Water Supply Feasibility Project

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Section 1 - General Background

For some time the City of Tigard has been evaluating opportunities to augment or own an adequate water supply to satisfy long-term demands of the system. Tigard has recently become a part of the Joint Water Commission (JWC) through an intergovernmental agreement. Currently the system receives water from the City of Portland (directly and through Tualatin Valley Water District’s Metzger system) and from the JWC, wheeled through the City of Beaverton system. Historically Tigard has received water from Lake Oswego and still has the infrastructure in place for use as an emergency connection.

Tigard has a maximum day demand now of about 12 million gallons per day (mgd) and expects an ultimate demand of about 20 mgd. The water supply alternatives to satisfy the ultimate demand are several, some being able to provide the full demand and others may be one of two or three source alternatives needed to satisfy the full demand. Aquifer Storage and Recovery (ASR) is being investigated currently and is expected to be able to provide up to 6 mgd of summer time capacity, reducing the required peaking source from others. The source alternatives are:

- JWC (Trask-Tualatin),
- City of Portland (Bull Run and Columbia Well Field),
- City of Lake Oswego (Clackamas River)
- South Fork Water Board (Clackamas River)
- Wilsonville Water Treatment Plant (Willamette River Water Treatment Plant owned by Wilsonville and Tualatin Valley Water District)

This scope of work focuses on the feasibility of obtaining a water supply for Tigard by acquiring up to 20 mgd of water rights from Lake Oswego and South Fork Water Board (SFWB), and working jointly with Lake Oswego to construct any required intake (expansion), raw water pipeline, water treatment plant, and finished water pipeline capable of up to the 20 mgd Tigard requirement and the additional capacity required for Lake Oswego to meet their ultimate maximum day demands anticipated.

The drivers for the water purveyors to enter into an arrangement described above are different for each:

Tigard – Tigard owns no source except the ASR that is being developed now. Even then there is no source water ownership to supply the ASR facility. ASR is more a resource management tool than a pure source of water, thus they are totally dependent on others to provide water to the City. Tigard wants to obtain ownership in a water supply and can possibly achieve that goal in working with Lake Oswego and SFWB.

Lake Oswego – Lake Oswego has more water rights than they anticipate using when the city is at build-out. Lake Oswego will require up to an additional 10 mgd of intake, raw water pipeline, treatment, and finished water pipeline capacity to serve the build-out demand. There is a definite economic advantage for Lake Oswego to partner with Tigard to further develop the Lake Oswego source facilities expansion to provide the balance of Lake Oswego’s needs and to supply Tigard demands to the extent water rights will provide it.
SFWB – SFWB has more water rights than they anticipate using when the two cities of Oregon City and West Linn are at build-out. There is an economic advantage to SFWB to provide source water to Tigard, be it raw water treated at the Lake Oswego WTP or finished water. SFWB can apply to WRD for obtaining another point of diversion which would be at the Lake Oswego intake site. They would place the amount agreed between SFWB and Tigard at that diversion. SFWB would either lease or sell the water rights to Tigard. An additional intake would need to be constructed for diversion of more than 32 mgd. To confirm Lake Oswego’s existing intake structure is capable of 32 mgd, additional evaluation must be done to determine the hydraulic capability of the wet well portion of the intake. The finished water option would be wheeled through West Linn to the Lake Oswego finished water pipeline. This study will include a review of the alternatives available for getting water supply from SFWB.

This report includes the following Sections:

- Water Source Opportunities
- Raw Water Diversion Requirements and Raw Water Conveyance
- Water Treatment Plant (WTP) Expansion
- Finished Water Pipeline
- Capital Construction Cost Estimates
- Conclusions

**Section 2 - Water Source Opportunities**

This section includes a review of the water rights held by Lake Oswego and SFWB, comparing their holdings with their anticipated buildout needs. For the scope of the rest of the feasibility report we will assume that Lake Oswego has 6 mgd available for Tigard and SFWB has 8 mgd available during the peak season for a total of 14 mgd, and that the Tigard ASR will provide 6 mgd for a total of 20 mgd.

The water rights held by Lake Oswego and SFWB are shown in Table 2-1.
TABLE 2-1
Summary of Clackamas River Water Rights Held by Lake Oswego and SFWB

<table>
<thead>
<tr>
<th></th>
<th>Total Permitted Rights and Pending Applications (mgd)</th>
<th>Certificated Rights (or Pending Certification) (mgd)</th>
<th>Remaining Permitted Rights to Certificate (mgd)</th>
</tr>
</thead>
<tbody>
<tr>
<td>South Fork Water Board²</td>
<td>52.66</td>
<td>18.34</td>
<td>34.32</td>
</tr>
<tr>
<td>City of Lake Oswego</td>
<td>38.14</td>
<td>16</td>
<td>22.14</td>
</tr>
<tr>
<td>Total</td>
<td>90.80</td>
<td>34.34</td>
<td>56.46</td>
</tr>
</tbody>
</table>

¹ Rounding error may have been introduced in conversion from cfs to mgd. Actual cfs should be used when making certification application.
² Actual permitted total is 74.98 mgd. The likely reduced amount available in summer and early fall because of low stream flows is 52.66 mgd.

Mgd = million gallons per day.
cfs = cubic feet per second.

South Fork Water Board
The South Fork Water Board (SFWB) manages four surface water right permits on the Clackamas River (see Table 2-2). Of these, one right supplying 3.88 mgd has been certificated and one partial proof of 14.46 mgd has been submitted to OWRD for review. The sum of the total rights permitted is 74.98 mgd. Low-flow conditions may result in the limitation of South Fork water rights to a total of 52.66 mgd of water from the Clackamas River if permits P-9982 and P-3778 are restricted to a combined total of 9.7 mgd. Any restriction imposed would only be during low flow months. Otherwise the full permit amount is available.

South Fork’s new intake will be used as the POD for these rights. All of South Fork’s rights are senior to the in stream water rights and all the other municipal water rights on the Clackamas River except for the City of Gladstone’s 1951 Certificate C79828 for 4 cubic feet per second (cfs).
<table>
<thead>
<tr>
<th>Permit Holder</th>
<th>Certificate/Permit No. (Application No.)</th>
<th>mgd</th>
<th>cfs</th>
<th>Status</th>
<th>Total Remaining Right to Certificate (mgd)</th>
<th>POD(^1)</th>
<th>Priority Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>City of Oregon City(^2)</td>
<td>P-3778 (S-5942)</td>
<td>12.93</td>
<td>20</td>
<td>Likely only able to certificate 5 mgd because of low stream flows</td>
<td>5</td>
<td>Section 29(^2)</td>
<td>1/16/1918</td>
</tr>
<tr>
<td>City of Oregon City(^2) and City of West Linn</td>
<td>P-9982 (S-11007)</td>
<td>19.39</td>
<td>30</td>
<td>Likely only able to certificate 5 mgd because of low stream flows</td>
<td>5</td>
<td>Section 29(^2)</td>
<td>8/11/1926; 1/16/1931</td>
</tr>
<tr>
<td>South Fork Water Board (SFWB)(^3)</td>
<td>P-22581 (S-28676)</td>
<td>38.78</td>
<td>60</td>
<td>Partial proof of 14.46 mgd has been submitted</td>
<td>24.32</td>
<td>SFWB new intake</td>
<td>8/3/1953</td>
</tr>
<tr>
<td>South Fork Water Board</td>
<td>T6162 confirming right of C1067 (P-2257)</td>
<td>3.88</td>
<td>6.0</td>
<td>T6162 order cancelled C1067, but a confirming right was to be issued. Status of confirming right unknown.</td>
<td>0</td>
<td>SFWB old intake</td>
<td>7/17/1914</td>
</tr>
<tr>
<td>Total Permit</td>
<td></td>
<td>74.98</td>
<td>116</td>
<td></td>
<td>34.32</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total Anticipated</td>
<td></td>
<td>52.65</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

