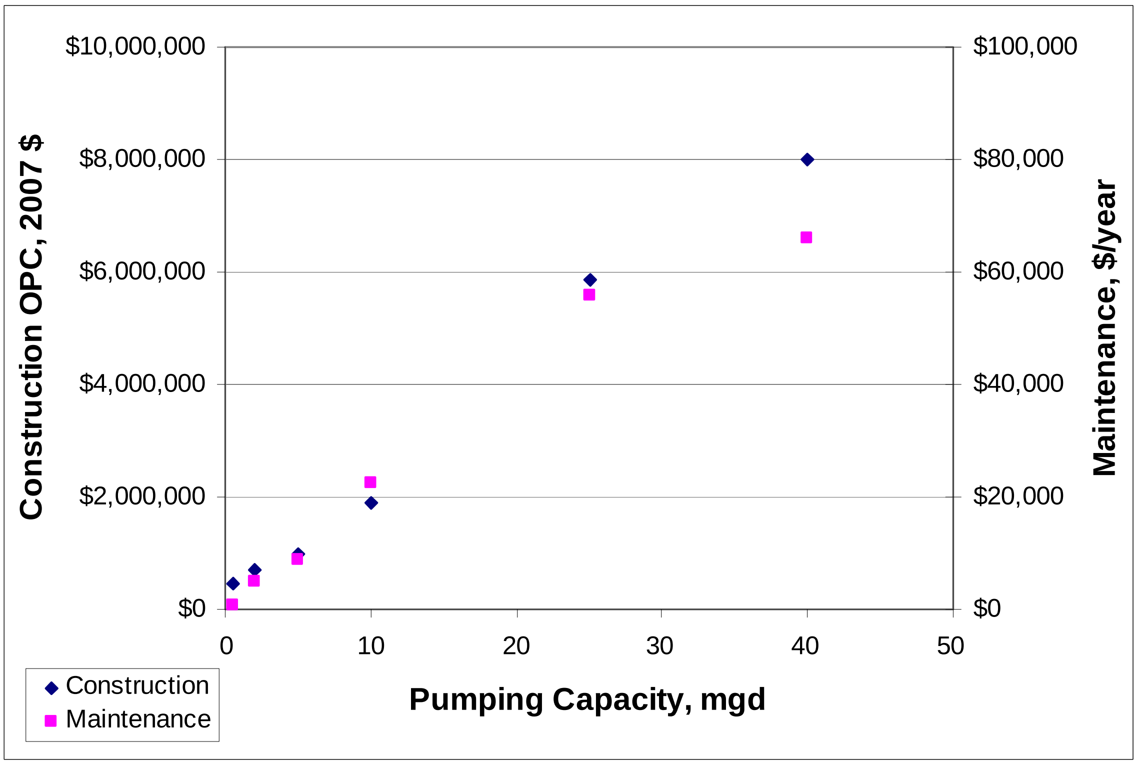

Figure 1.1.16 High Service Pumping System—Construction OPC and Maintenance.

1.1.17 Clearwell

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The clearwell is a square concrete basin, assumed to be built above ground. A detailed description of the clearwell, is in Appendix B-1.1.17: Clearwell Background. The opinion of costs includes the following:

- Concrete walls
- Reinforced concrete floor slab
- Gate
- General Requirements

The Construction OPC is presented in Table 1.1.17 and on Figure 1.1.17. Figure 1.1.17 plots the provided storage in gallons with the Construction OPC. Maintenance costs for the clearwell are usually not considered since they are insignificant for conceptual planning level cost.

Table 1.1.17 Clearwell—Construction OPC.

Unit Process Flow, mgd	Storage Provided, gal	Installed Equipment Costs	Construction OPC
0.5	3,472	$48,000	$52,000
2	13,889	$96,000	$104,000
5	34,722	$163,000	$177,000
10	69,444	$237,000	$257,000
25	173,611	$544,000	$588,000
40	277,778	$819,000	$885,000

NOTES: ***(1)*** *General Requirements (8%) has been added to the Construction OPC, as explained in Methods.* ***(2)*** *It is recommended that a Construction Markup (Part 1.1.22) be added to all prices.*

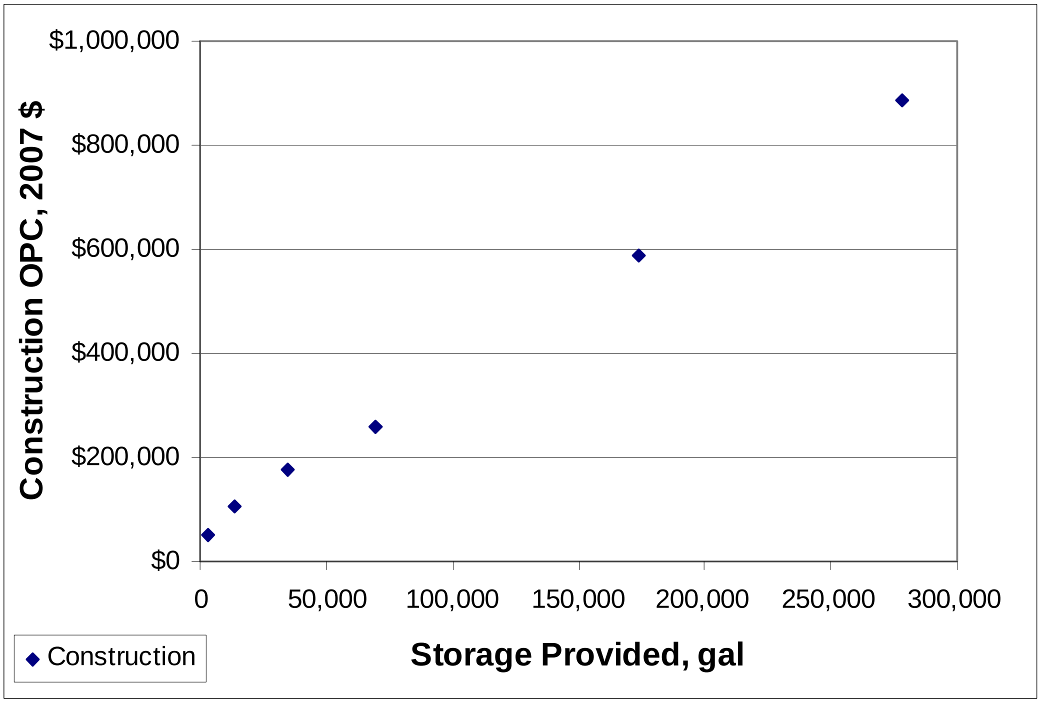

Figure 1.1.17 Clearwell—Construction OPC.

1.1.18 Sitework

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Sitework is defined as the work on an area extending more than 5 feet from the exterior of a structure and includes the following:

- Excavation/leveling
- Site roadways (with curb and gutter)
- Seeding/sodding
- Stormwater and drainage systems
- Landscaping
- Parking lot

All sitework costs in this report assume construction on a greenfield site. The cost of sitework depends largely on the size of the plant and the treatment systems it contains. For conceptual planning level costs 3-6 percent of the total cost of the treatment plant is recommended. The location of the treatment plant and the processes and equipment installed in it will need to be considered before applying a percentage rate for the sitework.

1.1.19 Operations Building and Laboratory

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Typical plant layouts and building sizes were determined for each plant flow capacity. The capacities were classified into three groups: small (5 mgd and less), medium (10 mgd), and large (25 mgd and larger).

The construction OPC includes the building, a fully furnished laboratory, training and break/lunch rooms, office spaces, and restrooms. Probable costs for the buildings are based on the MDPC of the plant and are shown in Table 1.1.19 and on Figure 1.1.19. Maintenance costs are not normally considered for operations building and are insignificant for a conceptual planning level cost.

Table 1.1.19 Operations Building and Laboratory—Construction OPC.

MDPC mgd	Approx. Building Size, sq ft	Installed Equipment and Building	Electrical and I&C	Construction OPC
0.5	3,400	$680,000	$142,800	$889,000
2	3,400	$680,000	$142,800	$889,000
5	3,400	$680,000	$142,800	$889,000
10	8,000	$1,600,000	$336,000	$2,091,000
25	13,000	$2,600,000	$546,000	$3,398,000
40	13,000	$2,600,000	$546,000	$3,398,000

NOTES: (1) *General Requirements (8%) has been added to the Construction OPC, as explained in Methods.* ***(2)*** *It is recommended that a Construction Markup (Part 1.1.22) be added to all prices.*

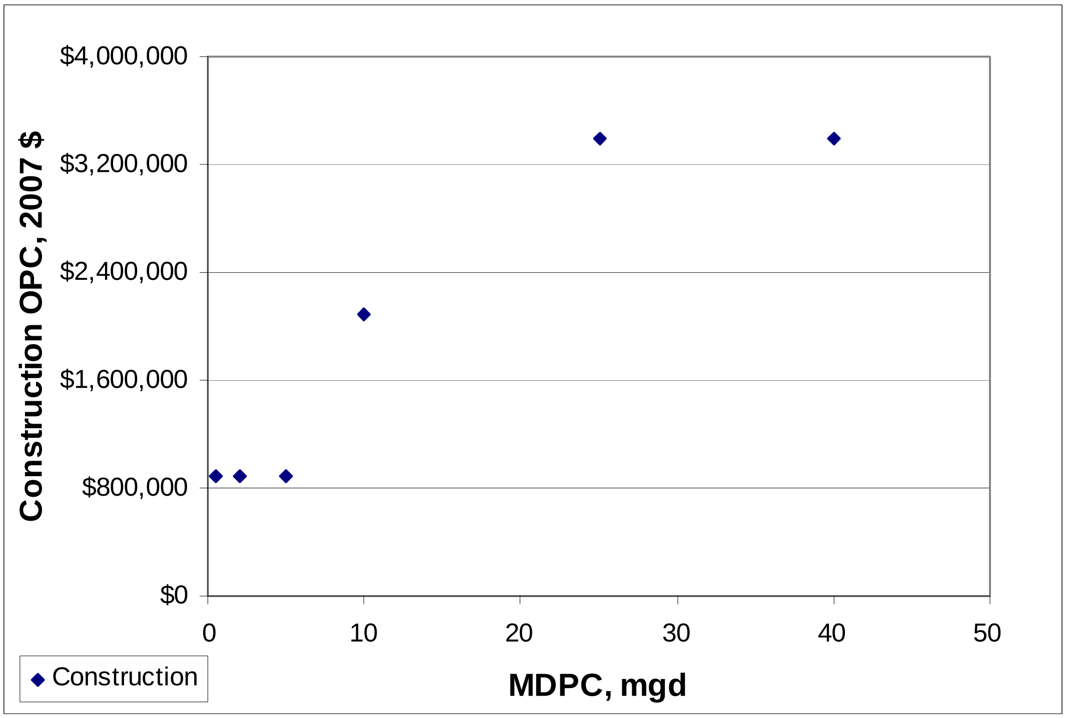

Figure 1.1.19 Operations Building and Laboratory—Construction OPC.

1.1.20 Yard Piping

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Yard piping, also called process piping, consists of the piping within the plant site which connects the various equipment in the plant. For design, the pipe was assumed to be restrained, with cover in compliance with AASHTO standards. The costs in this OPC are for restrained piping and include the following:

- Trenching
- Backfilling
- Excavation
- Sitework
- Pipe materials
- Wasting of spoil

The costs do not include maintenance, added expenses for removal of rock or contaminated soil, or disposal or treatment of contaminated water or soil. They also do not include any processes/items included elsewhere in the report, such as chemical feed systems or valves. For conceptual planning level costs, 7-15 percent of the total cost of the treatment plant is recommended. The location (urban, rural), site area, and processes of each treatment plant will need considered before applying an actual percentage rate for the yard piping.

1.1.21 Electrical and I&C (Instrumentation and Controls)

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For the electrical and I&C costs, it was assumed that the power grid can accommodate the additional demand. The costs of electrical equipment include all cable, conduit, switchgears, and emergency lighting. The costs of instrumentation include automated PLC, supervisory control and data acquisition (SCADA system), and other computer programs. The included cost for all power use meets state and federal regulations. Maintenance costs exclusive to electrical and I&C are not included, as they are not normally considered for these processes and are insignificant for a conceptual planning level.

Costs are listed in tables for each component throughout the report. The electrical and I&C costs are included in the Construction OPC.

1.1.22 Construction Markup

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The construction markup should be added to cover unforeseen expenses, mobilization/demobilization, and contractor's overhead and profit during a project. Unless project-specific reasons call for a different percentage, it is suggested that a 35 percent markup be used that includes the following:

- Contingencies – 20%
- Contractor's overhead and profit – 10%
- Mobilization/demobilization – 5%

The 35 percent should be applied to all equipment and wells. For pipelines, tunneling, and valves, a construction markup of 15 percent is recommended. This item has the following breakdown:

- Contingencies – 5%
- Contractor's overhead and profit – 8%
- Mobilization/demobilization – 2%

1.2 Transmission Piping

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Transmission piping costs include materials, construction, and sitework for the minimum right-of-way widths for pipe ranging from 10 to 96 inches in diameter. The following pipe materials were considered: polyvinyl chloride (PVC), ductile iron, and steel. The costs listed are for rural, suburban, and urban installations, as follows:

- Rural: 85 percent of the ROW is seeded and 15 percent is pavement/road crossings.
- Suburban: 60 percent of the ROW is sodded and 40 percent is pavement/road crossings.
- Urban: 40 percent of the ROW is sodded and 60 percent is pavement/road crossings.

More information about the design assumptions and calculations is included in Appendix B-1.2: Transmission Piping Background. The cost of the pipe includes the following:

- Excavation
- Backfill
- Bedding
- Hauling of spoil
- Dewatering and shoring
- Pipe material
- Pipe restraining
- Pavement replacement
- Seeding
- Sodding
- Equipment rental and labor
- Miscellaneous items (traffic control, cathodic protection, pipeline markers, pressure testing and disinfection)

The probable costs per foot of pipe are listed in Table 1.2. Maintenance costs are normally not considered for transmission piping and are insignificant for a conceptual planning level.

Table 1.2 Transmission Piping—Construction OPC.

Nominal Pipe Diameter, in.	Material	Cost of Pipe, $/lin ft		
		Rural	Suburban	Urban
10	PVC[1]	$97	$108	$111
12	PVC	$105	$119	$122
14	PVC	$108	$120	$123
16	PVC	$110	$123	$127
18	PVC	$156	$202	$238
20	PVC	$160	$205	$239
24	PVC	$177	$225	$260
30	DI[2]	$318	$385	$446
36	DI	$360	$431	$499
42	DI	$401	$479	$555
48	DI	$443	$525	$609
54	DI	$485	$573	$662
60	STEEL[3]	$623	$730	$845
66	STEEL	$676	$789	$914
72	STEEL	$839	$975	$1,129
78	STEEL	$902	$1,045	$1,211
84	STEEL	$962	$1,113	$1,290
90	STEEL	$1,024	$1,184	$1,372
96	STEEL	$1,085	$1,253	$1,450

***NOTES**: **(1)** PVC = polyvinyl chloride pipe. **(2)** DI = ductile iron pipe. **(3)** Steel = steel pipe. **(4)** The 60 inch and 66 inch steel pipe has a wall thickness of 0.5 inch and 72 inch and larger pipe has a wall thickness of 0.6 inch. **(5)** It is recommended that a* Construction Markup *(Part 1.1.22) be added to all prices.*

1.3 Valves

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Valve costs for water distribution pipelines were priced with the help of Henry Pratt Company for the butterfly valves and Mueller Company for the resilient gate valves. More information about these companies is included in Appendix C. Background information was deemed unnecessary. The probable cost of valves includes the following:

- Pressure class 150
- AWWA accepted
- Installation of valves

The opinion of probable costs of valves is presented in Table 1.3. The costs do not include such items as electric operators or adjacent piping/fittings. Maintenance costs for valves are normally not considered and are insignificant for a conceptual planning level.

Table 1.3 Valves—Construction OPC.

Valve Size, in.	Type of Valve	Valve Installation
10	Resilient gate valves	$1,800
12	Resilient gate valves	$2,200
14	Resilient gate valves	$5,400
16	Resilient gate valves	$7,000
18	Resilient gate valves	$11,200
20	Resilient gate valves	$13,900
24	Resilient gate valves	$19,600
30	Resilient gate valves	$33,900
36	Resilient gate valves	$43,100
42	Butterfly valves	$25,900
48	Butterfly valves	$35,000
54	Butterfly valves	$54,800
60	Butterfly valves	$72,450
66	Butterfly valves	$81,200
72	Butterfly valves	$91,000
78	Butterfly valves	$98,000
84	Butterfly valves	$112,000
90	Butterfly valves	$126,000
96	Butterfly valves	$140,000

NOTES: (1) *It is recommended that a* Construction Markup *(Part 1.1.22) be added to all prices.*

1.4 Trenchless Technology

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Trenchless technology includes probable costs for tunneling and horizontal directional drilling (HDD). More information about the processes and assumptions is presented in Appendix B-1.4: Trenchless Technology Background.

Because of the notable differences in construction methods, the tunneling and HDD costs were broken into three categories: Public Right-of-Way, Wetlands, and River Crossings.

- Public Right-of-Way: crossing through roadways, yards, or near to public or private property within cities, suburbs, or towns.
- Wetlands: crossings underneath federally defined wetlands or swamps.
- River Crossing: crossing of any body of water at least 100 feet wide.

The costs of HDD include the following:

- Setup of construction equipment
- High density polyethylene pipe, HDPE DR 11
- Tools used to install pipe[1]
- Disposal/hauling of spoil
- Mobilization

NOTE: For HDD, this includes the welding machine for HDPE DR 11, a generator, a rig, a mobile control room, and other equipment as outlined in Appendix B-1.4: Trenchless Technology Background.

Costs for HDD do not include variables or added expense for drilling in rock or adverse soil conditions, or dewatering. Table 1.4.a shows the opinion of probable costs for HDD.

For tunnels, the costs include the following:

- Dewatering
- Disposal of spoil
- Steel casing pipe, AWWA M11, wall thickness of 0.3 inch
- Coating of 80-mil rock shield
- Mobilization
- Carrier pipe skids and gravel fill

The tunnel costs do not include the added costs of removal of hazardous/contaminated soil or water, unstable or non-compressible soil, or tunnels with additional depth beyond 20 feet. The probable costs of tunneling are listed in Table 1.4.b. Cathodic protection is not included. Maintenance costs are normally not considered for these facilities and are insignificant for a conceptual planning level.

Table 1.4.a HDD—Construction OPC.

Length, ft	500	1000	2000	3000	4000
Public ROW, Pipe Dia, in.	**Unit cost $/ft**	**Unit cost $/ft**	**Unit cost $/ft**	**Unit cost $/ft**	**Unit cost $/ft**
8	$115	$112	$111	$110	$110
10	$144	$140	$139	$138	$138
12	$173	$168	$166	$166	$165
14	$202	$197	$194	$193	$193
16	$230	$225	$222	$221	$220
18	$259	$253	$249	$248	$248
20	$288	$281	$277	$276	$275
24	$346	$337	$333	$331	$330
30	$432	$421	$416	$414	$413
Wetlands, Pipe Dia, in.	**Unit cost $/ft**	**Unit cost $/ft**	**Unit cost $/ft**	**Unit cost $/ft**	**Unit cost $/ft**
8	$96	$94	$92	$92	$92
10	$120	$117	$116	$115	$115
12	$144	$140	$139	$138	$138
14	$168	$164	$162	$161	$161
16	$192	$187	$185	$184	$184
18	$216	$211	$208	$207	$207
20	$240	$234	$231	$230	$230
24	$288	$281	$277	$276	$275
30	$360	$351	$347	$345	$344
River Crossing, Pipe Dia, in.	**Unit cost $/ft**	**Unit cost $/ft**	**Unit cost $/ft**	**Unit cost $/ft**	**Unit cost $/ft**
16	$230	$225	$222	$221	$220
18	$259	$253	$249	$248	$248
20	$288	$281	$277	$276	$275
24	$346	$337	$333	$331	$330
30	$432	$421	$416	$414	$413

NOTE: *It is recommended that a Construction Markup (Part 1.1.22) be added to all prices.*

Table 1.4.b Tunnel—Construction OPC.

Length, ft	**200**	**500**	**1000**	**2000**	**3000**	**4000**
Public ROW. Pipe Dia, in.	**Unit cost $/ft**	**Unit cost $/ft**	**Unit cost $/ft**	**Unit cost $/ft**	**Unit cost $/ft**	**Unit cost $/ft**
36	$1,080	$920	$870	$840	$830	$830
48	$1,440	$1,230	$1,160	$1,120	$1,110	$1,100
54	$1,620	$1,380	$1,300	$1,260	$1,250	$1,240
60	$1,800	$1,530	$1,440	$1,400	$1,380	$1,380
72	$2,160	$1,840	$1,730	$1,680	$1,660	$1,650
78	$2,340	$1,990	$1,880	$1,820	$1,800	$1,790
84	$2,520	$2,150	$2,020	$1,960	$1,940	$1,930
Wetlands, Pipe Dia, in.	**Unit cost $/ft**	**Unit cost $/ft**	**Unit cost $/ft**	**Unit cost $/ft**	**Unit cost $/ft**	**Unit cost $/ft**
36	$900	$770	$720	$700	$690	$690
48	$1,200	$1,020	$960	$930	$920	$920
54	$1,350	$1,150	$1,080	$1,050	$1,040	$1,030
60	$1,500	$1,280	$1,200	$1,170	$1,150	$1,150
72	$1,800	$1,530	$1,440	$1,390	$1,380	$1,380
78	$1,950	$1,660	$1,560	$1,520	$1,500	$1,490
84	$2,100	$1,790	$1,680	$1,630	$1,610	$1,610
River Crossing, Pipe Dia, in.	**Unit cost $/ft**	**Unit cost $/ft**	**Unit cost $/ft**	**Unit cost $/ft**	**Unit cost $/ft**	**Unit cost $/ft**
36	$1,080	$920	$870	$840	$830	$830
48	$1,440	$1,230	$1,160	$1,120	$1,110	$1,100
54	$1,620	$1,380	$1,300	$1,260	$1,250	$1,240
60	$1,800	$1,530	$1,440	$1,400	$1,380	$1,380
72	$2,160	$1,840	$1,730	$1,680	$1,660	$1,650
78	$2,340	$1,990	$1,880	$1,820	$1,800	$1,790
84	$2,520	$2,150	$2,020	$1,960	$1,940	$1,930

NOTE: *It is recommended that a* Construction Markup *(Part 1.1.22) be added to all prices.*

1.5 Water Production Wells

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A detailed description of this component is presented in Appendix B-1.5: Water Production Wells Background. The cost listed is only for drilling; the cost of pumping is included under the Groundwater Pumping Systems (Part 1.1.1.1). Well depths of 100 feet, 300 feet, 700 feet, and 1,500 feet and well diameters of 10, 12, 16, 18 and 24 inches were considered. The costs include the following:

- Mobilization/demobilization
- Well drilling by mud rotary
- Well casing
- Materials (cement, drilling mud)
- Well testing (specific capacity tests, water quality, packer tests)
- Geophysical logging
- Well pad
- Site clearing and restoration
- General Requirements

The opinion of costs does not include such items as a well house, pump and motor, or power supply to the well. Maintenance costs for well drilling are normally not considered as they are insignificant for a conceptual planning level. Costs are shown in Table 1.5 and on Figure 1.5.

Table 1.5 Water Production Wells—Construction OPC.

Well Diameter in.	Depth of Well, ft			
	100	**300**	**700**	**1,500**
10	$73,900	$235,000	$369,000	$555,000
12	$73,900	$281,000	$407,000	$630,000
16	$99,800	$350,000	$500,000	$749,000
18	$109,000	$382,000	$525,000	$819,000
24	$139,000	$463,000	$601,000	$915,000

NOTES: (1) *General Requirements (8%) has been added to the Construction OPC, as explained in Methods.* ***(2)*** *For the well depths of 100 ft, 300 ft, 700 ft, and 1,500 ft the following casing depths were used: 75 ft, 250 ft, 500 ft, and 1,200 ft.* ***(3)*** *It is recommended that a Construction Markup (Part 1.1.22) be added to all prices*

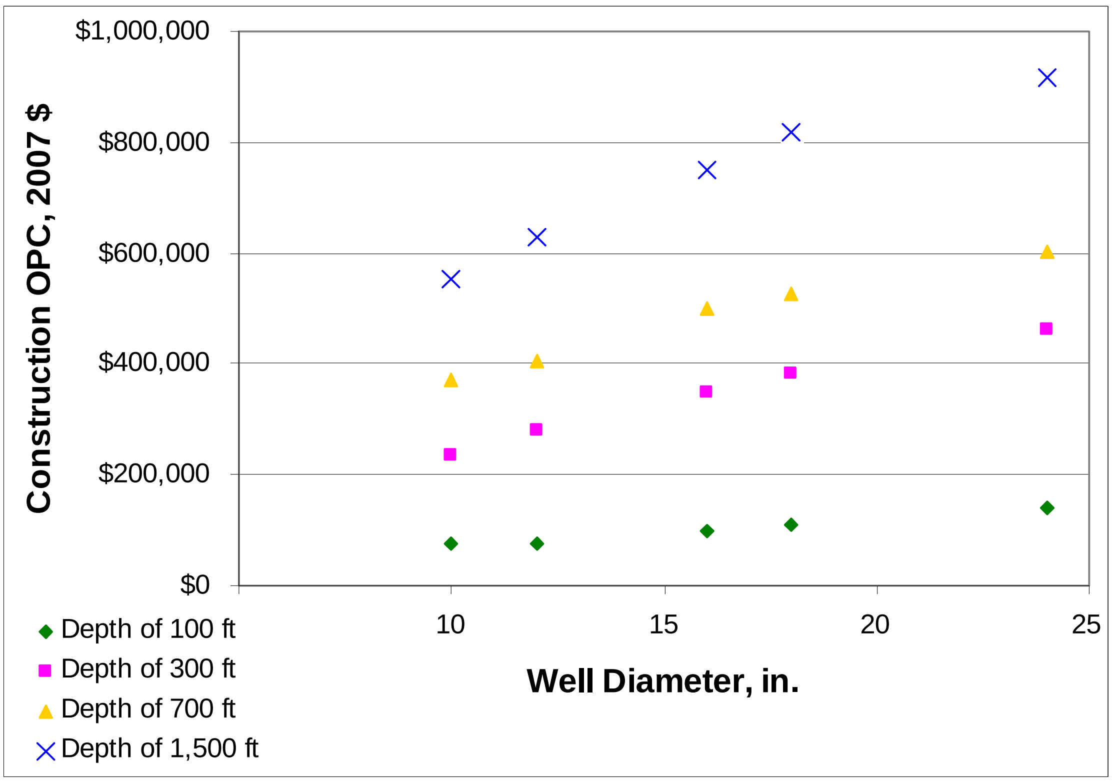

Figure 1.5 Complete Water Production Wells—Construction OPC.

1.6 Ground Storage Tanks

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Probable costs are supplemented by information provided by Crom Corporation and USA Tanks, as included in Appendix C. More detail about this component is included in Appendix B-1.6: Ground Storage Tank Background.

The Construction OPC includes the following:

- Concrete composite tank
- Highly reinforced concrete floor slab, 4 inches thick
- Dome cover
- Dome hatch with fiberglass cover
- Dome ventilator
- Painting of exterior surfaces
- Interior/exterior ladders
- General Requirements

Costs and storage capacity in million gallons (Mgal) are presented in Table 1.6 and Figure 1.6. Maintenance costs for ground storage tanks are normally not considered as they are insignificant for a conceptual planning level.

Table 1.6 Ground Storage Tanks—Construction OPC.

MDPC mgd	Minimum Storage, Mgal	Storage Provided, Mgal	Installed Equipment Costs	Construction OPC
0.5	0.08	0.10	$182,000	$197,000
2	0.30	0.50	$340,000	$367,000
5	0.75	1.00	$470,000	$508,000
10	1.50	2.00	$740,000	$799,000
25	3.75	4.00	$1,150,000	$1,242,000
40	6.00	6.00	$1,560,000	$1,685,000

NOTES: (1) *General Requirements (8%) has been added to the Construction OPC, as explained in Methods.* ***(2)*** *It is recommended that a Construction Markup (Part 1.1.22) be added to all prices.*

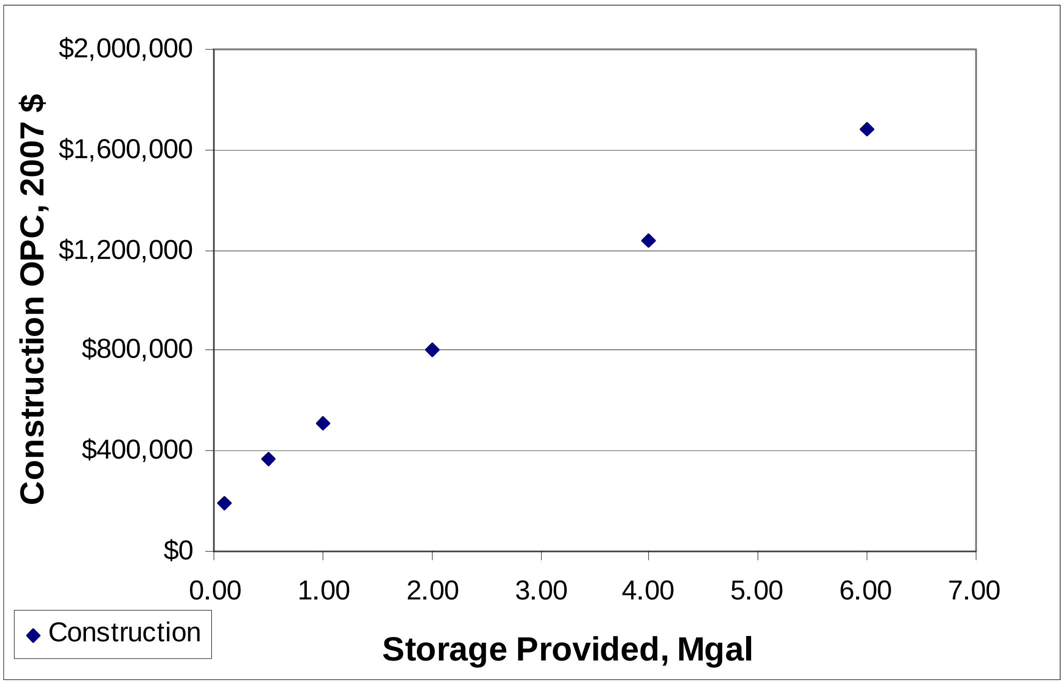

Figure 1.6 Complete Ground Storage Tanks—Construction OPC.

Part 2

SYSTEMS COSTS

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2.1 Wellfield

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A wellfield consists of two or more wells equipped with vertical turbine pumps. A pumphouse is not included. Figure B-1.1.1.a shows a typical above-ground set-up of the pump and pipes. The costs include the following:

- Well drilling
- Vertical turbine pumps and motors
- Water pressure gauge
- Fencing
- Earthwork and sitework
- Local electrical and I&C
- Construction according to drinking water standards
- Basic logging and aquifer performance testing
- General Requirements

The layout of the wellfields is as follows:

- 2 mgd: two 3 mgd wells
- 5 mgd: two 3 mgd wells
- 10 mgd: four 3 mgd wells
- 25 mgd: nine 3 mgd wells
- 40 mgd: fourteen 3 mgd wells

There are two drilling costs: one for wellfields in the upper part or the Floridan Aquifer system (350 ft to 550 ft, with casing of 250 ft to 400 ft) and another for wellfields in the lower part of the Floridan Aquifer system (700 ft to 1,100 ft, with casing of 500 ft to 900 ft). Operation and maintenance costs for the pumps include emergency power supply, semiannual vibration analysis, semiannual thermography of electrical components, semiannual lubricant analysis, water operations permit compliance, and replacement of impeller and bearings. O&M cost consists of labor for a two-person maintenance crew to check the wells once each quarter. Electricity consumption is included, assuming a utilization factor of 0.67 as discussed in Methods. Costs are listed in Tables 2.1.a and 2.1.b. and shown on Figures 2.1.a and 2.1.b.

Table 2.1.a Wellfield, Upper Floridan Aquifer—Construction OPC and O&M.

