Appendix A – Numerical Analysis of Options

Numerical Analysis of Options

This appendix contains a write up of each analysis that was performed for the Options that were deemed not to contain a "fatal flaw", as discussed in Section 2.0 of the Central Arizona Salinity Study (CASS) Planning Sub-Committee Report (Report), The Options were analyzed using the criteria developed by the CASS Planning Sub-Committee (Sub-Committee) and described in Chapter 3 of the Report. Cost estimates of the microfiltration (MF)/reverse osmosis (RO) facilities with evaporation ponds for concentrate disposal were made using the spreadsheet cost model developed by Reclamation for the Sub-Committee. The cost estimates provided in this appendix are accurate enough for reconnaissance level planning purposes, but not for construction purposes.

Analysis for Section 4.0: Preventing Salts from Entering Central Arizona

The following assumptions were used for analyzing the salinity control options presented in Section 4.0.

1. For the purposes of this study, Colorado River water is assumed to have a TDS concentration of 650 mg/L, which is equivalent to the 30-year average of TDS at Lake Havasu. The TDS of the Salt River varies at different locations, and the value used at any given location is stated in the text.

2. Evaporation ponds are the concentrate disposal/management approach for treatment options under consideration in this set of salinity control evaluations.

3. Costs included in these evaluations result primarily from the cost model developed in 2004 by the U.S. Department of Interior Bureau of Reclamation (Reclamation). This cost model utilizes cost curves developed in the Reclamation's 2004 *Appraisal Evaluation* entitled <u>Reverse Osmosis Treatment of Central Arizona Project Water for the City of Tucson</u> .

4. Efficiency is assumed to be 85 percent on all RO applications.

5. Replacement of water resources lost in the concentrate reject stream is assumed to be Indian Lease (IL) water at $1,700 per acre-foot (AF).

Several different treatment options were considered for reducing salt concentrations in Colorado River water, but only those options that would benefit central Arizona were selected for review.

4.1.2.1 Option: RO Facility Constructed at Davis Dam on the Colorado River

Description: This option consists of constructing a 2,050-million gallon per day (MGD) RO plant on the Colorado River at Davis Dam to treat a portion of river flow and send the permeate back into the river. Discharging the permeate back into the river, will cause a blending of the permeate and untreated river water, effectively reducing the TDS in the permeate. The reduction of salts would benefit central Arizona, southern California, and Mexico. Davis Dam was selected as the location to build the RO facility because of its location upstream from both the Central Arizona Project (CAP) aqueduct system and the California Colorado River Aqueduct. The Colorado River mean flow at Davis Dam is 9,883 MGD(15,290 cubic feet per second [cfs]), with an average TDS concentration of 650 mg/L over the last 30 years.

Concentrate disposal would be accomplished through evaporation ponds on U.S. Bureau of Land Management (BLM) land, which is located within five miles of Davis Dam. The water losses could be subtracted from the total river flow and not any individual allocation.

Institutional Considerations: Significant environmental permitting may be required for the construction of a RO plant adjacent to the river. An Arizona Aquifer Protection Permit (APP) from the Arizona Department of Environmental Quality (ADEQ) would be required for the construction and operation of the evaporation pond. APP requirements for evaporation pond liners are project-specific and will depend primarily on the chemical characteristics of the concentrate and depth to groundwater. If the land for the evaporation ponds, or any pipelines or conveyances, were to be located on federal lands, or the construction of this facility is federally-funded, National Environmental Protection Act (NEPA) regulations would have to be followed.

Water Resource Utilization: This option decreases water supply from the Colorado River due to loss in the concentrate disposal. This lost water will not be easily accepted by any of the Colorado River Basin States, the United States (U.S.) Federal government or the Mexican government, especially during drought periods.

Technical And Operational Feasibility: Although this facility is technically feasible, it would be extremely expensive to construct and operate due to its enormous size. The evaporation ponds are too large to be practical at 111 square miles to reduce the Colorado River by just 100 mg/L TDS. An alternative concentrate disposal method would be required, such as a pipeline to the Gulf of California.

Environmental/Public Acceptability: Reducing the salt content in the Colorado River would be readily accepted by the public, however, the loss of 15 percent of the water, estimated to be approximately 307 MGD, to concentrate management would be unacceptable. The Lower Colorado River Multi-Species Conservation Program (MSCP), a multi-agency effort to conserve and recover endangered species, may oppose this idea because of the reduction in water that would result in the river. Additionally, disposing of the concentrate would require over 100 square miles of evaporation ponds which may create environmental problems and concerns.