\(^1\) Section 29 refers to the intakes authorized as follows:
P-3778 point of diversion (POD): Section 29 T4S R5E WM at a point from which the \(\frac{3}{4}\) section corner between Sections 29 and 30 bears N 37 degrees and 3 minutes W 1402.0' distant.
P-9982 POD: From south fork near SW corner of S29, being upstream approximately 1,300 feet from the junction of Memaloose Creek and South Fork. From Memaloose Creek, South 18 degrees 6 minutes East, 4.427 feet from the NW corner of S29.

\(^2\) The water right P-9982 is permitted for a total of 30 cubic feet per second (cfs) (19.39 million gallons per day [mgd]), 10 cfs to supplement Permit 2257 (C1067) from Memaloose Creek and 20 cfs from South Fork to supplement P3778. South Fork believes that because of low stream flows, likely only 15 cfs (9.2 mgd) would be available to certificate. The actual amount is to be determined in the future from long-term monitoring data.

\(^3\) POD changed by Declaratory Ruling, Vol. 49, p. 173.

\(^4\) In stream water right is 400 cfs July 1 - Sept 15 and 640 cfs Sept 16-June 30 from Three Lynx to mouth.

POD = point of diversion.

**City of Lake Oswego**

Lake Oswego holds two surface water permits on the Clackamas River, for a total of 38.14 mgd (see Table 2-3). A partial proof of 16 mgd of the larger senior permit (32.32 mgd) has been submitted to OWRD and is awaiting certification. The city also holds a permit for 3.88 mgd on the Willamette River and a groundwater right for 0.29 mgd. The groundwater right represents less than 1 percent of the water supply used by the city, and typically is used only in the summer.
TABLE 2-3
Clackamas River Water Rights Managed by City of Lake Oswego

<table>
<thead>
<tr>
<th>Permit Holder</th>
<th>Certificate/Permit No. (Application No.)</th>
<th>Amount</th>
<th>Status</th>
<th>Total Remaining Right to Certificate (mgd)</th>
<th>POD</th>
<th>Priority Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>City of Lake Oswego (LO)</td>
<td>S-32410 (S-43365)</td>
<td>32.32</td>
<td>50 Certificate received for 25 cfs of this permit.</td>
<td>16.16</td>
<td>LO</td>
<td>3/14/1967</td>
</tr>
<tr>
<td>City of Lake Oswego</td>
<td>S-37839 (S-50819)</td>
<td>5.82</td>
<td>9.0 Permit</td>
<td>5.82</td>
<td>LO</td>
<td>7/5/1975</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>38.14</td>
<td>59</td>
<td>22.14</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

mgd = million gallons per day.
cfs = cubic feet per second.
POD = point of diversion.

The instream water rights are of particular interest because they are senior to Lake Oswego's 1975 right of 9 cfs. The size and timing of the instream right is shown in Table 2-4.

Table 2-4
Clackamas River Water Rights Managed by OWRD as Instream Water Rights

<table>
<thead>
<tr>
<th>Certificate Number</th>
<th>River Mile</th>
<th>Flow in Critical Months</th>
<th>Priority Date</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>(mgd)*</td>
<td>(cfs)</td>
</tr>
<tr>
<td>C-59490</td>
<td>47.8 to 0</td>
<td>258.5</td>
<td>400 cfs (July and August)</td>
</tr>
<tr>
<td>C-59491</td>
<td>47.8 to 0</td>
<td>413.6</td>
<td>640 cfs (last half of September through June)</td>
</tr>
<tr>
<td>C-59492</td>
<td>-65.1 to 0</td>
<td>155.1</td>
<td>240 cfs (October through June)</td>
</tr>
</tbody>
</table>

1 Note that the certificates provide flow in cfs. Flow in mgd is calculated.
2 mgd = million gallons per day.
3 cfs = cubic feet per second.

The maximum day demands (MDD) for Lake Oswego and Tigard estimated in recent water master plans for each entity are used for this water supply evaluation. The Table 2-5 shows these values as they will be used in the following sections to determine the opportunities for service from Lake Oswego and SFWB to Tigard.
TABLE 2-5
Tigard and Lake Oswego Maximum Day Demands (mgd)

<table>
<thead>
<tr>
<th>Water Provider</th>
<th>MDD - 2005</th>
<th>MDD – Build-Out</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tigard</td>
<td>12</td>
<td>20</td>
</tr>
<tr>
<td>City of Lake Oswego</td>
<td>13</td>
<td>26</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>26</strong></td>
<td><strong>46</strong></td>
</tr>
</tbody>
</table>

Notes:
1) Tigard source requirements from Lake Oswego WTP of 20 mgd for MMD projection can be reduced to about 14 mgd when 6 mgd of ASR capacity is installed.
2) Using high estimated projection for Stafford Urban Reserve Area (URA) Lake Oswego’s MDD is 26 mgd. Without Stafford URA projection for MDD is 19 mgd.

Section 3 - Raw Water Diversion Requirements and Raw Water Conveyance
The raw water diversion and conveyance facilities for Lake Oswego and SFWB require improvements to fully support the demands from Tigard. Table 3-1 shows the intake, raw waterline, WTP, and the finished waterline capacities.

TABLE 3-1
Supply Components Capacities (in million-gallons-per-day [mgd])

<table>
<thead>
<tr>
<th>Water Provider</th>
<th>Intake Pumping/Structure</th>
<th>Raw Waterline</th>
<th>WTP</th>
<th>Finished Waterline</th>
</tr>
</thead>
<tbody>
<tr>
<td>City of Lake Oswego</td>
<td>16/32</td>
<td>14</td>
<td>16</td>
<td>10</td>
</tr>
<tr>
<td>SFWB</td>
<td>20/53</td>
<td>22.5</td>
<td>30</td>
<td>30</td>
</tr>
</tbody>
</table>

Both Lake Oswego and SFWB have completed facilities plans that give an understanding of the expansion opportunities at each facility. Lake Oswego has property to expand to the full Clackamas water rights holdings and perhaps more. To exceed the capacity that can fit onto the original WTP 6.05 acre-site, the city will have a permitting challenge that is unclear at this time if it could be overcome. There is likely the ability to construct 32 mgd on the original site using newer space-saving technologies. The SFWB water supply facilities can be constructed up to the expected summertime flow available, 53 mgd.
TABLE 3-2
Tigard and Lake Oswego Maximum Day Demands (mgd)

<table>
<thead>
<tr>
<th>Water Provider</th>
<th>MDD - 2005</th>
<th>MDD – Build-Out</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tigard</td>
<td>12</td>
<td>20</td>
</tr>
<tr>
<td>City of Lake Oswego</td>
<td>13</td>
<td>26</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>25</strong></td>
<td><strong>46</strong></td>
</tr>
</tbody>
</table>

Notes:
1) Tigard source requirements from Lake Oswego WTP of 20 mgd for MMD projection can be reduced to about 14 mgd when 6 mgd of ASR capacity is installed.
2) Using high estimated projection for Stafford Urban Reserve Area (URA) Lake Oswego’s MDD is 26 mgd. Without Stafford URA projection for MDD is 19 mgd.