Wellfield Capacity mgd	No. of Wells	Drilling Cost	Equipment Cost	Electrical and I&C	Construction OPC	O&M $/year
2	2	$890,000	$250,000	$15,000	$1,240,000	$32,300
5	2	$890,000	$250,000	$15,000	$1,240,000	$56,500
10	4	$1,760,000	$500,000	$30,000	$2,480,000	$111,000
25	9	$3,970,000	$1,130,000	$68,000	$5,570,000	$268,000
40	14	$6,170,000	$1,750,000	$106,000	$8,670,000	$424,000

NOTES: (1) *General Requirements (8%) has been added to the Construction OPC, as explained in Methods.* ***(2)*** *It is recommended that Construction Markup (Part 1.1.22) be added to all prices.*

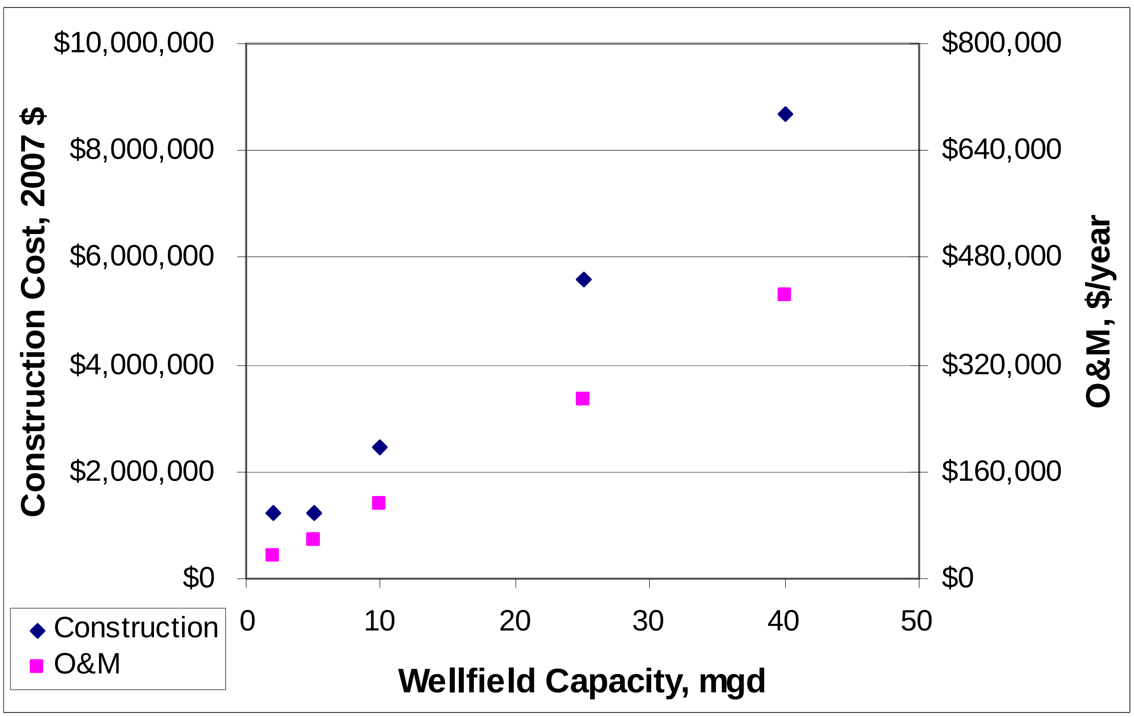

Figure 2.1.a Wellfield, Upper Floridan Aquifer—Construction OPC and O&M.

Table 2.1.b Wellfield, Lower Floridan Aquifer—Construction OPC and O&M.

Wellfield Capacity mgd	No. of Wells	Drilling Cost	Equipment Cost	Electrical and I&C	Construction OPC	O&M $/year
2	2	$1,300,000	$250,000	$15,000	$1,690,000	$32,300
5	2	$1,300,000	$250,000	$15,000	$1,690,000	$56,500
10	4	$2,610,000	$500,000	$30,000	$3,390,000	$111,000
25	9	$5,870,000	$1,130,000	$68,000	$7,630,000	$268,000
40	14	$9,130,000	$1,750,000	$106,000	$11,900,000	$424,000

NOTE: *It is recommended that a Construction Markup (Part 1.1.22) be added to all prices.*

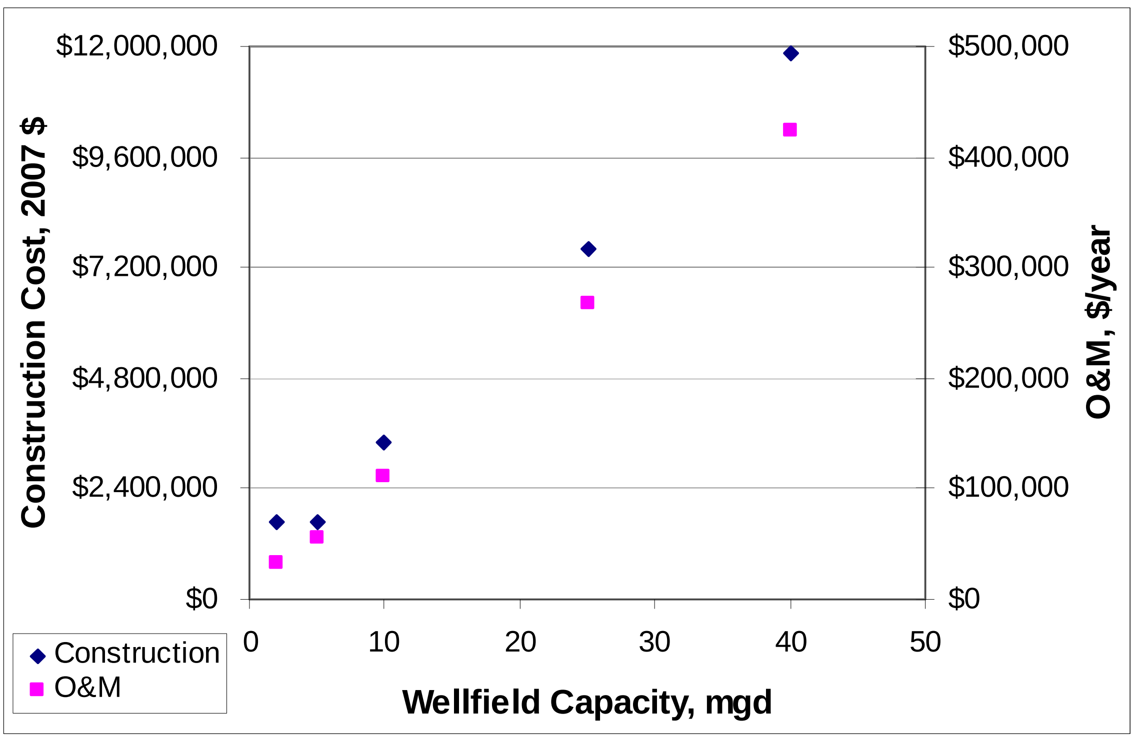

Figure 2.1.b Wellfield, Lower Floridan Aquifer—Construction OPC and O&M.

2.2 Treated Water Aquifer Storage Recovery (ASR) Systems

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The ASR system consists of multiple wells, each with the capacity to store and recover 1 mgd. Each well has a vertical turbine pump used for recovery only. It was assumed that line pressure would be adequate to achieve aquifer storage. A pumphouse is not included. The costs include the following:

- Well drilling
- Vertical turbine pumps and motors and non-reverse ratchet
- Water pressure gauge
- Water quality monitoring sample valve
- Flowmeter
- Fencing
- Earthwork and sitework
- Well pad
- Local electrical and I&C
- Drilling according to Class V injection well standards
- Geophysical logging, water quality sampling, well development and aquifer testing
- General Requirements

ASR systems for pumping capacities of 2, 5, 10, 25 and 40 mgd, were considered. The cost of drilling was based on wellhead construction for Class V injection wells, using a rotary drilling method with mud for the pit casing. The costs do not include any yard piping required to link the wells together or to connect the wells to a treatment plant. The costs do not include any chemical system as that cost is site-specific. The ASR well depth is 1,500 ft with 1,000 ft of casing. Operation and maintenance costs consist of wellhead maintenance, rehabilitation of the well by acidizing, emergency power supply, semiannual vibration analysis, semiannual thermography of electrical components, semiannual lubricant analysis, water operations permit compliance, and replacement of pump impellers and bearings. O&M cost consists of labor for a two-person maintenance crew to visit the site once each a quarter. Electricity consumption is included, assuming a utilization factor of 0.20, as explained in Methods. Costs are listed in Table 2.2 and shown on Figure 2.2.

Table 2.2 ASR Systems—Construction OPC and O&M.

ASR Capacity mgd[1]	Drilling Cost	Equipment Costs	Electrical and I&C	Construction OPC	O&M $/year
2	$700,000	$150,000	$32,000	$960,000	$53,000
5	$1,760,000	$380,000	$80,000	$2,390,00	$93,000
10	$3,510,000	$760,000	$160,000	$4,790,000	$170,000
25	$10,600,000	$1,910,000	$400,000	$13,900,000	$380,000
40	$16,900,000	$3,050,000	$640,000	$22,200,000	$580,000

***NOTES:* *(1)* *One ASR well is required for each mgd, thus for 2 mgd capacity there are 2 ASR wells, for 5 mgd capacity, there are 5 ASR wells, etc.* *(2)* *Costs do not include any monitoring wells as the number of wells required depends on the project and FDEP permits. The construction cost for one 6 inch upper zone monitoring well is $130,000 and for one 6" storage zone monitoring well is $160,000.* *(3)* *Acidizing of new well bores can be used to increase productivity by 30-50%, if used, $35,000 should be added to the cost of each well.* *(4)* *General Requirements (8%) has been added to the Construction OPC, as explained in Methods.* *(5)* *It is recommended that a Construction Markup (Part 1.1.22) be added to all prices.*

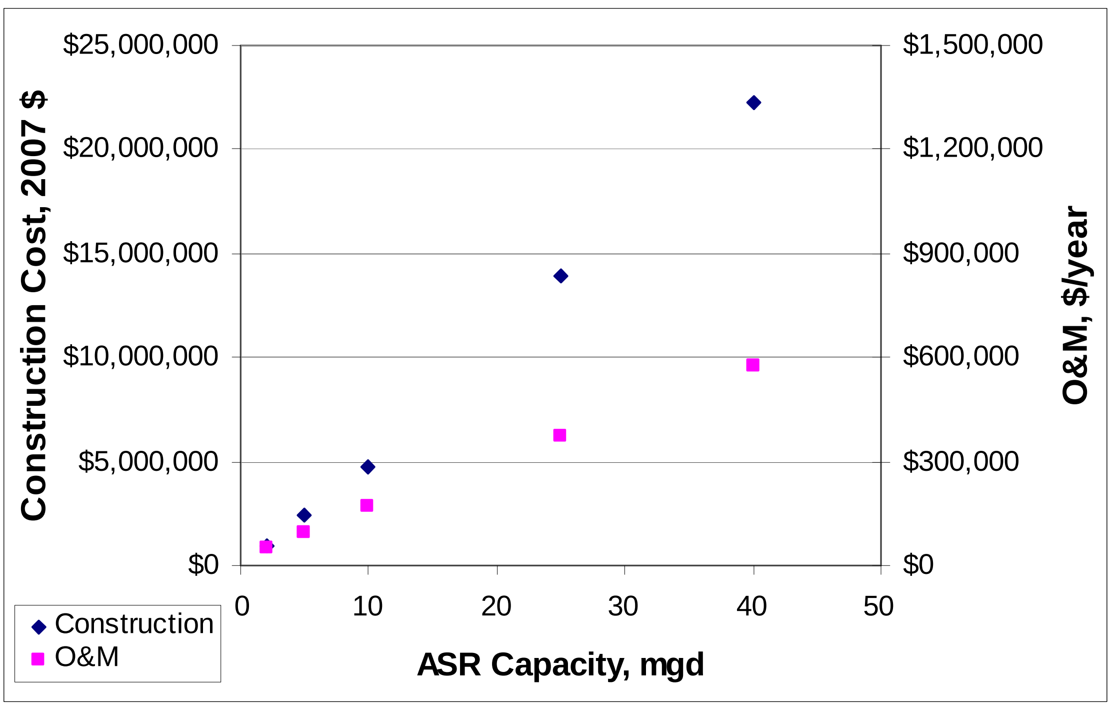

Figure 2.2 ASR Systems—Construction OPC and O&M.

2.3 Booster Pump Station

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The booster pump station includes a triplex system consisting of two duty pumps and one standby unit for a 3 mgd facility and quadruplex systems with three duty pumps and one standby unit for the 10, 25, and 50 mgd facilities. The 80 mgd pumps station consists of four duty pumps and one standby unit. The configuration of the larger systems is similar to the triplex system configuration. Costs include the following:

- Pumps and motors
- Hydropneumatic tank for 3 mgd systems
- AFDs for 10, 25, 50, and 80 mgd systems
- Valves
- Sitework
- Brick and block concrete pump house
- Backup generator
- Electrical and I&C
- General Requirements

The O&M costs include emergency power supply, semiannual vibration analysis, semiannual thermography of electrical components, semiannual lubricant analysis, water operations permit compliance, and replacement of impellers and bearings for the pumps. O&M cost consists of labor for a two-person maintenance crew to visit the site once each a quarter. Electric power consumption is included. The costs are listed in Table 2.3 and shown graphically on Figure 2.3.

Table 2.3 Booster Pump Station—Construction OPC and O&M.

Pumping Capacity, mgd	No. of Pumps	Construction OPC	O&M, $/year
3	3	$805,000	$53,000
10	4	$920,000	$168,000
25	4	$1,690,000	$418,000
50	4	$2,620,000	$831,000
80	5	$4,270,000	$1,330,000

NOTES: (1) *General Requirements (8%) has been added to the Construction OPC, as explained in* Methods. ***(2)*** *It is recommended that a* Construction Markup *(Part 1.1.22) be added to all prices.*

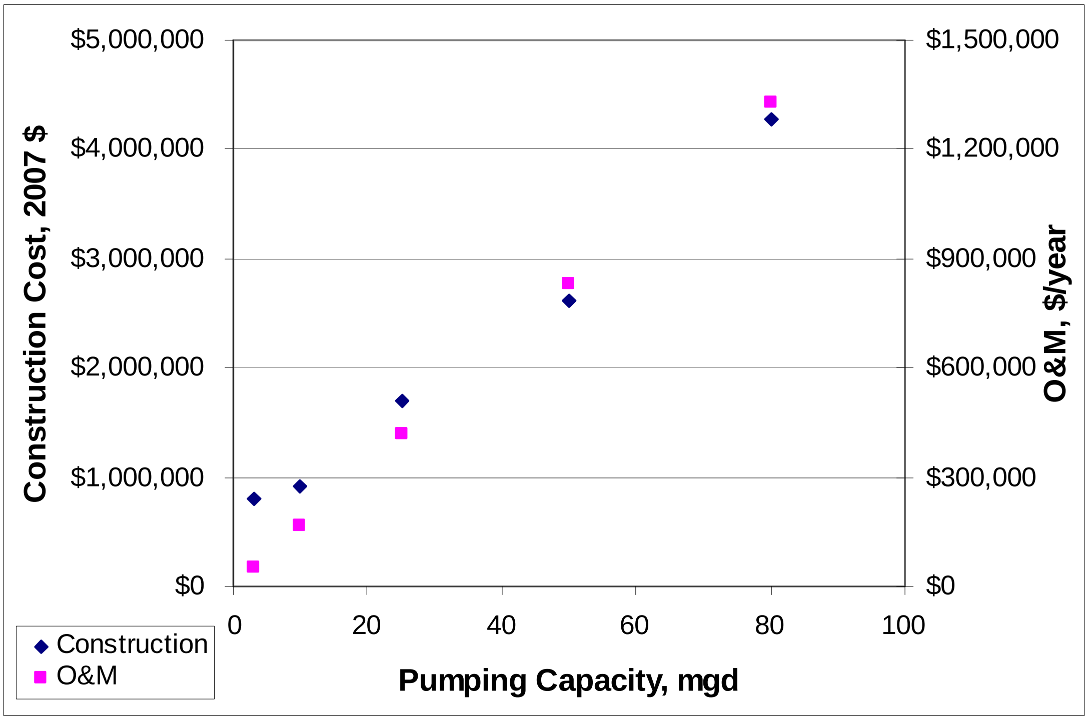

Figure 2.3 Booster Pump Station—Construction OPC and O&M.

2.4 Residual Disinfection for Transmission Systems

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The residual disinfection for transmission systems consists of a chloramine booster station to monitor the chloramine residual in the treated water. Appendix B-2.4 Residual Disinfection Background describes in more detail the chemical feed system for this station. The system includes the following:

- Chemical feed building
- Ammonia tank
- Hypochlorite tank
- Chlorine detector
- Metering pumps
- Diffusers
- Sitework
- General Requirements

The O&M costs include the cost of upkeep and routine maintenance of equipment, a two-person maintenance crew visiting the facility once each quarter, and the cost of chemicals. A breakdown of chemical costs is included in Methods. Costs are presented in Table 2.4 and on Figure 2.4.

Table 2.4 Residual Disinfection for Transmission Systems—Construction OPC and O&M.

Max. Flow, mgd	Construction OPC	O&M, $/year
3	$460,000	$7,000
10	$569,000	$12,000
25	$723,000	$20,900
50	$897,000	$35,300
80	$1,050,000	$56,600

NOTES: (1) *General Requirements (8%) has been added to the Construction OPC, as explained in Methods.* ***(2)*** *It is recommended that a Construction Markup (Part 1.1.22) be added to all prices.*

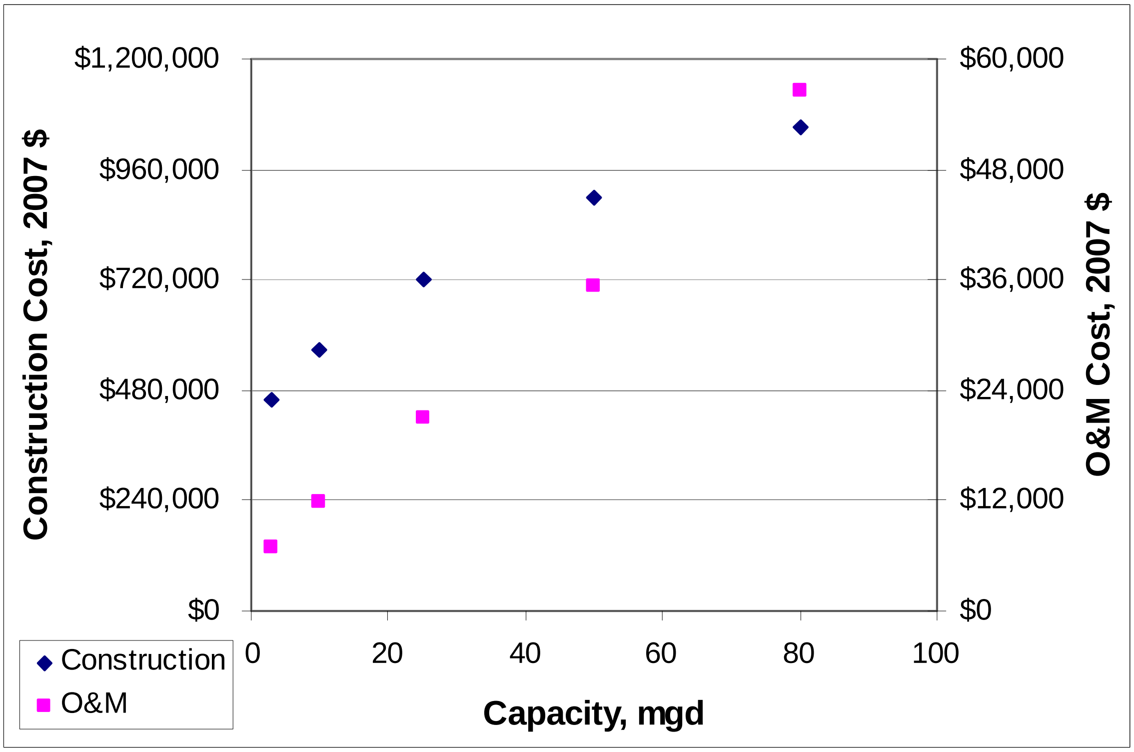

Figure 2.4 Residuals Disinfection for Transmission Systems—Construction OPC and O&M.

2.5 Fresh Groundwater Treatment Plants

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A fresh groundwater treatment plant consists of aeration, disinfection, and pumping into the distribution system. Background information was deemed unnecessary. The treatment system components include the following:

- Gravity aeration and storage tank
- Chloramines disinfection
- High service pump station
- Sitework
- Operations and administration building (for 25 and 40 mgd plants only)
- Yard piping
- General Requirements

The operations and administration building was added only to the larger treatment plants because of the simplicity of the process. The components are described in more detail in Part 1. The cost of a wellfield is not included for the fresh groundwater treatment plant. The O&M costs include electric power consumption, annual chemical costs, an operator, and a maintenance crew. O&M costs include the following:

- 2 mgd: one operator, 5 visits per week, one maintenance person 3 visits per week.
- 5 mgd: one operator, 6 hours per day, 5 days per week, one maintenance person 2 hours per day, 5 days per week.
- 10 mgd: one operator, 6 hours per day, 5 days per week, one maintenance person 2 hours per day, 5 days per week.
- 25 mgd: one operator and one maintenance person, 8 hours per day, 5 days per week.
- 40 mgd: one operator and one maintenance person, 8 hours per day, 5 days per week.

The costs of a groundwater treatment plant are listed in Table 2.5 and shown graphically on Figure 2.5.

Table 2.5 Fresh Groundwater Treatment Plant—Construction OPC and O&M.

MDPC, mgd	Storage Tank, Mgal[1]	Construction OPC[2]	O&M, $/year
2	2	$2,160,000	$59,000
5	5	$3,300,000	$229,000
10	10	$5,760,000	$366,000
25	30	$17,110,000	$841,000
40	45	$24,070,000	$1,220,000

***NOTES: (1)** One tank is provided for the 2, 5, and 10 mgd plants. The 25 mgd plant has two tanks and the 40 mgd plant has three tanks. **(2)** Only the 25 and 40 mgd plants include an administration and operations building. **(3)** General Requirements (8%) has been added to the Construction OPC, as explained in Methods. **(4)** It is recommended that a Construction Markup (Part 1.1.22) be added to all prices.*

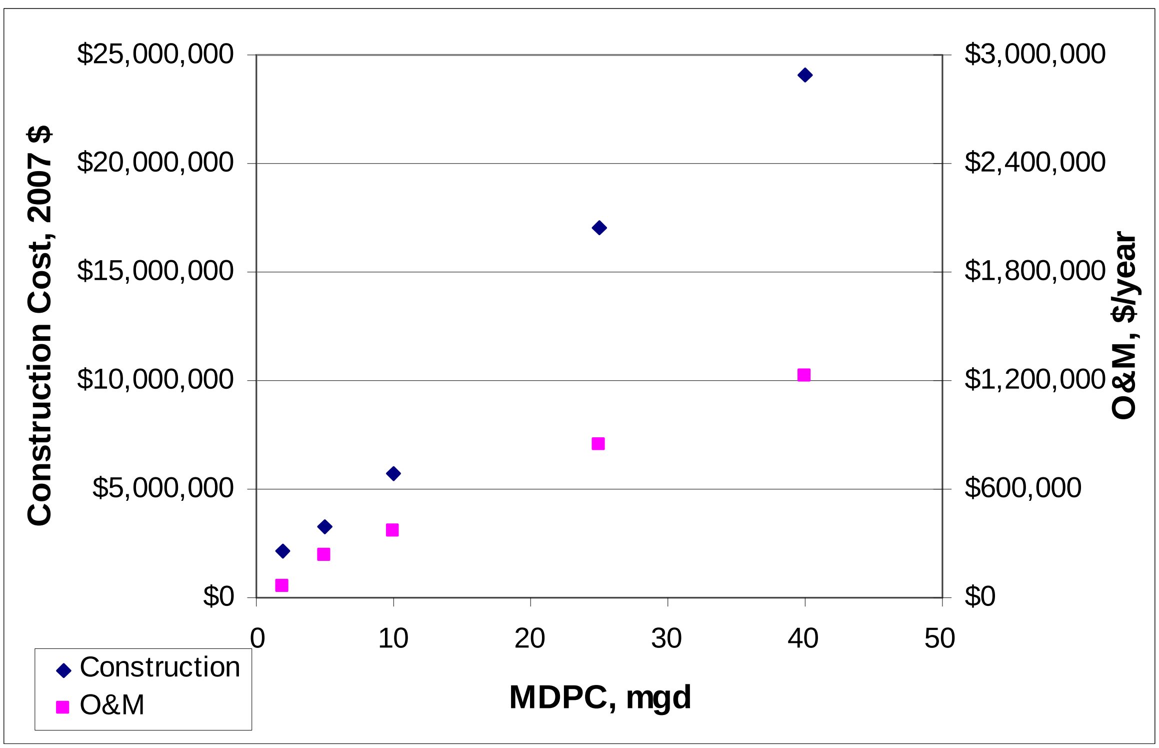

Figure 2.5 Fresh Groundwater Treatment Plant—Construction OPC and O&M.

2.6 Brackish Groundwater Treatment Plant

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The brackish groundwater treatment system was priced for four level of groundwater quality, with TDS concentrations of 750, 1,500, 3,000, and 8,000 mg/L. The system includes the following components:

- Brackish water RO
- Chemical feed systems
- High service pump station
- Clearwell
- Sitework
- Operations and administration building
- Yard piping
- General Requirements

The components are described in more detail in Part 1. It was assumed that iron and manganese in the groundwater would be in a reduced state so pretreatment was not needed for the RO. The costs do not include a ground storage tank. The O&M costs include the following:

- 2 mgd: one operator, one maintenance person, 2 shifts per day, 7 days per week.
- 5 mgd: two operators, one maintenance person, 2 shifts per day, 7 days per week.
- 10 mgd: two operators, two maintenance persons, 3 shifts per day, 7 days per week.
- 25 mgd: two operators, two maintenance persons, 3 shifts per day, 7 days per week.
- 40 mgd: three operators, two maintenance persons, 3 shifts per day, 7 days per week.

O&M costs include electricity consumption and chemical costs. The cost of treating the RO concentrate is not included in the O&M costs. Further information is included in Appendix B-2.6 Brackish Groundwater Background. Tables 2.6.a-d list the costs for the different brackish groundwater treatment plants.

Table 2.6.a. Brackish Groundwater Treatment Plant, 750 mg/L—Construction OPC and O&M.

MDPC, mgd	Construction OPC	O&M, $/year
2	$7,730,000	$855,000
5	$12,040,000	$1,550,000
10	$20,340,000	$2,950,000
25	$42,340,000	$4,590,000
40	$60,730,000	$6,800,000

***NOTES: (1)** General Requirements (8%) has been added to the Construction OPC, as explained in Methods. **(2)** It is recommended that a Construction Markup (Part 1.1.22) be added to all prices.*

Table 2.6.b. Brackish Groundwater Treatment Plant, 1,500 mg/L—Construction OPC and O&M.

MDPC, mgd	Construction OPC	O&M, $/year
2	$9,210,000	$950,000
5	$15,050,000	$1,760,000
10	$25,150,000	$3,320,000
25	$51,660,000	$5,520,000
40	$73,850,000	$8,310,000

***NOTES: (1)** General Requirements (8%) has been added to the Construction OPC, as explained in Methods. **(2)** It is recommended that a Construction Markup (Part 1.1.22) be added to all prices.*

Table 2.6.c. Brackish Groundwater Treatment Plant, 3,000 mg/L—Construction OPC and O&M.

MDPC, mgd	Construction OPC	O&M, $/year
2	$9,950,000	$1,050,000
5	$16,600,000	$2,000,000
10	$27,400,000	$3,770,000
25	$56,000,000	$6,650,000
40	$80,000,000	$10,100,000

***NOTES: (1)** General Requirements (8%) has been added to the Construction OPC, as explained in Methods. **(2)** It is recommended that a Construction Markup (Part 1.1.22) be added to all prices.*

Table 2.6.d. Brackish Groundwater Treatment Plant, 8,000 mg/L—Construction OPC and O&M.

MDPC, mgd	Construction OPC	O&M, $/year
2	$10,420,000	$1,190,000
5	$17,100,000	$2,330,000
10	$28,010,000	$4,390,000
25	$56,680,000	$8,210,000
40	$80,770,000	$12,600,000

NOTES: (1) *General Requirements (8%) has been added to the Construction OPC, as explained in Methods.* ***(2)*** *It is recommended that a Construction Markup (Part 1.1.22) be added to all prices.*

2.7 Conventional Surface Water Treatment Plant

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A conventional surface water treatment plant was based on the Ocklawaha River water quality. This system includes the following components:

- Equalization tank
- High rate flocculation and clarification (Actiflo)
- Deep bed filter
- Transfer pump station
- Chemical feed system
- Residual handling
- High service pump station
- Clearwell
- Operations and administration building
- Sitework
- Yard piping
- General Requirements

The components are described in more detail in Part 1. The costs do not include a ground storage tank. The residuals handling includes gravity thickening basins and dewatering by drying beds for the 2 and 5 mgd, and belt filter presses for the 10, 25, and 40 mgd systems. Further information about the residuals handling and the chemical feed system is included in Appendix B-2.7 Conventional Surface Water Treatment Plant Background. The O&M costs include the following:

- 2 mgd: one operator, one maintenance person, 2 shifts per day, 7 days per week.
- 5 mgd: two operators, one maintenance person, 2 shifts per day, 7 days per week.
- 10 mgd: two operators, one maintenance persons, 3 shifts per day, 7 days per week.
- 25 mgd: two operators, two maintenance persons, 3 shifts per day, 7 days per week.
- 40 mgd: two operators, two maintenance persons, 3 shifts per day, 7 days per week.

O&M costs include electricity consumption and the chemical costs per year. Table 2.7 and Figure 2.7 show the costs for the conventional surface water treatment plant.

Table 2.7 Conventional Surface Water Treatment Plant—Construction OPC and O&M.

MDPC, mgd	Construction OPC	O&M, $/year
2	$11,590,000	$670,000
5	$17,040,000	$1,310,000
10	$22,650,000	$2,200,000
25	$39,250,000	$4,000,000
40	$52,380,000	$5,600,000

***NOTES:* *(1)* *The 2 and 5 mgd plants use drying beds for dewatering, which has a higher maintenance cost than the belt filter presses used for 10, 25, and 40 mgd.* *(2)* *General Requirements (8%) has been added to the Construction OPC, as explained in* Methods*.* *(3)* *It is recommended that a* Construction Markup *(Part 1.1.22) be added to all prices.*

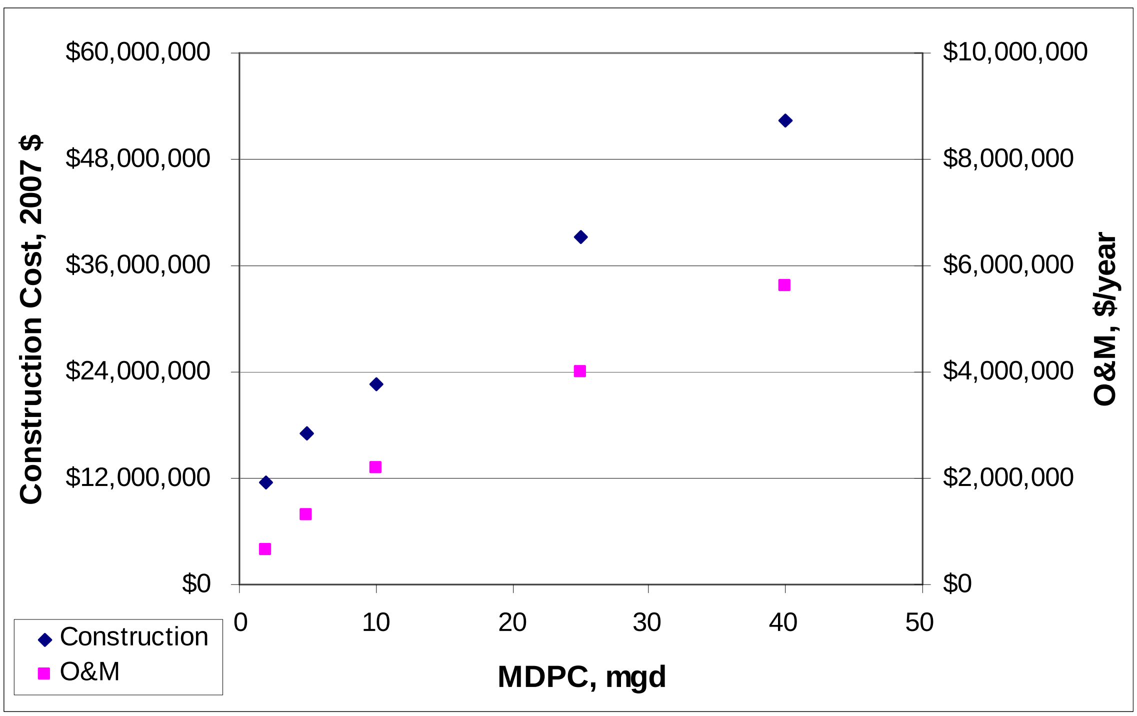

Figure 2.7 Conventional Surface Water Treatment Plant—Construction OPC and O&M.

2.8 Brackish Surface Water Treatment Plant

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The brackish surface water treatment plant cost was based on Lake Monroe water quality data. Further information about both the potable and non-potable portions are included in Appendix B-2.8 Brackish Surface Water Treatment Plant Background.

2.8.1 Brackish Surface Water Treatment for Potable Public Supply

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The cost for a brackish surface water treatment plant for potable public supply was based on Lake Monroe water quality. This system includes the following components:

- Equalization tank
- Plate settlers (flocculation/clarification)
- MF/UF
- Brackish water RO
- Chemical feed system
- Residual handling
- High service pump station
- Operations and administration building
- Clearwell
- Sitework
- Yard piping
- General Requirements

Each of the components is described in more detail in Part 1. The costs do not include a ground storage tank. The residuals handling system includes gravity thickener basins and a belt filter press for dewatering. The 2 mgd system includes a drying bed for dewatering instead of a belt filter press.

