

# Section 7

## Treatment System Comparison



## 7. Treatment System Comparison

This section summarizes the comparison of the treatment system alternatives for pretreatment, RO desalination, post-treatment, and residuals handling. The comparison included quantitative factors such as costs and qualitative factors such as reliability. Two workshops were held with SCWD and SqCWD to present the results of the comparison and receive their input on selection of treatment systems.

### 7.1 Comparison Approach and Key Assumptions

#### 7.1.1 Comparison Categories

The comparison approach identified qualitative and quantitative factors for each system. Quantitative factors included estimates of capital costs, operation and maintenance (O&M) costs, and energy use. Qualitative factors included issues related to plant reliability and neighborhood issues such as noise and traffic. Environmental factors other than carbon footprint and site footprint were not evaluated because the site location has not yet been identified.

The categories considered for each system are as follows:

| Quantitative Comparison   | Qualitative Comparison   |
|---|--|
| <ul style="list-style-type: none"> <li>• Construction cost</li> <li>• Annual operations and maintenance cost</li> <li>• Energy usage per 1,000 gallons produced</li> <li>• Plant acreage (footprint)</li> </ul> | <ul style="list-style-type: none"> <li>• Production reliability</li> <li>• Water quality reliability</li> <li>• Neighborhood issues</li> <li>• DPH approval</li> <li>• Consistency with existing SCWD treatment system technology</li> </ul> |

#### 7.1.2 Cost Assumptions

Construction cost estimates for the comparison were developed using recent construction costs for similar facilities; the costs were escalated at 3% per year to the midpoint of construction (June 2014). Construction costs presented in this section do not include engineering services, construction management, legal services, permitting, and labor costs for SCWD and SqCWD staff during design, permitting, and construction. The capital cost estimate presented for the recommended facility in Section 8 and the Executive Summary includes an estimate for engineering services and construction management.

#### 7.1.3 Assumptions for Water Production and Design Capacity

The SCWD will use up to 2.5 mgd of desalinated water during drought conditions, which statistically occur for 210 days every 6 years. When the SCWD is not taking water from the plant, the SqCWD may use up to 2.5 mgd to meet demands and restore the groundwater basin. Once the basin has been restored, the SqCWD will continue to use desalinated water to supplement their groundwater source. Based on planning level estimates provided by the SqCWD, the average production from the desalination facility will be 1.6 mgd. These assumptions were used to develop plant construction and annual O&M cost estimates.

### **7.1.4 Other Assumptions**

Other key assumptions for the comparisons presented in this section are: the cost of land, electricity, and labor. The cost for land was assumed to be \$1 million per acre based on direction provided by SCWD. The 2009 electrical cost of \$0.13 per kWh was escalated at 5% per year to the midpoint of construction (June 2014). Federal guidelines estimate that electrical costs will escalate at 2.5% annually in California; however, a more conservative estimate was used because power in the Santa Cruz area will increase with the cost of power from PG&E which generates approximately 50% of their electrical power from natural gas. Based on 5% annual escalation, the June 2014 power cost is estimated at \$0.16 per kWh. The hourly labor costs for operations and maintenance staff were assumed to be the same as SCWD staff in similar jobs and were increased by 30% to account for overhead costs.

## **7.2 RO Configuration and Membrane System Comparison**

### **7.2.1 Treatment Systems Considered**

Single-stage RO configurations without a second pass (a.k.a. single pass systems) are used in locations with relatively cold water temperatures like the Pacific Ocean and two-pass systems are used in locations with warmer temperatures like the Persian Gulf. However, the necessity of a two-pass system depends on the project-specific salinity goals.

Three different RO configurations and multiple SWRO membranes were tested at the pilot plant. The RO configurations included 1) a single-stage RO without a second pass, 2) a single-stage RO followed by a partial second pass, and 3) a hybrid two-stage RO utilizing low pressure RO (LPRO) membranes in the first stage and SWRO membranes in the second stage. The membranes tested included the latest generation of low energy (LE) SWRO membranes from multiple manufacturers and the latest generation of high boron rejection LPRO membranes.

The pilot plant results indicated that only two of the three RO configurations achieved the project water quality goals. The two were the single-stage configuration and the single-stage followed by a partial second pass configuration. The results also indicated that the latest generation of LE SWRO membranes will not provide sufficient salt rejection to achieve project-specific salinity goals for boron and bromide during long-term use.

After using RO software projections to simulate long-term operations, it was determined that high rejection (HR) SWRO membranes or a hybrid combination of HR SWRO membranes and LE SWRO membranes would provide the necessary salt rejection to achieve boron and bromide goals.

The RO configuration and membrane combinations selected for the RO system comparison are as follows:

- Single-stage RO configuration utilizing HR SWRO membranes
- Single-stage RO configuration utilizing a hybrid combination of HR and LE SWRO membranes
- Single-stage RO configuration with LE SWRO membranes followed by a 25% LPRO 2<sup>nd</sup> pass

## 7.2.2 Comparison of Quantitative Factors

Construction costs, O&M costs, and energy use were estimated and compared for each RO system for a new 2.5 mgd facility. It was assumed that the RO systems will be designed to operate at similar parameters as the pilot systems; this includes a recovery rate of 45% to 50% and flux rates of 8 to 10 gfd.

### Construction Costs

The construction cost for the single-stage configuration and SWRO membranes is estimated to be \$9 million whether LE or HR membranes are used. The cost for a single-stage plus a 25% partial 2<sup>nd</sup> pass is \$10 million.

### Annual Operations and Maintenance Costs

The annual operations and maintenance costs include RO membrane and cartridge filter replacement, chemicals, and energy costs. The single-stage configuration utilizing a hybrid combination of HR and LE SWRO membranes is expected to provide the lowest annual operations cost of \$960,000 to achieve the project water quality goals (e.g., boron and bromide). The single-stage configuration utilizing HR SWRO membranes is expected to achieve lower salinity goals at a cost of \$1 million per year. The annual O&M cost for the single-stage configuration followed by a 25% partial second pass is also expected to be \$1 million per year.