The sum of 2005 MDDs for Tigard and Lake Oswego exceed the existing WTP capacity by 9 mgd. We recommend expanding the existing 16 mgd WTP to 32 mgd to provide some cushion for demand growth and further evaluation of need. This expansion uses the full 32 mgd of the water rights senior to the instream water right. In addition, the existing intake fish screens are designed for a capacity of 32 mgd. An evaluation of the existing wet well is needed to determine the existing pumping capacity.

There is a potential of receiving 2 to 6 mgd or perhaps more of SFWB capacity via the West Linn/Lake Oswego emergency intertie. The hydraulics and intertie capacity from West Linn to Lake Oswego have not been determined but should be able to pass at least the design capacity designed for the Lake Oswego to West Linn direction which is 5.76 mgd. Testing to confirm actual flow capability under presumed operating conditions would be prudent. The West Linn transmission system would have to be studied (Flow testing to confirm actual flow capability under presumed operating conditions would be prudent) to determine the firm capacity from the SFWB during a MDD scenario with the existing system. In addition the evaluation could consider what improvements are required to obtain 8 mgd via West Linn. A modification of the Intermic TGA would have to occur if a change is made to the way the intertie is used.

The Portland Water Bureau (PWB) intertie could be improved to obtain 8 mgd into the Lake Oswego system. The system improvements in the Lake Oswego system need to be considered. Perhaps either or both of these interties could be improved with less expense than expanding the Lake Oswego WTP beyond the 32 mgd capacity. These options can be compared at a later date with the WTP expansion to accurately determine the most feasible way to proceed when more than 32 mgd is needed.

Tigard could consider buying into an additional source in the future if it were needed to satisfy some of the build-out capacity requirements. The Willamette River would likely be available. If in 15 to 20 years there has been successful operational experience evident with the Willamette River WTP at Wilsonville, the Tigard citizens may wish to obtain some capacity from Tualatin Valley Water District, the owner of 83-percent of the Willamette
River intake and 33-percent of the treatment facility. Tigard has a pending water right application to divert up to 40 cfs at the Willamette River WTP intake.

Several options are possible for satisfying the Tigard maximum day demand. Table 3-3 shows four combinations of sources that could be available for Tigard.

<table>
<thead>
<tr>
<th></th>
<th>Option 1</th>
<th>Option 2</th>
<th>Option 3</th>
<th>Option 4</th>
<th>Option 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tigard LO WTP</td>
<td>20</td>
<td>14</td>
<td>6</td>
<td>6</td>
<td>14</td>
</tr>
<tr>
<td>Tigard ASR</td>
<td>6</td>
<td>6</td>
<td>6</td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td>Lake Os/West Linn</td>
<td></td>
<td></td>
<td>8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Willamette River</td>
<td></td>
<td></td>
<td></td>
<td>8</td>
<td></td>
</tr>
<tr>
<td>Tigard Subtotal</td>
<td>20</td>
<td>20</td>
<td>20</td>
<td>20</td>
<td>20</td>
</tr>
<tr>
<td>Lake Oswego LO WTP</td>
<td>26</td>
<td>26</td>
<td>26</td>
<td>26</td>
<td>18</td>
</tr>
<tr>
<td>West Linn/SFWB</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>8</td>
</tr>
<tr>
<td>Lake Oswego Subtotal</td>
<td>26</td>
<td>26</td>
<td>26</td>
<td>26</td>
<td>26</td>
</tr>
<tr>
<td>Total Demands</td>
<td>46</td>
<td>46</td>
<td>46</td>
<td>46</td>
<td>46</td>
</tr>
<tr>
<td>LO WTP Ultimate Capacity</td>
<td>46</td>
<td>40</td>
<td>32</td>
<td>32</td>
<td>32</td>
</tr>
</tbody>
</table>

These options are further defined below.

Option 1
- Need expansion of WTP to 46 mgd minimum.
- Need to obtain additional point of diversion (POD) for SFWB water right to Lake Oswego intake (16 mgd to get senior priority).
- Size water rights, raw water pipeline, and finished water pipeline for 48 mgd total (multiple of 16 mgd)

Option 2
- Need expansion of WTP to 40 mgd
- Need to obtain additional POD for SFWB water right to Lake Oswego intake (8 mgd to get senior priority)
- Size water rights, raw water pipeline, and finished water pipeline for 40 mgd (multiple of 8 mgd)

Option 3
- Need expansion of WTP to 32 mgd
- Contract finished water purchase with SFWB/West Linn for 4 mgd.
- Contract finished water purchase with PWB for 4 mgd.
- Alternative is to get 8 mgd from only one - SFWB/West Linn or PWB
- Size raw water pipeline for 32 mgd total; size finished water pipeline for 36 to 40 mgd total.
- Tigard to rely on ASR for 6 mgd capacity of the required 20 mgd

Option 4
- Need expansion of WTP to 32 mgd
- Contract with TVWD for 8 mgd (coordinate with timing of TVWD’s need)
- Size raw water and finished water pipelines for 32 mgd total

Option 5
- Need expansion of WTP to 32 mgd
- Contract with West Linn/SFWB for 8 mgd to Lake Oswego.
- Rely on Tigard ASR for 6 mgd capacity of the required 20 mgd.
- Raw water pipeline sized for 32 mgd (for possible future capacity and for redundancy for existing (nearly 40 year) old pipe.
- Finished water pipeline sized for 40 mgd total (32 mgd-WTP; 8 mgd-SFWB via West Linn)

Any of the options could include upfront buy-in to the existing Lake Oswego supply facilities by Tigard, providing for early ownership of facilities and the earliest evidence of a successful IGA that would be negotiated between Lake Oswego and Tigard.

Of the options shown, one would require the ultimate WTP capacity to be 46 mgd, one that would require the ultimate capacity to be 40 mgd, and two that would allow the maximum capacity to be 32 mgd, the amount of intake structural and screen capacity. By using the senior and junior water rights Lake Oswego can obtain 38 mgd from the river at the intake. Any additional diversion would require a permit amendment of SFWB rights to obtain an additional point of diversion at the Lake Oswego intake. To have senior rights for all the water needed, 14 mgd of SFWB rights would be needed. If Lake Oswego included their own 6 mgd of junior rights in the diversion, only 8 mgd of SFWB rights would be required.

The raw water pipeline size will depend on the ultimate diversion requirements. The routing can be similar to the existing line. Consideration should be given to horizontal directional drilling (HDD) under the Willamette River to minimize the permitting requirements. The permitting requirements and construction techniques should be further evaluated in future concept/preliminary design tasks.