The O&M costs include the following:

- 2 mgd: one operator, 2 shifts per day, 7 days per week, one maintenance person, 1 shifts per day, 7 days per week.
- 5 mgd: two operators, 2 shifts per day, 7 days per week, one maintenance person, 1 shifts per day, 7 days per week.
- 10 mgd: two operators, 3 shifts per day, 7 days per week, two maintenance persons, 2 shifts per day, 7 days per week.
- 25 mgd: two operators, 3 shifts per day, 7 days per week, two maintenance persons, 2 shifts per day, 7 days per week.
- 40 mgd: three operators, 3 shifts per day, 7 days per week, three maintenance persons, 2 shifts per day, 7 days per week.

O&M costs include electric power consumption and chemical costs. Additional information is in Appendix B-2.8 Brackish Surface Water Treatment Plant Background. The costs for the conventional surface water treatment plant for potable public supply are presented in Table 2.8.1 and Figure 2.8.1.

Table 2.8.1 Brackish Surface Water Treatment Plant for Potable Public Supply—Construction OPC and O&M.

MDPC, mgd	Construction OPC	O&M, $/year
2	$23,350,000	$1,400,000
5	$33,460,000	$2,770,000
10	$50,480,000	$5,210,000
25	$103,040,000	$10,080,000
40	$140,190,000	$15,710,000

NOTES:* *(1) *The 2 and 5 mgd plants use drying beds for dewatering, which has a higher maintenance cost than the belt filter presses used for 10, 25, and 40 mgd.* ***(2)*** *General Requirements (8%) has been added to the Construction OPC, as explained in Methods.* ***(3)*** *It is recommended that a Construction Markup (Part 1.1.22) be added to all prices.*

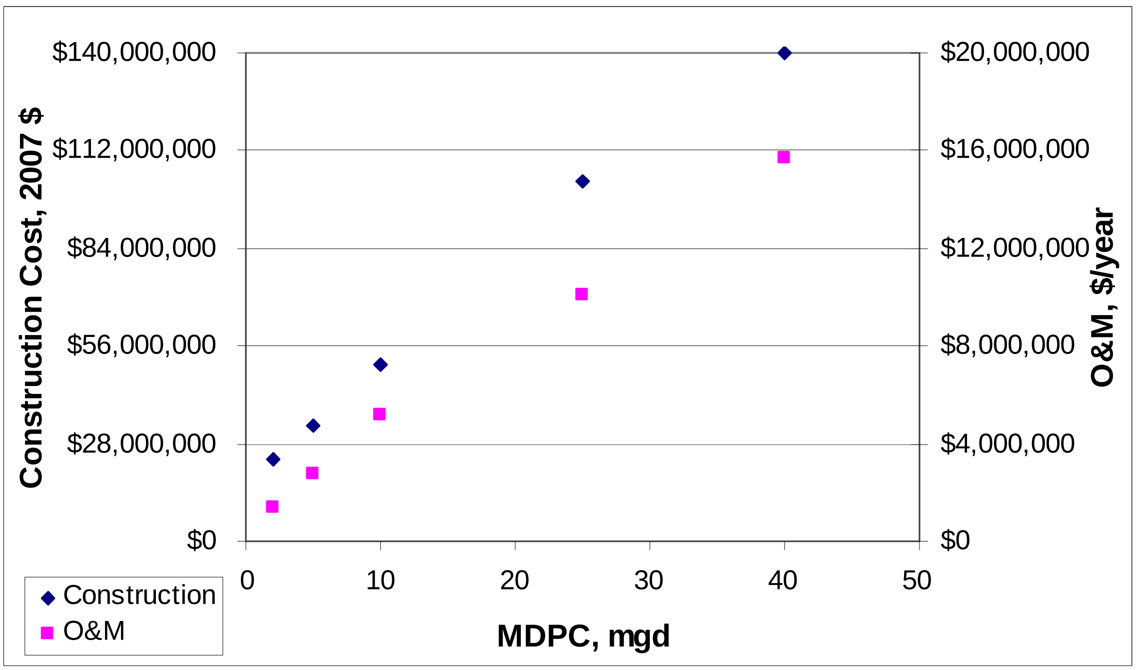

Figure 2.8.1 Brackish Surface Water Treatment Plant for Potable Public Supply—Construction OPC and O&M.

2.8.2 Brackish Surface Water Treatment for Reuse Augmentation

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The cost for brackish surface water treatment plant for reuse augmentation was based on Lake Monroe water quality, with an average turbidity of 5.5 NTU. For water supplies with higher turbidity, a clarification/flocculation process may be required (Part 1.1.2). The components included in this system are as follows:

- Equalization tank
- Deep bed filter
- Chemical feed system
- Transfer pump station
- Residuals handling
- Clearwell
- High service pump station
- Operations and administration building
- Sitework
- Yard piping
- General Requirements

The components are described in more detail in Part 1. The costs do not include a ground storage tank. The residuals handling system includes gravity thickener basins and a belt filter press for dewatering. The 2 mgd system includes a drying bed for dewatering instead of a belt filter press.

The O&M costs include the following:

- 2 mgd: one operator, 2 shifts per day, 7 days per week, one maintenance person, 1 shift per day, 7 days per week.
- 5 mgd: one operator, 3 shifts per day, 7 days per week, one maintenance person, 1 shifts per day, 7 days per week.
- 10 mgd: one operator, 3 shifts per day, 7 days per week, one maintenance person, 1 shifts per day, 7 days per week.
- 25 mgd: one operator, 3 shifts per day, 7 days per week, one maintenance person, 1 shifts per day, 7 days per week.
- 40 mgd: two operators, 3 shifts per day y, 7 days per week, one maintenance person, 1 shifts per day, 7 days per week.

The cost for electric power consumption and chemical consumption are included in the O&M. Additional information is in Appendix B-2.8 Brackish Surface Water Treatment Plant Background. The costs for the conventional surface water treatment plant are presented in Table 2.8.2 and on Figure 2.8.2.

Table 2.8.2 Brackish Surface Water Treatment Plant for Reuse Augmentation—Construction OPC and O&M.

MDPC, mgd	Construction OPC	O&M, $/year
2	$9,980,00	$574,000
5	$12,820,000	$926,000
10	$18,880,000	$1,270,000
25	$35,190,000	$2,280,000
40	$45,670,000	$3,800,000

NOTES:* *(1) *The 2 and 5 mgd plants use drying beds for dewatering, which has a higher maintenance cost than the belt filter presses used for 10, 25, and 40 mgd.* ***(2)*** *General Requirements (8%) has been added to the Construction OPC, as explained in* Methods. ***(3)*** *It is recommended that a* Construction Markup *(Part 1.1.22) be added to all prices.*

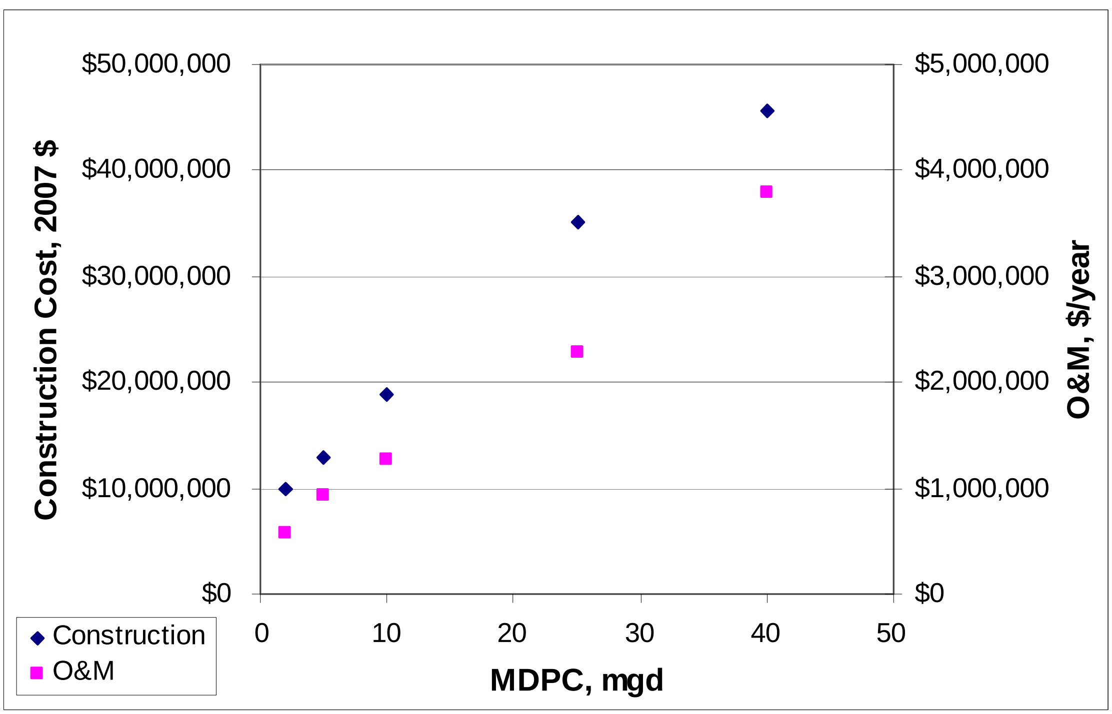

Figure 2.8.2 Brackish Surface Water Treatment Plant for Reuse Augmentation—Construction OPC and O&M.

2.9 Seawater Desalination Plant Co-Located with a Power Plant

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The design of a complete seawater desalination plant, co-located with a power plant, was based on typical ocean water quality. The plant would share an intake and an outfall structure with the power plant, so the cost for these components includes only a connection to the power plant structures. It was assumed that the ocean water would be used as cooling water in the power plant and then be directed to the water treatment plant. The concentrate from the membranes is diluted with the spent power plant cooling water and discharged to the ocean. This system includes the following components:

- Intake structure
- Plate settlers (flocculation and clarification)
- Deep bed filter
- Seawater RO
- Chemical feed system
- Residuals handling
- Operations and administration building
- High service pump station
- Clearwell
- Sitework
- Yard piping
- Outfall shared with power plant
- General Requirements

The components are described in more detail in Part 1. The costs do not include a ground storage tank. The residuals handling system includes gravity thickening basins and dewatering. The 2 and 5 mgd systems include drying beds for dewatering, and the 10, 25, and 40 mgd systems include belt filter presses for dewatering. Appendix B-2.9 and 2.10 Seawater Desalination Plant Background includes further information about the residuals handling.

The O&M costs include the following:

- 2 mgd: two operators and one maintenance person, 2 shifts per day, 7 days per week.
- 5 mgd: two operators and one maintenance person, 2 shifts per day, 7 days per week.
- 10 mgd: three operators and two maintenance persons, 3 shifts per day, 7 days per week.
- 25 mgd: three operators and two maintenance persons, 3 shifts per day, 7 days per week.
- 40 mgd: four operators and three maintenance persons, 3 shifts per day, 7 days per week.

O&M costs include electricity consumption and chemical costs. The costs for the seawater desalination plant are presented in Table 2.9 and on Figure 2.9.

Table 2.9 Seawater Desalination Plant Co-Located with a Power Plant—Construction OPC and O&M.

MDPC, mgd	Construction OPC	O&M, $/year
2	$28,920,000	$2,460,000
5	$53,360,000	$4,520,000
10	$83,130,000	$9,220,000
25	$161,570,000	$19,360,000
40	$228,160,000	$30,370,000

***NOTES: (1)** The 2 and 5 mgd plants use drying beds for dewatering, which has a higher maintenance cost than the belt filter presses used for 10, 25, and 40 mgd. **(2)** General Requirements (8%) has been added to the Construction OPC, as explained in Methods. **(3)** It is recommended that a Construction Markup (Part 1.1.22) be added to all prices.*

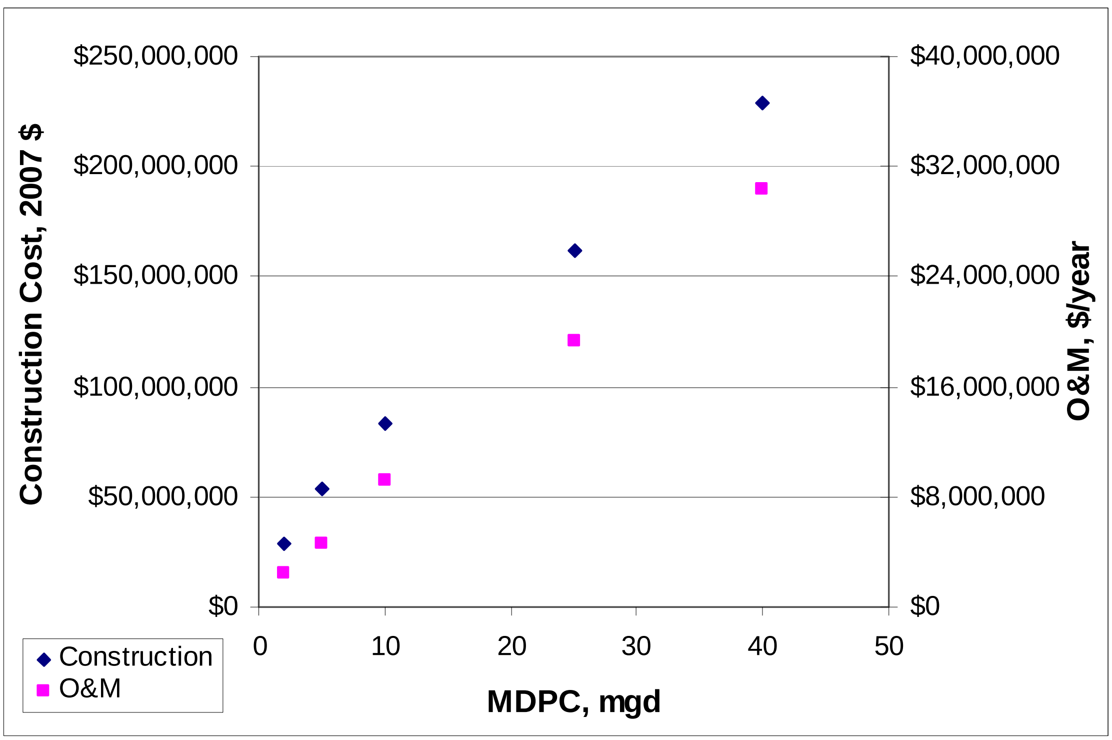

Figure 2.9 Seawater Desalination Plant Co-Located with a Power Plant—Construction OPC and O&M**.**

2.10 Seawater Desalination Plant

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The design for a seawater desalination plant was based on typical ocean water quality. The plant has a subsurface intake structure located 1 mile off-shore. The intake structure is made of coated concrete, with stainless steel piping. A pipe connects the intake structure to a screening and pumping station which conveys the raw water to the desalination plant. The RO concentrate and wastewater from the plant are returned to the ocean through an outfall pipe with diffusers located 1.73 miles (1.5 nautical miles) offshore. Appendix B-2.9 and 2.10 Seawater Desalination Treatment Plant Background includes a list of assumptions and further information. This system includes the following components:

- Offshore ocean intake
- Plates settlers (flocculation/clarification)
- MF/UF
- Seawater RO
- Chemical feed system
- High service pump station
- Operations and administration building
- Residuals handling
- Clearwell
- Sitework
- Yard piping
- Ocean outfall
- Bathymetric study
- General Requirements

The components are described in more detail in Part 1. The costs do not include a ground storage tank. The residuals handling includes gravity thickening basins with a dewatering system. The 2 and 5 mgd systems have drying beds for dewatering and the 10, 25, and 40 mgd systems have belt filter presses for dewatering. The O&M costs include the following:

- 2 mgd: two operators and one maintenance person, 2 shifts per day, 7 days per week.
- 5 mgd: two operators and one maintenance person, 2 shifts per day, 7 days per week.
- 10 mgd: three operators and two maintenance persons, 3 shifts per day, 7 days per week.
- 25 mgd: three operators and two maintenance persons, 3 shifts per day, 7 days per week.
- 40 mgd: four operators and three maintenance persons, 3 shifts per day, 7 days per week.

O&M costs include electric power consumption and chemical costs. The costs for the desalination plant are presented in Tables 2.10.a-c and on Figure 2.10 show.

Table 2.10.a Intake—Construction OPC and Maintenance.

MDPC mgd	Raw Water, mgd	Offshore Intake	Ocean Pipeline	Pump and Screening Station	Subtotal	Maintenance $/year
2	5	$610,000	$2,110,000	$838,000	$3,840,000	$67,100
5	12.4	$617,000	$3,170,000	$1,210,000	$5,390,000	$96,800
10	24.9	$641,000	$5,070,000	$1,760,000	$8,070,000	$141,000
25	62.2	$692,000	$7,600,000	$2,490,000	$11,650,000	$199,000
40	99.6	$728,000	$8,870,000	$3,250,000	$13,870,000	$260,000

***NOTES: (1)** General Requirements (8%) has been added to the Construction OPC, as explained in Methods. **(2)** It is recommended that a Construction Markup (Part 1.1.22) be added to all prices.*

Table 2.10.b Outfall—Construction OPC and Maintenance.

MDPC, mgd	Subtotal	Maintenance, $/year
2	$3,170,000	$64,000
5	$4,750,000	$95,000
10	$7,130,000	$143,000
25	$10,700,000	$214,000
40	$13,080,000	$262,000

***NOTES**: **(1)** Outfall pipe is assumed to be HDPE. **(2)** General Requirements (8%) has been added to the Construction OPC, as explained in Methods. **(3)** It is recommended that a Construction Markup (Part 1.1.22) be added to all prices.*

Table 2.10.c Seawater Desalination Plant—Construction OPC and O&M.

MDPC, mgd	Construction OPC	O&M, $/year
2	$46,530,000	$2,840,000
5	$77,510,000	$5,260,000
10	$119,770,000	$10,550,000
25	$236,790,000	$22,360,000
40	$323,440,000	$34,860,000

***NOTES: (1)** The 2 and 5 mgd plants include drying beds, which have a higher maintenance cost than the belt filter presses in the 10, 25, and 40 mgd plants. **(2)** General Requirements (8%) has been added to the Construction OPC, as explained in Methods. **(3)** It is recommended that a Construction Markup (Part 1.1.22) be added to all prices.*

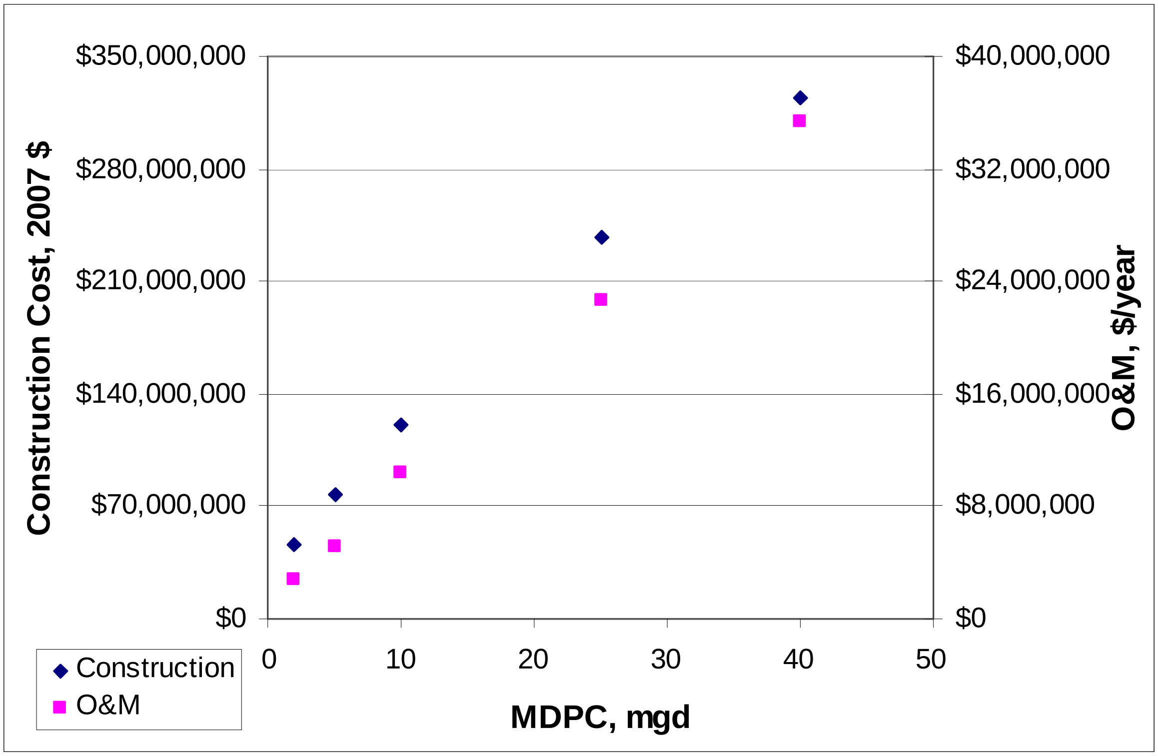

Figure 2.10 Seawater Desalination Plant—Construction OPC and O&M**.**

2.11 Modifications to an Existing Wastewater Treatment Plant

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The design of modifications to an existing wastewater treatment plant was based on the FDEP regulations pertaining to wastewater effluent. Residuals handling is not included in the cost tables presented in Part 2.11, as it was assumed that all wastes would be recycled to the wastewater treatment plant and treated there.

An operations and administration building was not included, it was assumed the building would be a part of the existing wastewater treatment plant. Similarly, the O&M cost does not include the services of an operator or maintenance person as it as assumed personnel from the wastewater treatment plant would be performing this work. Two scenarios were considered for modifying a wastewater treatment plant.

2.11.1 Modifications to Meet Public Access for Reuse

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Modifications of a wastewater treatment plant to meet public access for reuse standards were based on FDEP requirements in FAC 62-600.420. It is assumed that the filter backwash is circulated to the head of the wastewater treatment plant. It was also assumed that the wastewater is conveyed to the cloth media filter and then disinfected at the existing wastewater treatment plant. Background information was deemed unnecessary. The system will include the following:

- Cloth media filter
- Sitework
- Yard piping
- General Requirements

Aqua Aerobics aided in determining the cost of the cloth media filter, as included in Appendix C. The O&M cost consists of electric power consumption. Labor costs for O&M were not included, as it was assumed no additional personnel would be required. The costs for modifying a wastewater treatment plant to public access for reuse standards are presented in Table 2.11.1 and on Figure 2.11.1.

Table 2.11.1 Modifications to Meet Public Access for Reuse—Construction OPC and O&M.

MDPC, mgd	Construction OPC	O&M, $/year
2	$600,000	$3,600
5	$900,000	$5,800
10	$1,450,000	$10,300
25	$3,470,000	$24,400
40	$4,610,000	$33,600

NOTES: (1) *General Requirements (8%) has been added to the Construction OPC, as explained in Methods.* ***(2)*** *It is recommended that a Construction Markup (Part 1.1.22) be added to all prices.*

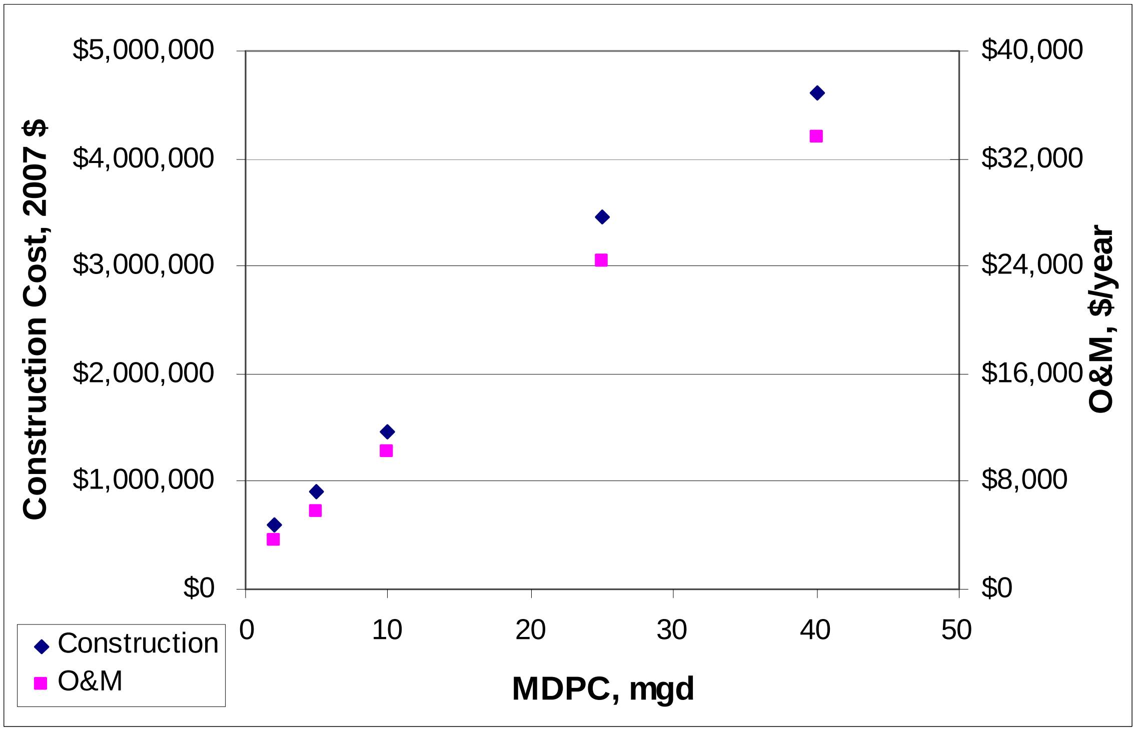

Figure 2.11.1 Modifications to Meet Public Access for Reuse—Construction OPC and O&M.

2.11.2 Modifications to Meet Wekiva River Protection Zone Standards

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Modifications of a wastewater treatment plant to meet Wekiva River Protection Zone standards were based on FDEP requirements in FAC 62-600.550. It was assumed that the filter backwash is circulated to the head of the wastewater treatment plant. It was also assumed that the wastewater is diverted to the denitrifying filter and then disinfected at the existing wastewater treatment plant. Background information was deemed unnecessary. The components included in this system are as follows:

- Denitrifying filter
- Methanol feed system (building not included)
- Sitework
- Yard piping
- General Requirements

The costs do not include a ground storage tank. The O&M costs include annual chemical costs and electric power consumption. Labor costs were not included for O&M, as it was assumed no additional personnel would be needed. The costs of the modifications to meet Wekiva River Protection Zone Standards are presented in Table 2.11.2 and on Figure 2.11.2.

Table 2.11.2 Modifications to Meet Wekiva River Protection Zone Standards—Construction OPC and O&M.

MDPC, mgd	Construction OPC	O&M, $/year
2	$1,480,000	$39,000
5	$2,840,000	$84,000
10	$4,880,000	$133,000
25	$10,430,000	$303,000
40	$14,740,000	$460,000

NOTES:* *(1) *General Requirements (8%) has been added to the Construction OPC, as explained in Methods.* ***(2)*** *It is recommended that a Construction Markup (Part 1.1.22) be added to all prices.*

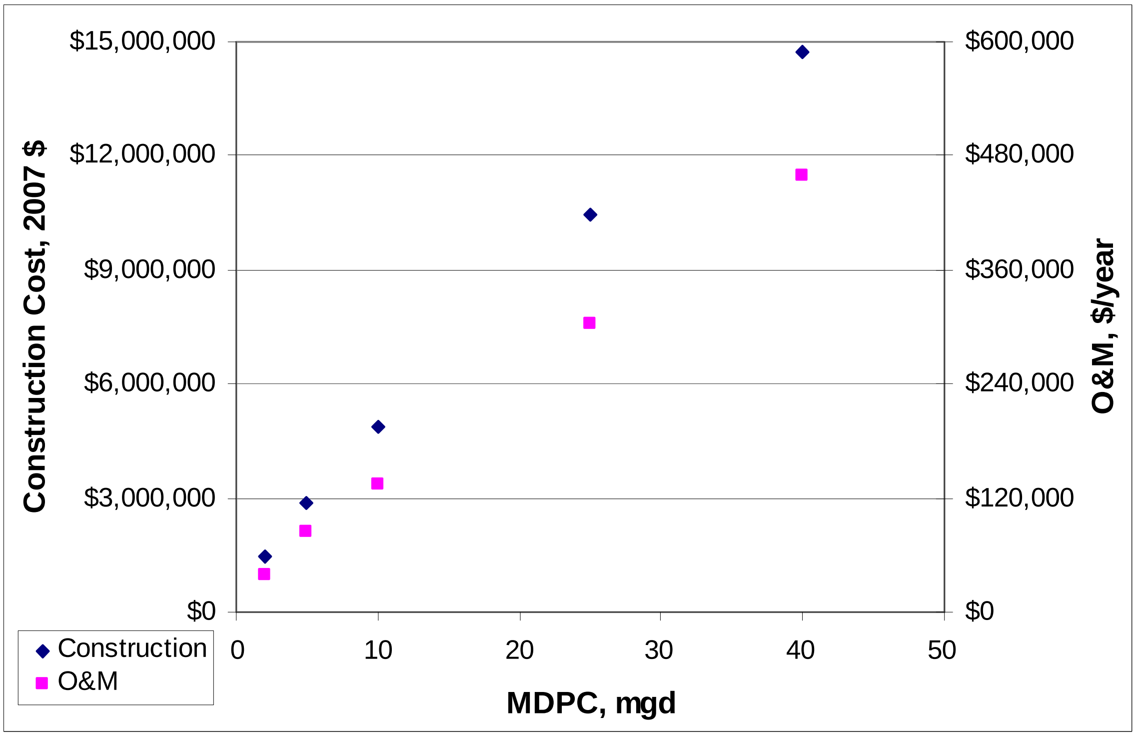

Figure 2.11.2 Modifications to Meet Wekiva River Protection Zone Standards—Construction OPC and O&M.

2.12 Reclaimed Water Storage Ponds

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Reclaimed water storage ponds were sized according to the guidelines of the Water Reuse Foundation (WRF). More information on reclaimed storage ponds can be found in Appendix B-2.12 Reclaimed Water Storage Ponds Background. The costs include the following:

- One pond for each capacity
- Synthetic liner of HDPE
- Emergency spillway
- Sidewater depth of 7 ft
- Maximum pond depth of 10 ft
- Stormwater diversion system
- Mobilization/demobilization
- Excavation and sitework
- Site restoration and sodding
- Asphalt-paved access roads
- Overflow and diversion structures
- General Requirements

As noted in Methods, land costs were not included. The site area required for the storage ponds, which include the ponds, berms, access roads, and stormwater diversion systems, along with the construction and O&M costs is included in Table 2.12. The area does not include a setback or right-of-way from the road as those distances are site-specific and will vary with the selected capacity. O&M costs include probable costs for compliance monitoring, berm inspection, mowing, and road maintenance. The costs are presented graphically on Figure 2.12.

Table 2.12 Reclaimed Water Storage Ponds—Construction OPC and O&M.

Max. Capacity, Mgal	Site Area Required, acres	Construction OPC	O&M, $/year
2	1.7	$500,000	$25,000
5	7.3	$1,250,000	$56,300
10	13.8	$2,250,000	$90,000
25	26.5	$5,250,000	$125,000
40	43.5	$8,000,000	$160,000

NOTE: *It is recommended that a Construction Markup (Part 1.1.22) be added to all prices.*

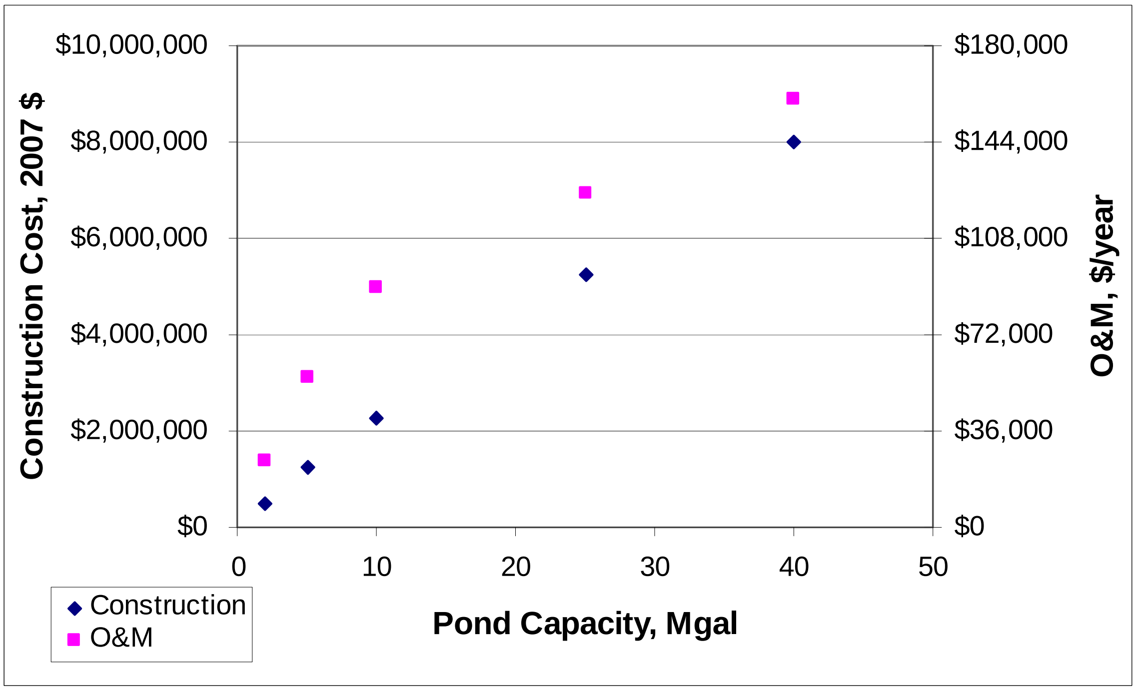

Figure 2.12 Reclaimed Water Storage Ponds—Construction OPC and O&M.