### Energy use

The single-stage configuration utilizing a hybrid combination of HR and LE SWRO membranes is expected to require approximately 9.7 kWh per 1,000 gallons on average. The remaining two RO system alternatives are each expected to require approximately 10.5 kWh per 1,000 gallons on average. These numbers assume existing commercially available RO membranes and energy recovery devices. Ongoing research and advancements in RO membranes and energy recovery devices may reduce this energy requirement another 5 to 10%.

### Land and Footprint Requirements

There is no difference assumed in footprint requirements for the different RO system configurations. This is because all configurations assume a single-stage RO system with either a 2<sup>nd</sup> pass system or an allotted space for a future 2<sup>nd</sup> pass system if necessary.

## 7.2.3 Comparison of Qualitative Factors

Production reliability, water quality reliability, and other factors were compared for each RO system. It is assumed that the RO systems will be designed to operate at similar parameters as the pilot systems; this includes a recovery rate of 45% to 50% and flux rates of 8 to 10 gfd.

### Production Reliability

Factors considered for production reliability include expected equipment maintenance and replacement requirements, and downtime for O&M activities. O&M and equipment replacement requirements are expected to be the same for each single-stage RO system with minor increases for a partial 2<sup>nd</sup> pass. In general, there are no significant differences in production reliability for the three systems.

## Water Quality

There are differences in water quality assuming an average SWRO membrane age of 5 years. The single-stage RO configuration utilizing HR SWRO membranes will achieve a bromide goal of 0.3 mg/L. The single-stage RO configuration utilizing a hybrid combination of HR and LE SWRO membranes will achieve a bromide goal of 0.5 mg/L. A single-stage RO configuration followed by a partial 25% LPRO 2<sup>nd</sup> pass is expected to achieve a bromide goal of 0.2 mg/L.

It is important to note two key optimization issues regarding the RO systems. The first is that the concentrations of bromide and other salts will be below the target during the first 5 years of operation, thus there is time to assess if higher rejection is needed. Therefore, if a hybrid combination of HR and LE SWRO membranes is selected, the LE membranes can be replaced with HR membranes at any time as needed. The second is that a partial 2<sup>nd</sup> pass can be retrofitted relatively easily into the plant if it is required.

## Other Qualitative Issues

Neighborhood issues are not expected to differ since footprint, noise, and vehicle traffic to the site will be similar for all three alternatives. DPH approval is not expected to differ because all three systems will achieve better than 2-log removal of TDS. Consistency with existing SCWD technology is not a differentiating factor because SWRO systems are not currently used at existing facilities.

## Recommended System

On July 20, 2009, a treatment process selection workshop was held among CDM, the SCWD and the SqCWD to review the comparison of treatment system alternatives. At the workshop a preliminary consensus was made to select the single-stage design with a combination of low energy and high rejection RO membranes. This selection was confirmed during a second workshop on October 6, 2009.

This approach will achieve the water quality goals for bromide, boron and chloride with the lowest energy use, construction cost, and annual O&M cost. After 2 to 3 years of operation of the SWRO desalination facility, it will be clear whether or not the bromide goal will need to be lowered to control disinfection by-product formation in the distribution system. If necessary, all high rejection membranes can be added to the system during scheduled replacement to reduce the bromide concentrations to 0.3 mg/L or less. It is also recommended that an allowance for a 2<sup>nd</sup> pass system be included in the design in case the bromide goal is decreased to 0.2 mg/L or less in the future.

## 7.3 Pretreatment System Comparison

### 7.3.1 Treatment Systems Considered

In the majority of SWRO facilities with open ocean intakes, the pretreatment system uses coagulation, flocculation, and either two stages of granular media filters or sedimentation and one stage of granular media filters. Recent trends in pretreatment have included using dissolved air flotation (DAF) clarification to remove algae prior to filtration and utilizing microfiltration (MF) or ultrafiltration (UF) membrane filters instead of

granular media filters to improve removal of particulate material. For example, DAF clarification is used at existing SWRO facilities in Tuas, Singapore and Barcelona, Spain, and membrane filters are used at several existing facilities in the Middle East and have been selected for planned facilities in Australia and California.

Four different pretreatment systems were tested at the pilot plant. The systems included slow sand filters (SSF), granular media filters (GMF) with coagulation, flocculation, and sedimentation, and two different types of UF membrane filters. The UF systems were evaluated in three operational modes: 1) without coagulation, 2) with coagulation and flocculation, and 3) with coagulation, flocculation, and sedimentation. Because of the similarity of the two different types of UF filters, submerged and pressurized, in the comparison below both will be designated under the heading of “UF system.”

Slow sand filtration (SSF) is not typically used for SWRO pretreatment, but was selected for testing because SSF mimics the biological treatment of beach wells (which reduces RO biofouling naturally) and requires no chemicals.

The pilot plant results indicated that SSF, GMF, and UF are all expected to achieve target pretreated water quality goals, but there were differences in how well each system achieved operational goals. For example, there were differences in chemicals required, washwater requirements, and energy use.

There were also differences in how each system minimized fouling of the downstream RO membranes. Minimal fouling was observed downstream of SSF, biofouling was observed downstream of UF during algal blooms, and both biofouling and particulate iron fouling were observed downstream of GMF.

Analysis of the pilot test results indicated methods to optimize design of the pretreatment systems. The first was that using DAF clarification upstream of GMF and UF is expected to control biofouling of RO membranes. The second was that pre-oxidation with sodium hypochlorite followed by deep bed, gravity GMF filters is expected to minimize iron breakthrough and particulate fouling of RO membranes.