Section 4 - Water Treatment Plant (WTP) Expansion

Introduction and 1997 Facility Plan Review

The purpose of this section is to present findings and recommendations resulting from review of the 1997 Lake Oswego Water Treatment Plant (LOWTP) Facility Plan (1997 Plan). The 1997 Plan provides a roadmap for upgrading and expanding the LOWTP from the current 16 mgd capacity to an ultimate capacity of 48 mgd with incremental expansions to
24 and 32 mgd. The 1997 Plan recommends a conventional treatment process for the LOWTP. Since 1997, there have been advances in water treatment technologies that we believe merit evaluation in preliminary design stages of future upgrade and expansion projects. In addition, key assumptions in the Plan should be revisited, including the following:

- Tigard has developed Aquifer Storage and Recovery (ASR) wells to augment peak summer demand. This technology tends to reduce the needed treatment plant capacity as water is treated and stored during winter low demand periods. This will have the effect of reducing Tigard’s peak demands. The source water for the ASR wells would come from winter (off-peak) WTP production.
- As discussed elsewhere in this report, the LOWTP site constraints and intake capacity are reasons to consider limiting the LOWTP capacity to 32 mgd.
- Winter demands are approximately one-half the summer peak or maximum day demand (MDD). Therefore, the expanded 32 mgd LOWTP would have capacity to meet winter demands for both communities and supply recharge supply for the Tigard ASR storage. [To maximize winter production, winter/spring raw water quality may dictate process selection and sizing.]
- The projected Lake Oswego MDD is 26 mgd while the projected Tigard MDD is 20 mgd. Treatment capacity is typically sized for the MDD. The following table presents the basic planning data which is discussed in more detail elsewhere in this report:

<table>
<thead>
<tr>
<th>Source</th>
<th>Lake Oswego</th>
<th>Tigard</th>
<th>Combined</th>
</tr>
</thead>
<tbody>
<tr>
<td>LOWTP (Clackamas River)</td>
<td>26 mgd</td>
<td>8 mgd</td>
<td>32 mgd</td>
</tr>
<tr>
<td>ASR</td>
<td>n/a</td>
<td>6 mgd</td>
<td>6 mgd</td>
</tr>
<tr>
<td>Lake Oswego/West Linn</td>
<td></td>
<td>8 mgd</td>
<td>8 mgd</td>
</tr>
<tr>
<td>Total</td>
<td>26 mgd</td>
<td>20 mgd</td>
<td>46 mgd</td>
</tr>
</tbody>
</table>

Note:
1) An alternative is to obtain 8 mgd via West Linn and not obtain any from FWB.

The 1997 Plan assumed that the Willamette river would be the raw water source for the LOWTP beyond the 38 mgd capacity. If the Lake Oswego WTP capacity is expanded beyond 38 mgd, an alternative to tapping the Willamette River as a Lake Oswego WTP source is to obtain Clackamas River rights from SFWB and add the Lake Oswego intake as another point of diversion.

A schematic of the process configuration recommended in the 1997 Facility Plan is presented in Figure 1. Refer to attached site plans from the same report. Some key process recommendations from the 1997 Plan include the following:
• Replace inline mechanical mixer with pump diffuser flash mixer in conjunction with first plant expansion. (Construction completed)

• Upgrade the current Direct Filtration process (with contact basins) to a Conventional process with addition of flocculation and sedimentation unit processes. The conceptual design includes retrofit of the existing contact basins with flocculators, high rate tube or plate clarifiers and sludge removal equipment. Construct new basins in kind with 3-stage flocculation with 30 minutes detention time and high-rate sedimentation basins with assumed loading rate of 1.5 gpm/sf.

• Upgrade existing filters and construct new filters with deeper basin geometry and gravel less underdrain system for deeper bed depth and higher filtration rate. (Construction completed) Filter upgrades to dual media and gravel less underdrain.)

• Replace unlined sludge settling ponds with concrete lined lagoons which will thicken and dewater the plant residuals. (Construction completed) The supernatant from the lagoons will be recycled.

• Add a 2.2 MG finished water clearwell with the first plant expansion.

• Addition of the following chemical systems: liquid cationic polymer and carbon dioxide, and site planning for possible future addition of ammonia, and ozone. (Completed improvements, including liquid polymer and carbon dioxide chemical systems.)

• Upgrade of lime, PAC, and chlorine storage and feed systems. The Plan recommends switching from gaseous chlorine to sodium hypochlorite (bulk or onsite generated). A bulk lime silo storage system with saturator is recommended to replace the bag feed system. Similarly, a PAC slurry tank storage and feed system is recommended. (Completed improvements, including sodium hypochlorite and bulk lime storage.)

Other key assumptions from the 1997 Plan include the following:

• The Willamette River will be the source of supply for the LOWTP for capacity beyond 38 mgd capacity.

• Proprietary high-rate clarifiers were not recommended for reasons of cost, process stability, and ease of operation.

• Because of site constraints the ultimate expanded plant layout includes 8 new filters which increases the filter loading rate from current 5.1 gpm/sf to 6.6 gpm/sf. The higher design filtration rate was based on lower solids loading with addition of the flocculation and sedimentation processes, improved filter design, and optimized pretreatment.

• The recommendation to add 2.2 MG of storage capacity satisfies disinfection requirements, however, falls short of the recommended volumes (10% to 20% of plant capacity).
FIGURE 1
1997 Facility Plan Recommended LOWTP Process Configuration
1997 Plan Process Evaluation

Because of the limited scope of this study, our process evaluation will consist of a brief assessment of the 1997 Plan process recommendations followed by alternative recommendations. More detailed predesign studies are recommended to validate these preliminary recommendations and to establish water specific design criteria. At the very least, the alternative processes discussed should be evaluated during preliminary design phase of next expansion project.

In general, the 1997 Plan recommends a conservative process for the future LOWTP. The conventional process with coagulation/flash mix, flocculation, sedimentation, media filtration, and disinfection is a robust process that will meet all current and known forthcoming water quality regulations. It is a process suitable for treating Clackamas River, Willamette River, or a combination of the two sources. Although additional processes of ozone and/or UV may be appropriate when treating the Willamette River.

The proposed conventional process and method of solids handling are space intensive and as laid out cannot fit on the current 6.05 Acre site. Beyond 24 mgd capacity, the City owned, adjoining Mapleton Frontage property is required to site solids handling lagoons. It is our understanding that adding sludge thickening/dewatering lagoons on the 3.3 Acre Mapleton Frontage site will likely meet with resistance from local residents and perhaps planning department. While the 1997 Plan is schematic, it depicts construction of new facilities abutting existing older structures. While this is feasible, our experience is that it is oftentimes best to separate new facilities from older to allow for upgrades, e.g., deeper filter basins, and to avoid building code issues. This approach can also be lower construction cost. Based on site constraints and advances in technology, we recommend evaluating alternative processes that result in smaller footprints and better fit within the original 6.0 acre-plant site.

**Capacity:** An assumption is made that the ultimate LOWTP capacity will match the 32 mgd existing Clackamas River intake capacity. [An alternative to match plant capacity to the 38 mgd Lake Oswego Clackamas water rights could also be considered, however, requires an expansion of the existing intake.]

**Rapid Mixer:** The choice between an inline mechanical mixer and a pumped injection type mixer is largely an engineer/owner preference. Both types of mixers will meet the process needs for the future plant.