2.13 Rapid Infiltration Basin System

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Rapid infiltration basins (RIBs) were sized based on the assumption of highly pervious sandy soil and an infiltration rate of 3 inches per day. More information on the RIBs can be found in Appendix B-2.13 Rapid Infiltration Basin System Background. Costs include the following:

- Mobilization/demobilization
- Excavation and sitework
- Site restoration and sodding
- Stormwater swales
- Asphalt-paved access roads
- Overflow and diversion structures
- General Requirements

As noted in Methods, land costs were not included. However, the site area required for the RIBs, along with the construction and O&M costs, is included in Table 2.13. O&M costs include probable costs for compliance monitoring, berm inspection, mowing, and road maintenance. The costs are shown graphically on Figure 2.13.

Table 2.13 Rapid Infiltration Basin System—Construction OPC and O&M.

Maximum Capacity mgd	Total Surface Area, acres	No. of Basins	Construction OPC	O&M, $/year
2	28	3	$3,300,000	$132,000
5	68	3	$8,200,000	$287,000
10	134	4	$16,400,000	$492,000
25	330	6	$41,000,000	$820,000
40	530	8	$65,500,000	$983,000

NOTE: *It is recommended that a* Construction Markup *(Part 1.1.22) be added to all prices.*

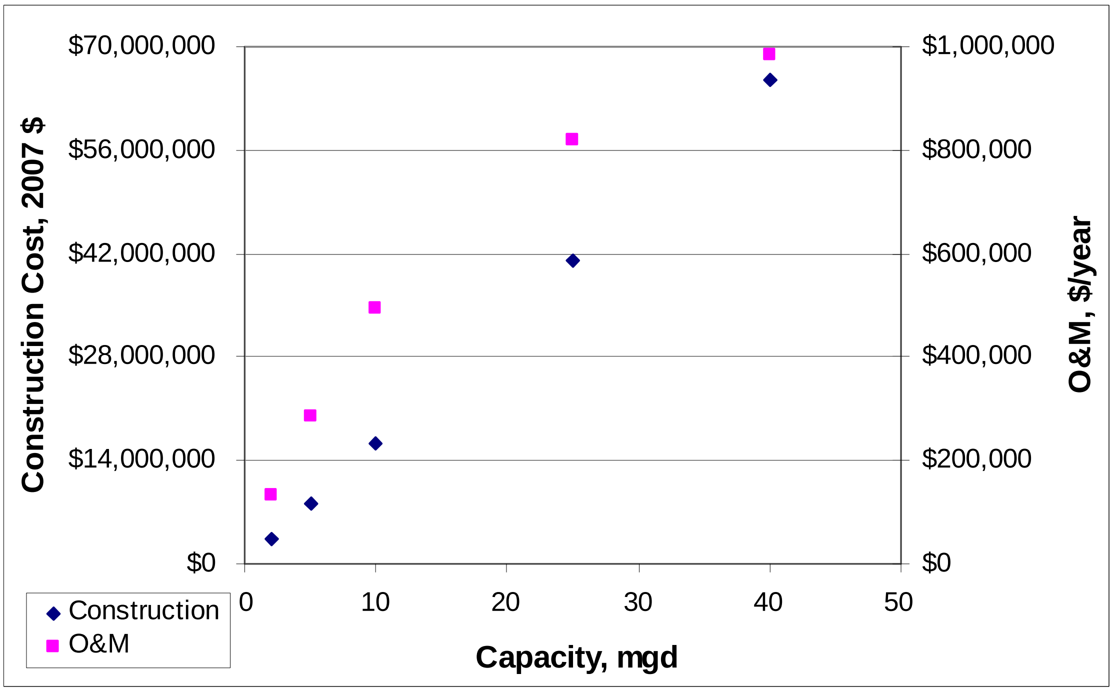

Figure 2.13 Rapid Infiltration Basin System—Construction OPC and O&M.

2.14 Surface Water Intake

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The surface water intake consists of an intake pipe, screens, and a pumping station. For the 2 and 5 mgd plants, the intake consists of a triplex installation with two continuous duty pumps and one standby unit. The system for the 10, 25, and 40 mgd plants consists of three continuous duty pumps and one standby unit. Figure B-1.1.1.a and Figure B-1.1.1.b are sketches of the systems and are included in Appendix B-1.1.1 Raw Water Pumping Background.

Surface water pumping costs include the following:

- Discharge riser/header piping
- Suction riser/header piping
- Valving
- Vertical turbine pumps and motors
- Fine intake screens
- Water pressure gauge
- Fencing
- Flowmeters
- Air backwash system
- Pump station building
- Local electrical and I&C
- General Requirements

The costs are listed in Table 2.14 and shown on Figure 2.14. The O&M costs include annual electric power consumption.

Table 2.14 Surface Water Intake—Construction OPC and O&M.

Intake Capacity mgd	Intake Capacity cfs	Construction OPC	O&M, $/year
2	3.09	$3,110,000	$12,700
5	7.74	$3,810,000	$24,300
10	15.5	$6,040,000	$43,100
25	38.7	$7,710,000	$77,100
40	61.9	$8,540,000	$116,100

NOTES: (1) *General Requirements (8%) has been added to the Construction OPC, as explained in Methods.* ***(2)*** *It is recommended that a Construction Markup (Part 1.1.22) be added to all prices.*

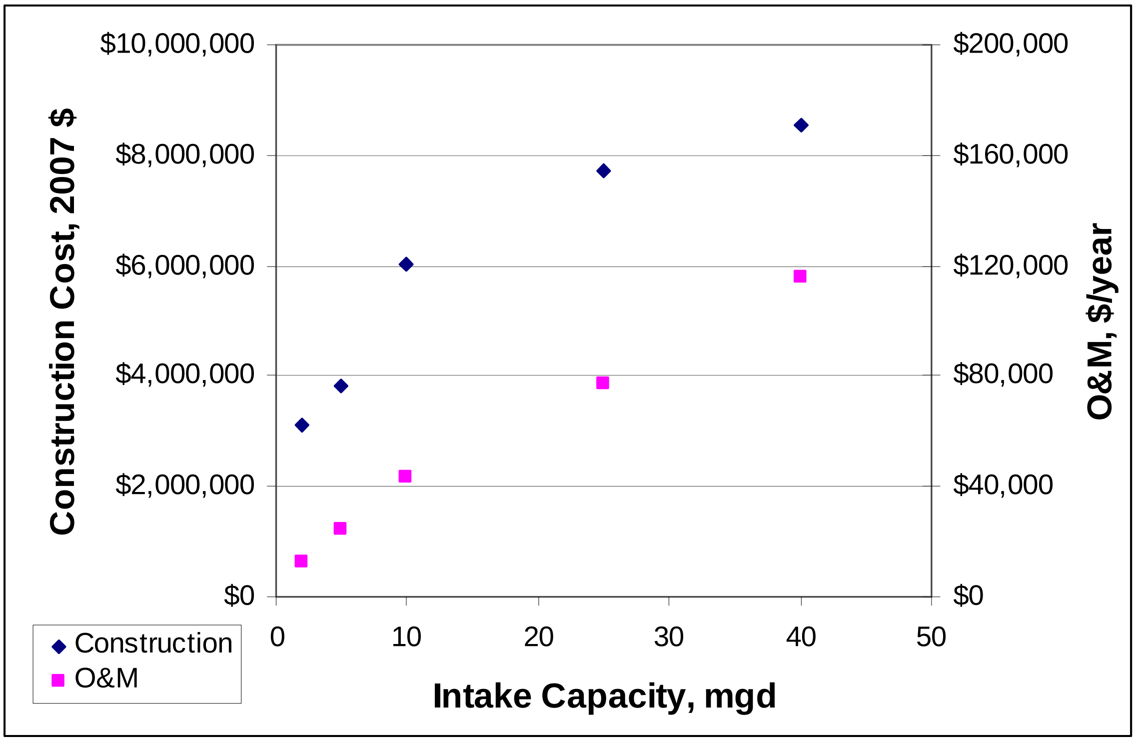

Figure 2.14 Surface Water Intake—Construction OPC and O&M.

2.15 Injection Well System

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The injection well system costs were based on drilling one well, and emergency storage tank for 24 hours' of flow. The well construction costs are based on Class I injection well standards using a mud rotary drilling method to a depth of 3,000 ft and a casing depth of 2,500 ft. The cost of the double casing assumes either 0.50 inch wall seamless steel casing or 0.312 inch wall 2205 duplex steel. The construction costs include the following:

- Emergency 24-hour storage tank
- Pump and motor
- One dual zone monitoring well
- Double well casing
- Geophysical logging
- Water quality sampling
- Well development and pump testing
- General Requirements

The O&M costs for the well include wellhead maintenance and rehabilitation by acidizing every 5 years, monitoring and reporting, and mechanical integrate testing (MIT) every 5 years. The pump O&M cost includes emergency power supply, semiannual vibration analysis, semiannual thermography of electrical components, semiannual lubricant analysis, water operations permit compliance, and replacement of impellers and bearings. It was assumed that a two-person maintenance crew would come check the pump and well every quarter. The O&M cost includes electric power consumption.

Table 2.15 Injection Well—Construction OPC and O&M.

Injection well, mgd	No. of Wells	Well Drilling	Emergency Storage Tank[1]	Construction OPC	O&M, $/year
1	1	$4,100,000	$470,000	$5,020,000	$88,000
3	1	$4,500,000	$960,000	$6,000,000	$149,000
5	1	$4,900,000	$1,380,000	$6,930,000	$251,000
10	1	$5,500,000	$2,410,000	$8,810,000	$555,000

NOTES:* *(1) *The emergency storage tank was sized to hold 1, 3, 5, and 10 Mgal.* ***(2)*** *General Requirements (8%) has been added to the Construction OPC, as explained in Methods.* ***(3)*** *It is recommended that a Construction Markup (Part 1.1.22) be added to all prices.*

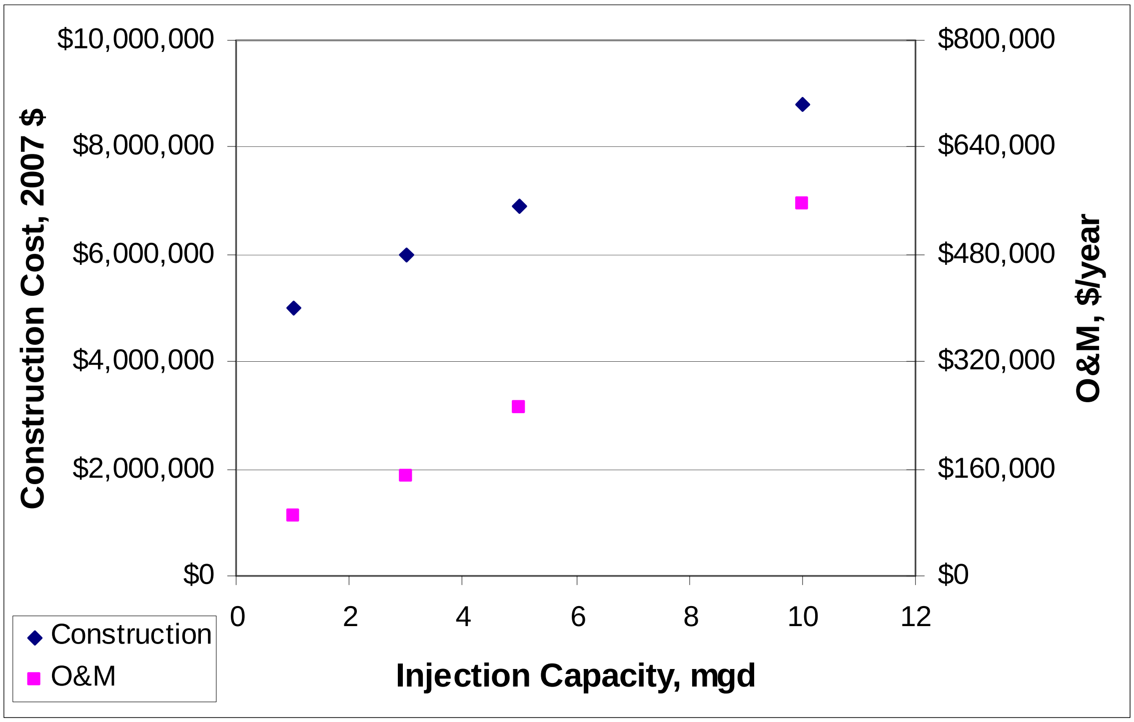

Figure 2.15 Injection Well—Construction OPC and O&M.

Appendices

Appendix A: Water Quality Information

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Brackish Groundwater Water Quality

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	Maximum	Average	Minimum
Dissolved Oxygen, mg/L	8.3	3.57	0.10
pH	9.80	7.32	4.40
SpC, lab, µS/cm	1270	447	170
SpC, field, µS/cm	47,100	1,074	3
Temperature, °C	30	23.7	15.7
Calcium, mg/L	800	67.2	0.30
Alkalinity, mg/L	452	119	3

NOTE*: pH given in standard units, SpC is specific conductance.*

Adamski, James C. and Leel Knowles, Jr. *Groundwater Quality of the Surficial Aquifer System and the Upper Floridan Aquifer, Ocala National Forest, and Lake County, Florida*. USGS: 2001.

Phelps, G.G. *Chemistry of Ground Water in the Silver Springs Basin, Florida, with an Emphasis on Nitrate*s. USGS: 2004.

Phelps, G.G. *Geochemistry and Origins of Mineralized Waters in the Floridan Aquifer System, Northeastern Florida*. USGS: 2001.

Lake Monroe Water Quality Data

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	Lake Monroe		
	St. Johns River at Sanford		
	Average	**Maximum**	**Minimum**
Temperature, degrees Celsius	25	32.3	10.1
pH	7.5	8.9	6.8
Alkalinity, mg/L as $CaCO_3$	68	108	38
Conductivity, S/m	124	235	41
Total Dissolved Solids, mg/L	753	1400	278
Turbidity, NTU	5.5	45	0.9
Total Suspended Solids, mg/L	19	140	1
DOC, mg/L	20	33	4
Color, Pt-Co	119	320	10
UVA254, cm^{-1}	0.81	1.69	0.15
UVT, percent	15%	2%	71%
Barium (dissolved), ug/L	29	45	16
Barium (total), ug/L	33	51	18
Bromide (dissolved), mg/L	1	2	0.4
Calcium (dissolved), mg/L	53	89	24
Calcium (total), mg/L	61	87	31
Chloride (dissolved), mg/L	285	560	81
Hardness (total), mg/L as $CaCO_3$	230	390	89
Iron (dissolved), ug/L	140	518	3
Iron (total), ug/L	306	1400	55
Magnesium (dissolved), mg/L	22.3	40	6.9
magnesium (total), mg/L	27	39	14
Potassium (dissolved), mg/L	7.1	12	3.8
Silica (dissolved), mg/L	5	12	0.1
Sodium (dissolved), mg/L	158	300	44
Strontium (dissolved), ug/L	1300	2400	550
Strontium (total), ug/L	1495	2300	690
Sulfate (dissolved), mg/L	90	200	8
Sulfide (total), mg/L as Sulfur	1	3	<1

***NOTES: (1)** $CaCO_3$ is calcium carbonate, NTU is nephelometric turbidity units, Pt-Co is platinum-cobalt scale. **(2)** Data is from USGS biweekly grab samples (January 2000 to August 2002) and daily grab samples by CH2M Hill (August 2001 to April 2003). A severe drought affected the region for the first 18 months of sampling followed by the rainy season.*

CH2M Hill. *Surface Water Treatability and Demineralization Study*. SJRWMD Special Publication SJ2004-SP20.

Ocean Water Quality Data

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Element	Concentration, mg/L Typical
Chlorine	18,980
Sodium	10,561
Magnesium	1,272
Sulfur	884
Calcium	400
Potassium	380
Bromine	65
Carbon (inorganic)	28
Strontium	13
Silicon Oxide	0.0-7.0
Boron	5
Silicon	0.02-4.0
Carbon (organic)	1.2-3.0
Aluminum	0.16-0.19
Fluoride	1.4
Nitrogen (as nitrate)	0.001-0.7
Nitrogen (as organic nitrogen)	0.03-0.2
Rubidium	0.2
Lithium	0.1
Phosphorus (as phosphate)	>0.001-0.10
Barium	0.05
Iodine	0.05
Nitrogen (as nitrite)	0.0001-0.05
Nitrogen (as ammonia)	>0.005-0.05
Arsenic	0.003-0.024
Iron	0.002-0.02
Phosphorus (as organic phosphate)	0-0.016
Zinc	0.005-0.014
Copper	0.001-0.09
Manganese	0.001-0.01
Lead	0.004-0.005
Selenium	0.004
Tin	0.003
Cesium	0.002
Uranium	0.00015-0.0016
Molybdenum	0.0003-0.002

Ocean Water Quality Data (continued)

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Element	Concentration, mg/L Typical
Gallium	0.0005
Nickel	0.0001-0.0005
Thorium	<0.0005
Cerium	0.0004
Vanadium	0.0003
Lanthanum	0.0003
Yttrium	0.0003
Mercury	0.00003
Silver	0.00015-0.0003
Bismuth	0.0002
Cobalt	0.0001
Scandium	0.00004
Gold	0.000004-0.000008

Handbook of Chemistry and Physics, 82nd Edition. Editor David R. Lide. CRC Press: 2001.

Ocklawaha River Water Quality Data

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Data summarized from the District website, “Watershed Facts: Ocklawaha River”, found at: http://www.sjrwmd.com/archydro/factPages/20020012.html#waterquality.

Analytes	Data Years	Minimum	Median	Maximum
pH (standard units)	10	6.43	7.61	8.17
total alkalinity (mg/L as $CaCO_3$)	10	80.1	154	170
total nonfiltrable residue (mg/L)	10	0	4	21
total organic carbon (mg/L as C)	10	1.6	5.5	40
total filtrable residue (mg/L dried, 180°C)	10	160	258	416
lab turbidity (NTU)	3	0.45	1.6	4.2
hardness (mg/L Ca+Mg)	10	127	211	270

Orange County, Florida, Groundwater Quality Data

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One hundred percent of the flow was treated from a hardness concentration of 350 mg/L to 150 mg/L.

Source: City of Lakeland Water Treatment Plant, Lakeland, Florida.

Appendix B: Background Information

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B-1.1.1 Raw Water Pumping Background

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Overall assumptions for raw water pumping, based on standard practice, are listed below:

1. Velocity of 5 fps.
2. Operating cost includes electricity (only for Part 2.14, Surface Water Intake).
3. Maintenance cost includes the cost of repairs (e.g., impellers, seals, bearings), pumping tests, and oil changes.

Groundwater

Costs were determined for flows of 2, 3, 5, 6.5, and 10 mgd for Part 1.1.1.1 and 2, 5, 10, 25, and 40 mgd for Part 2.1. It was assumed that the required lifting head from the ground surface to the water treatment plant was 25 ft at all flows. A total head of 100 ft was assumed. Pump and motor costs are from inflation-adjusted historical bid data on file at B&V. Figure B-1.1.1.a shows a typical pump used in Florida, with all the components listed in the opinion of cost.

Surface Water

The surface water intake system was built for redundancy. As indicated on Figure B-1.1.1.c and B-1.1.1.d, a triplex pump station was used for the 2 and 5 mgd systems, and a quadruplex station for the 10, 25, and 40 mgd systems. Each pump station includes one standby pump. Isolation valves allow one arm of the intake to be isolated for maintenance, if required.

Design of the pump stations was guided by information from the Hydraulic Institute, limiting the maximum suction velocity to 4 fps and the overall minimum velocity to 2 fps. The maximum velocity for all other pipes was set at 5 fps. The layout was established by experience and by knowledge of local conditions. The discharge riser was taken as a minimum of 5 times the pipe diameter or 10 feet, whichever was greater. The center of the intake pipe was designed to be located 10 feet below the water level in the river, allowing for fluctuation of flow without endangering the pumps.

The screens on the intakes were based on costs from Johnson Screens stainless steel, No. 69, triangular profile wire screens with a maximum slot width of 2 millimeters. Production information is listed in Appendix C. The intakes will be cleaned by an air backwash system. The air backwash system includes rotary screw air compressors, an air receiver consisting of a welded steel tank, valves, and a control panel.

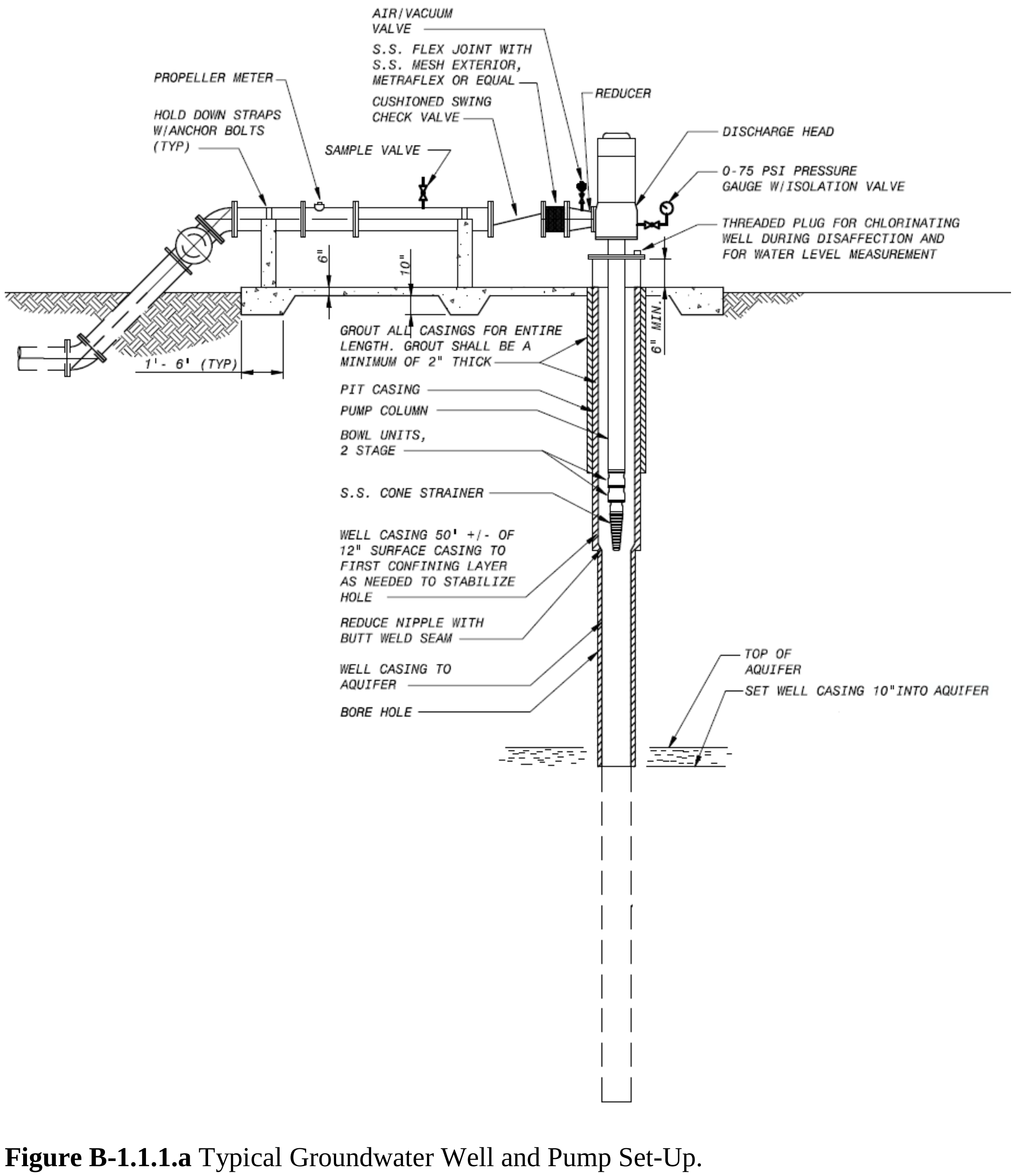

Figure B-1.1.1.a Typical Groundwater Well and Pump Set-Up.

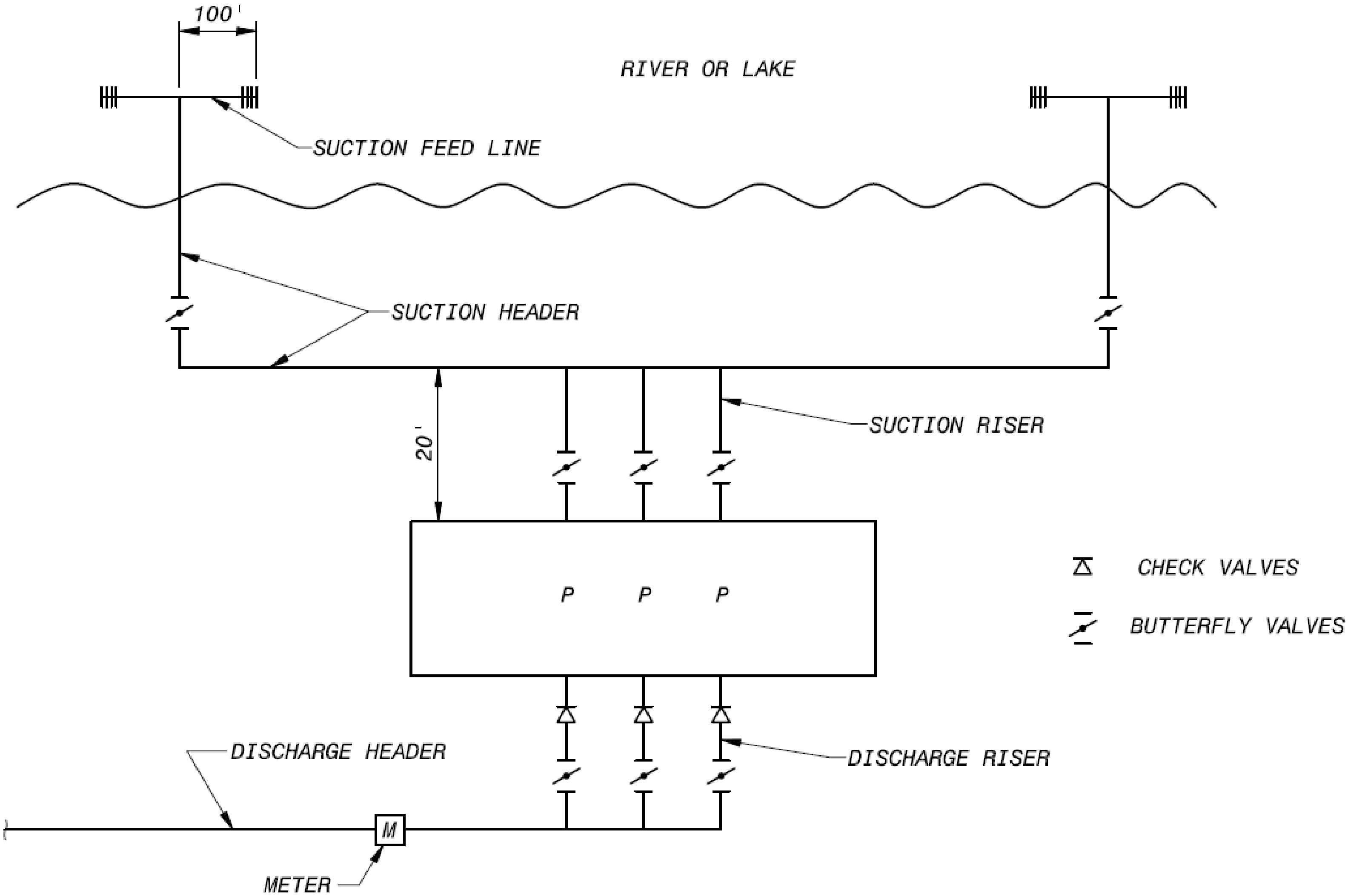

Figure B-1.1.1.b Surface Water Intake for Triplex System.

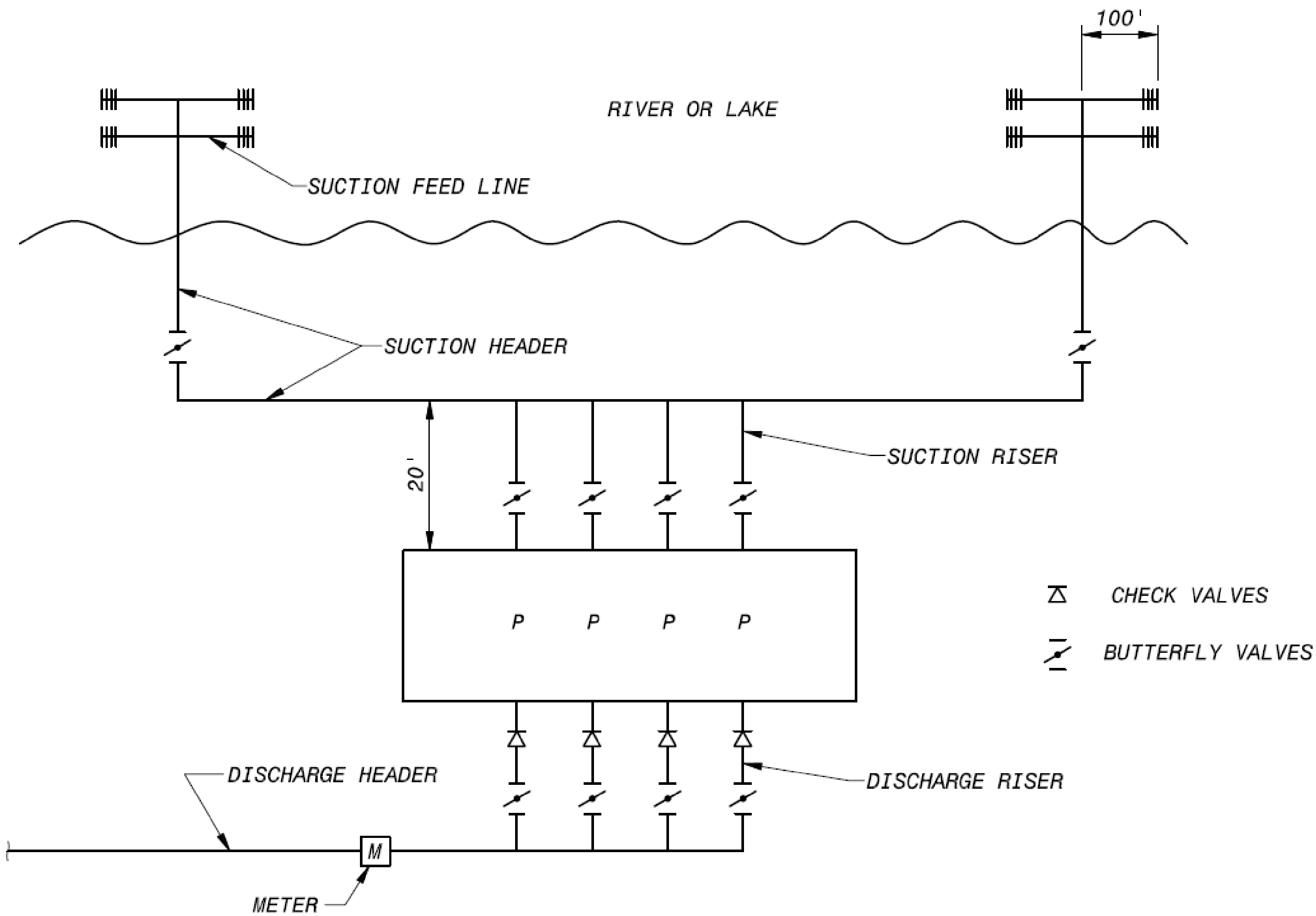

Figure B-1.1.1.c Surface Water Intake for Quadruplex System.

B-1.1.2 High-Rate Flocculation/Clarification Background

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One type of ultra-high rate flocculation/clarification system is the ballasted flocculation or Actiflo clarifier, which uses microsand and polymer to weight the floc to cause it to rapidly settle. Tube settlers are used to provide a compact clarification system.

The Actiflo system consists of four tanks: (1) rapid mixing, (2) sand injection, (3) maturation, and (4) sedimentation. A coagulant is added to the flow in the rapid mixing tank; microsand and polymer are added and mixed into the coagulated water in the sand injection tank; in the maturation tank the floc agglomerates under gentle mixing; and in the sedimentation tank fitted with tube settlers, the sludge is allowed to settle. The Actiflo clarifier is usually designed for a flow of 20-30 gpm/sq ft for low turbidity waters. This loading rate allows a very compact facility layout. The settled sludge collected from the bottom of the sedimentation basin is pumped to a hydroclone where the microsand is separated from the sludge and recirculated to the mixing tank for reuse.

The proposed design includes two Actiflo units, regardless of plant capacity. For maximum plant capacity, the design loading rate is 15 gpm/sf. Therefore with one unit out of service, the loading rate would be 30 gpm/sf. Design flow can be accommodated with one basin out of service; however, treatment may degrade, as the mixing energy and flocculation contact times would be shorter. Overloading the system during periods when one unit is out of service, must be discussed with the Florida regulatory agency to confirm that the design meets minimum redundancy requirements. Designs of systems incorporating more than two units may be considered during preliminary design. The design includes redundancy of equipment in the form of multiple hydrocyclones and solids pumps.