After evaluating variations in source water quality and the pilot plant results, all three types of pretreatment filters were retained for the comparison. Coagulation, flocculation and DAF were selected prior to UF and GMF to improve algae removal and minimize UF and RO biofouling. The pretreatment systems selected for comparison are as follows:

- DAF followed by granular media filters (GMF)
- DAF followed by UF filters (UF)
- Slow sand filters (SSF)

### **7.3.2 Comparison of Quantitative Factors**

Construction costs, O&M costs, and energy use were estimated for each pretreatment system for a new 2.5 mgd facility. The estimates assume the following for the different types of filtration technologies:

1. UF: Relatively conservative flux rates of 40 gfd for pressurized UF systems and 25 gfd for submerged UF systems with overall recovery rates of greater than 92%.
2. GMF: Deep-bed gravity filters with a relatively conservative 3 gpm/sf filtration rate, air scour, and filter-to-waste capabilities.
3. SSF: a 0.1 gpm/sf filtration rate, a harrowing cleaning approach, and uncovered and lined gravity filters.

### Construction Costs

The construction cost estimates including land costs range from approximately \$15.5 million for the SSF and GMF systems to \$20 million for the UF systems. The SSF cost does not include the cost of a cover to block sunlight and minimize algal growth and the potential for clogging. Typically, SSF are not covered, but constructing an uncovered SSF is a concern because there is no long-term experience at existing SWRO facilities.

### Annual Operations and Maintenance Costs

The expected annual O&M costs are \$770,000 for the SSF, \$830,000 for GMF, and \$940,000 for the UF. The estimate includes chemicals, media or membrane replacement, plant labor, energy costs, and differences in solids disposal costs.

### Energy use

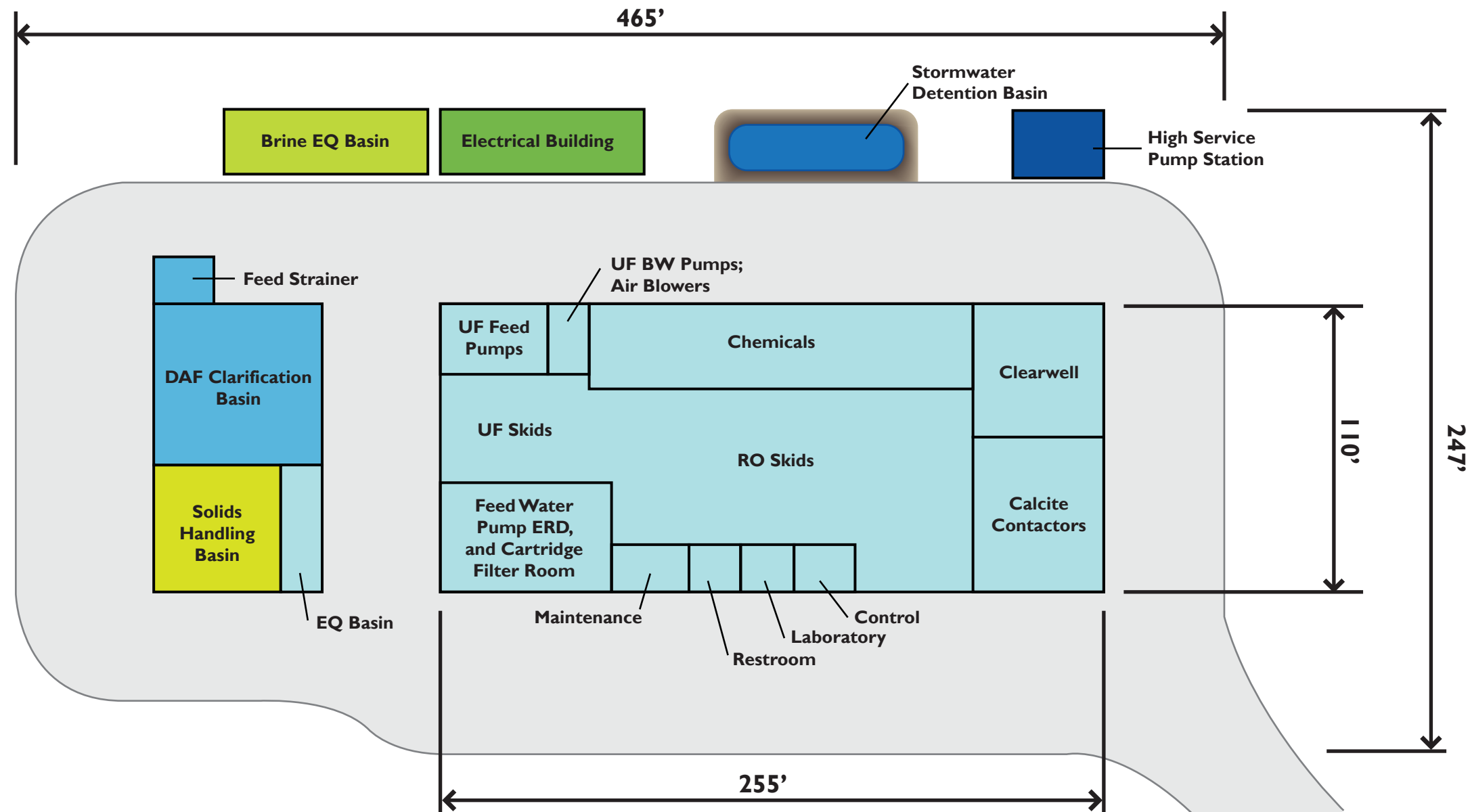
The difference in energy use for the pretreatment systems is minor in comparison to the overall energy use of the facility. A UF pretreatment system is expected to have the highest energy use in the range of 0.9 to 1.4 kWh per 1,000 gallons depending on whether the UF membranes operate in the pressurized or submerged mode. A system utilizing only a 100 micron strainer and SSF will require approximately than 0.1 kWh per 1,000 gallons. A GMF pretreatment system is expected to be approximately 0.6 kWh per 1,000 gallons. The potential difference is approximately 5 to 10% of the total anticipated energy use at a facility depending on the RO configuration, post-treatment system, and other processes selected.