Benefits/Risks of Salinity Control/Reduction Option: Beneficiaries of a this option would be all Colorado River users below the RO facility, including CAP-supplied central Arizona, southern California metropolitan areas, farmers in Coachella and Imperial Irrigation Districts, and Mexico. The benefits would be through longer life in household appliances, better crop yields, longer life in water treatment facilities, and similar saved costs associated through the reduction of TDS. Central Arizona would see $15 million in savings for the reduction of 100 mg/L TDS in the Colorado River.

Economic/Financial Feasibility: For a reduction in TDS of 100 mg/L, the capital costs for a MF/RO plant would be approximately $1.85 billion. Capital costs for evaporation ponds would cost on the order of $5.65 billion. Total annual O&M would is estimated at $300 million. This idea is not financial feasible.

Change in TDS	Required Treatment Size (MGD)	Capital				O&M			Annualized Total (Million $)
		MF plant (Million $)	RO plant (Million $)	Evaporation Pond (Million $)	Pipeline (Million $)	MF Plant (Million $)	RO plant (Million $)	Evaporation Pond (Million $)	
100	2,048	$549.5	$1,315.5	$5,649.3	$38.6	$113.1	$166.5	$28.3	$818.40
200	3,973	$873.7	$2,415.2	$10,909.0	$52.7	$219.4	$322.8	$54.6	$1,563.30
300	5,785	$1,136.6	$3,408.8	$15,889.0	$59.7	$319.0	$470.0	$79.5	$2,259.20

Table 1 - Summary of Costs for RO Facility on Colorado River at Davis Dam

Conclusion: A RO plant to treat the Colorado River would have to handle two billion gallons per day and the cost to construct the plant would be approximately $2 billion. This plant would produce 300 MGD of concentrate, which equates to about 100 square miles of evaporation ponds for concentrate disposal, or an 11-foot diameter pipeline if the concentrate were to be transported to the Gulf of California. Overall, this alternative is rated very poor on technical/operational feasibility, economic/financial feasibility, environmental/public acceptability and water resource utilization.

4.1.2.2 Option: RO Facility Constructed at Mark Wilmer Pumping Plant

Description: This option consists of constructing a 400-MGD RO facility at the Mark Wilmer Pumping Plant to reduce salts in Colorado River water conveyed through the CAP aqueduct. This reduction of salts would benefit all of CAP water users and indirectly benefit people living in central Arizona. The Mark Wilmer Pumping Plant was selected as the location to build the RO facility because it offers some unique advantages. The Mark Wilmer Pumping Plant pumps approximately 1,939 MGD (or 3,000 cfs) of Colorado River water, which averaged about 650 mg/L TDS over the last 30 years. The concept of the RO facility would be to treat Colorado River water and blend with raw river water to produce the desired TDS in the water delivered by the CAP to central Arizona.

The RO plant would be designed as a one-stage membrane treatment facility. With the permeate flowing into the canal and the concentrate discharged to the Colorado River downstream of the plant. This scheme would reduce pressure requirements, which, in turn, would reduce energy consumption. However, the biggest savings in capital costs would be the elimination of a costly concentrate disposal scheme. There would be very little increase in TDS concentrations in the downstream river. Preliminary calculations indicate that the TDS concentrations in the Colorado River downstream of the plant ,where the concentrate was returned to the river, would increase by only 28 mg/L. Under most conditions this would not violate the standard set by the Colorado River Basin Salinity Control Forum of 747 mg/L TDS for this location.

Institutional Considerations: Significant environmental permitting may be required for the construction of a RO plant adjacent to the river. Water users downstream, especially the Imperial Irrigation District (IID), may not approve of this option because it will increase the salinity of the Colorado River, potentially leading to reduced crop production for farmers in the Imperial and Coachella Valleys. The Mexican government may be opposed to this option, although it should not violate the Colorado River water quality agreement with Mexico.

Water Resource Utilization: This option does not lose any water through concentrate management, which is one of the benefits of this option. Water that flows to Mexico or irrigation in southern California (IID) will be of poorer quality but the water which goes to central Arizona will be of better quality.

Technical and Operational Feasibility: Technically, this option has some advantages, thousands of tons of salts would not be pumped with the water from Mark Wilmer pumping plant or through the many pumping plants between the Colorado River and Tucson. Less energy would be required for a RO facility at this site because the plant would be a one-stage RO plant. Power is readily available. Concentrate management would be inexpensive because the concentrate would immediately re-enter the Colorado River. The disadvantage of this option is that the design of the RO plant would take significant effort because of site limitations.