The Actiflo system is proprietary, which precludes competitive bidding. The supplier, Kruger, provided estimates of equipment costs, which include the mixers, hydrocyclones, mechanical scraper, motors, solids pumps, and startup services. The typical hydraulic retention times were used to calculate the dimensions of the basin, which were then used to determine the volume of concrete. The units will be located outdoors and will include a cover over the sedimentation tank to discourage algae growth. A summary of the design and the estimated cost for the process is listed in Table B-1.1.2.

Table B-1.1.2 Actiflo Process Design Assumptions.

Unit Process Flow, mgd	Number of Units	Basin Complex Footprint, sq ft	Single Basin Dimensions, ft (L x W x H)
0.5*	2	450	30 x 14 x 20
2*	2	900	38 x 22 x 20
5	2	1,500	50 x 28 x 20
10	2	2,200	60 x 36 x 20
25	2	4,500	80 x 56 x 20
40	2	6,300	95 x 66 x 20

NOTE: *Package type Actiflo units are available for flows less than 1.5 mgd.*

B-1.1.3.a Chemical Feed Background: Chemical Feed Systems

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Back to Part 1.1.3 Chemical Feed and Storage.

Ammonia

An aqueous ammonia (aqua ammonia) feed system will be located in the chemical building. Liquid aqua ammonia at a concentration of 19 percent will be delivered in 250 gallon tote bins and fed from one feed point equipped with two (one duty, one standby) peristaltic tube type metering pumps and a scale for monitoring the chemical remaining in the tote. Carbon steel piping with ball valves will be used inside the building. The buried yard piping will be high density polyethylene (HDPE). The chemical feed pumps will be controlled by flow pacing proportional to the plant flow and the measure of chlorine residual. A gas detector will be provided in the ammonia storage/feed room. A typical schematic of this chemical feed system is provided on Figure B-1.1.3.a, which is also applicable to 0.5, 2, and 5 mgd systems.

For plants with capacities of 10, 25, and 40 mgd, the system will be slightly different. The system will be both located adjacent to and within the chemical building. For the 10 mgd plant the 19 percent aqueous ammonia will be delivered by tank truck and stored outdoors in a 2,000 gallon carbon steel tank. The 25 and 40 mgd plants will be provided with 8,000 gallon outdoor tank and two (one duty, one standby) motor driven diaphragm type chemical feed metering pumps. A dedicated air compressor will be provided to pressurize the storage tank to increase the net positive suction head (NPSH) to the metering pumps. A typical schematic of the chemical feed system is provided on Figure B-1.1.3.b.

Antiscalant

One antiscalant feed system will be installed in the chemical building equipped with two solenoid driven diaphragm type metering pumps (one duty, one standby). The liquid chemical will be delivered in 55 gallon drums and will be transferred by a vertical drum pump to a 100 gallon fiberglass reinforced plastic (FRP) storage tank. From the storage tank, the chemical will be fed to a single feed point. PVC piping with ball valves will be used inside the building. The buried yard piping will be HDPE. The chemical feed pumps will be controlled by flow, pacing proportional to plant flow. A typical schematic of this chemical feed system is on Figure 1.1.3.c, which also applies to the 0.5 and 2 mgd plants. At the 5, 10, and 25 mgd plants, the liquid chemical will be delivered to a 250 gallon tote bin. For the 40 mgd plants, it will be delivered to a 1,500 gallon FRP storage tank. The cost will also include a scale used for monitoring the chemical remaining in the tote. A typical schematic for plants of these sizes is shown on Figure B-1.1.3.a.

Caustic (Sodium Hydroxide)

The 0.5 mgd plant will include a caustic chemical feed system located in the chemical building. Liquid sodium hydroxide at a concentration of 50 percent will be delivered in bulk truckloads and stored in a 5,000 gallon steel tank. The chemical will be fed from three feed points equipped with six (one duty and one standby for each feed point) solenoid driven diaphragm type metering pumps. Carbon steel piping with plug valves will be used inside the building. The buried yard piping will be HDPE. The chemical feed pumps will be controlled by flow pacing proportional to the plant flow with pH train chemicals.

The storage and feed room will be heated to prevent the 50 percent caustic, which has a freezing point of 55°F, from freezing. A typical schematic of this chemical feed system is on Figure B-1.1.3.d. For the 2 mgd plant, a 10,000 gallon steel storage tank, two solenoid driven diaphragm type metering pumps, and four motor driven diaphragm type metering pumps, are included. The 5 mgd plant includes a 20,000 gallon steel storage tank and motor driven diaphragm type metering pumps. Figure B-1.1.3.d is a typical schematic for 0.5, 2, and 5 mgd plants.

The 10 mgd plant includes three 15,000 gallon steel storage tanks and six motor driven diaphragm type metering pumps (one duty and one standby for each feed point). From the storage tanks, the chemical will be fed to three feed points. The 25 mgd plant will include five 20,000 gallon steel storage tanks, and the 40 mgd plant needs eight 20,000 gallon tanks. Figure B-1.1.3.e is typical for the 10, 25, and 40 mgd plants.

Ferric Sulfate

For the 0.5 mgd plant, one ferric sulfate feed system will be located within the chemical building. Liquid ferric sulfate at a concentration of 43 percent will be delivered in bulk truckloads and stored in a 5,000 gallon FRP tank. From the storage tank, the chemical will be fed to one feed point using two (one duty and one standby) motor driven diaphragm type metering pumps. PVC piping with ball valves will be used inside the building. The yard piping will be buried HDPE. The chemical feed pumps will be controlled by flow pacing proportional to the plant flow. A typical schematic of this chemical feed system is provided on Figure B-1.1.3.d.

For the 2 mgd plant, two 6,000 gallon FRP storage tanks will be provided, as shown on Figure B-1.1.3.e. For the 5 mgd plant there are two 15,000 gallon tanks; the 10 mgd plant requires three 20,000 gallon tanks; the 25 mgd plant requires eight 20,000 gallon tanks; and the 40 mgd plant requires twelve 20,000 gallon tanks. Figure B-1.1.3.e is typical for the 2, 5, 10, 25, and 40 mgd plants.

Hydrofluosilicic Acid (Fluoride)

The 0.5 mgd has one hydrofluosilicic acid chemical feed system located within the chemical building. The liquid chemical will be delivered in 55 gallon drums and will be transferred by a vertical drum pump to a 100 gallon FRP storage tank. From the storage tank, the chemical will be fed to a single feed point by two solenoid driven diaphragm type metering pumps (one duty, one standby). PVC piping with ball valves will be used inside the building. The buried yard piping will be HDPE. The chemical feed pumps will be controlled by flow pacing proportional to the plant flow. A typical schematic of this chemical feed system is provided on Figure B-1.1.3.c.

For the 2 and 5 mgd plants the chemical will be delivered in 250 gallon tote bins complete with a scale to measure the chemical remaining in the tote. The chemical will be transferred by a magnetic drive centrifugal pump to a 100 gallon FRP day tank. A typical schematic of this system is on Figure B-1.1.3.f. For the 10 mgd plant, the chemical will be delivered in bulk and stored in a 1,500 gallon FRP day tank; the rest of the process is the same as described above and shown on Figure B-1.1.3.f. The 25 and 40 mgd plants require a 6,000 gallon FRP tank for storage, and a typical schematic is as shown on Figure B-1.1.3.f.

Powdered Activated Carbon (PAC)

One PAC feed system will be located in the chemical building. The PAC will be delivered and stored in 900 pound bags on a steel support stand with hoist and monorail, which conveys the PAC to a dry volumetric type screw feeder leading to a wetting cone-eductor assembly, where it is wetted to form a slurry, and discharged into the eductor. The water-operated eductor wets the carbon again and discharges it to the feed point. The piping inside the building is stainless steel and hose with diaphragm valves. The buried yard piping will be HDPE or hose. The dry screw feeder will be controlled by flow pacing proportional to plant flow. All electrical equipment and motors inside the storage and feed room will be explosionproof. This chemical feed system is used for the 0.5 mgd plant and a typical schematic is provided on Figure B-1.1.3.g.

For the 2 and 5 mgd plants, the PAC will be delivered in bulk truckloads and stored in a 3,500 cubic foot outdoor silo. The sidewalls of the storage silo will extend to the ground to form the walls of the chemical feed room under the storage compartment. From the silo, carbon will be discharged to the dry volumetric type screw feeder, which discharges into a wetting cone-eductor assembly. The remainder of the process is as described for the 0.5 mgd plant. A typical schematic of this system is provided on Figure B-1.1.3.h. The capacity of the silo for the 10 mgd plant will be 5,000 cubic feet; the 25 mgd plant will have two 6,000 cubic feet silos; and the 40 mgd plant will have three 7,000 cubic feet silos. The typical schematic of the PAC feed systems for the 2, 5, 10, 25, and 40 mgd plants is presented on Figure B-1.1.3.h.

Coagulant Polymer

The 0.5, 2, 5, and 10 mgd plants require one coagulant polymer feed system located in the chemical building. Liquid polymer will be delivered in 55 gallon drums and transferred to a 100 gallon FRP storage tank by a vertical drum pump. From the storage tank, the chemical will be fed to a single feed point using two polymer feeder/blenders (one duty, one standby). Each feeder/blender unit consists of a progressing cavity pump and a polymer activation device, where neat polymer is diluted and mixed with water, before it is fed to the feed point. PVC piping with ball valves will be used inside the building. The buried yard piping will be HDPE. The neat polymer feed pump will be controlled by flow pacing proportional to the plant flow. A typical schematic of this polymer feed system is provided on Figure B-1.1.3.i.

The 25 and 40 mgd plants receive liquid polymer in 250 gallon tote bins. A scale will be provided for monitoring the chemical remaining in the tote. From the tote bin the chemical will be fed to a single feed point in the same manner as the 0.5 mgd plant. Figure B-1.1.3.j shows a typical schematic of the polymer system.

Sodium Hypochlorite

A sodium hypochlorite feed system will be located within the chemical building. Liquid sodium hypochlorite at a concentration of 12.5 percent will be delivered in 250 gallon tote bins for two feed points using four motor driven diaphragm type metering pumps (one duty and one standby pump at each feed point). A scale will be provided to monitor the chemical remaining in the tote. CPVC piping with diaphragm valves will be used inside the building. The buried yard piping will be Teflon tubing/hose. The chemical feed pumps will be controlled by flow pacing proportional to plant flow. A typical schematic of the system used for the 0.5 mgd plant is provided on Figure B-1.1.3.a.

Liquid sodium hypochlorite for the 2 mgd plant is delivered in bulk truckloads and stored in two 1,000 gallon FRP tanks. The rest of the process remains the same as in the 0.5 mgd plant, and a schematic is shown on Figure B-1.1.3.e.

The 5 mgd plant includes two 2,000 gallon FRP storage tanks; the 10 mgd plant two 4,000 gallon tanks; the 25 mgd plant has two 9,000 gallon tanks; and the 40 mgd plant has two 15,000 gallon tanks. Figure B-1.1.3.e is a typical schematic of this chemical feed system.

Sulfuric Acid

One sulfuric acid feed system will be located in the chemical building. Liquid sulfuric acid at a concentration of 93 percent from 250 gallon tote bins will be delivered to two feed points by four motor driven diaphragm type metering pumps (one duty and one standby pump for each feed point). A scale will be provided to monitor the chemical remaining in the tote. Alloy 20 piping with ball valves will be used inside the building. The buried yard piping will be Teflon tubing/hose. The chemical feed pumps will be controlled by flow pacing proportional to the plant flow. A typical schematic of chemical feed system for the 0.5 mgd plant is provided on Figure B-1.1.3.a.

The liquid sulfuric acid for the 2 and 5 mgd plants is delivered by bulk truckloads and stored in a 3,500 gallon chemical-resistant lined carbon steel storage tank located outdoors. The chemical will be fed to two feed points by four motor driven diaphragm type metering pumps (one duty and one standby pump for each feed point). The rest of the process is the same as described for the 0.5 mgd plant, with a schematic shown on Figure B-1.1.3.d. The layout for the 10 mgd plant is similar except that it uses a 6,000 gallon storage tank and the 25 mgd plant which uses a 15,000 gallon tank.

Figure B-1.1.3.e shows the process for the 40 mgd plant, which is provided with two 12,000 gallon storage tanks, the rest of the process is identical to that used at the other plants.

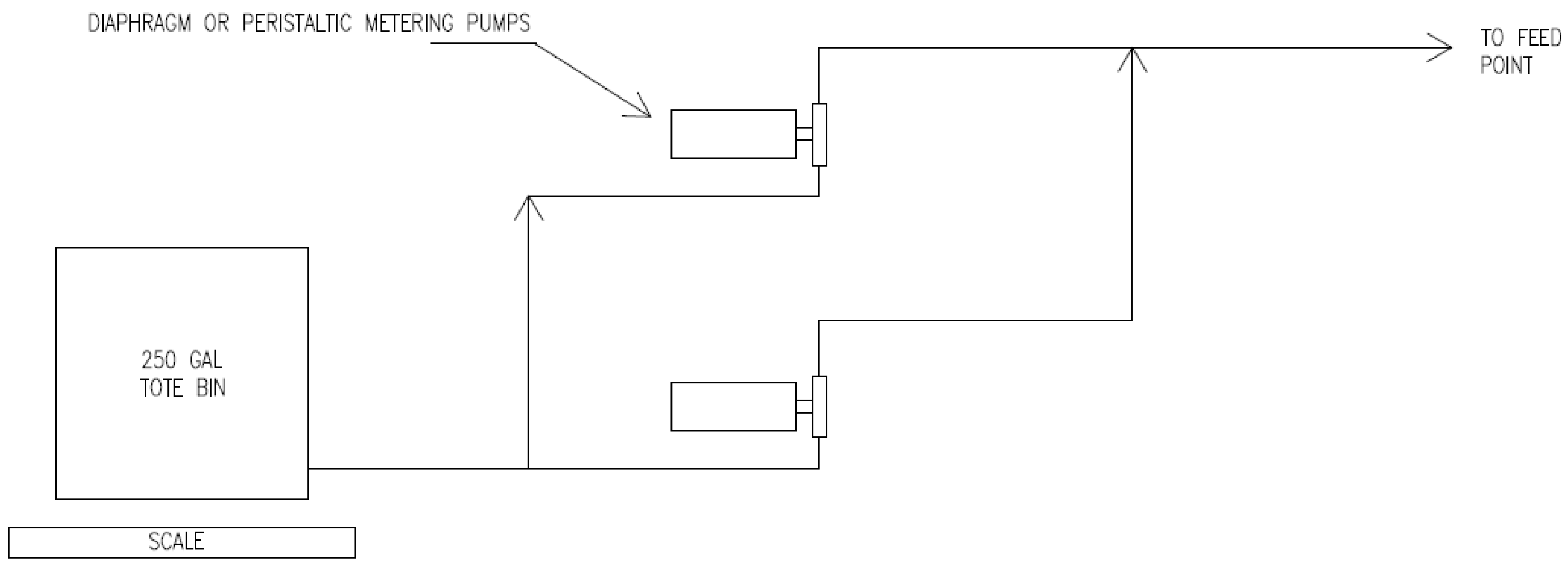

Figure B-1.1.3.a Chemical Feed Tote System.

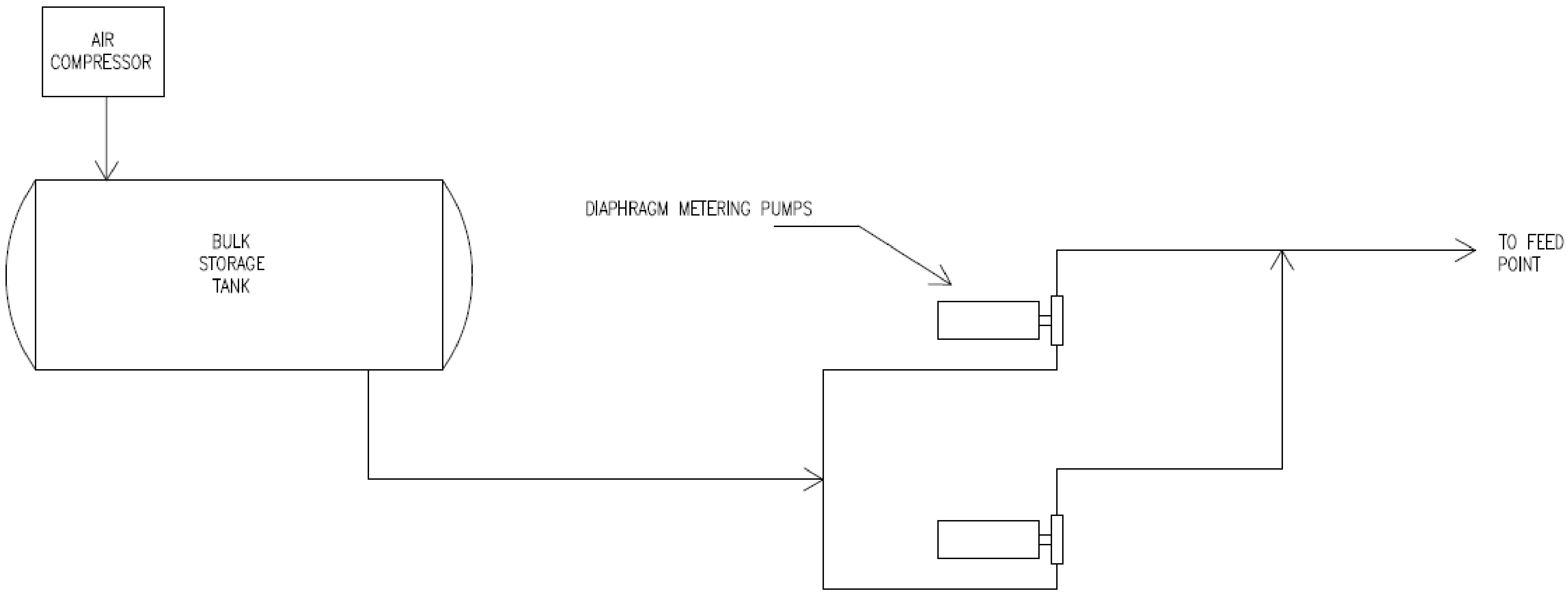

Figure B-1.1.3.b Chemical Feed Ammonia Tank System.

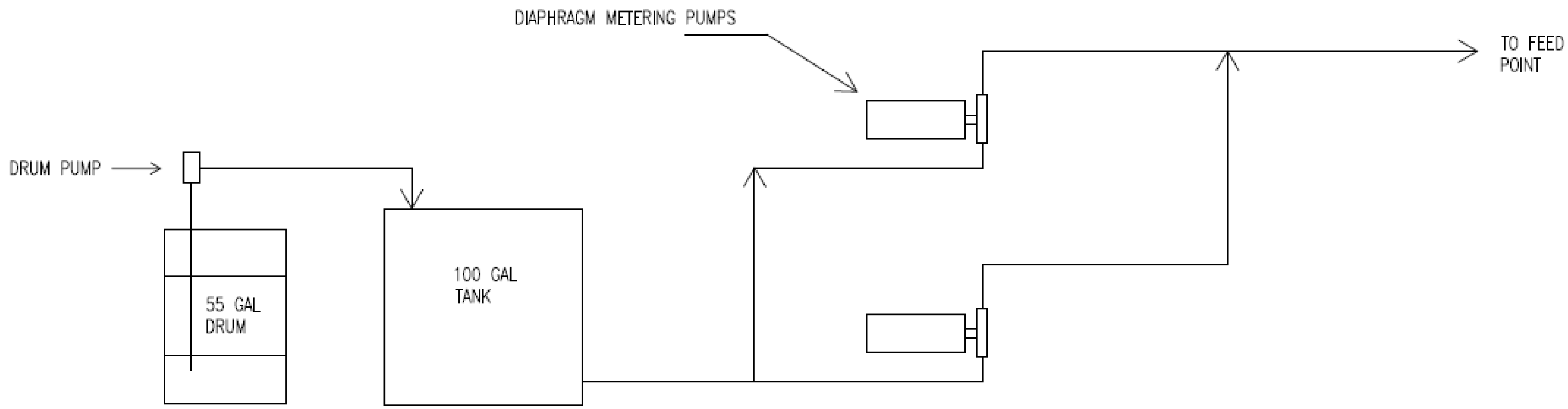

Figure B-1.1.3.c Chemical Feed Drum System.

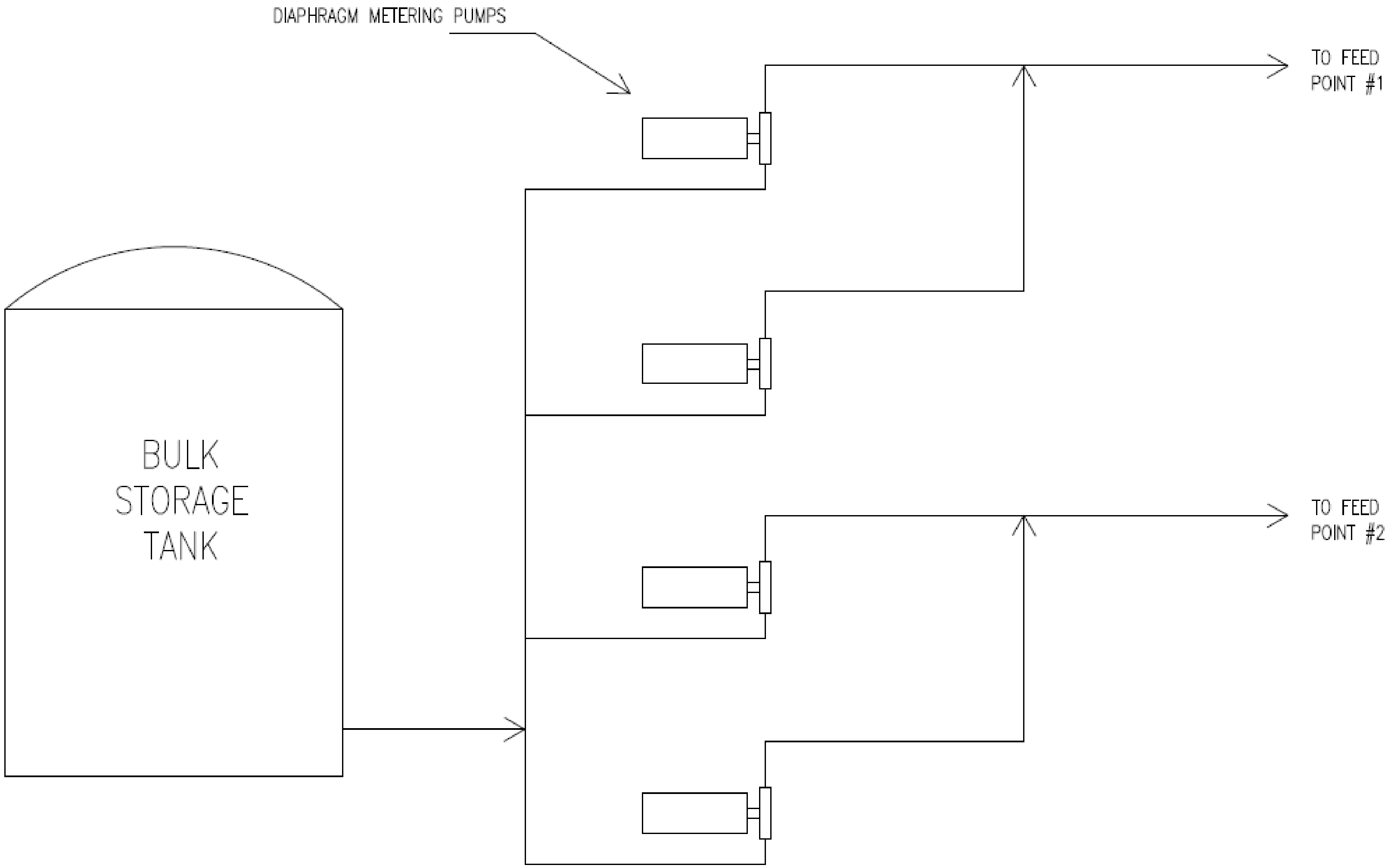

Figure B-1.1.3.d Chemical Feed Single Tank System.

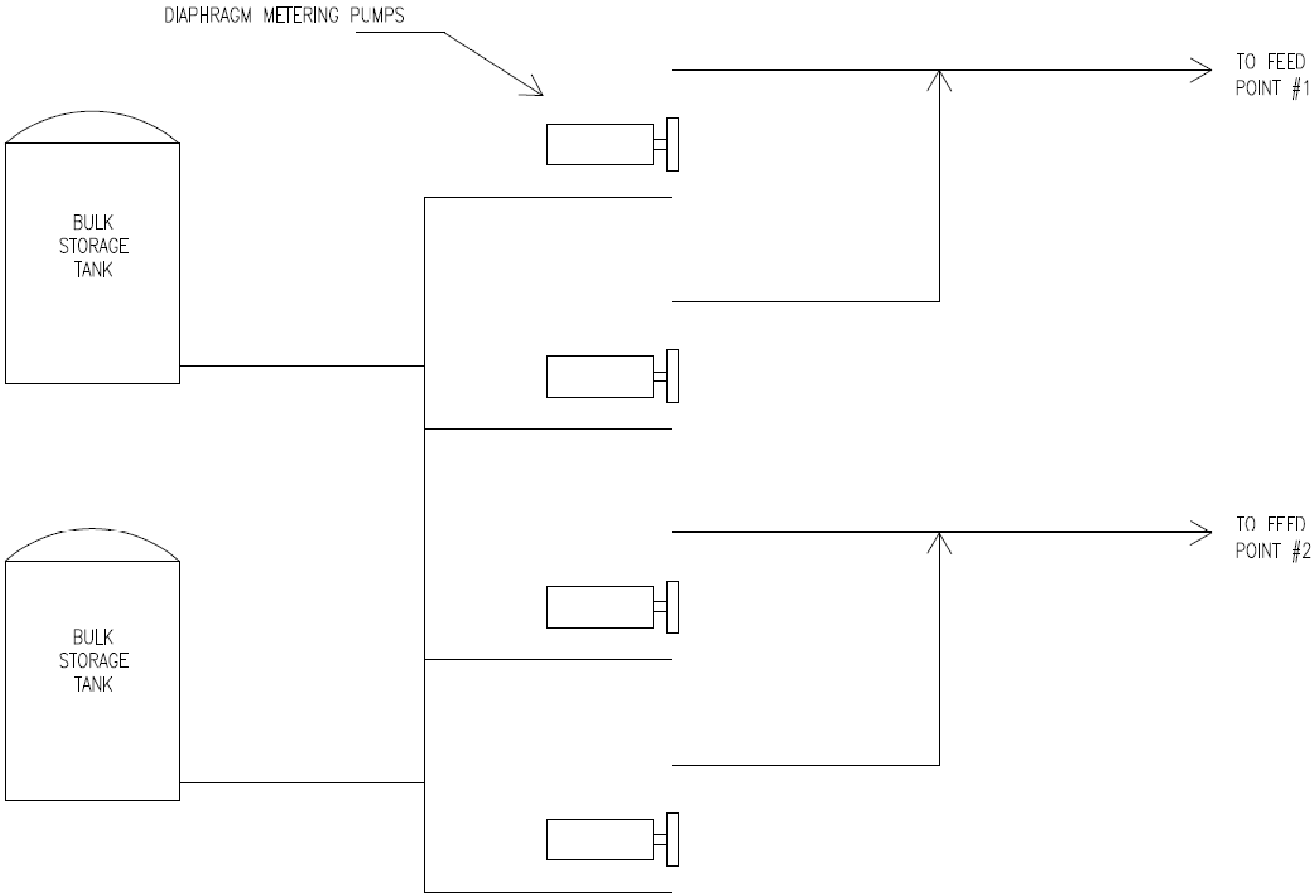

Figure B-1.1.3.e Chemical Feed Multiple Tank System.

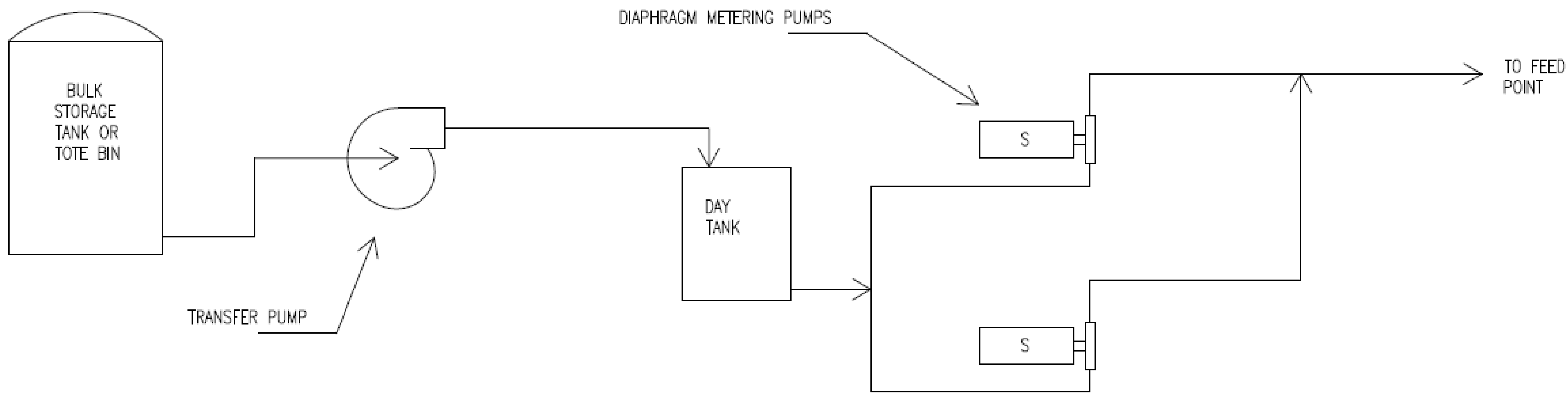

Figure B-1.1.3.f Chemical Feed Fluoride System.

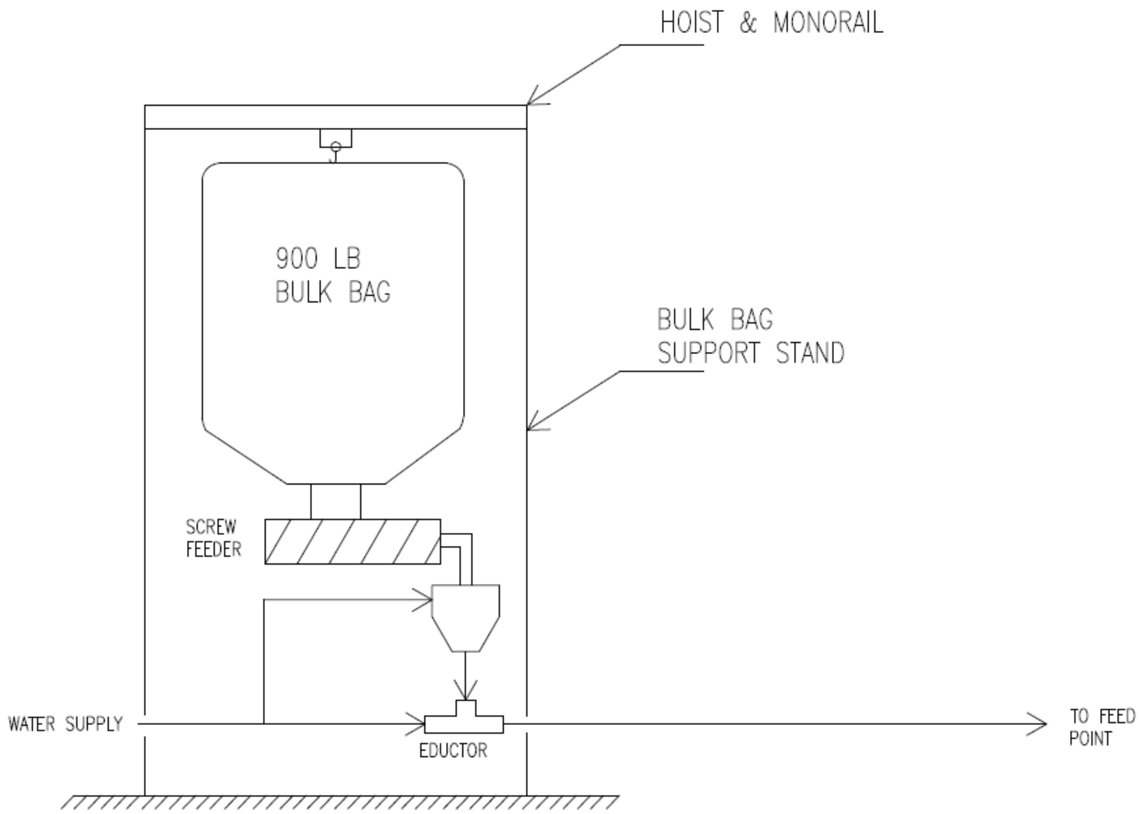

Figure B-1.1.3.g Chemical Feed PAC Bulk Bag System.