### Land and Footprint Requirements

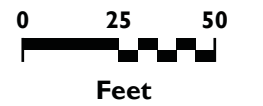
In general, SSF requires a much larger footprint than the other options. For example, the estimated footprint of a 2.5 mgd facility utilizing SSF pretreatment is 8.5 acres compared to approximately 3.5 acres for a facility utilizing UF or GMF pretreatment. Figures 7-1, 7-2, and 7-3 present potential site layouts which compare the footprint required for different pretreatment and solids handling alternatives.

### 7.3.3 Comparison of Qualitative Factors

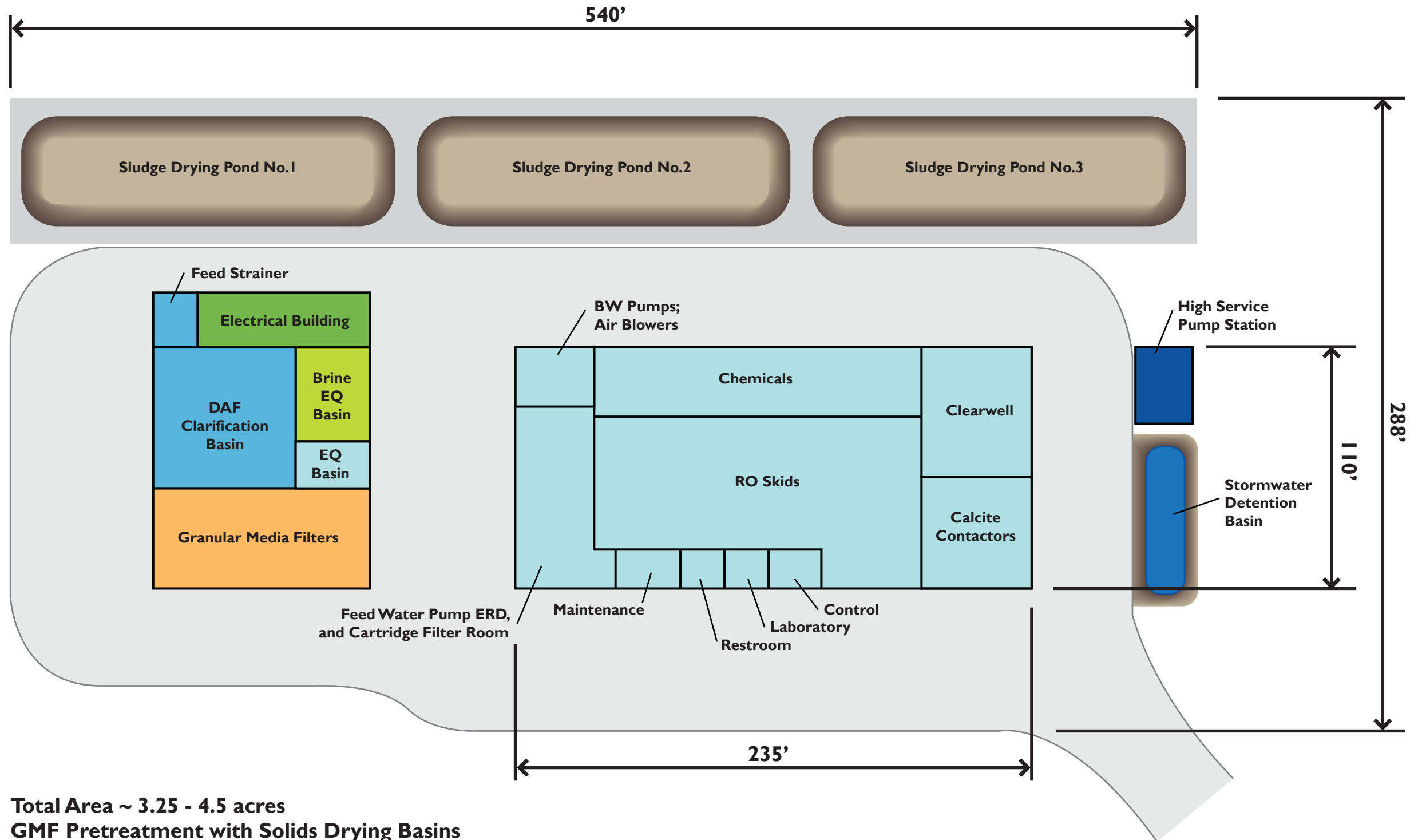
Production reliability, water quality, and other factors were compared for each pretreatment system for a new 2.5 mgd facility.



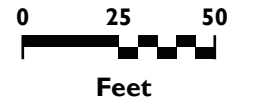
**Total Area ~ 2.5 - 3.5 Acres**  
**UF Pretreatment with Solids Thickening**  
**and Mechanical Dewatering**