**Flocculation:** The 1997 Plan conceptual design criteria is standard for the industry. The multiple mixers and drives take up considerable space on site. The decision to not consider proprietary clarifiers that combine the flocculation and sedimentation steps should be revisited based on site constraints.

**Sedimentation:** The high-rate tube or plate settlers are both effective clarifier technologies. The 1997 Plan leaves the choice of tubes or plates open and provides a conservative footprint which would accommodate either process. Plates typically provide double the capacity of tubes in the same footprint. In general, we recommend plates over tubes because they are higher rate and substantially more durable. Tube settlers have a 10 to 15 year expected life. Plate settler’s life is about __ years. Plates are substantially more expensive than tubes first cost.
Filters: The recommendation to go with deeper filters with gravel less underdrains is consistent with industry trends. While the justifications given in the Plan are reasonable, we would not recommend increasing the design filtration rate above approximately 5 gpm/sf simply to accommodate site constraints. Deeper filters will require air scour for more effective cleaning.

Clearwell: We concur with the clearwell capacity goals in the report. From an operational perspective, you can never have too much. Looking for opportunities to reduce the footprint of other unit processes will potentially allow for more storage capacity on site. This is one component, if buried, that may be permitable on the Mapleton Frontage parcel.

Solids Handling: The proposed lagoons are low-tech and an effective means of handling plant residuals, and generally is the preferred alternative where sufficient land is available. For the LOWTP we would recommend mechanical thickening and dewatering facilities to reduce handling and better fit the existing site.

Disinfection: The recommendation to stay with free chlorine disinfection appears valid for the Clackamas source. Chloramination provides the City with an alternative method to control DBPs at low cost in the future, if needed. Ultraviolet Irradiation (UV) should be considered as a possible future primary disinfection process. UV was not known to be an effective inactivator of Cryptosporidium and other pathogens when the Plan was prepared.

Chemical Systems: We generally concur with the proposed chemical system upgrades and additions. Alternatives to lime should be evaluated for reduced maintenance.

Proposed Alternative Process

Our approach to developing an alternative process for the LOWTP consists of the following steps:

1. Select the recommended filtration technology
2. Select the disinfection strategy and DBP goals
3. Select the appropriate pretreatment to compliment filters and meet aesthetic goals

Filters: As an alternative to media filters, we recommend membrane micro filtration or ultrafiltration for the upgraded and expanded LOWTP. Since the Facility Plan was completed, membrane technologies have emerged as a viable, economical alternative to media filters. They have been embraced by the water industry primarily because they provide a positive barrier against microbial pathogen transmission and other inherent advantages including small footprint, automation, increased disinfection inactivation/removal credit, product water not dependent upon optimized coagulation chemistry, and potential for reduced pretreatment and sludge production. Membranes are generally well positioned for the future regulations. In the last 5 years, CH2M HILL’s Corvallis office has designed membrane plants for several communities including Warrenton, Young’s River, Pendleton, Albany-Millersburg Joint Water System, and Salmon Idaho. Capacities range from less than 1 mgd to 16 mgd. The Albany-Millersburg plant can be expanded to 26 mgd. Membrane plants in the 50 to 100 mgd capacity range are being built in the U.S.
A fundamental switch in treatment process poses some significant challenges and therefore, needs to be carefully evaluated. A full evaluation is beyond the scope of this study. With that said, the source water quality and LOWTP site constraints appear to be a good match for membranes. The switch to membranes could be phased in with old and new processes operated together. Immersed membrane technologies are likely the most economical membrane alternative for the LOWTP. Immersed membrane systems are being retrofitted into existing filter basins in some water treatment plant renovations.

We would recommend continuing with free chlorine disinfection until a change is necessitated by regulation. The possibility of adding UV and/or ammonia to combine chlorine provide future operational flexibility toward meeting more stringent DBP regulations. The site should be planned for these processes in lieu of ozonation.

Microfiltration and ultrafiltration membranes act as strainers and without pretreatment would not be effective at removing organics or controlling seasonal taste and odors. PAC, while considered a high-maintenance chemical system, has been effective at controlling T&Os, is compatible with membranes, and should be maintained. [If the City continues with media filters, GAC filter adsorbers are an effective alternative to anthracite and silica sand filters. This alternative was not discussed in the 1997 report. The Corvallis, Oregon Taylor WTP has been operating filter adsorbers since 1995 with good results.]

PAC slurry storage and feed systems reduce handling and dust issues, and are a good choice for the future plant. Alternatively a bulk 'super-sack' PAC feed system could be considered, and may provide chemical management advantages over the slurry system. The 1-ton super-sacks are positioned over the feed hopper using a hoist and trolley system to minimize bag handling.

Clarification can reduce solids loading on the membranes and allow for higher flux rates and lower membrane equipment cost. In addition, clarification step may be necessary to maximize winter production to provide ASR recharge. If required, or if clarification/membrane combination results in lower overall cost, an Inflco Degremont SuperPulsator™ clarifier should be considered. This high-rate, upflow solids contact clarifier is reasonably responsive to changing water quality conditions and provides extended detention time for PAC in the solids blanket. The clarifier is mechanically simple with no submerged equipment. Actifo is an even higher rate clarifier technology utilizing ballasted sand to enhance floc settling; however, it does not compliment the PAC adsorptive process. It is likely that the clarifier could be used seasonally and bypassed for much of the year. A description of the SuperPulsator™ process is attached.

The LOWTP has insufficient space on the 6.05 acre site for lagooning the plant residuals. Mechanical thickening and dewatering is higher cost, however, provides a better fit for this plant and site. The backwash wastewater would be equalized and pumped to gravity thickeners. The blow-down from the thickeners would be dewatered using centrifuges.

**Alternative Conceptual Design**

A schematic of the recommended alternative process configuration is presented in Figure 2. Relative footprints of the major process recommendations are depicted on the 32 mgd site
plan from the 1997 Plan. The high rate processes discussed will provide an expansion to 32 mgd within the original 6.05 acre-site. Expansion to 32 mgd is near the maximum capacity that could be constructed on the original site. This should be confirmed in further concept/preliminary design tasks.

Cost Estimates
Our approach to the cost evaluation included the following steps:

1. Update the 1997 Facility Plan costs to 2005 dollars. The January 1997 Seattle ENR cost index of 6020 was adjusted upwards. The May 2005 ENR is 8195, for an adjustment factor of 1.361.

2. Using CH2M HILL's Parametric Cost Estimating System (CPES) the cost of the proposed alternative process was estimated. This process consists of inputting preliminary sizing criteria into costing spreadsheets. The software has modules for all major unit processes and is updated periodically to reflect current equipment and materials pricing and recent project costs.

3. For a better comparison between the 1997 Plan estimate and the proposed alternative process, CPES was used to estimate the 1997 Plan proposed improvements.