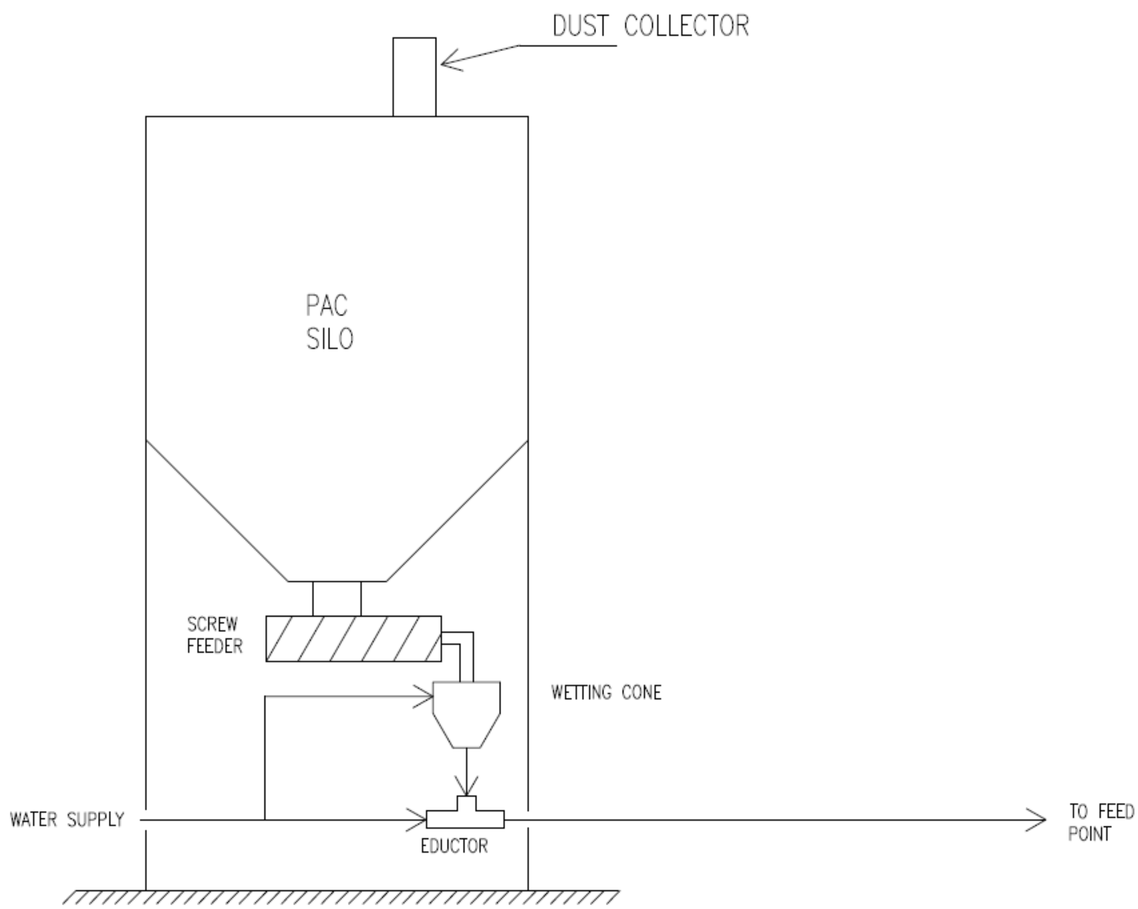

Figure B-1.1.3.h Chemical Feed PAC Silo System.

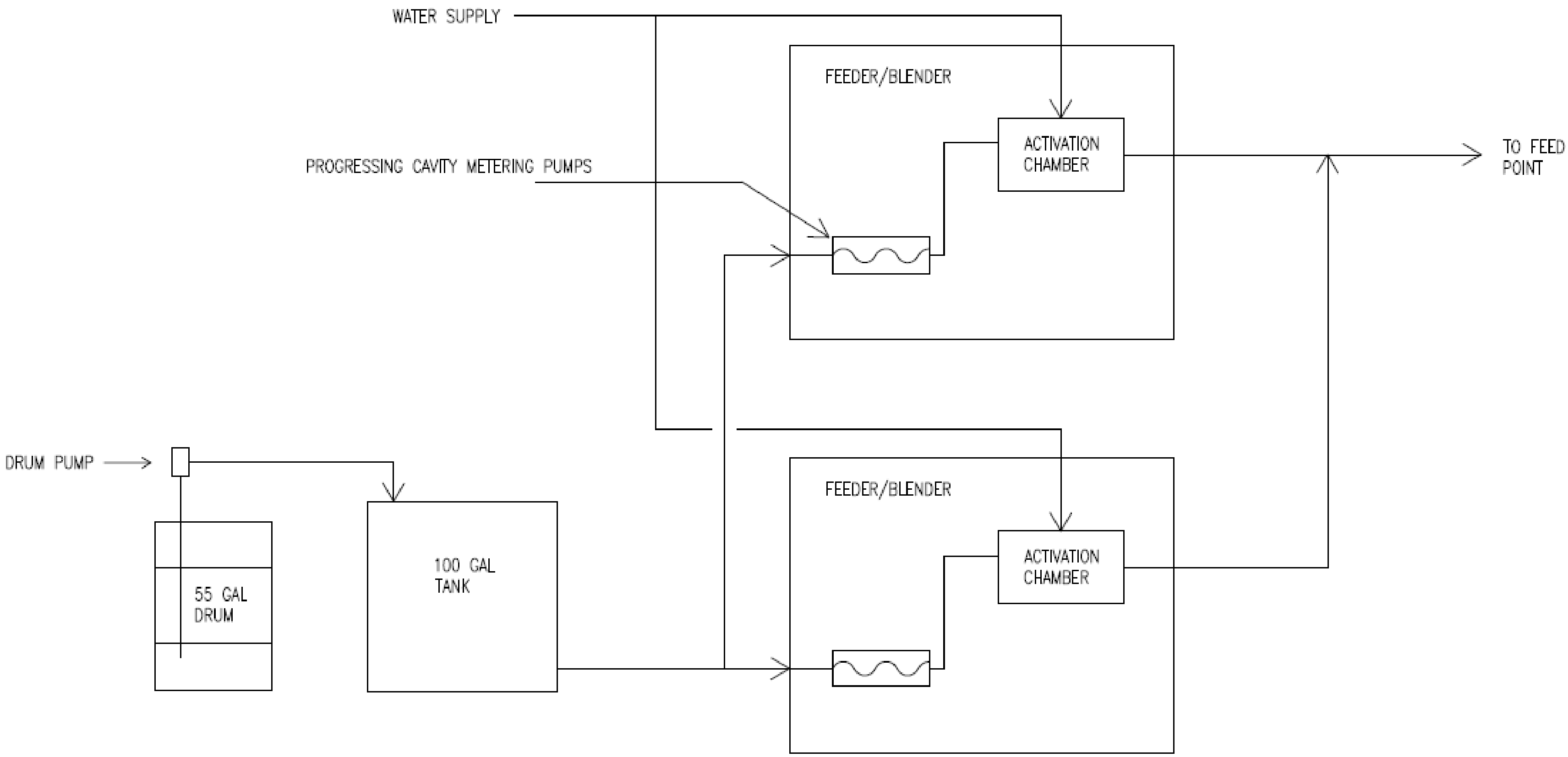

Figure B-1.1.3.i Chemical Feed Polymer Drum System.

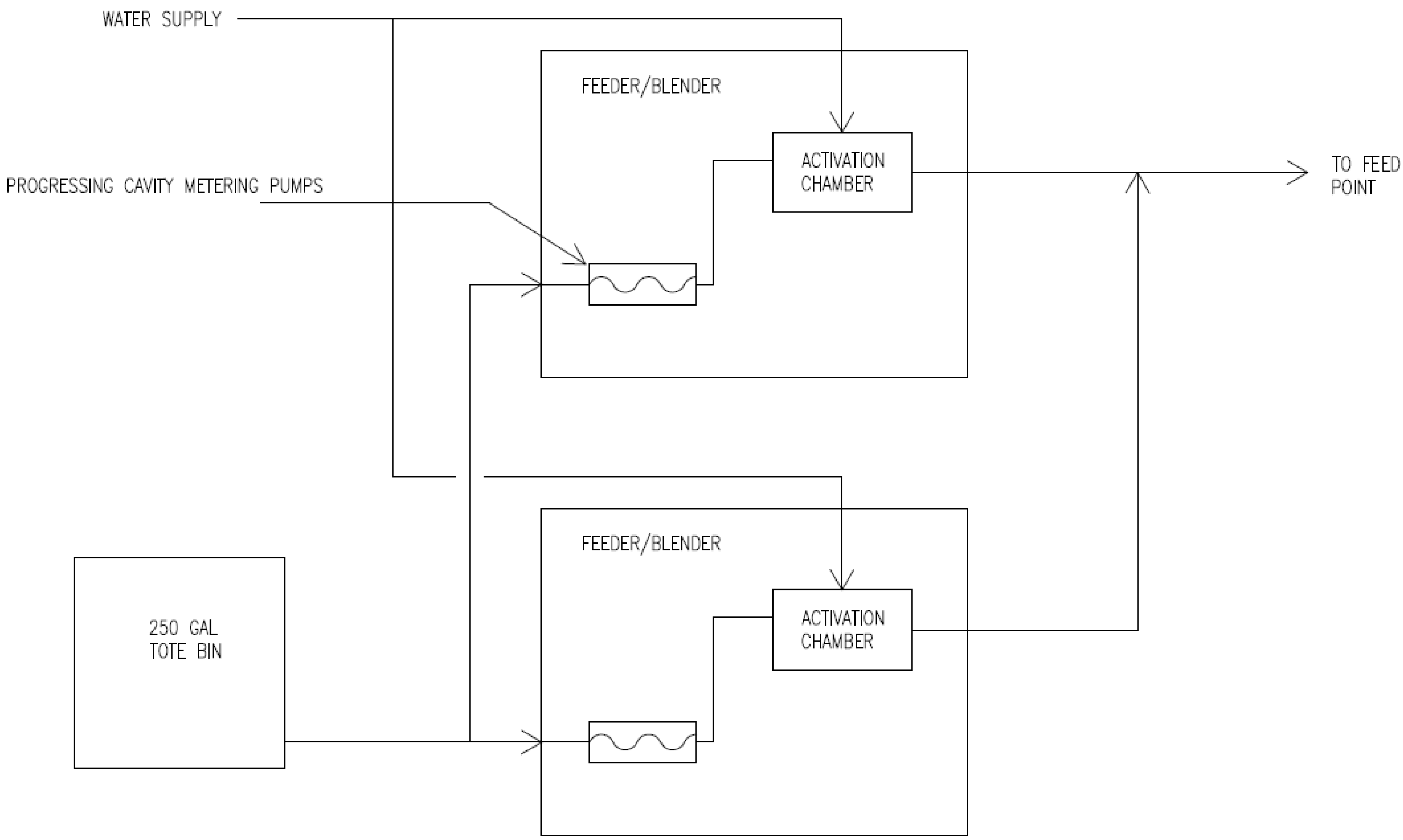

Figure B-1.1.3.j Chemical Feed Polymer Tote System.

B-1.1.3.b Chemical Feed Background: Basis and Assumptions

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Back to Part 1.1.3 Chemical Feed and Storage.

General

- Where multiple treatment trains are used, the number of chemical feed points and chemical feeders is based on a single common feed point for all plant sizes.

Chemicals

- All chemicals will be delivered in liquid form except powdered activated carbon.
- Chemicals will be delivered and fed in the following concentrations:
    - Ammonia: 19% NH_3.
    - Antiscalant: Will be fed in the concentration delivered (concentration varies with manufacturer).
    - Sodium Hydroxide: 50% NaOH.
    - Ferric Sulfate: 43% $Fe_2(SO_4)_3$.
    - Hydrofluosilicic Acid (Fluoride): 24% H_2SiF_6.
    - Polymer: Delivered as 35% active solution and fed as 0.5% neat solution ("neat polymer" as defined in Appendix B-1.1.3.a Chemical Feed Background).
    - Powdered Activated Carbon: Delivered as dry powder and fed as dilute slurry.
    - Sodium Hypochlorite: 12.5% Trade percent (10.6% available chlorine).
    - Sulfuric Acid: 93% H_2SO_4.
- Hydrated lime, $Ca(OH)_2$, used in 0.5 and 2 mgd plants because of the high cost of quicklime slaking equipment.
- Quicklime, CaO, is used in 5 mgd and larger plants because of its lower cost.
- On-site generation of sodium hypochlorite was not considered because the capital cost of systems using on-site generation is typically at least three times the cost of using bulk delivered sodium hypochlorite. On-site generation systems may be competitive with bulk deliveries when chemical costs over a 20-year period are considered.
- Where significant quantities of a chemical are used, the chemical will be delivered is bulk truck loads of 45,000 pounds, which is the preferred method because of the lower chemical costs. For smaller chemical use 250 gallon tote bins or 55 gallon drums will be used as needed.

Storage

- Storage tanks are sized for 30 days of chemical use at average plant flow and average dosage.
- Storage tanks were sized to hold at least one full truckload plus one week's use at average conditions.
- Storage for partial truckloads will be provided only where a full truckload would last for an excessively long period or where degradation is a concern (i.e., sodium hypochlorite).
- At least two tanks were provided for redundancy for storage of sodium hypochlorite; 5 mgd and smaller WTPs do not include this redundancy.
- Maximum storage tank diameter was set at 12 feet to accommodate truck delivery.
- Maximum storage tank volume was set at 20,000 gallons, which limited the tank height 25 feet.
- Chemicals delivered in 55-gallon drums will be transferred to a 100 gallon storage tank for better monitoring.
- All chemical storage tanks will be of FRP except those used for storage of sodium hydroxide, sulfuric acid, and aqueous ammonia.
    - Sodium hydroxide tanks are bare carbon steel, at atmospheric pressure.
    - Aqueous ammonia tanks are bare carbon steel, pressurized to 50 psi.
    - Sulfuric acid tanks are corrosion resistant lined carbon steel.
- Powdered activated carbon will be stored in silos except at the 0.5 mgd plant where 900 pound bulk bags will be used.
- Day tanks and transfer pumps are provided only for fluoride.
- Transfer pumps for fluoride will be nonmetallic sealless magnetic drive type.
- Lime will be delivered in bulk by truck and stored in silos except for the 0.5 mgd plant where 55 pound bags will be delivered.
- Maximum diameter of lime and carbon silo is 12 ft to allow shop fabrication.
- Maximum height of lime and carbon silo is 80 ft to allow shop fabrication and for appearance.
- Chemical storage areas will be provided with spill containment in compliance with all applicable codes.

Metering Pumps and Feeders

- Metering pumps are sized to feed chemicals at maximum plant flow and maximum dosages.
- At least one standby pump will be installed for each chemical.
- Motor-driven diaphragm metering pumps will be used for most chemicals.
- Solenoid driven diaphragm metering pumps will be used only for noncritical chemicals used at feed rates less that 10 gph.
- Peristaltic tube pumps will be used for ammonia where tote storage is used.

- Progressing cavity pumps will be used for polymer.
- Each pump will be equipped for automatic feed rate control.
- Lime slakers are Tekkem type, rather than the traditional paste type.

Piping and Valves

- Piping materials are as described in Appendix B-1.1.3.a Chemical Feed Background.
- Minimum size for plastic pipe is 1 inch for mechanical and structural strength.
- Double contained piping is NOT used.
- Valve types are described in Appendix B-1.1.3.a Chemical Feed Background.
- Carbon and lime slurry feed lines are hose rather than pipe.

Controls

- Automatic flow pacing control will be provided for feeding of all chemicals.
- Feedback control based on chlorine residual or pH will be provided for ammonia, sodium hypochlorite, and sodium hydroxide to allow trimming the feed rate in addition to the flow pacing control.
- Storage tanks will be equipped with ultrasonic level transmitters for continuous monitoring and alarm.
- Tote bins will be provided with electronic scales to monitor the amount of chemical remaining.

Equipment Locations

- Chemical storage will be located inside the chemical feed building except for aqueous ammonia, sulfuric acid, powdered activated carbon, and lime.
- All chemical metering pumps will be located inside the chemical feed building.
- Dry feeders for powdered activated carbon will be located under the storage silo.

Maintenance Costs

- Maintenance costs include normal replacement parts.
- Maintenance costs do not include chemicals.
- Maintenance costs do not include complete equipment replacement. Maintenance costs are calculated as a percentage of the total installed equipment cost ranging from 2.25 percent for the 0.5 mgd system to 1.5 percent for the 40 mgd system.

B-1.1.4 Deep Bed Filters Background

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The deep bed gravity filters are constructed of concrete with an integrated media support (IMS) cap underdrain or equivalent and equipped with dual media (anthracite and sand). They are sized for a loading rate of 6 gpm/sf, which allows one filter cell to be taken out of service for backwashing or maintenance. However, under normal conditions, when all filter cells are in service, the loading rate will be less than 6 gpm/sf.

The top layer of media consists of 48 inches of anthracite with an effective size of 1.3 mm and a uniformity coefficient of 1.5. The lower layer consists of 10 inches of sand with an effective size of 0.6 mm and a uniformity coefficient of 1.5. The anthracite serves to remove the majority of the suspended solids from the settled water and the sand serves as a polishing step. The media depth and size were selected to allow higher filter loading rates, longer run times, and an effluent turbidity less than 0.10 NTU 95 percent of the time.

The backwashing system includes provisions for air/water backwashing, which is usually the first step in a backwashing cycle to break up mudballs or solids cake that may have formed in the filter. Each filter cell is then washed with water for 10-20 minutes to displace the solids removed during filtration. The backwashing system was designed to expand the filter bed by 30 percent. To determine the operation and maintenance requirements for Part 2, it was assumed that the filters would be backwashed daily, although generally, filters of this type need to be backwashed only every other day. The filter includes provisions for filter-to-waste operation, whereby for the first 10-20 minutes after start-up, the filtered water is discharged to waste.

The dimensions of filters of the various sizes are listed in Table B-1.1.4. The dimensions include all filter cells as well as the concrete walls between cells.

Table B-1.1.4 Deep Bed Filter Design Assumptions.

Unit Process Flow, mgd	Number of Filter Cells	Number of Backwash Pumps	Number of Air Compressors	Total Length, ft	Total Width, ft
0.5	2	2	2	26.5	24
2	4	2	2	47.5	30
5	4	3	2	67.5	40
10	6	3	3	100.5	44
25	10	4	3	194	58.5
40	12	4	3	268.5	62.5

B-1.1.5 Lime Softening Background

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Lime softening is traditionally used for treatment of groundwater containing high concentrations of calcium and magnesium hardness. The groundwater quality information used as the basis for determining the lime feed rates was for Orange County, Florida. It was assumed that 100 percent of the water would be treated. Descriptions of plants of different sizes considered are included below. Hydrated lime was determined to be the most cost-effective softening chemical for the 0.5 and 2 mgd plants. The remaining plants (5, 10, 25, and 40 mgd) were designed to use quicklime.

The plants of all sizes will include lime softening steel basins sized using a rise rate of 0.75 gpm/sf. The dimensions of the basins are listed in Table B-1.1.5. The mixing detention time was set for 20 minutes and the settling detention time was set at 2 hours. The 0.5 and 2 mgd plants include a simple brick and concrete block building for the lime storage. In the other plants, the space under the lime silo was utilized. More information about lime softening is included in Appendix B-1.1.3.B Chemical Feed Background.

Table B-1.1.5 Lime Basin Design Assumptions.

Unit Process Flow, mgd	Number of Basins	Depth, ft	Diameter, ft
0.5	2	12	13.3
2	2	12	26.6
5	2	12	42.1
10	3	12	42.1
25	3	12	66.5
40	3	12	84.1

0.5 mgd Plant

A hydrated lime system will be located in the chemical building. Hydrated lime will be delivered and stored in 55 pound bags. The bags are manually loaded into the hopper using the bag unloading device. From the hopper the lime is discharged into a volumetric screw feeder, which discharges it into a lime slurry tank equipped with a mixer. In the slurry tank the lime is diluted and the resulting slurry is discharged from the tank to the feed point. Stainless steel piping and hose with diaphragm valves will be used inside the building. The yard piping will be hose or an open trough. The dry chemical screw feeder will be controlled proportionally to plant flow. All electrical equipment and motors inside the storage and feed room must be rated explosionproof. A typical schematic of this lime feed system is on Figure B-1.1.5.a.

2 mgd Plant

A hydrated lime system will be located adjacent to the softening basin. Hydrated lime will be delivered in bulk truckloads and stored in an 8 ft diameter by 10 ft high straight-sided silo. The silo will be located above a 14 ft by 14 ft building which will house the volumetric screw feeder and the lime slurry tank. The hydrated lime is discharged from the silo into a volumetric screw feeder leading into a lime slurry tank, equipped with a mixer, where the lime is diluted and the resulting slurry discharges to the feed point. Stainless steel piping and hose with diaphragm valves will be used inside the building. The yard piping will be hose or open trough. The dry chemical screw feeder will be controlled proportional to the plant flow. All electrical equipment and motors inside the silo chemical feed room will need to be rated explosionproof. A typical schematic of this lime feed system is on Figure B-1.1.5.b.

5 mgd Plant

A quicklime feed system will be located outdoors in the lime silo system. Quicklime will be delivered in truckloads and stored in a 12 ft diameter by 11 ft high straight-sided silo. The sidewalls of the storage silo will extend to the ground to form the walls of the chemical feed room under the storage compartment. Quicklime will discharge from the silo to the dry volumetric screw feeder leading to a Tekkem type batching lime slaker. Quicklime is diluted to react and form calcium hydroxide in the slaker and fed to a lime slurry tank. The contents of the slurry tank are recirculated, and part of the recirculation stream discharges to the feed point. The feed rate is controlled by a flowmeter and a control valve. Stainless steel piping and hose with diaphragm valves will be used inside the building. The recirculation line will be a hose. A typical schematic of this lime feed system is on Figure B-1.1.5.c.

10 mgd Plant

A quicklime feed system will be located outdoors within the lime silo system. Quicklime will be delivered in bulk truckloads and stored in a 12 ft diameter by 22 ft high straight-sided silo. The sidewalls of the storage silo will extend to the ground to form the walls of the chemical feed room under the storage compartment. Quicklime will discharge from the silo to the volumetric screw feeder which leads into a Tekkem type batching lime slaker. Quicklime is diluted to react and form calcium hydroxide in the slaker and fed to a lime slurry tank. The contents of the slurry tank are recirculated and a part of the recirculation stream discharges to the feed point. The feed rate is controlled by a flowmeter and a control valve. Stainless steel piping and hose with diaphragm valves will be used inside the building. The recirculation line will be a hose. A typical schematic of this lime feed system is on Figure B-1.1.5.c.

25 mgd Plant

A quicklime feed system will be located outdoors within the lime silo system. Quicklime will be delivered in bulk truckloads and stored in a 12 ft diameter by 55 ft high straight-sided silo. The sidewalls of the storage silo will extend to the ground to form the walls of the chemical feed room under the storage compartment. Quicklime will discharge from the silo to the dry volumetric screw feeder which leads into a Tekkem type batching lime slaker. Quicklime is diluted to react and form calcium hydroxide in the slaker and fed to a lime slurry tank. The contents of the slurry tank are recirculated with a part of the stream discharged to the feed point. The feed rate is controlled by a flowmeter and a control valve. Stainless steel piping and hose with diaphragm valves will be used inside the building. The recirculation line will be a hose. A typical schematic of this lime feed system is provided on Figure B-1.1.5.c.

40 mgd Plant

A quicklime feed system will be located outdoors within the lime silo system. Quicklime will be delivered in bulk truckloads and stored in a 12 ft diameter by 45 ft high straight side silo. The sidewalls of the storage silo will extend to the ground to form the walls of the chemical feed room under the storage compartment. Quicklime will discharge from the silo to the dry volumetric screw feeder which leads to the Tekkem type batching lime slaker. Quicklime is diluted to react and form calcium hydroxide in the slaker and fed to a lime slurry tank. The contents of the slurry tank are recirculated with a part of the stream discharged to the feed point. The feed rate is controlled by a flowmeter and a control valve. Stainless steel piping and hose with diaphragm valves will be used inside the building. The recirculation line will be a hose. A typical schematic of this lime feed system is provided on Figure B-1.1.5.c.

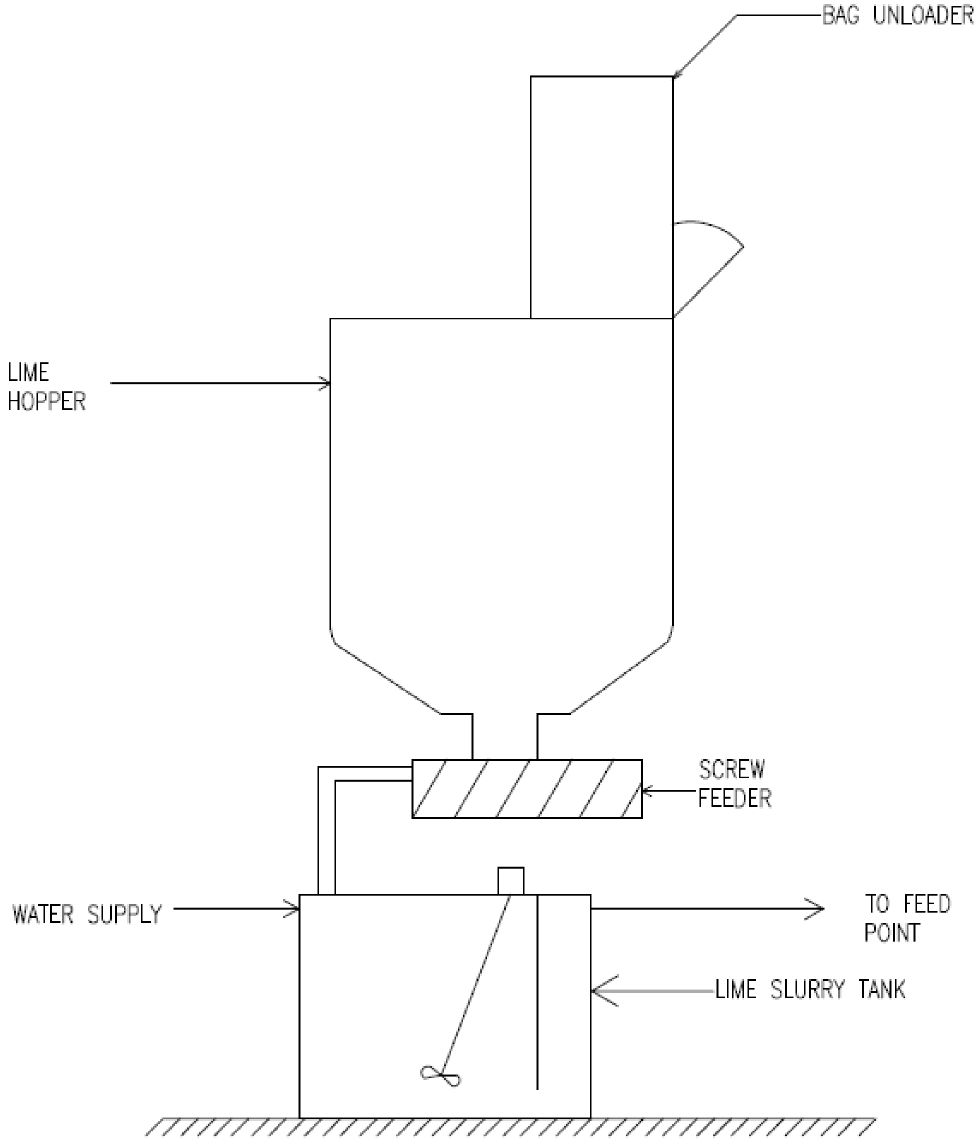

Figure B-1.1.5.a Lime Softening Lime 50 lb Bag Feed System.

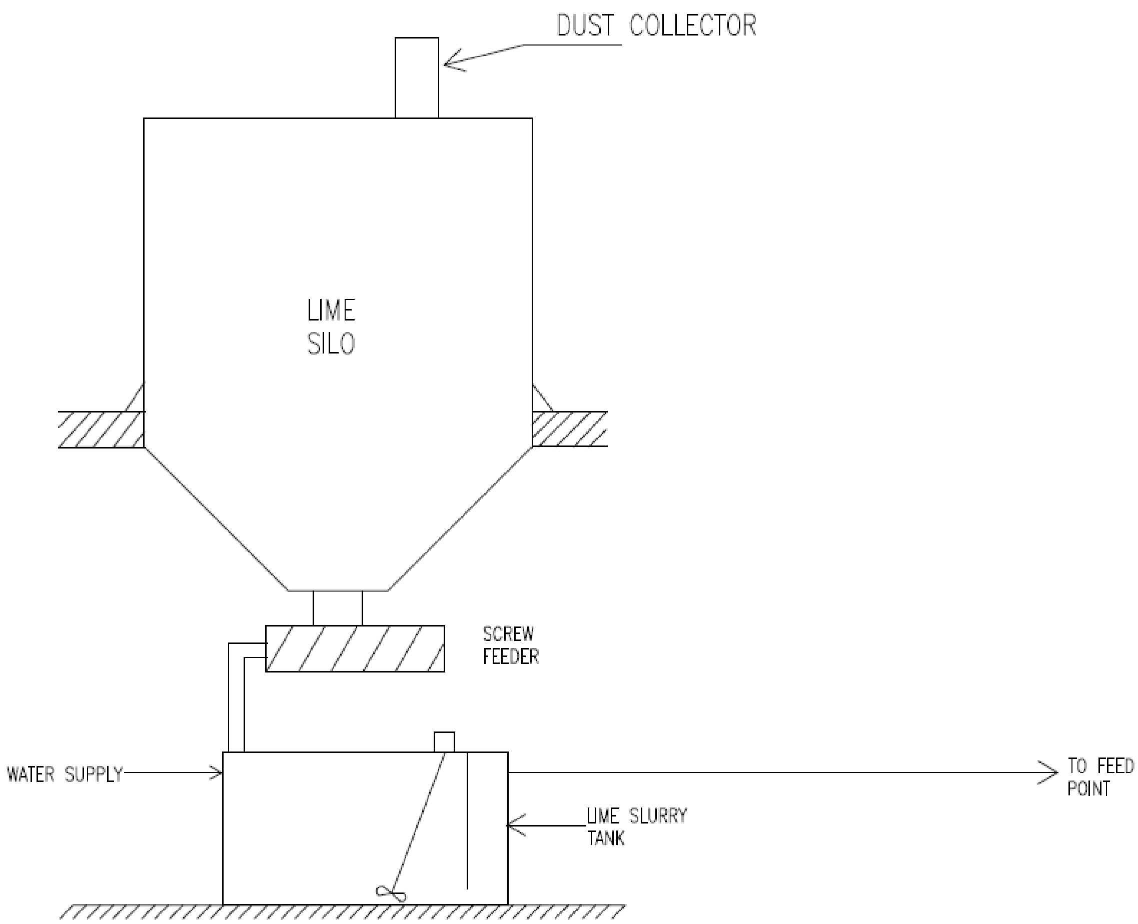

Figure B-1.1.5.b Lime Softening Hydrated Lime Silo Feed System.

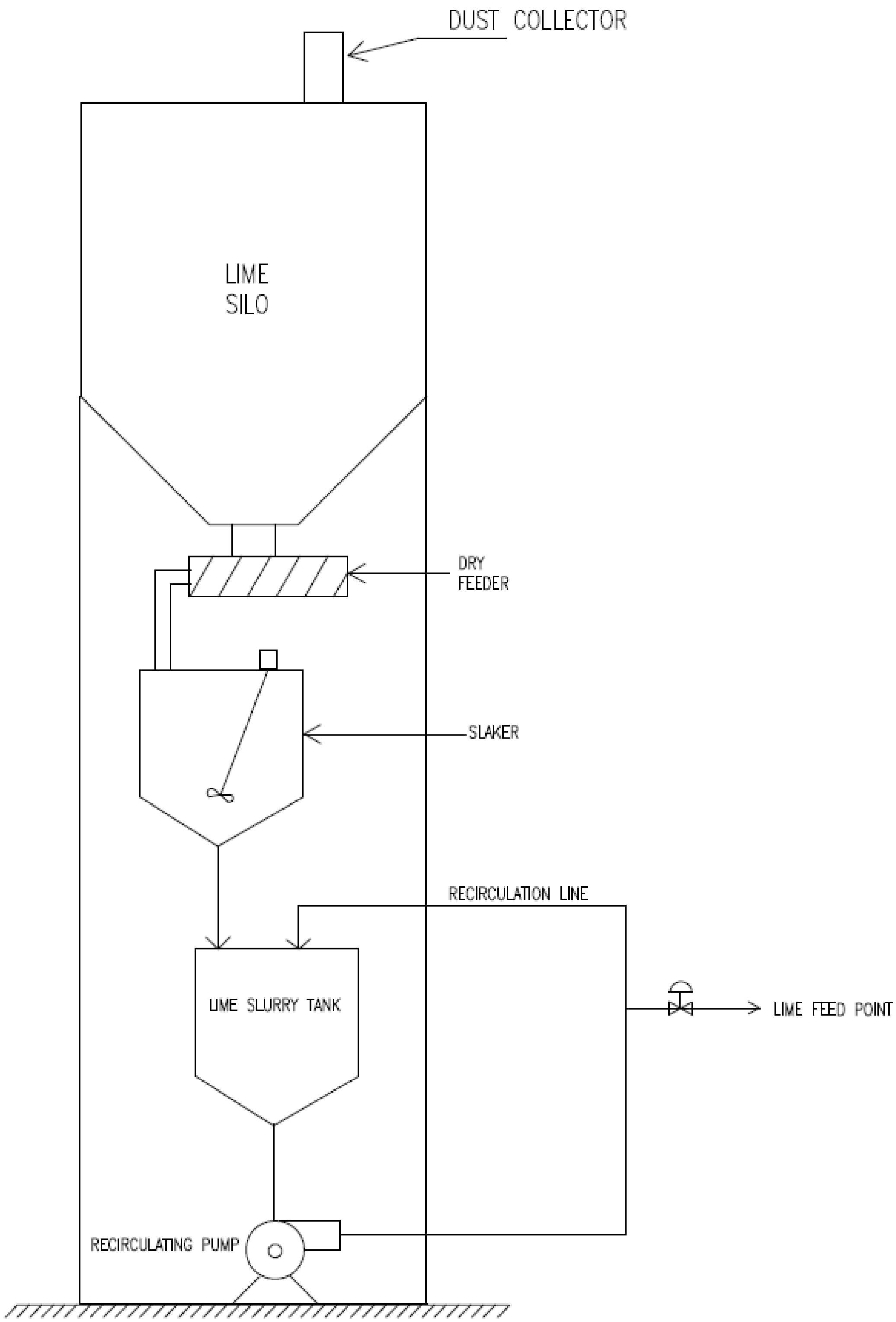

Figure B-1.1.5.c Lime Softening Tekkem Type Lime Silo Feed System.