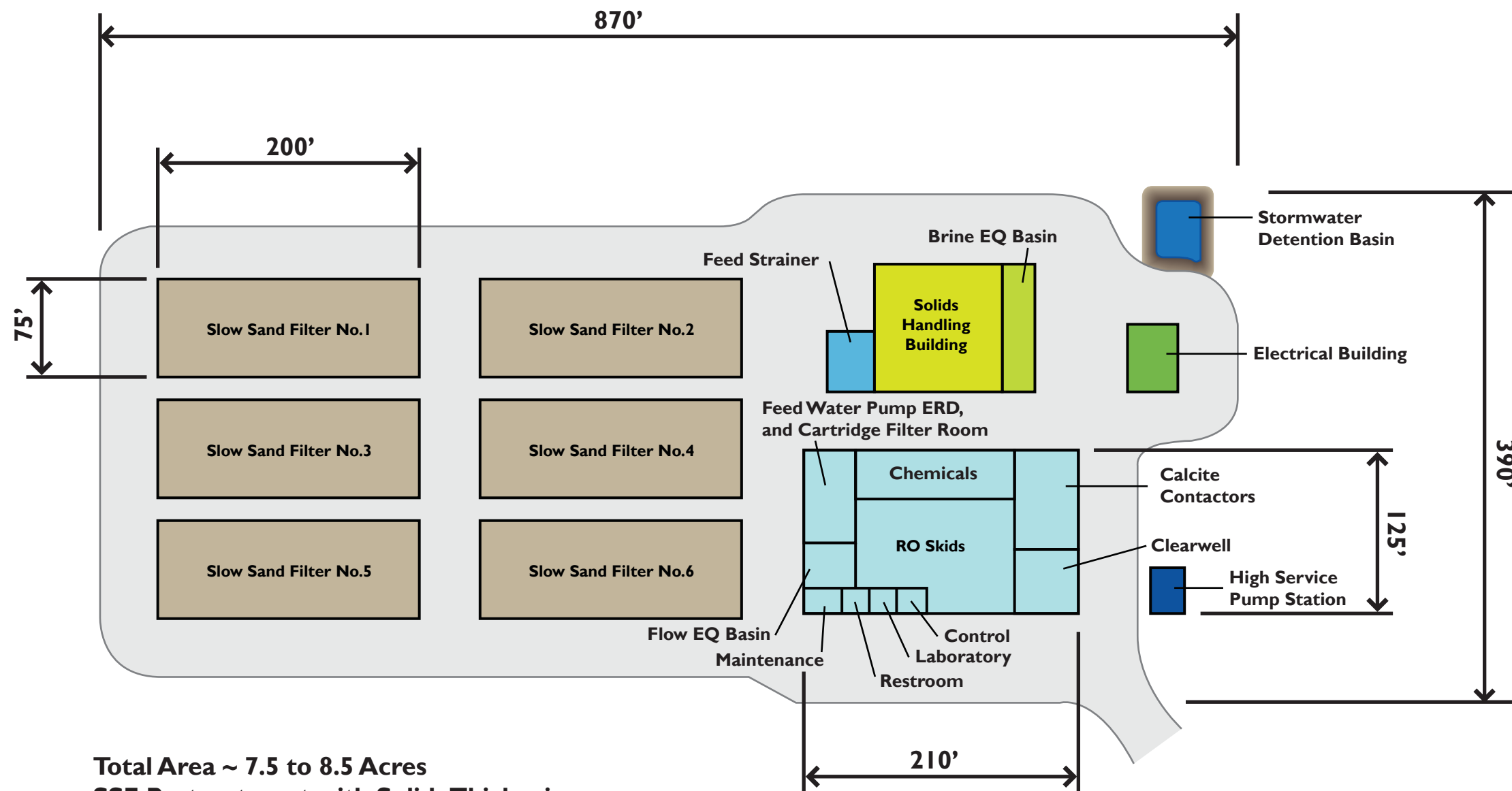
**Figure 7-1**  
 Preliminary Site Layout: SWRO Facility with  
 UF Pretreatment and Solids Thickening/Mechanical Dewatering



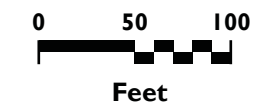
**Total Area ~ 3.25 - 4.5 acres**  
**GMF Pretreatment with Solids Drying Basins**  
**Additional Area for Solids Drying Basins ~ 0.75 - 1.0 Acres**



**Figure 7-2**  
 Preliminary Site Layout: SWRO Facility with GMF Pretreatment and Solids Drying Basins



**Total Area ~ 7.5 to 8.5 Acres**  
**SSF Pretreatment with Solids Thickening**  
**and Mechanical Dewatering**



**Figure 7-3**  
 Preliminary Site Layout: SWRO Facility with  
 SSF Pretreatment and Solids Thickening/Mechanical Dewatering

## Production Reliability

There are some differences in the expected production reliability for the different systems. Factors considered for production reliability include expected equipment maintenance and replacement requirements, and typical downtime for O&M activities.

There is a potential for fiber breakage with the UF systems. No fiber breaks were observed during pilot testing; however, it is common for fibers to break in large systems and require isolated shutdowns for repair. UF systems also require a minor increase in downtime for chemical cleanings to limit fouling. Additionally, UF systems include more mechanical and electrical control systems to maintain. N+1 redundancy (e.g., one redundant UF skid) is necessary to provide sufficient production when one unit is offline for maintenance and cleaning. The pilot test results indicated that scheduled cleanings are expected to provide a typical membrane replacement frequency of 5 years. However, the actual membrane replacement frequency could be greater due to variations in source water quality including conditions that were not encountered during the 13 months of pilot-scale testing. GMF filters include less equipment to maintain, but require more frequent operator optimization to achieve desired production rates and water quality goals. N+1 redundancy is recommended to provide sufficient production when one unit is offline for maintenance.

SSF has the least equipment to maintain, and although production reliability was not an issue during pilot testing, it is currently unknown if there will be long-term production issues with using SSF for seawater pretreatment. Due to the unknowns during long-term use, greater than N+1 redundancy may be desired to provide sufficient production when multiple units are offline for maintenance or cleaning.

In summary, the production reliability is expected to be similar for all three systems with a certain amount of risk. The risk is expected to be minimal assuming 1) that UF fiber breakage will meet specifications during long-term use, 2) that GMF operations will be frequently optimized, and 3) that the SSF will operate similarly to the pilot-scale filters.

## Water Quality

All systems met the pilot test program water quality goals. Although there were differences in RO fouling during pilot testing, using DAF clarification upstream of the GMF and UF filters is expected to minimize RO fouling. The SSF demonstrated excellent results in minimizing RO fouling, but there is no long-term experience at existing SWRO facilities.

## Neighborhood Issues

UF and GMF require more vehicle traffic for chemical deliveries than SSF. There is potential for odors from SSF.

## DPH Approval

There are differences in pathogen log removal credits for the different systems. UF provides the highest number of removal credits, while SSF and GMF provide fewer credits. This may impact the selection of the pretreatment systems depending on DPH requirements. A SWRO plant with UF would achieve the maximum

required removal/inactivation credits, while SSF or GMF would also need UV disinfection to achieve maximum removal/inactivation credits.