Environmental/Public Acceptability: This option will potentially cause conflict amongst other Colorado River users, especially California and Mexico because of the increase of salinity resulting from concentrate being returned to the river. The Lower Colorado River Multi-Species Conservation Program may consider this project to be detrimental to the Colorado River.

Benefits/Risks of salinity control/reduction option: The major benefit would be the reduction of salt entering central Arizona which indirectly would benefit all of central Arizona water users. All CAP water users would benefit directly by receiving better quality water, reduced salinity related damages and better re-use of the water.

Economic/Financial Feasibility: It is estimated that the cost of this MF/RO facility would be close to $500 million. Costs may more because of the difficult terrain and small area where the MF/RO plant could be constructed. O&M costs are estimated to be $55 million annually.

Change in TDS	Required Treatment Size (MGD)	Capital			O&M		Annualized Total
		MF plant (Million $)	RO plant (Million $)	Pipeline (Million $)	MF Plant (Million $)	RO plant (Million $)	(Million $)
100	401.8	$175.73	$295.46	$2.06	$22.20	$32.70	$98.35
200	779.5	$279.42	$542.44	$3.14	$43.05	$63.38	$116.75
300	1135.02	$363.49	$765.59	$3.83	$62.69	$92.96	$264.53

Table 2 - Summary of Costs for RO Facility at Mark Wilmer Pumping Plant

Conclusion: The concept of constructing and operating a RO facility at Mark Wilmer Pumping Plant would be beneficial to central Arizona because of the prevention of salts entering the study area. Use of this existing site reduces the capital cost by approximately 50 percent because the need for constructing evaporation ponds for concentrate management is eliminated.   Secondly, there is no loss of water resources to concentrate disposal because the concentrate is blended back into the Colorado River. Thirdly, energy costs would be lower because of reduced pressure requirements in the RO facility and thousands of tons of salts would not be pumped with the water delivered to central Arizona.

It is estimated that the RO facility at Mark Wilmer Pumping Plant would cost about $470 million and annual O&M costs would be about $55 million. These combined costs are much higher than the annual benefits of about $15 million with the reduction of 100 mg/L TDS in the CAP waters. As with all the large sized options, the capital and O&M costs are exorbitant. This option is rated very poor for Economic/Financial Feasibility and marginal for Environmental/Public Acceptability.

4.1.3.2 Option: RO Facility Constructed on the Salt River and Roosevelt Lake

Description: This option consists of constructing a 47 MGD RO facility on the Salt River, just upstream of the flood zone of Roosevelt Lake for the purpose of preventing salinity from entering central Arizona, specifically the Phoenix metropolitan area. The mean flow for the Salt River at this location, since 1914, has been 585 MGD.   The TDS concentration in the Salt River varies according to wet and dry cycles.   In 1983, a wet year, the Salt River, at the same location, had an average TDS of 800 mg/L and a total flow of 1.3 million AF. In the year 2000, a dry year, the Salt River at this location had an average TDS of 2280 mg/L with a total flow of .66 million AF.   The RO facility would desalinize water during low flow conditions when the TDS was high. For the purposes of this study, an average flow of 585 MGD was used for the river with an average TDS concentration of 1,540 mg/L.

A cursory review of land uses in the area of the Salt River and Roosevelt Lake indicates that there is land available to build the required 1,600 acres of evaporative ponds for concentrate disposal.

Institutional Considerations: Significant environmental permitting may be required for the construction of a RO plant adjacent to a major, perennial river. In addition, the Willow Fly Catcher inhabits many areas around the lake.

Water Resource Utilization: Approximately 1 percent of the Salt River flow at this location would be lost to concentrate disposal for every 100 mg/L reduction in TDS.

Technical and Operational Feasibility: Construction of a RO facility at this location would be feasible because of access to roads and power. Operation of the plant would require significant effort to maintain due to the variations in TDS concentration.

Environmental/Public Acceptability: There are no environmental "fatal flaws" that are known at this point in time. The size of the evaporative ponds for concentrate disposal could be an issue for some people and organizations.

Benefits/Risks of Salinity Control/Reduction Option: Beneficiaries would be SRP customers and, indirectly, the Phoenix metropolitan area because of less salt entering into the Phoenix groundwater.