B-1.1.6 Residuals Handling Background

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Residuals handling includes holding, thickening, or dewatering the sludge generated at the water treatment plants. The most cost-effective sludge handling methods for the different flow rates were determined. The goal was to achieve a solids concentration of at least 15 percent, as mandated by the EPA for disposal of sludge in a landfill.

Several assumptions were made in determining the costs of sludge handling. First, to assess the amount of wastes generated, it was assumed that the residuals handling water is generated in flocculation/clarification, deep bed filters, membrane treatment, and chemical feed. All brine is sent to a wastewater treatment plant, and the solids processing return flows are returned to the head of the water treatment plant. The minimum solids concentrations of these flows are as follows: drying bed – 18 percent dry solids, belt filter press – 20 percent dry solids, and centrifuges – 25 percent dry solids.

The sizes of the paved drying beds used for the 0.5 and 2 mgd plants were based on the average annual solids production, with an annual average evaporation rate of 47 inches. Reclamation of spent filter backwash water is used for 10, 25, and 40 mgd plants. At the smaller plants (0.5, 2, and 5 mgd) the spent filter backwash was assumed to be combined with the solids from the Actiflo units.

Gravity thickening was provided for all plant sizes with the exception of 0.5 mgd as that flow is too small to make it economically viable. The gravity thickeners and paved drying beds are outside, but the other dewatering and thickening processes are inside. Processes were determined by a loading rate of 100,000 lb/day of solids. This was based off design calculations from the different processes and adjusted to correspond with actual working plants based on experience (the capture rates were assumed). Table B-1.1.6 shows a summary of what treatments were used.

Table B-1.1.6 Summary of Residuals Handling Treatments Considered.

Unit Process Flow, mgd	Dewatering[1]	Gravity Thickeners[2]	Belt Filter Presses	Separate Reclamination[3]	Centrifuge[4]
0.5	X				
2	X	X			
5		X	X		
10		X		X	X
25		X		X	X
40		X		X	X

NOTES: (1) *Paved drying beds were used, 0.6 acres for 0.5 mgd and 2.1 acres for 2 mgd.* ***(2)*** *The 2 mgd used a 40 ft diameter thickener, 5 mgd - two 50 ft dia.; 10 mgd - three 50 ft dia.; 25/40 mgd - four 85 ft dia.* ***(3)*** *For spent filter backwash, an equalization tank is required.* ***(4)*** *Westfalia 535 was used for the 10 mgd, and Westfalia 635 was used for the 25 mgd and 40 mgd plants.*

For Part 2, it was assumed that the design solids loading operation times of 8 hrs/day for 0.5, 2, and 5 mgd (this operation is 24/7 – operators only need to check periodically); 12 hrs/day for 10 mgd; 24 hrs/day for 25 mgd and 40 mgd. A 5-day week for mechanical dewatering and a 7 day operation for thickening was taken as part of these costs.

The costs do not include any pumps or piping before the handling equipment. Also, not examined for this study, is the use of only gravity thickening for the small (0.5 to 2 mgd) plant sizes. The thickened sludge could then be hauled to another facility (such as a wastewater treatment plant) for treatment and disposal.

B-1.1.8 Membrane Treatment System Background

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Back to Part 1.1.8 Membrane Treatment System

Membrane processes are an important part of operations for water treatment. Recent developments in these technologies have resulted in membrane processes capable of more effective contaminant removal at lower capital and operating costs.

The following are the main types of membrane technologies used in water treatment:

- Microfiltration (MF)
- Ultrafiltration (UF)
- Nanofiltration (NF)
- Reverse Osmosis (RO)
- Electrodialysis/Electrodialysis Reversal (ED/EDR)

The general removal capability of each technology is summarized in Table B-1.1.8 and Figure B-1.1.8.a below. It is important to note that the filtration membranes (MF and UF) are used in most new surface water treatment plants because of their effectiveness in removing *Giardia* and *Cryptosporidium*. NF and RO membranes are used to remove dissolved material from water (such as, DBPP, TOC, and inorganic ions), with NF frequently referred to as "membrane softening" and RO providing almost complete desalination. ED/EDR is not a filtration process, but it removes charged materials, such as ions, so it is used for desalination in specialized applications. It is not considered for this report.

These processes can be categorized by pressure use or energy consumption. MF and UF are sometimes called low pressure processes, because typical transmembrane pressures are 14 to 36 psi (1 to 2.5 bar). NF operating pressures are 90 to 200 psi (6 to 14 bar), low salinity RO has 100 to 290 psi (7 to 20 bar), and seawater desalination with RO is 800 to 1000 psi (55 to 69 bar).

To meet the EPA secondary MCL guidelines, the RO and NF processes were sized using 80 percent of the raw water total dissolved solids (TDS) concentration as recorded in the water quality data.

A layout of a typical RO and NF membrane building is shown on Figure B-1.1.8.b, and a layout of a typical MF/UF membrane building is shown on Figure B-1.1.8.c.

The opinion of cost for the MF/UF membrane system is based on the GE Zenon system Models M52, L96, and L192. For Part 2 O&M costs, all membranes include the assumption that backwashing accounts for 30 percent of the feed pump energy use, assuming an energy cost of $0.08 per kW/hr.

Utilities use membrane technology to solve a wide array of municipal water treatment problems as summarized by Table B-1.1.8, including the following:

- Surface water treatment with MF or UF.
- Water reclamation with MF followed by RO.
- Desalination with RO.
- Softening with RO or NF.
- Nitrate (and other ion) removal with RO.
- Color, TOC, and DBP-precursor removal with RO or NF.
- Recovery of filter backwash water with MF/UF.
- Industrial processing for ultrapure water and reuse.

The membrane system maintenance costs include future membrane replacement (every five years) and cleaning chemicals. Ongoing maintenance chemicals such as pretreatment acid and antiscalant are not included in membrane costs, but are listed in Part 1.1.3 Chemical Feed and Storage.

Chemical cleaning is done once every 1 to 4 months and the MF/UF backwashing is generally done 1 to 3 times per hour, depending on site-specific and equipment-specific requirements. Backwashing is generally fully automated; chemical cleaning is manually selected by the operator and proceeds semi-automatically.

Table B-1.1.8 Typical Removal by Membrane Technologies.

Contaminant	**MF**	**UF**	**NF**	**RO**
Cysts	> 3 log (99.9%)	> 3 log (99.9%)	*Note 1*	*Note 1*
Viruses	> 0 – 2 log (0-99%)	> 3 log (99.9%)	*Note 1*	*Note 1*
TOC	0 – 20%	0 – 20%	90 – 98%	90 – 98%
Color	*Note 2*	*Note 2*	96%	96%
DBP-precursors	*Note 2*	*Note 2*	96%	98%
Atrazine	*Note 2*	*Note 2*	90%	96%
Hardness (Ca & Mg)	0%	0%	80 – 85%	98%
TDS	0%	0%	40 – 60%	90 – 98%
Arsenic (+5)	0%	0%	< 40%	95%
Chloride	0%	0%	10 – 50%	99%
Fluoride	0%	0%	10 – 50%	98%
Nitrate	0%	0%	10 – 30%	96%
Sulfate	0%	0%	80 – 95%	99%

NOTES: (1) *MF and UF are generally credited with at least 2.5 log removal of cysts by state agencies and in many cases at least 4-log. Actual removals exceeding 6-log have been observed. In ideal cases rejection of small particles (including cysts and viruses) by NF and RO is probably higher; however, equipment design makes it more difficult to verify this routinely; therefore, regulators may not grant such log removal values for NF/RO. NF/RO is typically not used for cyst removal, and frequently only a percentage of the raw water is treated.* ***(2)*** *Without chemical pretreatment, MF does not remove dissolved material and removal of such material by UF is minimal. Dissolved organic material can be removed by operating MF/UF in conjunction with a coagulant and/or by adding PAC.* ***(3)*** *Typical ion removal per stage is 40-50 percent. MF/UF is routinely used in many states for surface water treatment instead of granular media filtration. Its use is less common in Florida, because in this state treatment of surface water has been limited. Because of the excellent pretreatment that MF/UF provides for NF/RO, it has been used in some dual-membrane plants, such as for water reclamation. It is likely that MF/UF will be used in the future for pretreatment of seawater and brackish water.*

NF and RO have been widely used in Florida, primarily to treat brackish or hard groundwaters or waters containing high concentration of color-causing substances, but also for desalination of highly brackish water and seawater. Figure B-1.1.8.a. illustrates the various membrane types by the size of particles removed. It was assumed for calculation that the temperature of the water would be approximately 50°F (10°C).

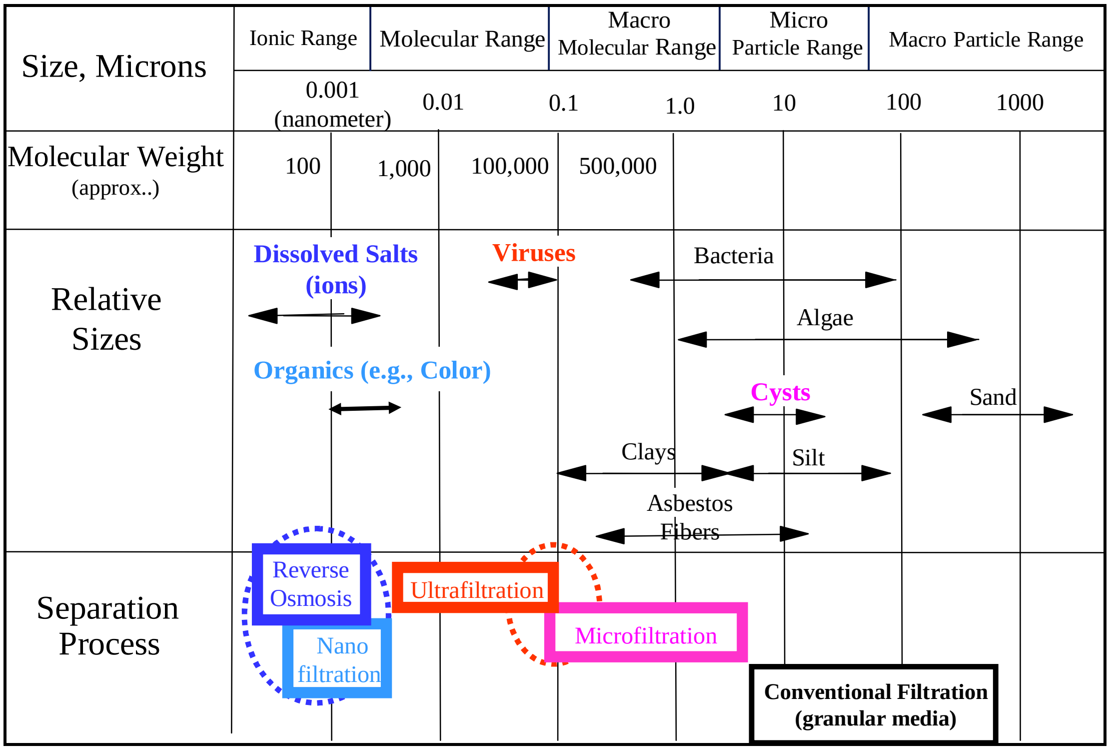

Figure B-1.1.8.a Membrane Removal Size Ranges.

Additional information is available in the following publications:

- AWWA (2007), Manual of Practice M: Reverse Osmosis and Nanofiltration, 2nd ed, AWWA, Denver.
- AWWA (2005), Manual of Practice M53: Microfiltration and Ultrafiltration Membranes for Drinking Water, 1st ed, AWWA, Denver.

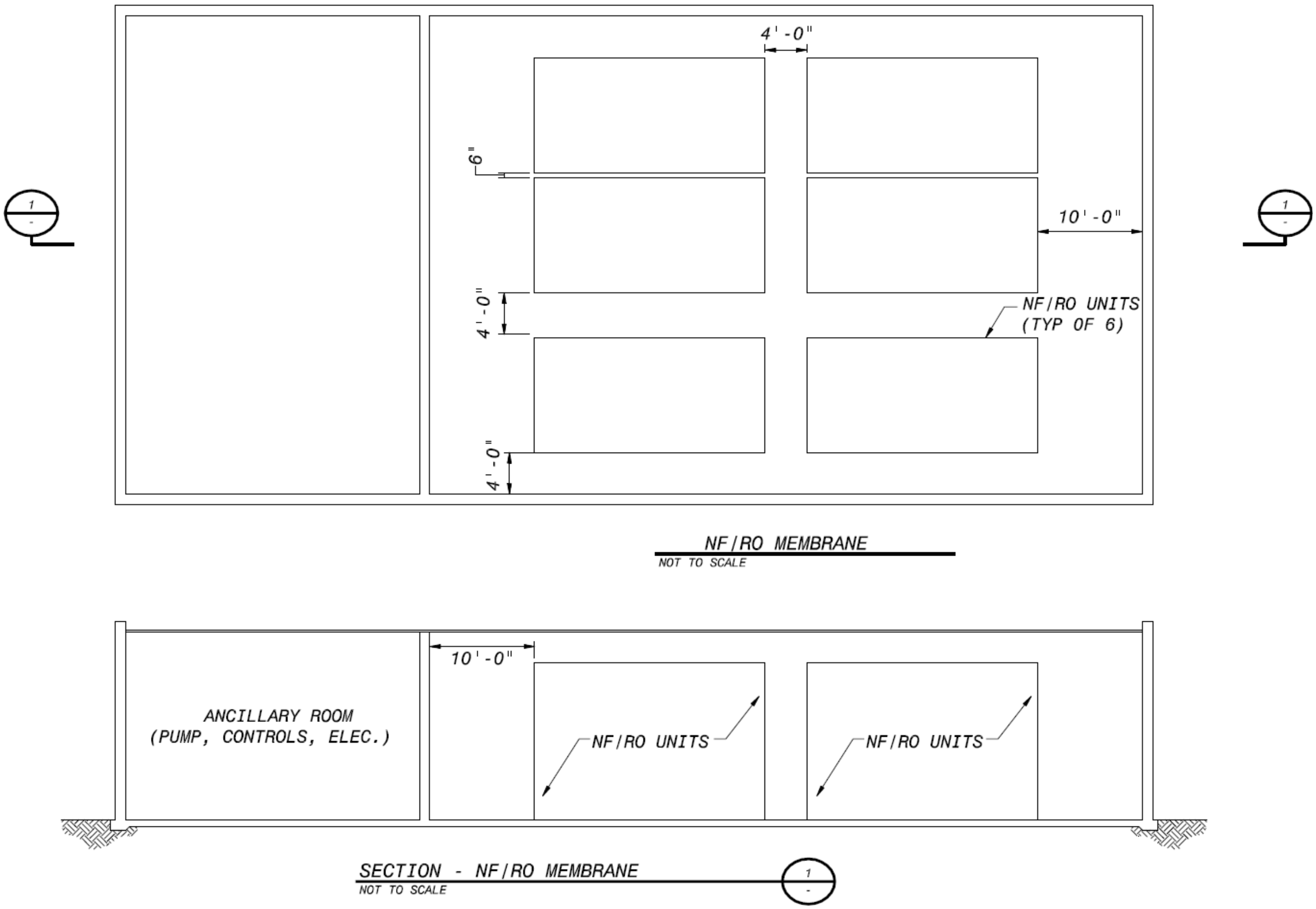

Figure B-1.1.8.b Typical NF/RO Membrane Building Layout.

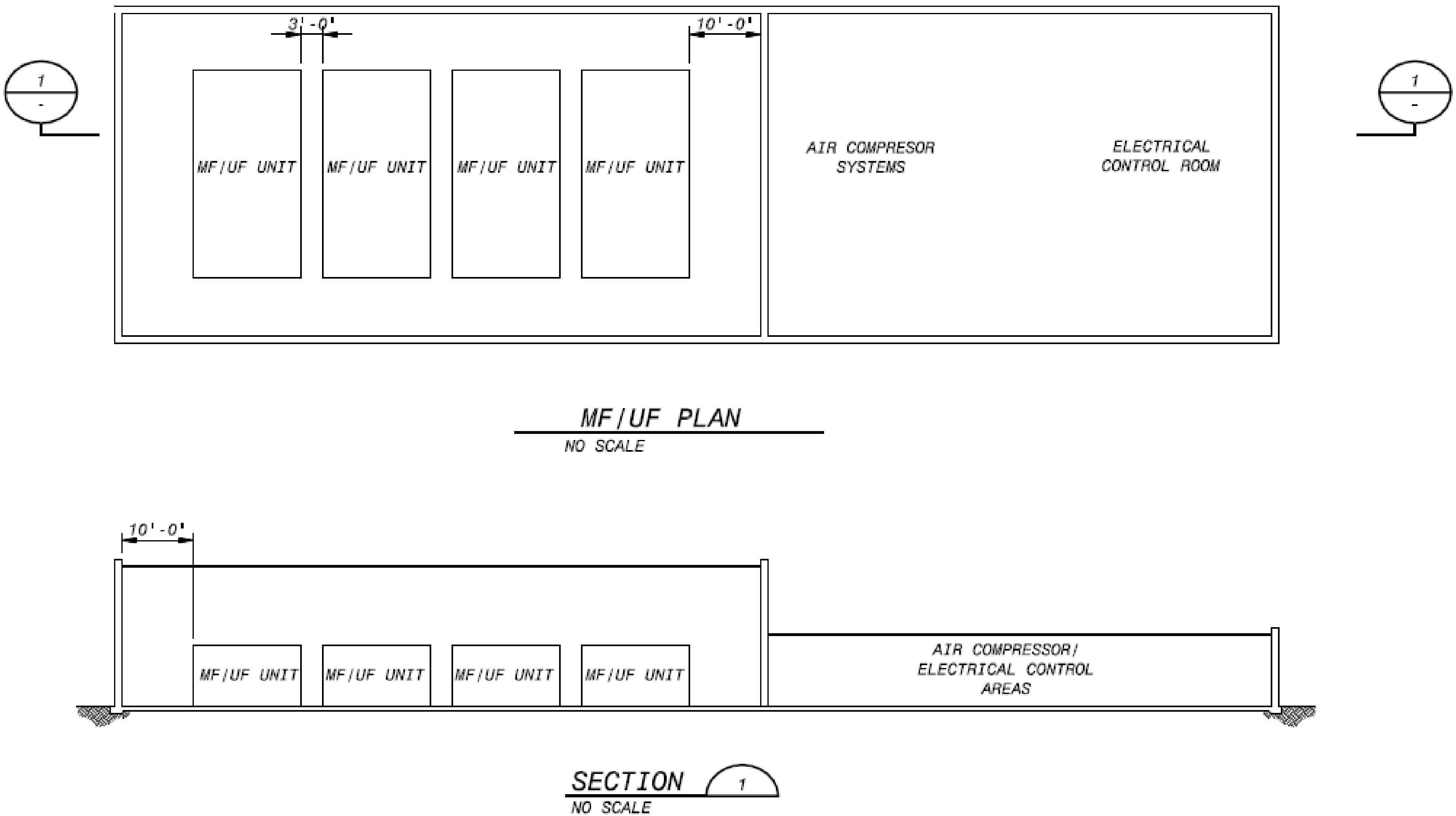

Figure B-1.1.8.c Typical MF/UF Membrane Building Layout.

B-1.1.9 Aeration Background

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Aeration is required only for groundwater treatment systems. Aeration is commonly done using cascading trays or perforated trays, both of which work by forming little waterfalls that cause the water to aerate naturally. Figure B-1.1.9.a, Cascading Aerator, and Figure B-1.1.9.b, Perforated Tray Aerator, show layouts of the two systems.

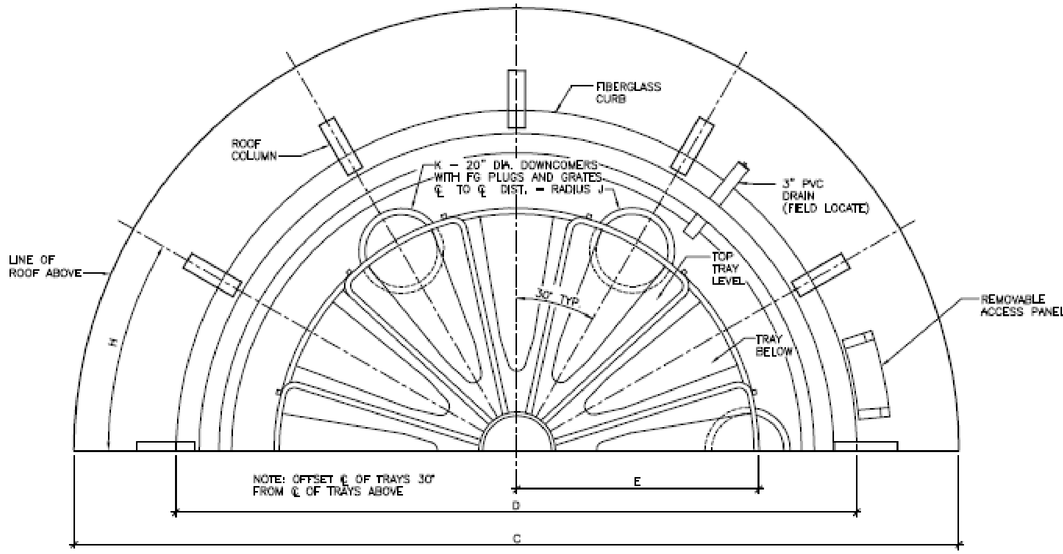
The perforated tray aerator consists of a series of horizontal perforated trays stacked 6 to 8 inches apart. The water enters the top tray, splashes over it, and passes through the holes into the next tray. The cascade aerator (also called a weir edge aerator) is quite similar to perforated tray aerators except that instead of trays, the water spills over a series of steps; each step is slightly larger than the one above it. Design data for the two systems are presented in Tables B-1.1.9.a and 1.1.9.b.

Table B-1.1.9.a Weir Edged Aerator Design Assumptions.

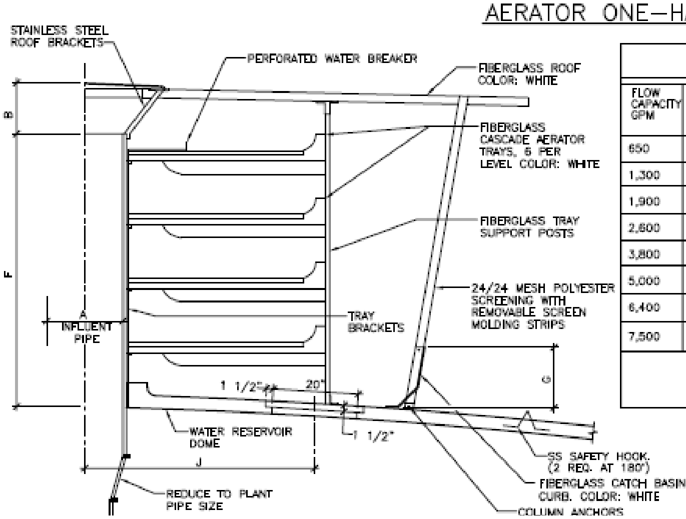
Capacity mgd	Capacity gpm	Total Weir Length, in.	Pipe Size in.	Number of Trays	Levels
0.94	650	47	14	6	1
1.87	1,300	94	14	12	2
2.74	1,900	141	14	18	3
3.74	2,600	188	18	24	4
5.47	3,800	276	20	18	3
7.20	5,000	368	24	26	4
9.22	6,400	460	24	30	5
10.80	7,500	552	30	36	6

Table B-1.1.9.b Perforated Tray Aerator Design Assumptions.

Capacity mgd	Number of Units	Capacity, gpm	Pipe Size in.	Number of Trays	Levels
7.20	1	5,000	24	12	1
14.40	1	10,000	30	24	2
21.60	1	15,000	36	36	3
28.80	2	20,000	30	24	2



AERATOR ONE–HALF PLAN



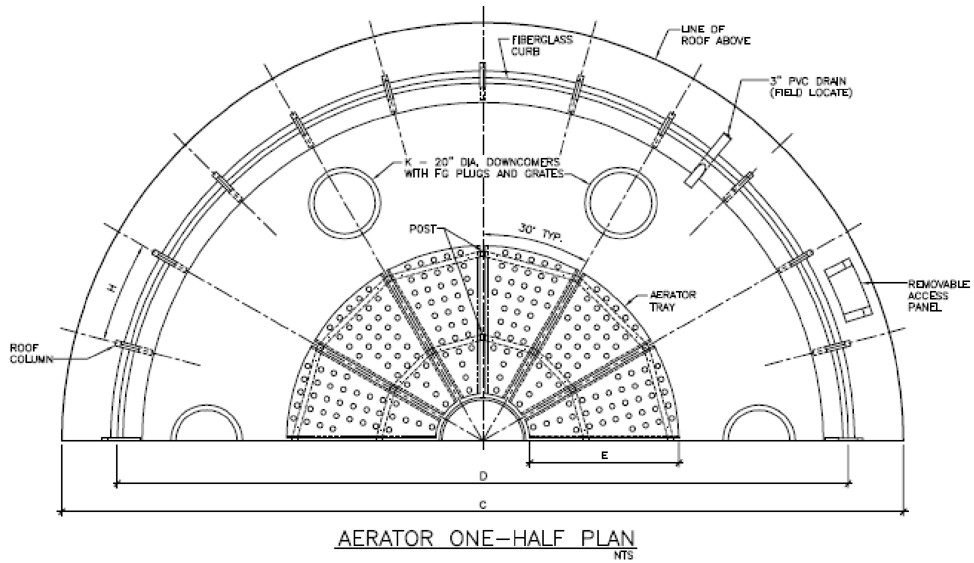
FLOW CAPACITY AND DIMENSION TABLE

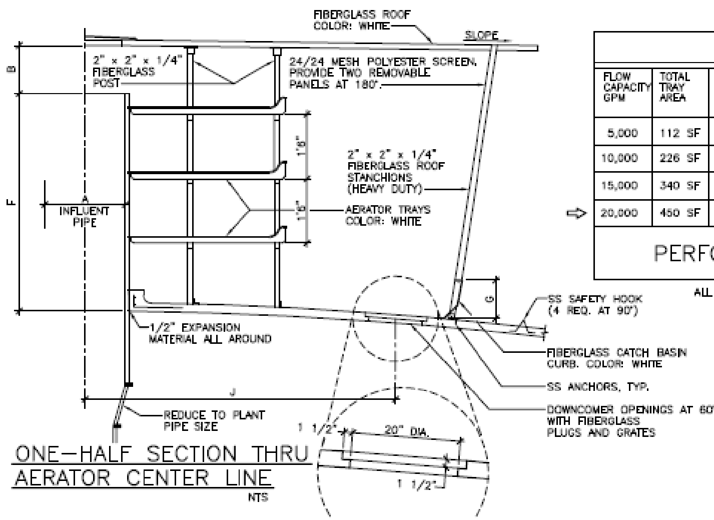
FLOW CAPACITY GPM	TOTAL WEIR LENGTH	A PIPE SIZE	B CLEAR	C ROOF DIA.	D CURB DIA.	E TRAY RADIUS	F PIPE HEIGHT	G CURB HEIGHT	H ROOF COLUMN SPACING	I TOTAL TRAYS (LEVELS)	J DOWN–COMERS RADIUS	K NUMBER DOWN–COMERS
650	47'0"	14"	1'0"	17'4"	13'4"	4'9"	5'4"	1'4"	30'	6 (1)	4'7"	2
1,300	94'0"	14"	1'0"	17'4"	13'4"	4'9"	5'4"	1'4"	30'	12 (2)	4'7"	2
1,900	141'0"	14"	1'0"	17'4"	13'4"	4'9"	5'4"	1'4"	30'	18 (3)	4'7"	2
2,600	188'0"	18"	1'0"	17'4"	13'4"	4'9"	5'4"	1'4"	30'	24 (4)	4'7"	2
3,800	276'0"	20"	1'6"	28'0"	23'4"	9'0"	5'4"	1'6"	15'	18 (3)	9'7"	3
5,000	368'0"	24"	1'6"	28'0"	23'4"	9'0"	5'4"	1'6"	15'	24 (4)	9'7"	3
6,400	460'0"	24"	1'6"	28'0"	23'4"	9'0"	7'2"	1'6"	15'	30 (5)	9'7"	3
7,500	552'0"	30"	1'6"	28'0"	23'4"	9'0"	8'4"	1'6"	15'	36 (6)	9'7"	4

CASCADE TRAY NATURAL DRAFT AERATORS

ALL FIBERGLASS CONSTRUCTION WITH STAINLESS STEEL HARDWARE

Figure B-1.1.9.a Cascading Aerator.





FLOW CAPACITY AND DIMENSION TABLE

FLOW CAPACITY GPM	TOTAL TRAY AREA	A PIPE SIZE	B CLEAR	C ROOF DIA.	D CURB DIA.	E TRAY LENGTH	F PIPE HEIGHT	G CURB HEIGHT	H ROOF COLUMN SPACING	I TOTAL TRAYS (LEVELS)	J DOWN–COMERS RADIUS	K NUMBER DOWN–COMERS
5,000	112 SF	24"	1'6"	28'0"	23'4"	5'0"	5'4"	1'6"	15'	12 (1)	9'7"	3
10,000	226 SF	30"	1'6"	28'0"	23'4"	5'0"	5'4"	1'6"	15'	24 (2)	9'7"	5
15,000	340 SF	36"	1'6"	28'0"	23'4"	5'0"	5'4"	1'6"	15'	36 (3)	9'7"	6
⇨ 20,000	450 SF	42"	1'6"	28'0"	23'4"	5'0"	7'3"	1'6"	15'	48 (4)	9'7"	6

PERFORATED TRAY NATURAL DRAFT AERATORS

ALL FIBERGLASS CONSTRUCTION WITH STAINLESS STEEL HARDWARE

Figure B-1.1.9.b Perforated Tray Aerator**.**

B-1.1.12 UV Disinfection Background

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UV disinfection is the process of irradiating water with UV light and it is effective for inactivating *Cryptosporidium* and *Giardia*. Inactivation of *Cryptosporidium* and other pathogens is most efficient around a wavelength of 254 nm, the wavelength that maximizes the mutation of DNA. The clearer the water, or the lower the adsorption of light at 254 nm, the deeper the light can penetrate and achieve greater inactivation of *Cryptosporidium*. Clarity of water at 254 nm is referred to as UV transmittance (UVT) (0-100 percent).

The size of UV facilities is determined by the intensity of the light, the distance of the pathogen from the UV light, and the duration of exposure to the pathogen with UV light. The UV reactor is generally located downstream from coagulation, filtration, and other treatment processes that remove the light-absorbing organic molecules and suspended particles. Unlike chlorine and other oxidants used in drinking water treatment, UV leaves no residual; therefore a secondary disinfectant is required to provide a residual.

The UV facility was sized for the volume of finished water produced, with an additional reactor for redundancy. Generally, B&V evaluates reactors of various sizes and types from several suppliers during detailed design to ensure that the client receives a system that will provide adequate disinfection at the lowest present worth cost.

UV reactors of two types are usually evaluated: low pressure high output (LPHO) and medium pressure (MP). LPHO lamps have lower intensity than MP lamps; therefore, the reactors are larger in diameter and include many more lamps to achieve the same level of disinfection. These systems may be more expensive in terms of capital cost and building footprint, but may have a lower present worth cost, as they are more efficient in terms of electric power consumption. MP reactors are usually much smaller, with fewer lamps, but are less efficient from the electric power consumption standpoint.

One important design consideration for a UV system is the design UVT of the water. In order to optimize the system design, B&V recommends that UVT data be collected for at least 6 months, or up to one year. For this analysis, a design UVT of 84 percent was assumed. The design UVT is usually lower than the average UVT of the water, since the design value selected typically represents the 95th percentile of the dataset. Therefore, to determine the anticipated power costs of a system, the power consumption is based on the average UVT value. For this analysis, an average transmittance of 90 percent was assumed. Waters pretreated by RO may have a much higher UVT, which would result in slightly less expensive UV facilities.