### Consistency with Existing SCWD Technology

GMF filters are currently used at the Graham Hill WTP and SCWD operators are familiar with operations of small-scale UF systems. There are no slow sand filters at SCWD facilities; however, SSF requires less training and optimization compared to GMF and UF filters.

### Recommended System

During the first process selection workshop, it was determined that the slow sand filtration has the following disadvantages: 1) it is unlikely that the required amount of land would be available, 2) it is an unproven technology for SWRO pretreatment and 3) results indicated that SSF may need to be covered and adding a cover will make it the most expensive alternative. During the follow-up process selection workshop, it was determined that additional information (e.g., land cost and availability) is needed to assess the feasibility of SSF.

Furthermore, it was determined that there are advantages and disadvantages with each pretreatment (i.e., SSF, GMF, and UF) system, and that selection of the preferred alternative will be deferred until the preliminary design phase of the project when the type of intake has been selected for the proposed facility.

## 7.4 Post-treatment Alternatives

### 7.4.1 Treatment Systems Considered

The majority of existing SWRO and similar RO facilities utilize calcite contactors and carbon dioxide as simple and effective methods to adjust pH and add alkalinity to both improve taste and stabilize the water for corrosion control. Calcite contactors are similar to granular media filters except that limestone media is used instead of anthracite and sand. Some RO facilities include lime saturators instead of calcite contactors to reduce site footprint requirements. Lime saturators require a greater amount of operator attention and optimization and increase sludge disposal requirements when compared to calcite contactors.

Lime and carbon dioxide were used for post-treatment during pilot testing to condition the water for taste testing. Lime addition required optimization based on temperature and pH, but was able to achieve alkalinity and pH goals.

In addition to dose optimization, lime saturators require additional optimization to prevent lime carryover into the treated water stream. Calcite contactors are expected to perform equally as well with fewer O&M requirements.

After evaluating the expected ranges of RO permeate water quality, both calcite contactors with carbon dioxide addition and lime saturators with carbon dioxide addition were selected for comparison.

## 7.4.2 Comparison of Quantitative Factors

Construction costs, O&M costs, and energy use were estimated for each post-treatment system. The estimates assume typical loading rates for gravity calcite contactors and lime saturators.

### Construction Costs

The construction cost for calcite contactors and carbon dioxide is estimated to be \$2.9 million. The cost estimate for lime saturators is \$1.6 million.

### Annual Operations and Maintenance Costs

The operations costs are expected to be approximately \$92,000 per year for calcite contactors and \$110,000 per year with lime saturators.

### Energy use

The difference in energy use for the post-treatment systems is less than 1% of the overall energy use of the facility and is not considered a differentiating factor.

### Land and Footprint Requirements

In general, calcite contactors require a larger footprint than lime saturators. However, this difference is small because the capacity of the proposed facility is relatively small and is not anticipated to significantly impact the amount of land required for the proposed facility.

The footprint required for calcite contactors depends on whether they are operated in a gravity or pressurized mode. If the facility were to be constructed on a very small site that requires the least possible footprint, lime saturators can be constructed and operated in a smaller area than calcite contactors.

## 7.4.3 Comparison of Qualitative Factors

Production reliability, water quality, and other factors were compared for each post-treatment system for a new 2.5 mgd facility.

### Production Reliability

Calcite contactors require minimal downtime for O&M activities, cleaning, and media replacement. N+1 redundancy is expected to be sufficient for reliable operation.

Lime saturators require additional optimization and operator attention especially with variations in water temperature. Lime saturators will require additional time to achieve goals after downtime for maintenance. Lime saturators also include more mechanical equipment and will include the typical housekeeping challenges of storing and working with lime. N+1 redundancy is expected to be sufficient for reliable operation.

### Water Quality

Both systems are expected to reliably achieve target pH, alkalinity, and hardness goals. Both systems are also expected to increase the turbidity of the product water, but this can be minimized with design and operational strategies. The strategies include proper specifications of the chemicals and incorporating lessons learned from existing facilities during both design and operations.

### Other Qualitative Issues

The differences in other qualitative issues are expected to be negligible. Neighborhood issues are not expected to differ since footprint, noise, and vehicle traffic to the site will be similar. DPH approval is not expected to differ because the systems have both been approved for post-treatment at existing RO facilities in California. Consistency with existing SCWD technology is not a differentiating factor because neither lime nor calcite are currently used by the SCWD.

### Recommended System

During the process selection workshops, it was determined that calcite contactors would be recommended rather than lime saturators based on the increased operational requirements and solids production associated with lime.

## 7.5 Residuals Handling Alternatives

### 7.5.1 Treatment Systems Considered

The majority of recently constructed SWRO facilities use washwater clarification. Solids disposal methods vary; however, thickening and mechanical dewatering are common due to footprint restrictions typically associated with coastal facilities. Typical brine discharge methods include discharge via a new outfall or discharge via an existing treated wastewater effluent outfall after mixing. **scwd**<sup>2</sup> is evaluating the latter in a separate study.

Solids at the pilot plant were disposed by discharging the backwash streams and settled sludge directly to the sewer without washwater clarification. Brine was disposed by blending with the RO permeate and transferring the blend to the LML filtered seawater line for reuse.

Three residual handling options were included for comparison and are described as follows:

- Washwater clarification and recycle to SWRO plant headworks (i.e. inlet), solids thickening, and disposal to the sewer. This is similar to how washwater is recycled and solids are disposed at the Graham Hill Water Treatment Plant in Santa Cruz.
- Washwater clarification and recycle to SWRO plant headworks, solids thickening, mechanical dewatering, and disposal to a landfill. This is a common method used at existing water treatment plants in California and seawater desalination plants in Tampa, Florida; Australia; and Europe.

- Solids settling and drying basins for washwater clarification, dewatering, and disposal of dried solids to a landfill. Cost estimates assume such basins are sized large enough so that collected solids are only required to dry during the warmer and drier summer months. In other words, either the basins are being filled during the winter, or they are sitting idle during the winter. This is a common method used at existing water treatment plants in California when land is available at an affordable price.