For the CPES generated estimates, the two LOWTP process alternatives appear comparable. The conventional process recommended in the 1997 Plan is approximately 15 percent lower cost than the membrane alternative. If clarification is not required for pretreatment ahead of the membranes, the costs will be comparable. For the conceptual design and order-of-magnitude cost estimates, the difference in cost may not be significant. Additionally, the proposed alternative process may provide significant benefits beyond the first time cost. Table 4-2 shows the varying cost estimates as described in this section.
## Table 4-2
Comparative Cost Estimating

<table>
<thead>
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<td>Rapid Mixer</td>
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<td>Membranes</td>
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<td>Filter Subtotal</td>
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<td>Construct New 2.2 MG Res</td>
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<td>Construct New Lagoons</td>
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<td>$300,000</td>
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<td>24 to 32 mgd</td>
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<td>$408,339</td>
<td>New Lagoons</td>
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<td>$14,680,807</td>
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<td>$20,000,000</td>
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FIGURE 2
Recommended Alternative LOWTP Process Configuration

CLACKAMAS RIVER
RAW WATER PUMP STATION
POLYALUMINUM
CHLORIDE
ANIONIC PAC
FLASH MIX
PULSED-BLANKET CLARIFIER
IMMERSED MEMBRANE FILTRATION
UV DISINFECTION (FUTURE)
CLEARWELL
FINISHED WATER PUMPING
DEWATERING POLYMER
THICKENER
BACKWASH SURGE
DEWATERING CENTRIFUGE
TREATED WATER TO DISTRIBUTION
CENTRATE TO SEWER
SLUDGE CAKE TO LANDFILL
AQUAAMMONIA (FUTURE)
SODIUM HYDROXIDE
CARBON DIOXIDE
Section 5 - Finished Water Pipeline

The existing 24-inch finished water pipeline is at capacity with the 16 mgd WTP output. Any increased WTP capacity will trigger new finished water pipeline construction. The new pipeline would be sized to carry the expected flow in excess of the current 16 mgd, whether it is from the WTP or the WTP plus SFWB via West Linn (if contracted for MDD flow augmentation).

To realize the cost saving of carrying the flow required for Lake Oswego and for Tigard, the new pipeline would need to follow the general alignment of the existing 24-inch pipeline to Lake Oswego’s Waluga Reservoir. Tigard currently can obtain supply through the existing Bonita Pump Station. It is capable of pumping up to 8 mgd at a head of 90 feet, lifting it to 410 feet elevation. For Tigard to obtain all its water supply from Lake Oswego, the Bonita Pump Station would have to be increased to 20 mgd. If Tigard has ASR in place to provide 6 mgd of summer capacity to the system, the Bonita pump Station would only have to be capable of 14 mgd, or an expansion of 6 mgd. Further evaluation is required to determine if the expansion can be accomplished on the available property. The full length from the WTP to Waluga Reservoir is about 30,000 lineal feet.

Further evaluation is required to determine if the piping from Waluga to the Bonita Pump Station is adequate to flow Lake Oswego’s needs and Tigard’s. Tigard’s water model should be run to determine the Tigard system capability to receive 14 to 20 mgd from the Bonita Pump Station.

An alternative that could be evaluated is providing a way to offset a portion of Lake Oswego’s need for the existing 24-inch pipeline from the downtown area of Lake Oswego to the Waluga Reservoir. Some amount could be offset by diverting water in the downtown area by pumping to higher service levels from that point. This alternative implementation may delay the need to construct the last half of the transmission line for some years, allow a downsizing of it, or both.

Section 6 - Capital Construction Cost Estimates

The project assumed for the preparation of cost estimates is based on expanding the Lake Oswego WTP to 32 mgd, Tigard’s MDD being 20 mgd and Lake Oswego’s MDD being 26 mgd. Tigard’s 20 mgd demand is assumed to be satisfied with:

- 6 mgd of developed ASR,
- at least 6 mgd from Lake Oswego’s intake and WTP, and
- the balance of up to 8 mgd being provided from SFWB via West Linn’s system.

This approach:

- uses the existing Lake Oswego intake to its maximum without requiring significant additional structural expansion or a new intake and all the permitting required for that type of project.
- uses the entire senior Clackamas River right of Lake Oswego and senior rights of SFWB.
- maximizes the ASR opportunity in Tigard.
- which reduces reliance on others during peak demand periods and
- reduces treatment plant and transmission costs.
- Provides for IGAs for system buy-in.

The raw water pipeline will be sized so that the combination of the existing and new pipeline can supply 38 mgd (total of Lake Oswego’s Clackamas River rights). This study assumes the new pipeline will be 30-inches in diameter.

The source water for the ASR facility would come from the Lake Oswego WTP capacity and/or SFWB as these two sources will supply the needed water for ASR source water and the daily demand during the non-peak times of the year. The ASR source water supply rate is assumed to be no more than 3 mgd during the storage phase, or half the ultimate capacity of the ASR facility.

The concept-level estimated construction cost and the cost sharing between Tigard and Lake Oswego are shown in Tables 6-1 and 6-2.

**TABLE 6-1**
Water Supply System Construction Cost Estimate

<table>
<thead>
<tr>
<th>System Component</th>
<th>Capacity</th>
<th>Estimated Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intake Facility</td>
<td>Increase firm pumping capacity to 32 mgd</td>
<td>$3.0</td>
</tr>
<tr>
<td>Raw Water Pipeline</td>
<td>Size for 18 mgd</td>
<td>$5.5</td>
</tr>
<tr>
<td>WTP Expansion</td>
<td>Expand from 16 mgd to 32 mgd</td>
<td>$20.0</td>
</tr>
<tr>
<td>Finished Water Pipeline</td>
<td>Size for 30 mgd (22 mgd/LO + 8 mgd/SFWB)</td>
<td>$14.0</td>
</tr>
<tr>
<td>Bonita Pump Station Expansion</td>
<td>Expand capacity from 8 mgd to 14 mgd</td>
<td>$2.0</td>
</tr>
<tr>
<td>SFWB/West Linn Facilities</td>
<td>Expand capacity from 6 mgd to 8 mgd</td>
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<tr>
<td>Construction Contingencies (30%)</td>
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<td><strong>Total Estimated Construction Cost</strong></td>
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<td><strong>$60</strong></td>
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**TABLE 6-2**
Water Supply System Construction Cost Sharing

<table>
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<th>Cost ($MII)</th>
<th>Tigard Share</th>
<th>Lake Oswego Share</th>
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<tr>
<td>Intake Facility</td>
<td>$3.0</td>
<td>37.5%/(6/16)/$1.13</td>
<td>62.5%/$1.67</td>
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<td>Raw Water Pipeline</td>
<td>$5.5</td>
<td>33.3%/(6/18)/$1.83</td>
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<td>WTP Expansion</td>
<td>$20.0</td>
<td>37.5%/(6/16)/$7.5</td>
<td>62.5%/$12.5</td>
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<tr>
<td>Finished Water Pipeline</td>
<td>$14.0</td>
<td>46.7%/(14/30)/$6.5</td>
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<tr>
<td>Bonita Pump Station Expansion</td>
<td>$2.0</td>
<td>100%/$2.0</td>
<td>0%/$0</td>
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<tr>
<td>SFWB/West Linn Facilities</td>
<td>$1.5</td>
<td>100%/$1.5</td>
<td>0%/$0</td>
</tr>
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<td>Construction Contingencies (30%)</td>
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<tr>
<td>Total Estimated Construction Cost</td>
<td>$60.0</td>
<td>$26.76</td>
<td>$33.24</td>
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</table>

Note:
This cost opinion is in September 2005 dollars and is construction cost only. It does not include future escalation, unusual material cost increase, sales tax, engineering, financing, construction management or O&M costs.
The cost opinion shown has been prepared for guidance in project evaluation from the information available at the time of preparation. The final costs of the project will depend on actual labor and material costs, actual site conditions, productivity, competitive market conditions, final project scope, final project schedule and other variable factors. As a result, the final project costs will vary from the cost presented above. Because of these factors, funding needs must be carefully reviewed prior to making specific financial decisions or establishing final budgets.