The area required for the UV system varies widely, depending on the manufacturer, size and type of reactors, and client preference; thus the area presented in Table B-1.1.12

should be considered an average. The building would house the UV reactors, electrical equipment, flowmeters, valves, and control systems. A large portion of the space is allocated to accommodating laminar flow at the reactor, which may require up to five pipe diameters upstream and three pipe diameters downstream from the reactor, as well as a flowmeter and two isolation valves for maintenance at each UV train. The costs in Part 1, Table 1.1.12, are the midpoint of the two extremes, taking into consideration the differences in building areas and proprietary equipment; and are considered reasonable for the planning level.

Equipment cost data and approximate building area were determined using a probable cost tool developed by B&V for the American Water Works Research Association Foundation (AWWARF). The dimensions of the designed systems are listed in Table B-1.1.12.

Table B-1.1.12 UV Disinfection Design Assumptions.

Unit Process Flow, mgd	Number of Duty Reactors	Number of Standby Reactors	Reactor Flange Diameter Range, in.	Building Area, Range sq ft
0.5	1	1	12 – 18	600 – 1,000
2	1	1	12 – 24	800 – 1,200
5	1	1	20 – 42	1,600 – 2,800
10	2	1	20 – 42	1,900 – 3,500
25	2	1	24 – 48	2,100 – 4,800
40	2	1	40 – 48	3,100 – 5,100

B-1.1.13 Ozone Disinfection Background

Back to Appendix B.

Ozone (O_3) is a powerful oxidizing agent that is widely used for disinfection, oxidation of organics, inorganics, removal of color, oxidation of DBPP, removal of taste- and odor-causing compounds, and in some cases, to improve TOC removal when used in combination with coagulation and biological filtration.

Ozone must be generated onsite, as it is not stable and decomposes very quickly to oxygen. Ozone is generated through a process that consists of applying electricity to a gas that contains oxygen and transferring the gas into water. The gas is usually treated air or nearly pure oxygen that is essentially free of particles and hydrocarbons and has very low relative humidity (dewpoint). The oxygen-containing gas is usually delivered to the site as at least 99.99 percent pure liquid oxygen (LOX). The LOX is vaporized to gaseous oxygen (GOX) using ambient vaporizers that use the heat in the air to evaporate the LOX to GOX. The gas is filtered and its pressure is regulated to approximately 10 to 20 psi before it enters the ozone generators. Sometimes a small amount of nitrogen or air, 1-5 percent, may be introduced upstream from the generators to improve the generator efficiency. Only a portion of the GOX that enters the generator, typically 10-12 percent, is converted to O_3, and most of the energy added is removed in the cooling water system in the form of heat.

The gas is then conveyed to the feed point and injected into a sidestream that is blended with the main flow or diffused into the water. Many utilities are installing sidestream injection systems that offer greater flexibility in terms of the dimensions and types of ozone contactors, and eliminate contactor maintenance. The tradeoff between the two transfer methods is that the sidestream system may or may not have lower capital cost, and sidestream systems have higher operating costs. Downstream from the dissolution system, the water may have a dissolved ozone residual which is monitored for disinfection and process control.

The size of the contactor varies, but typically it has a hydraulic retention time of 5 to 20 minutes. Large contactors are necessary for disinfection and for very low water temperatures. The ozone residual at the outlet of the contactor must be less than 0.05 mg/L, and in some cases, it may be quenched with chemicals.

Probable costs were developed for an intermediate ozonation system, located downstream from the pretreatment process and upstream from filtration. This location should have a lower ozone demand. The system was designed to deliver a firm (largest unit out of service) ozone dosage of 5 mg/L, which was selected to provide an ozone dosage to TOC ratio of 0.5 mg/mg. The settled water TOC concentration was assumed to be 10 mg/L. Waters lower in TOC are likely to have lower ozone demand, which may allow a smaller, less expensive system.

The average TOC to ozone ratio was assumed to be 0.25 mg/mg; and the annual operating cost is based on an ozone dosage of 2.5 mg/L. This dosage should be adequate to provide some preoxidation, reduction of chlorination DBPP, and some control of taste- and odor-causing compounds. The maintenance cost does not include LOX, which can be obtained from a local supplier and added to the cost based on the assumption that 10 pounds of oxygen is needed for every one pound of ozone generated.

The system equipment consists of a LOX storage tank, LOX vaporizers, two ozone generators, dissolution system, ozone contactor, ozone off-gas destruction units, instrumentation, and buildings. The equipment costs were developed based on projects of similar size. The sizes of the building, generators, and ozone contactors are listed in Table B-1.1.13.

Table B-1.1.13 Ozone System Design Assumptions.

Unit Process Flow, mgd	Generator Size, ppd	Number of Units	Building Area, sq ft	Contactor Footprint, sq ft
0.5	25	2	800	50
2	90	2	1,000	150
5	210	2	1,200	500
10	420	2	2,000	1,500
25	1,050	2	3,000	5,000
40	1,700	2	3,500	10,000

B-1.1.14 Granular Activated Carbon (GAC) Filters Background

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A granular activated carbon (GAC) filter is similar to a deep bed filter, using GAC media instead of anthracite and sand. Activated carbon is highly effective in removing organic contaminants from water. GAC is used in water treatment plants because of its ability to adsorb a variety of dissolved organic contaminants: disinfection byproduct precursors, synthetic organic chemicals, color, and taste- and odor-causing compounds.

The GAC was assumed to have a depth of 8 ft and was designed for a loading rate of 4 gpm/sf with all basins in service. The empty bed contact time (EBCT) for the GAC filter at design flow and with all units in service was 15 minutes. Shorter EBCTs typically result in efficient use of the GAC. Longer contact times may result in slightly better performance or in longer intervals between GAC regenerations. Industry practice is to provide 10 to 20 minutes of contact time, although 15 to 20 minutes is standard for removal of DBPP.

The GAC filters are concrete basins through which filtered water flows by gravity. Because the water is already filtered, the GAC filters do not capture any turbidity, and therefore, need to be backwashed only once or twice a month to remove the small amount of solids that may accumulate and to eliminate preferential flow through the basins. The underdrain is an integrated media support (IMS) cap, or equivalent, and the filter includes an air/water backwash system. The filter can also operate in the filter-to-waste mode, whereby for the first 10 to 20 minutes after a filter start-up, the filtered water is wasted. Data on the filters and their sizes are presented in Table B-1.1.14.

Maintenance costs for the GAC basins were developed assuming that the filters would be operated to remove total organic carbon (TOC) by adsorption. The GAC would be replaced every six months at a cost of $1.10 per pound. GAC weighs approximately 30 pounds per cubic foot.

Table B-1.1.14 GAC Filter Design Assumptions.

Unit Process Flow, mgd	Number of Filters	Number of Backwash Pumps	Number of Air Compressors	Total Length, ft	Total Width, ft
0.5	2	2	2	18.5	26
2	4	2	2	59.5	42
5	4	3	2	95.5	54
10	6	3	3	184.5	54
25	10	4	3	264	66.5
40	12	4	3	316.5	78.5

B-1.1.16 High Service Pumping

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Due to size limitations, hydropneumatic tanks were used only for plant capacities of 0.5, 2, and 5 mgd. For the larger sizes where hydropneumatic tanks are cost prohibitive, an AFD system was installed for each pump. The cost includes training, field testing, spare parts, conduit and wire, PLC, and programming costs for each pump.

For design, a horizontal split case pump was used with one pump as standby. A pressure head of 300 ft, a pumping efficiency of 80 percent, and motor efficiency of 95 percent was used. The remaining data on pump sizes are listed in Table B-1.1.16.

Table B-1.1.16 High Service Pump Station Design Assumptions.

Pumping Capacity, mgd	Pumping Capacity, gpm	Pressure Head, ft	No. of Pumps in Use	Flow per Pump	Motor HP Required
0.5	347	300	2	175	20
2	1,389	300	2	695	100
5	3,472	300	2	1,736	200
10	6,944	300	3	2,314	250
25	17,361	300	3	5,787	600
40	27,778	300	3	9,260	1,000

B-1.1.17 Clearwell Background

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A clearwell serves as the source of water for the transfer pumps and is typically sized for 15 minutes of the total plant flow. In this case, the clearwell is an above ground concrete structure.

The dimensions of the tanks are listed in Table B-1.1.17.

Table B-1.1.17 Clearwell Design Assumptions.

Flow, mgd	Storage, gal	Length, ft	Width, ft	Height, ft
0.50	3,472	20	20	3
2	13,889	30	30	3
5	34,722	40	40	4
10	69,444	60	40	4
25	173,611	100	60	4
40	277,778	150	60	5

B-1.2 Transmission Piping Background

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The values for ROW and other design information used to approximate the piping costs shown in Table B-1.2. Pavement replacement was assumed to be saw-cut, as defined in B&V standard specifications. The cost of road resurfacing was not included. The probable costs do not include tunnels for railroads or river crossings. The costs were based on manufacturer's pricing and knowledge of recent Florida pipeline projects. The piping material costs were determined with help from the American Cast Iron Pipe Company, as included in Appendix C.

Table B-1.2 Transmission Piping Right of Way.

Pipe Size, in.	Material	Construction ROW, ft	Trench Box Used
10	PVC	25	No
12	PVC	25	No
14	PVC	30	No
16	PVC	30	No
18	PVC	30	No
20	PVC	30	No
24	PVC	30	No
30	DI	65	Yes
36	DI	65	Yes
42	DI	65	Yes
48	DI	65	Yes
54	DI	65	Yes
60	STEEL	65	Yes
66	STEEL	65	Yes
72	STEEL	65	Yes
78	STEEL	65	Yes
84	STEEL	65	Yes
90	STEEL	65	Yes
96	STEEL	65	Yes

B-1.4 Trenchless Technology Background

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Back to Part 1.4 Trenchless Technology.

Trenchless technology includes both horizontal directional drilling (HDD) and tunneling. There are variances in prices depending on the pipeline location and what it is crossing. Thus, the probable cost was broken down into public right-of-way (ROW), wetlands, and river crossing. Public ROW consists of roads or road ROW, railways or railway ROW, private or public property, and public areas, such as parks. An example would be a tunnel under a highway or a private parking lot. Wetlands consists of a federally or state defined wetland or swamp area. River crossing would be a river or stream crossing, from one bank to the next.

The cost of trenchless technology depends greatly on the type of soil and ground conditions. For this design, it was assumed that soil conditions were acceptable, consisting of materials such as a silty-sand, with few or no rocks/boulders. It was also assumed that no contaminated water or soil, and no unstable or non-compressible soil would be encountered.

HDD does not involve dewatering, so no dewatering cost was included in the prices. The probable cost includes the disposal (hauling) of waste, labor, materials, equipment, and drilling and mobilization costs. For HDD, the actual installation of pipe is typically 95 percent of the total cost; the remaining 5 percent covers the equipment setup and sitework. Figure B-1.4 shows the typical HDD process of installing pipe.

For tunneling, which can require dewatering, a well point was included for every 150 linear feet of alignment. The probable costs for tunneling include set-up, pipe materials, labor, and tools. Also included in the cost is the disposal (hauling) of wastes, trench box shafts and steel plates, casing pipe, skids in casing pipe with sand or pea gravel fill, and mobilization costs. The actual tunneling work typically accounts for 75 percent of the total cost; the remaining 25 percent covers the shaft and mobilization. For these costs, to be valid, only tunnels from 10 to 20 feet in depth were considered. Deeper tunnels would be an additional cost.

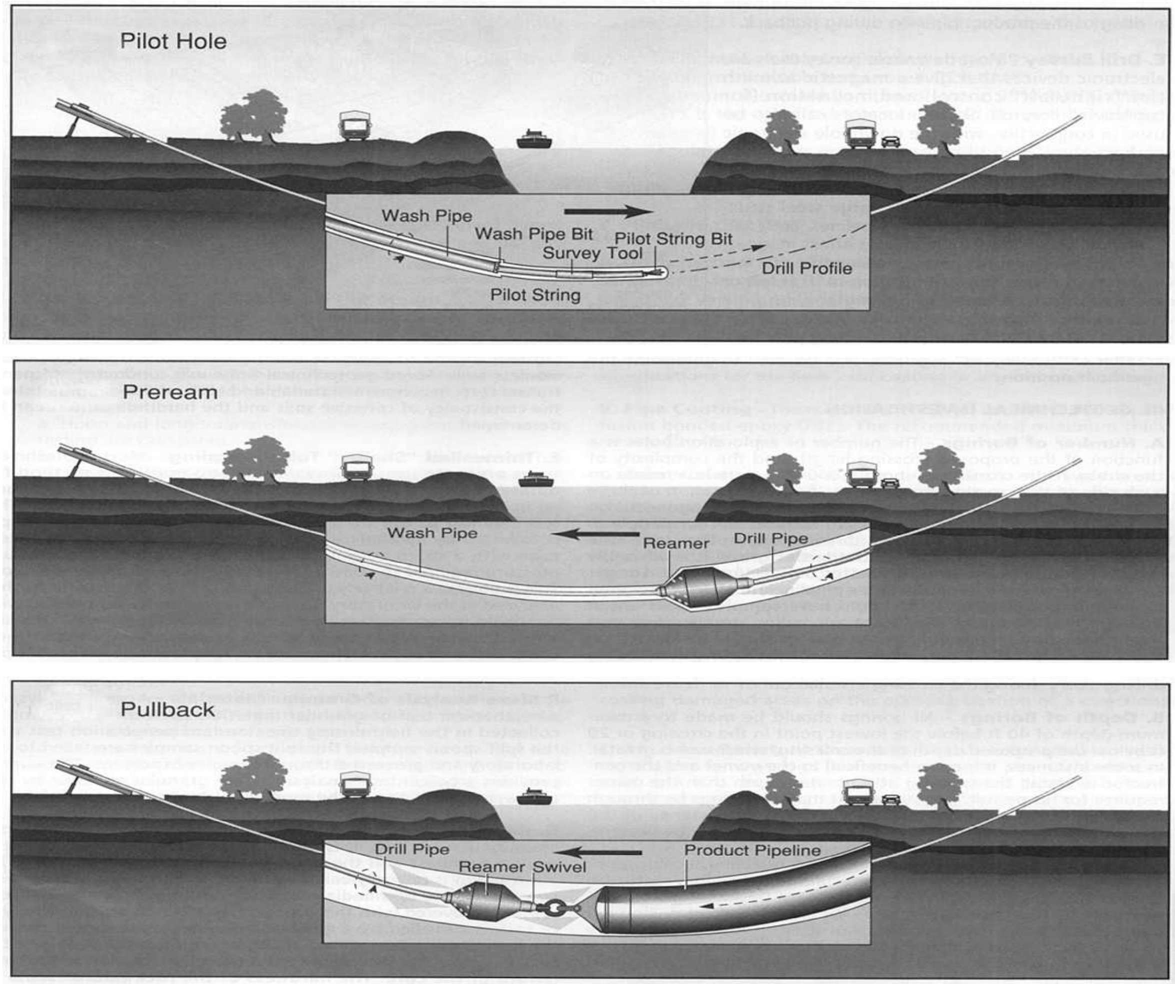

Figure B-1.4 HDD Process.

B-1.5 Water Production Wells Background

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Back to Part 1.5 Water Production Wells.

The water production wells do not include any costs for pumping or piping of the water. The opinion of probable cost includes driller mobilization/demobilization costs, sitework, drilling of well and casing, well and pumping tests, geophysical logging, and a 12-inch thick, 6-foot by 6-foot reinforced concrete pad.

Sitework includes clearing, access roads, the drilling pad, pad for monitor wells, an on-site project office, water and power supplies, and site restoration. The drilling costs include the drilling rig with all associated construction labor and materials, permitting, and construction supervision. The cost opinion was based on the use of a steel casing, but the prices of fiberglass or PVC pipe for larger wells are comparable. PVC can be used only for less than 300 feet deep wells. Testing includes geophysical logging, packer tests, specific capacity tests, and aquifer performance tests. Production logging includes measurement of temperature, gamma, caliper, resistivity, flow, and includes downhole video.

B-1.6 Ground Storage Tanks Background

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Back to Part 1.6 Ground Storage Tanks.

The ground storage tanks for each plant flow are sized to hold approximately 15 percent of the total flow. The tanks are prestressed concrete with a domed cover, 4-inch thick reinforced concrete floor slab, exterior painting, interior and exterior ladders, a dome ventilator, dome hatch with fiberglass cover, and a wall manhole.

The required storage volume (15 percent of the flow) and the actual storage volume provided, as well as the dimensions of the tanks are listed in Table B-1.6. The probable costs were determined with aid from Crom Corporation.

Table B-1.6. Ground Storage Tanks Design Assumptions.

Flow mgd	Required Storage Volume, Mgal	Actual Storage Volume, Mgal	Number of Tanks	Height ft	Diameter ft
0.5	0.08	0.10	1	13.92	35
2	0.30	0.50	1	20.17	65
5	0.75	1.00	1	30.34	75
10	1.50	2.00	1	34.08	100
25	3.75	4.00	1	37.42	135
40	6.00	6.00	1	42.42	155

B-2.4 Residuals Disinfection Background

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Back to Part 2.4 Residuals Disinfection.

Referenced figures are from Appendix B-1.1.3.a Chemical Feed and Storage.

Ammonia

An aqueous ammonia feed system will be located within the chemical building. Liquid aqueous ammonia at a concentration of 19 percent will be delivered in 250 gallon tote bins and fed to one feed point using two (one duty, one standby) peristaltic tube type metering pumps. A scale will be provided to monitor chemical remaining in the tote. Carbon steel piping with ball valves will be used inside the building. The buried yard piping will be high density polyethylene (HDPE). Control of the chemical feed pumps will be achieved by flow pacing proportional to the transmission main and measure of chlorine residual. An ammonia gas detector will be provided in the ammonia storage/feed room. For the 3 mgd station, a typical schematic is shown on Figure B-1.1.3.a.

There are slight differences between the equipment for the transmission mains with capacities of 10, 25, 50 and 80 mgd. The aqueous ammonia feed system will be located adjacent to and within the chemical building. For the 10 mgd system, the liquid aqua ammonia will be delivered by bulk truck loads and stored in a 1,000 gallon carbon steel storage tank located outdoors; the 25 mgd system requires a tank of 2,500 gallons, the 50 mgd system a 5,000 gallon tank, and the 80 mgd system a 7,000 gallon tank. The chemical will be fed using two (one duty, one standby) motor driven diaphragm type metering pumps. For the larger plants, a dedicated air compressor will be provided to pressurize the storage tank to increase the NPSH to the metering pumps. A typical schematic is shown on Figure B-1.1.3.b.

Sodium Hypochlorite

A sodium hypochlorite feed system will be located in the chemical building. Liquid sodium hypochlorite at a concentration of 12.5 trade percent will be delivered and stored in two 1,000 gallon FRP storage tanks for the 3 mgd system, two 2,500 gallon tanks for the 10 mgd system, two 5,500 gallon tanks for the 25 mgd system, two 10,000 gallon tanks for the 50 mgd system, and two 16,000 gallon tanks for the 80 mgd system. The chemical will be fed to the transmission main using two (one duty, one standby) motor driven diaphragm type metering pumps for each plant. CPVC piping with diaphragm valves will be used inside the building. The buried yard piping will be Teflon tubing or hose. Control of the chemical feed pumps will be achieved by flow pacing proportional to the plant flow. A typical schematic is shown on Figure B-1.1.3.e.

B-2.6 Brackish Groundwater Treatment Plant Background

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Back to Part 2.6 Brackish Groundwater Treatment Plant.

The chemical feed system includes sodium hypochlorite, antiscalant, sodium bisulfate, fluoride, ammonia, corrosion inhibitor, and caustic.

The residuals handling conventional surface water treatment plant includes gravity thickening and dewatering. The design information used to determine the costs is listed below in Table B-2.6.

Table B-2.6 Residual Handling for Brackish Groundwater.

MDPC mgd	**Design Solids Production, ppd**	**Gravity Thickeners**		**Drying Beds, acre**
		Number	**Diameter, ft**	
2	80	1	20	0.2
5	200	1	30	0.6
10	390	1	40	0.8
25	980	1	60	2.0
40	1,580	1	70	3.2

NOTE: *Belt filter presses were not used; ppd is pounds per day.*

B-2.7 Conventional Surface Water Treatment Plant Background

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Back to Part 2.7 Conventional Surface Water Treatment Plant.

The chemical feed system includes sulfuric acid, ferric sulfate, powdered activated carbon, caustic, polymer, sodium hypochlorite, lime, fluoride, ammonia and corrosion inhibitor.

The residuals handling conventional surface water treatment plant includes gravity thickening and dewatering. The design information used to determine the costs is listed below in Tables B-2.7.

Table B-2.7 Residual Handling for Conventional Surface Water.

MDPC mgd	Design Solids Production, ppd	Reclamation, mgd	Gravity Thickeners	
			Number	Diameter, ft
2	1,500	-	1	30
5	3,800	-	1	40
10	7,600	0.71	1	60
25	18,900	1.79	2	60
40	30,200	2.86	3	60

(Table B-2.7 Continued)

MDPC mgd	Drying Bed Dewatering, acre	Belt Filter Presses	
		Number	Belt Width, m
2	1.4	-	-
5	3.4	-	-
10	-	2	2
25	-	2	2
40	-	3	3

NOTE: *ppd stands for pounds per day and belt widths are given in meters.*

B-2.8 Brackish Surface Water Treatment Plant Background

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Back to Part 2.8 Brackish Surface Water Treatment Plant.

The chemical feed system includes potassium permanganate, sulfuric acid, ferric sulfate, powdered activated carbon, caustic, polymer, sodium hypochlorite, sodium bisulfate, antiscalant, carbon dioxide, lime, fluoride, ammonia and corrosion inhibitor.

The residuals handling for the potable and non-potable treatment options of the brackish surface water includes gravity thickening and dewatering. The design information used to determine the costs is listed below in Tables B-2.8.1 and B-2.8.2.

Table B-2.8.1 Residual Handling for Brackish Surface Water for Potable Treatment.

MDPC Mgd	Design Solids Production, ppd	Reclamation mgd	Gravity Thickeners	
			Number	Diameter, ft
2	2,100	-	1	40
5	5,200	0.6	1	50
10	10,400	1.2	1	60
25	26,000	3.0	3	60
40	41,600	4.8	4	60

(Table B-2.8.1 Continued)

MDPC mgd	Drying Beds acre	Belt Filter Presses	
		Number	Belt Width, m
2	2.4	-	-
5	-	2	2
10	-	2	2
25	-	3	2
40	-	3	2

NOTE: *ppd stands for pounds per day and belt widths are given in meters.*

Table B-2.8.2 Residual Handling for Brackish Surface Water for Non-Potable Treatment.

MDPC Mgd	Design Solids Production, ppd	Reclamation, mgd	Gravity Thickeners	
			Number	Diameter, ft
2	2,100	-	1	30
5	5,200	0.3	1	50
10	10,400	0.5	1	60
25	26,000	1.3	3	60
40	41,600	2.1	4	60

(Table B-2.8.2 Continued)

MDPC mgd	Drying Beds, acre	Belt Filter Presses	
		Number	Belt Width, m
2	2.4	-	-
5	-	2	2
10	-	2	2
25	-	3	2
40	-	3	2

NOTE: *ppd stands for pounds per day and belt widths are given in meters.*

B-2.9 and B-2.10 Seawater Desalination Plant Background

Back to Appendix B.
Back to Part 2.9 Seawater Desalination.
Back to Part 2.10 Seawater Desalination.

The chemical feed systems for the desalinization plants in described in Parts 2.9 and 2.10 include sulfuric acid, ferric sulfate, powdered activated carbon, sodium hypochlorite, sodium bisulfate, antiscalant, carbon dioxide, lime, caustic, fluoride, ammonia, and corrosion inhibitor.

Several assumptions were made in determining the cost of a complete desalination plant. The cost of the desalination plant co-located with the power plant (Part 2.9) includes a Hobas pipe connecting the spent power plant cooling water to the intake of the desalination plant. The wastewater and concentrate from the water treatment plant was conveyed by a Hobas pipe to a shared outfall with the power plant. The treatment processes are listed in Part 2.9 Seawater Desalination Co-Located with Power Plant.

For the complete desalination plant in Part 2.10, the costs were divided into three different segments: (1) the intake system, (2) the treatment processes, (3) the outfall system. The treatment processes are listed in Part 2.10 Seawater Desalination.

The intake system consists of an offshore ocean-floor intake, a pipeline from the intake to shore, and a screening and pumping station. These costs are based on the following assumptions:

- Pipe material is HDPE.
- Maximum depth of pumping station is 30 ft below ground level.
- Offshore intake is 20 ft underwater and 0.85 mile from shore.
- Use of traveling bar screens.
- Compressed air systems for maintenance and cleaning.

Not included is a cost of a chlorination diffuser on the off-shore intake. The diffuser could be installed to impede marine growth within the pipeline.

The outfall costs are based on the following assumptions:

- Pipe material is HDPE.
- Final depth 40 ft vertical below low tide level.
- Diffusers located 1.5 nautical miles from shore.
- Discharge pumps are not required.
- Diffusion orifices are cut into the pipe.

Not included is an emergency storage tank. This cost can be added if needed.

The residuals handling for the desalination plant was based on dewatering and gravity thickening. The methods are detailed in Table B-2.9 and are the same for Part 2.10.

Table B-2.9 Residual Handling Design Assumptions.

MDPC mgd	Design Solids Production, ppd	Reclamation, mgd	Gravity Thickeners	
			Number	Diameter, ft
2	1,100	-	1	40
5	2,600	-	2	50
10	5,100	1.9	1	50
25	12,800	4.5	2	50
40	20,500	7.4	3	50

(Table B-2.9 Continued)

MDPC mgd	Drying Beds, acre	Belt Filter Presses	
		Number	Belt Width, m
2	1.2	-	-
5	2.9	-	-
10	-	2	2
25	-	2	2
40	-	2	2

NOTE: *ppd stands for pounds per day and belt widths are given in meters.*

An alternative to the offshore intake would be the Taprogge package system, which includes screens and an air backwash system. The opinion of cost for this system is presented in Table B-2.10. The Taprogge system must be installed on the shoreline, so while the construction costs are lower, the intake is above ground and requires beachfront property which could be cost prohibitive. More information about Taprogge is available in Appendix C. The O&M costs for the Taprogge system do not include electric power consumption or necessary operators and maintenance personnel.

Table B-2.10 Taprogge Package Intake System—Construction OPC and Maintenance.

MDPC mgd	Equipment Installation	Intake Pipe	Pumping Station	Total System	Maintenance $/year
2	$137,000	$72,000	$698,000	$907,000	$44,000
5	$183,000	$112,000	$1,070,000	$1,360,000	$66,000
10	$296,000	$168,000	$1,660,000	$2,120,000	$103,000
25	$455,000	$240,000	$2,440,000	$3,130,000	$150,000
40	$604,000	$312,000	$3,250,000	$4,160,000	$202,000

B-2.12 Reclaimed Water Storage Ponds Background

Back to Appendix B.
Back to Part 2.12 Reclaimed Water Storage Ponds.

Reclaimed water is used to balance production and demand in reclaimed water supply systems, and depending on the method of system operations, can provide long-term or seasonal storage. Reclaimed water storage basins are normally constructed partially below ground. In highly permeable soils, such as those in Florida, the basins must be lined in order to retain the reclaimed water.

Because storage in open reservoirs changes the characteristics of reclaimed water, a variety of design features and operating strategies can be implemented to avoid water quality problems. B&V prepared a report for the Water Environment Research Foundation (WERF) in 2003 titled *Impact of Surface Storage on Reclaimed Water for Non-Potable Use: Seasonal and Long Term* (Project 99-PUM-4); and B&V is currently working on a follow-on report for the Water Reuse Foundation (WRF) titled *Selecting Treatment Trains for Seasonal Storage of Reclaimed Water: Treatment of Influence to and Withdrawals from Storage* (WRF-04-021). Both these studies indicate that impacts to water quality in impoundments are related to the design (generally its depth) and the treatment processes used to produce the reclaimed water.

Utilities that plan to use large reclaimed water storage ponds may find, the information in the WERF report and in the WRF study in its current stage of some value. Of particular interest may be the current research on treatment processes to minimize water quality problems, particularly in larger basins such as contemplated for the 40 million gallons (Mgal) system.

The construction cost and required land areas for total storage capacities of 2, 5, 10, 25, and 40 Mgal were developed using the following assumptions:

- Synthetic liner of HDPE.
- Emergency spillway.
- Maximum pond depth of 10 ft (includes 3 ft of freeboard).
- Sidewater depth of storage is 7 ft.
- Contractor mobilization/demobilization.
- Excavation, including stripping, site excavation, backfilling.
- Sodding and restoration.
- Stormwater earthwork and swales (to isolate the pond from surface runoff).
- Asphalt paved roads (along the top of the berms).
- Overflow and other diversion structures.

Operation and maintenance costs are generally site-specific and depend on management practices. However, to establish a general planning level cost, maintenance of a reclaimed water storage facility will include the following tasks:

- Compliance monitoring.
- Updating daily log sheet (depth of water in the pond, special observations).
- Inspection of the berms for unwanted vegetative growth.
- Inspection of the stormwater diversion facilities.
- Mowing the grass surrounding the pond.
- Road maintenance.

Other costs that are not included but may be required for reclaimed water storage pond projects are land costs and pumping stations. O&M costs range from 2 to 5 percent of the construction cost.

B-2.13 Rapid Infiltration Basins Background

Back to Appendix B.
Back to Rapid Infiltration Basins.

The use of rapid infiltration basins (RIBs) is a cost-effective alternative to the traditional practice of discharging reclaimed water (treated wastewater) to surface waters or a means of recharging underground aquifers. Experience indicates that RIBs can be used to provide cost-effective tertiary treatment through percolation of reclaimed water within the biologically and chemically active soil column.

RIBs are permeable earthen basins, designed and operated to treat and disperse municipal wastewater, as they are typically operated in conjunction with a secondary wastewater treatment facility. A RIB system is managed by repetitive cycles of flooding, infiltration and drying. Rapid infiltration is based on a relatively high rate of infiltration into the soil followed by rapid percolation, either vertically or laterally.

Particulates, BOD, trace metals, and suspended solids are removed at least in part at or near the soil surface. Pathogen removal by RIB systems may be as high as 99.99 percent, with less attenuation in coarser sands and gravel. Limited studies indicate that RIBs may provide removal of volatile organics, through volatilization, sorption, and degradation.

The construction costs and required land areas for total infiltration capacities of 2, 5, 10, 25, and 40 Mgal are based on the assumptions presented below.

- Project site to be an area of highly pervious sandy soil.
- Water table is not a factor.
- Control of water is by weirs (not gates).
- Effective infiltration rate of 3 inches/day (approximately 12 acres per mgd).

Elements of the costs included:

- Contractor mobilization/demobilization.
- Excavation, including stripping, site excavation, and backfilling.
- Site restoration and sodding.
- Stormwater diversion by earthwork and swales.
- Asphalt paved roads (along the top of berms).
- Overflow and other diversion structures.
- Total water depth of 5 ft.
- Importing 50 percent of basin soil.

Table B-2.13 Rapid Infiltration Basin Design Assumptions.

RIBs, mgd	Number of Basins	RIB Surface Area acres	Total Surface Area acres
2	3	24	28
5	3	60	68
10	4	120	134
25	6	300	330
40	8	480	530

NOTE: *"RIB Surface Area" is used for permitting; "Total Surface Area" includes the berms, access roads, and stormwater system.*

Operation and maintenance costs are generally site-specific and depend on management practices. However, to establish a general planning level cost, a RIB system will include the following tasks. The O&M cost ranges from 1 to 4 percent of the construction cost.

- Compliance monitoring.
- Updating daily log sheet (depth of water in the pond, special observations).
- Inspection of the berms for unwanted vegetation.
- Inspection of stormwater diversion facilities.
- Mowing the grass surrounding the pond.
- Road maintenance.

Appendix C: Product Information

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1. Johnson Screens; http://www.weatherford.com/weatherford/groups/public/documents/johnsonscreens/js_johnsonscreens.hcsp?js=1

2. Actiflo by Kruger; http://www.krugerusa.com/en/files/1/33C9zg82r50XpZIMFxkh.php

3. AquaDAF by Infilco Degremont; http://www.infilcodegremont.com/separations_3.html

4. Westfalia Centrifuges; http://www.wsus.com/us/

5. GE Zenon Membranes; http://www.zenon.com/products/

6. Layne Membranes; http://www.laynewater.com/water_treatment_membrane.html

7. Crom Corporation; http://www.cromcorp.com/

8. USA Tanks; http://www.usatanksales.com/

9. American Cast Iron Pipe Company; http://www.acipco.com/

10. Pratt Valves; http://www.henrypratt.com/

11. Mueller Valves; http://www.muellersales.com/

12. Layne Degasifiers; http://www.laynewater.com/wtp_air_stripping_towers.html

13. Hobas Pipe; www.hobas.com

14. Taprogge (IN-TA-CT, TAPIS intake system); http://www.taprogge.de/en/

15. Aqua-Aerobics; http://www.aqua-aerobic.com/aquaDisk.asp

16. Tetra Denite Filter; http://www.severntrentservices.com/LiteratureDownloads/Documents/650-0001.pdf

17. Whitaker Chemicals, LLC; www.whitakeroil.com