There are other hybrid versions of solids settling and drying basins/beds that incorporate systems to reduce footprint. These were not considered during this comparison because there is not a well established track record of operations and maintenance of these facilities; however, additional analysis may be warranted during the preliminary design phase.

### **7.5.2 Comparison of Quantitative Factors**

Construction costs, O&M costs, and energy use were estimated for each residuals handling system. The estimates assume typical loading rates for washwater clarifiers and solids drying basins and that the average solids production will be similar to that of the pilot plant due to similar average source water turbidity and coagulant doses.

#### **Construction Costs**

The construction costs for washwater clarification and solids thickening and mechanical dewatering is estimated to be \$3.3 million. The cost estimate for washwater clarification and solids disposal to the sewer is \$1.5 million. The cost estimate for solids drying basins is \$2.6 million including costs for the additional land that is required.

#### **Annual Operations and Maintenance Costs**

The annual operations and maintenance costs are expected to be approximately \$79,000 for washwater clarification and solids thickening and mechanical dewatering, \$93,000 for washwater clarification and solids disposal to the sewer, and \$20,000 for solids drying basins.

#### **Energy use**

The difference in energy use for the post-treatment systems is less than 3% of the overall energy use of the facility and is not considered a differentiating factor.

#### **Land and Footprint Requirements**

In general, solids drying basins require a much larger footprint than the other options and will require approximately 1 acre of additional land for a 2.5 mgd facility and approximately one additional acre for each 2 mgd of additional production capacity should an expansion be permitted. A mechanical dewatering system will require a larger footprint than what is required to discharge solids to the sewer; however, it is recommended that space for a mechanical dewatering system be included in the facility site plan in the case that discharge to the sewer is prohibited at some time in the future.

### 7.5.3 Comparison of Qualitative Factors

Production reliability and other factors were compared for each solids disposal option.

#### Production Reliability

Solids disposal to the sewer and solids drying basins require minimal O&M activities. Mechanical dewatering includes the most mechanical equipment and typically requires an additional operator and a significant amount of maintenance and repair.

#### Water Quality

Dedicated washwater clarifiers are expected to provide sufficient water quality for recycling the clarified water to the headworks of the plant. There are few options to improve the treatment of solids drying basins as they require gravity settling to improve water quality and may not provide desired water quality when buoyant algal material enters the basins during bloom events; however, additional analysis may be warranted during the preliminary design phase

#### Neighborhood Issues

Mechanical dewatering and solids drying basins will require an increase in vehicle traffic to haul the solids to the landfill; the increase in traffic will be more frequent for mechanical dewatering than for drying basins. Noise may be increased with mechanical dewatering. The land requirements of the solids drying basins will increase plant footprint by about 25%, and are expected to emit some marine like odor. Disposal to the sewer is not expected to increase footprint, noise, or vehicle traffic.

#### Consistency with Existing SCWD Technology

High-rate clarifiers are used for washwater clarification at the Graham Hill WTP and solids are discharged to the sewer.

#### Other Qualitative Issues

The differences in other qualitative issues are expected to be negligible. DPH approval is not expected to differ because the systems have all been approved at existing water treatment facilities in California.

#### Recommended System

During the process selection workshops, it was determined that washwater clarification, solids thickening and discharge to the sewer would be the preferred method. However, early indications from staff at the wastewater plant were that there is concern over both the amounts of solids and salts that will be in the discharge and how that may impact the treatment process and solids limits at the WWTF. Thus, the decision was postponed until the follow-up selection workshop. During the second workshop, it was determined that disposal to the sewer would be the preferred option which will require additional coordination with the wastewater treatment facility.

## 7.6 Comparison Matrix

During the second process selection workshop the SCWD and SqCWD asked that an alternatives comparison matrix be developed to assist in the final selection of the pretreatment process. An open ocean intake was assumed for the comparison and three alternatives were identified. Each alternative uses the same RO, post-treatment, washwater clarification, and residuals handling systems. The only difference is the pretreatment system. The matrix is shown in Table 7-1.

## 7.7 Footprint and Site Layout Requirements

The footprint for a SWRO desalination plant is dependent upon the pretreatment process and residuals handling method. For example, the plant footprint with slow sand filters will be significantly larger than a plant with GMF or UF filters, and a plant with solids drying basins will have a larger footprint than a plant with solids discharged to the sewer or solids thickening and mechanical dewatering. Additional choices between treatment alternatives (e.g., calcite contactors vs. lime saturators) will have only a minor impact on the site footprint and are considered negligible at this level of planning.

A facility with the smallest footprint would include GMF or UF pretreatment and solids thickening and mechanical dewatering or solids discharge to the sewer. For the 2.5 mgd SWRO plant, the estimated area required is expected to be between 2.5 and 3.5 acres depending on decisions made during subsequent design phases. Figure 7-1 is a preliminary site plan for such a facility with sufficient space allotted for access to each treatment unit.

Figure 7-2 is a site plan for the same 2.5 mgd facility with solids drying basins instead of mechanical dewatering. The solids drying basins require an additional 1.0 acre of land.

A plant including slow sand filters will have the largest footprint. Figure 7-3 is a site plan for a facility designed to provide 2.5 mgd of desalinated water with slow sand filters. The total estimated area required is between 7.5 and 8.5 acres.

It is not anticipated that additional space would be required to expand a plant with GMF or UF pretreatment up to 4.5 mgd of drinking water production. However, additional land would be required to expand a plant with SSF pretreatment. It is estimated that 12 acres would be required to accommodate an expansion of the plant to 4.5 mgd.

## 7.8 Summary

This section summarized the comparison of the treatment system alternatives for pretreatment, RO desalination, post-treatment, and residuals handling. The comparison included both quantitative factors such as costs and qualitative factors such as reliability. Two workshops were held with the SCWD and SqCWD to present the results of the comparison and receive their input on selection of treatment systems. This comparison process determined a clear recommendation for the RO, post-treatment, washwater clarification, and solids handling systems. A recommendation was not developed for the pretreatment system because the

outcomes from other studies will need to be understood prior to making a decision. Therefore, a recommendation for the pretreatment system will be deferred to the preliminary design phase of the project.