Economic/Financial Feasibility: Reducing the TDS concentration from 1,540 mg/L to 1,440 mg/L with these flows would require a MF/RO facility of approximately 47.2 MGD capacity. The capital costs for such a plant would be approximately $80 million, as shown below in Table 4.3. The evaporation ponds would cost an additional $156 million. O&M on the entire facility would be about $7.28 million. Annualized costs over 50 years at a 6 percent interest would be about $23.24 million.

Salt reductions of this magnitude would have annual savings in the Phoenix metropolitan area of about $15 million.

Change in TDS	Required Treatment Size (MGD)	Capital				O&M			Annualized Total (Million $)
		MF plant (Million $)	RO plant (Million $)	Evaporation Pond (Million $)	Pipeline (Million $)	MF Plant (Million $)	RO plant (Million $)	Evaporation Pond (Million $)	
100	47.2	$39.25	$41.47	$156.20	$1.00	$2.61	$3.89	$0.78	$23.25
200	93.3	$93.30	$77.44	$307.67	$1.30	$5.15	$7.63	$1.54	$44.64
300	138.3	$138.30	$111.09	$455.55	$1.50	$7.64	$11.29	$2.28	$65.21

Table 3 - Summary of Costs for RO Facility on Salt River at Roosevelt Lake

Conclusion: The salinity level is high at this point on the river and would be an ideal place to treat the water because the land is flat and access roads are available for constructing the facility. Power could easily be brought to the site.

The most expensive capital costs would be the evaporation ponds. An alternate method of concentrate disposal or more water extracted from the concentrate so the ponds could be reduced in size would reduce the costs.

This RO facility and evaporation ponds may be feasible if the capital costs could be reduced. Currently benefits would be about $15 million annually and the annualized capital and O&M costs would be about $23.24 million.

4.2.1.1 Option: RO Facility Constructed Along the CAP Canal in Western Arizona

Description: This option consists of constructing a 400 MGD RO facility along the CAP canal, possibly near Bouse Wash. This facility would reduce the salts in the CAP water delivered to central Arizona. Bouse Wash was selected because although it is isolated, it is near Interstate 10, which would provide easy access to the site. The CAP canal carries approximately 1,939 MGD (3,000 cfs) at 650 mg/L TDS (on average). The concept of this RO facility would be to treat a portion of the CAP water and blend it back to produce better CAP water for CAP customers.

Institutional Considerations: Normal environmental permitting would be required for the construction of a RO plant and evaporation ponds. As stated in Section 4.1.2.1, an APP would need to be obtained for the construction and operation of evaporation ponds. If the land for the evaporation ponds, or any pipelines or conveyances, were to be located on federal lands, or the construction of this facility is federally-funded, NEPA regulations would have to be followed.

Water Resource Utilization: This option will reduce the total amount of water delivered through the CAP canal by approximately 3 percent, which may not be considered the best use of imported water.

Technical and Operational Feasibility: This option would be relatively easy to construct from a technical point of view due to the easy access to the site, flat land, and a proven technology. The evaporation ponds would be extremely large, however, there are large amounts of open desert to construct them.

Environmental/Public Acceptability: The public may not be opposed to this option since they would be receiving water of better quality, however, it may be difficult to justify the destruction of large amounts of desert environment for the construction of evaporation ponds.

Benefits/Risks of salinity control/reduction option: Beneficiaries of this alternative would consist of all central Arizona CAP water users. Central Arizona would receive annual savings because of the lowered TDS. These savings would be longer life for household appliances, better crop yields, longer life for water treatment facilities and higher quality reuse water, etc.

Economic/Financial Feasibility: The cost of the MF/RO facility would be close to a $500 million and evaporation ponds are estimated to cost over $1 billion. The high costs on for the evaporation ponds are due to the cost of land and double lining the ponds. Estimated costs reflect a worst-case scenario and may be reduced if land trade agreements could be agreed upon with Bureau of Land Management (BLM). O&M costs for the MF/RO facility and the evaporation ponds would be close to $60 million annually. The benefits of reducing the CAP TDS by 100 mg/L is approximately $15 million therefore, the cost benefit ratio is not favorable.