Section 7 - Conclusions
The limited scope of this work does provide for an opportunity to assess the current situation regarding demand projections, available and potential capital facilities, and interest in having a cooperative effort among water purveyors for sharing water rights and existing and new facilities to satisfy regional demands. A cooperative approach will provide significant cost savings to both Tigard and Lake Oswego as Tigard seeks to develop ownership in a water supply and to Lake Oswego as they expand water supply facilities to meet future demands. Other benefits to Lake Oswego and SFWB including 1) emergency backfeed of Portland Water Bureau or Joint Water Commission water in case of catastrophic issues on the Clackamas River and 2) construction of a significant portion of the southern segment of the regional water providers transmission system.

Additional study is warranted to analyze the specifics of the design requirements, permitting needs, and intergovernmental agreements (IGAs). The design requirements will be based on the desired capacities for each system component as agreed to by all parties. The following are examples of optional sizing and study efforts:

- The raw water pipeline could be sized for the full Lake Oswego Clackamas River water rights totaling 38 mgd or sized for the WTP capacity of 32 mgd, based on the decision to use or not to use the junior rights.
- The finished water pipeline could be sized for 1) the full water rights plus up to 8 mgd from South Fork via the West Linn system, or 2) just the WTP 32 mgd plus the 8 mgd from South Fork, or 3) allow for the existing pipeline to be rehabilitated and left in service, thus making the new finished pipeline needing to handle 30 mgd, and 4) other combinations may be considered.
- Another study effort required is the evaluation of treatment processes to construct.
- The Lake Oswego-West Linn intertie and West Linn delivery system needs to be evaluated to determine if 8 mgd can be obtained through their system.

The federal, state and local permitting requirements need to be further defined and a strategy for success formulated. A negotiated IGA with Lake Oswego should include ownership interests in the Lake Oswego water rights, intake, WTP, and raw and finished pipelines. An
IGA with SFWB can consider either wholesale purchase of water from SFWB via West Linn or some facilities ownership such as water rights, intake, WTP, and transmission pipeline. An IGA with West Linn would provide a way to wheel water through their system to the new Lake Oswego-Tigard finished waterline near the existing West Linn-Lake Oswego intertie.
Appendix A – Alternative Processes

The following paragraphs provide descriptions of the alternative processes discussed in the Tigard Water Supply Study.

Filtration

Granular Media Filters
The 1997 Facility Plan recommends additional upgraded media filters for the LOWTP. Dual media filters are still the most common filters found at water treatment plants today. Most designs are anthracite/sand or GAC/sand, possibly with a high-density garnet sand (mixed media). The LOWTP filters are a mixed media design.

The typical media bed design is a shallow bed with 18 to 24 inches of anthracite or GAC followed by 9 to 12 inches of sand. Media sizes can vary to balance the particle removal and headloss, but the most common media size for the sand part of the filter is 0.5 mm (effective size), while the anthracite and GAC can range from 0.8 to 1.2 mm (effective size). Dual media filters exhibit additional headloss as compared to deep bed monomedia designs, but they provide equal finished water quality. The smaller sand media provides a barrier to particle breakthrough at higher loading rates or long filter run times. The finer the media, the greater the protection; however headloss increases with the finer media, thereby reducing filter productivity. A dual media filter is usually less productive than a monomedia filter, but depending upon the filter influent water quality, this may not be an important factor to consider.
Membranes

With the increasingly stringent requirements for better drinking water quality and reduction in use of disinfectants because of health concerns, the drinking water industry has looked into alternative processes to conventional treatment. Membrane treatment is gaining popularity in the U.S. The long-term experience with membranes is limited at this time, but installed capacity in the U.S. is in the hundreds of mgd.

Membrane processes can be separated into four basic categories—reverse osmosis, nanofiltration, ultrafiltration, and microfiltration. Reverse osmosis (RO) and nanofiltration (NF) are used to remove dissolved inorganic compounds such as sodium, calcium, and magnesium ions, or dissolved organic compounds such as humic and fulvic acids that make up the primary source of DBP precursors. They operate at transmembrane pressures of about 80 to 1,200 psi, depending upon the source water quality and degree of separation required. Some uses for RO and NF include desalination of seawater and membrane softening, respectively. Ultrafiltration (UF) and microfiltration (MF), on the other hand, cannot remove dissolved materials, and are limited to removal of particles. UF membranes have a nominal pore size of between 0.003 and 0.03 μm, whereas MF membranes have a nominal pore size of between 0.05 and 0.5 μm.

MF membranes, because of the pore size, are limited to removal of Giardia and Cryptosporidium, while UF membranes have the added feature of removing not only Giardia
and *Cryptosporidium* but also viruses. NF membranes remove particles but also can remove most DBP precursors and some dissolved salts. RO membranes remove everything the other membranes do, plus almost all dissolved salts. Figure A.2 shows the particle size removal capacity of each type of membrane.

**FIGURE A.2**
Membrane Process Application Guide

![Diagram showing particle size removal capacity of different membranes](image)

The earliest commercially available UF and MF membrane systems designed to filter-sterilize liquids are known as pressure-driven, hollow-fiber membranes. (Figure A.3). The liquid is passed either from the outside to the inside (lumen) of the hollow fiber (outside-in) or from the lumen to the outside of the fiber (inside-out). The hollow fibers are installed in vessels, which provide support for the pressure necessary to drive the liquid through the membrane pores. These units use water, air, or air/water backwash systems.
Immersed membranes are a relatively recent development in membrane process configuration. In this process, hollow fiber membranes are installed (immersed) in a raw water vessel and a small vacuum is applied to their downstream side. (Figure A.4). This process is much more energy efficient and can result in a smaller footprint than pressure-driven configurations. Process air is introduced at the bottom of the membrane feed vessel, which creates turbulence in the tank effectively scrubbing the solids from the membrane surface.
The advantage of a solids separation barrier with a known diameter makes MF or UF a feasible technology for control of microbes and provides effective filtration while achieving reasonable recovery of the product water. Product water recovery for MF and UF membranes ranges from 85 to 95 percent and can be even higher in some cases.

Advantages and disadvantages of membrane treatment compared to conventional treatment are:

<table>
<thead>
<tr>
<th>Advantages</th>
<th>Disadvantages</th>
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<tbody>
<tr>
<td>Increased particle and turbidity removal</td>
<td>Pretreatment of raw water is necessary to maintain</td>
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<tr>
<td>Reliability of consistent effluent quality</td>
<td>treatment capacity</td>
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<td>Removal of pathogens (protozoa and bacteria [MF]</td>
<td>Need to clean membranes using acids or surfactants</td>
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<td>protozoa, bacteria, viruses [UF])</td>
<td>(new waste stream)</td>
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<td>Ease of automation of the treatment system</td>
<td>Production of a more concentrated backwash stream</td>
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<tr>
<td>More flexibility in being able to meet future</td>
<td>(particles and pathogens)</td>
</tr>
<tr>
<td>finished water quality goals</td>
<td>Capital costs are still high as compared to most other</td>
</tr>
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<td></td>
<td>processes</td>
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Backwash Treatment and Recycle

Filter Backwash Treatment

Filter backwash water typically represents 2 to 5 percent of the total water processed at a plant. The most applicable technology for any treatment option that uses granular media filters is the treatment of spent backwash water through the use of an equalization basin followed by a thickener. This process can produce a clarified effluent that can be discharged to a sanitary sewer or local stream (with an NPDES permit), or it can be recycled to the head of the plant.