**Table 7-1. Alternatives Comparison Matrix**

| Categories for Comparison  | Alternative No. 1: GMF Pretreatment   | Alternative No. 2: UF Pretreatment  | Alternative No. 3: SSF Pretreatment  |                               |
|--|---|---|--|-------------------------------|
|  | Strainer, DAF, GMF, Single Pass RO, Calcite Contactors, Washwater Clarification, and Solids Disposal to the Sewer   | Strainer, DAF, MF/UF, Single Pass RO, Calcite Contactors, Washwater Clarification, and Solids Disposal to the Sewer   | Strainer, SSF with Shade Covers, Single Pass RO, Calcite Contactors, Washwater Clarification, and Solids Disposal to the Sewer   |                               |
| Land required for 2.5 mgd <sup>(1)</sup>   | 3.5 acres   | 3.5 acres   | 8.5 acres for 2.5 mgd plant  | 12 acres for 4.5 mgd plant    |
| Construction Cost <sup>(2)</sup><br>Incl. Land at \$1 million/acre<br>(2014 \$Million) | \$59<br>with 3.5 acres of land  | \$64<br>with 3.5 acres of land  | \$61<br>with 8.5 acres of land   | \$70<br>with 12 acres of land |
| Annual O&M Cost<br>(2014 \$Million)  | \$2.3   | \$2.4   | \$2.2  |                               |
| Energy Use<br>(kWh/1,000 gallons)  | 12.9  | 13.8  | 12.4   |                               |
| Production Reliability   | GMF pretreatment requires more operator optimization than the other two alternatives. Some risk for drop in plant output during storm or red tide events. Mitigate by providing standby units.  | UF pretreatment requires less operator optimization than GMF. Some potential for drop in plant output during storm or red tide events. Mitigate by providing standby units.   | SSF pretreatment requires virtually no operator optimization. Greatest uncertainty in plant output during storm and red tide events. Additional testing would be required to assess this risk.   |                               |
| Staffing Requirements  | 2 operators will be on-site for 8 hours per day and 1 operator on-site for the remaining 16 hours per day.  | 2 operators will be on-site for 8 hours per day and 1 operator on-site for the remaining 16 hours per day. Due to its high use of mechanical equipment and instrumentation, UF requires the most repair and replacement work of the three alternatives.   | 1 operator will be on-site for 24 hours per day. Another operator will be site 3 days per week for SSF cleanings at maximum flow and 2 days per week at average flow.  |                               |
| Consistency with Existing SCWD Technology  | Same filtration technology and basic filter operations as GHWTP system.   | New filtration technology and filter operations requirements.   | New filtration technology with significantly simplified filter operations requirements.  |                               |
| DPH Approval   | DPH approved filtration technology. Most commonly used pretreatment approach in SWRO facilities.  | DPH approved alternative filtration technology. Used in several newer SWRO facilities.  | DPH approved filtration technology. Although commonly used in Europe for drinking water plants, it has not been used before for SWRO pretreatment.   |                               |
| DPH Pathogen Log Removal Credits (e.g., 4 log credit = 99.99% removal)                 | Virus: 6<br>Giardia: 5<br>Crypto: 4   | Virus: 4.5 to 8<br>Giardia: 6.5<br>Crypto: 6  | Virus: 5<br>Giardia: 4.5<br>Crypto: 4  |                               |
| Coagulant Chemicals and Pre-chlorination   | GMF requires about 20% more coagulant chemicals than UF on a yearly basis. May require continuous pre-chlorination and de-chlorination to improve iron removal during pretreatment.   | Submerged UF does not require coagulant addition except during storms and algal events. Pressure UF requires a lower dose of coagulant addition than GMF. UF may require intermittent pre-chlorination and de-chlorination to improve iron removal during pretreatment.   | SSF doesn't require coagulant chemicals or pre-chlorination.   |                               |
| Chemical Truck Traffic   | 6 deliveries per month.   | 6 deliveries per month.   | 3 chemical deliveries per month.   |                               |
| Safety   | Safety considerations are expected to be similar for the three different treatment system alternatives.   |   |  |                               |
| Unknowns   | <i>Intake selection?</i> It is not known if pretreatment would be required with a subsurface intake. If it is, the cost of GMF probably would not change – i.e., would still require coagulants, same filtration rate, etc.<br><i>Pathogen removal requirements?</i><br>Anticipated to meet DPH dictated pathogen removal requirements; but does not provide the maximum level of treatment which could be required by DPH. | <i>Intake selection?</i> It is not known if pretreatment would be required with a subsurface intake. If it is, the UF might be reduced - i.e., may require fewer or no coagulants, allow higher flux rates, etc. This question is being evaluated by the ongoing Long Beach SWRO pilot plant.<br><i>Pathogen removal requirements?</i><br>Provides the maximum level of treatment which could be required by DPH. | <i>Intake selection?</i> It is not known if pretreatment would be required with a subsurface intake. If it is, the cost of SSF probably would not change – i.e., would still require same filtration rate, etc.<br><i>Pathogen removal requirements?</i><br>Anticipated to meet DPH dictated pathogen removal requirements; but does not provide the maximum level of treatment which could be required by DPH.<br><i>Land availability?</i> It is possible that sufficient land will not available.<br><i>Covers?</i> Additional testing is recommended to determine if covers will be required for long-term reliability of the SSF. |                               |

<sup>(1)</sup> From a standpoint of footprint, Alternatives 1 and 2 can accommodate production increases up to 4.5 mgd without additional acreage, whereas SSF would require additional acreage to accommodate for a potential expansion.

<sup>(2)</sup> Construction cost includes 30% contingency. Does not include design services, construction management, legal services, permitting, and labor costs for SCWD and SqCWD staff during design, permitting, and construction. For comparison purposes only and not for budgeting.