Recycle of treated backwash water must be handled carefully to ensure that proper treatment is still achieved by the water treatment processes. The recycle stream should be added at the head of the plant prior to flash mixing and should be returned at an equalized rate so that the flow is less than 10 percent of the total influent flow. The solids stream from the equalization and clarification processes needs to be handled by some measure of solids treatment, as discussed later in this section.

Membrane Concentrate Treatment

Membranes form a semipermeable barrier in the water treatment process and produce a concentrated waste of the rejected constituents in the raw water. Treatment of the membrane concentrate from MF or UF systems is usually much easier than that from an NF system because of the smaller pore size and removal of some molecular size compounds that can significantly affect the pH of the concentrate. Membranes are also periodically backwashed, which produces washwater that must also be treated.

Typical concentrate from an MF or UF system can be treated by the same treatment methods as those used for backwash recycle, or another membrane can be used with a high recovery rate to produce high quality filtrate that can be recycled or disposed of. The small volume of remaining concentrate can be combined with other solids residuals (if present) for further processing or possibly disposed of in a sanitary sewer.

A secondary waste stream that must be dealt with is that produced during cleaning of the membranes. Membranes are typically cleaned with low or high pH solutions on a periodic basis to maintain adequate production through the membrane. Treatment of this waste stream is usually done by using a tank for pH neutralization of the spent cleaning solution followed by a sanitary sewer discharge.

Solids Handling Processes

Solid residuals produced by treatment of backwash water or membrane concentrate, as well as residuals produced from coagulation processes, must be treated before final disposal. The treatment methods employed are designed to increase the percent solids of the residuals to decrease the total volume and therefore reduce the final disposal costs. State and local regulations may also influence the level of residuals treatment or the options available to the Authority for treatment of these solids. The solids concentration of metal hydroxide residuals treated by each process type is:
- Thickening: less than 8 percent solids
- Dewatering: between 8 to 35 percent solids
- Drying: greater than 35 percent solids

**Thickening**

Thickening is usually the first step in reducing the quantity of solid residuals. The effectiveness of the thickening process has a large impact on any downstream solids treatment. The water removed from the solids during the thickening process can be disposed of or recycled to the head of the plant, allowing for additional recovery of source water in addition to any backwash water recycle.

**Gravity Thickeners.** The most common method of thickening is the use of gravity thickeners. This method is used in most locations as the initial step in treatment. The thickener is usually a circular shaped settling basin that is operated in either a batch or continuous flow mode. The bottom of the thickener has either a hopper or scraper mechanism to remove the thickened solids. Solids can typically be thickened to 1 to 2 percent solids without polymer addition. Addition of polymer can increase the solids concentration as well as the quality of the supernatant for recycle. The thickener can also be used to provide some residuals storage and equalization to achieve constant solids flow to downstream processes.

**Dewatering**

**Centrifuges.** Centrifugal dewatering of solids is a process that uses the force generated by a fast rotation of a cylindrical bowl to separate solids from liquids. The main types of centrifuges used to dewater WTP residuals are basket and solid bowl. The solid bowl is the most common type used. It is a rotating cylindrical conical bowl with a scroll that rotates with the bowl at a different speed and carries the dewatered sludge to a discharge point. The centrate from the process is discharged from the shell of the bowl. Centrifuges can operate in either a cocurrent or countercurrent flow, although most centrifuges in the U.S. are of the countercurrent design.

Polymers are usually used to help condition the sludge before centrifugation. Typical solids concentrations can range from 15 to 30 percent with feed solids in the 1 to 3 percent range. The space required for the unit is minimal, and centrifugation is a proven technology. However, the energy requirements are high, and the centrate waste stream may have a high concentration of suspended solids that may be difficult to treat or recycle.

**CLARIFICATION TECHNOLOGIES**

- The majority of solids occurring naturally in the raw water and added in the coagulation process are removed as settled sludge.

**Inclined (Plate or Tube) Settlers.** This is the clarification technology recommended in the 1997 Facility Plan. Inclined plates can be installed in a sedimentation tank to improve clarification. Many high-rate clarifiers, including the Superpulsators and Actiflo® (both to be discussed later), also utilize the inclined settler technology. The inclined plates and tubes both improve settling efficiency by reducing the distance the particles must travel. The inclined
settlers can achieve surface loading rates in the 1 to 5 gpm/ft² range. Typically tube settlers, which are 2 to 3 feet deep, can double the loading rate to 2.0 to 2.5 gpm/sf. The deeper, 6 to 7 feet deep, parallel plates can achieve effective surface loading rates of 3 to 5 gpm/sf. The higher the loading rate, the smaller the required footprint, therefore, these clarification technologies are popular for retrofits. Mechanical sludge removal equipment is required for efficient operation. A tube settler schematic is presented in Figure A.5.

**FIGURE A.5**
Tube Settler Schematic

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**Upflow Blanket Clarifiers.** Upflow blanket clarifiers, also known as solids contact units, combine rapid mixing, flocculation, and sedimentation in one unit. These clarifiers are designed to maintain a large volume of floculated solids within the unit, which enhances flocculation by encouraging interparticle collisions. The floculated solids (solids blanket) are usually maintained at a set volume in the contactor, and cohesion of the blanket is achieved through the use of a polymer in addition to the coagulant. Upflow clarifiers are popular because of their higher loading rate, thus, reduced size.

One such unit is the Superpulsator®, manufactured by Infilco Degremont, Inc. In the Superpulsator®, rapid mixing occurs upstream of the unit where coagulant is added to begin the formation of floc. After rapid mixing, a polymer is added to promote sludge blanket cohesion. The coagulated water then enters the unit. The Superpulsator® uses a vacuum pump and vacuum chamber to produce a pulsing effect within the flocculation zone. The pulsing of the solids blanket expands the blanket and increases the rate of interparticle collisions. Clarification occurs with the aid of inclined settlers (tubes or plates) above the sludge blanket that settle the remaining floc. The clarified effluent is discharged at the top of the unit. Solids are maintained in the unit at a set height by use of a solids overflow weir. Solids overflow into a hopper and can be removed at a set interval.

Typical solids concentrations range from 0.5 to 2 percent in the concentrated sludge. These units have loading rates of up to 3 gpm/ft². At these loading rates the detention time is approximately 45 minutes, much less than conventional clarification. A polymer is required at doses between 0.1 to 0.4 mg/L for cohesion of the sludge blanket. These units have no submerged moving parts or mechanisms, and the sludge blanket is self-leveling. These units have been shown to be effective at removing turbidity and TOC. Since the sludge is partially
recirculated increasing the sludge age, use of powered activated carbon (PAC) is particularly effective at removing taste and odor (T&O)-causing compounds in these units.

FIGURE A.6
Upflow Clarifier Schematic