Change in TDS	Required Treatment Size (MGD)	Capital				O&M			Annualized Total (Million $)
		MF plant (Million $)	RO plant (Million $)	Evaporation Pond (Million $)	Pipeline (Million $)	MF Plant (Million $)	RO plant (Million $)	Evaporation Pond (Million $)	
100	401.8	$175.73	$295.46	$1,088.24	$7.80	$22.20	$32.70	$5.44	$167.52
200	779.5	$279.42	$542.44	$2,113.90	$17.59	$43.05	$63.38	$10.59	$318.87
300	1135.02	$363.49	$765.59	$3,078.61	$26.00	$62.69	$92.96	$15.39	$460.07

Table 4 - Summary of Costs for RO Facility on CAP in Western Arizona

Conclusion: Construction costs for the RO facility constructed on the CAP canal in western Arizona would be high due to the size, but the location would make the construction accessible. The amount of area required for evaporation ponds would be very large and would be very expensive if a double-liner system were required for aquifer protection. Possible land trade agreements with the BLM, who owns large tracts of land in the immediate area, could reduce the cost of the land required for the evaporation ponds. The topography, which consists of flat, desert lands broken by dry washes, would make for easy construction of both the MF/RO facility and the evaporation ponds.

This option rates very poor for economic/financial feasibility and poor for environmental/public acceptability because of the size of the evaporation ponds. The total size of evaporation ponds for just 100 mg/L reduction in TDS would be nearly 22 square miles. Water lost to concentrate disposal would be approximately 3 percent of the total CAP water supply.

4.2.2.1 Option: RO Facility Constructed on the Salt River at Granite Reef Dam

Description: This option consists of constructing an RO facility at the Granite Reef Dam to treat Salt River water. This 80 MGD RO facility would ensure that water low in TDS was delivered year around. A RO facility at this location would only require operation when SRP was delivering higher TDS water. Evaporation ponds for this project could be located on land owned by the Salt River-Pima Maricopa Indian Community.

Institutional Considerations: An APP would be required for the construction and operation of the evaporation ponds. Negotiating for land use for concentrate disposal with the Indian Community may be difficult. Other concentrate disposal options most likely would be necessary.

Water Resource Utilization: The concentrate produced from this RO plant would be about 3 percent of the flow of the Salt River. These losses may not be acceptable to SRP and the other users of the river.

Technical and Operational Feasibility: Designing and operating this plant would be difficult due to the fluctuations in TDS. It would have to be designed to handle higher TDS at lower flows and lower TDS at higher flows. It would also have to operate at higher flows when the Salt River was the primary delivered water and lower rates when the Verde River was the primary delivered water. For this evaluation, the low and high TDS concentrations of 700 and 1,000 mg/L, respectively, were analyzed for costs.

The location would have easy access for construction activities and power would be easily brought to the site. Operationally, the facility would have to be designed so the rare flood events do not damage it. Technically, this plant would be easy to construct and maintain.

Environmental/Public Acceptability: Aside from concentrate disposal issues, there are no environmental issues that are known at this time. If this plant was reducing 1,000 mg/L TDS water at a flow of 283 MGD to a 500 mg/L TDS quality (federal secondary Maximum Contaminant Level), it would take 9.2 square miles of evaporation ponds to dispose of the concentrate.

Benefits/Risks of salinity control/reduction option: Beneficiaries would be SRP customers and, indirectly, the entire Phoenix metropolitan area because of less salt entering into the Phoenix ,groundwater and environment.

Economic/Financial Feasibility: Reducing the TDS from 1,000 mg/L to 900 mg/L would take approximately a 80 MGD MF/RO facility. The capital costs for such a plant is estimated to be $120 million. The evaporation ponds would cost an additional $210 million and O&M on the entire facility would be about $11.6 million. Salt reductions of this magnitude would have annual savings in the Phoenix metropolitan area of about $15 million, but the Salt River TDS varies tremendously from decade to decade

Change in TDS	Required Treatment Size (MGD)	Capital				O&M			Annualized Total (Million $)
		MF plant (Million $)	RO plant (Million $)	Evaporation Pond (Million $)	Pipeline (Million $)	MF Plant (Million $)	RO plant (Million $)	Evaporation Pond (Million $)	
100	76.95	$55.25	$64.90	$210.26	$1.73	$4.25	$6.30	$1.05	$34.00
200	149.63	$88.00	$119.41	$408.26	$2.94	$8.26	$12.21	$2.04	$64.37
300	218.38	$114.67	$168.89	$596.15	$4.53	$12.06	$17.79	$2.98	$92.72

Table 5 - Summary of Costs for RO Facility on Salt River at Granite Reef Dam

Conclusion: This plant would require careful design and operation considerations because of the varying qualities of source water. This facility also rates poor economically and financially because the annualized costs over 50 years would be close to $34 million. Benefits to central Arizona would be less than $15 million. Agreements to dispose of concentrate on Tribal land may be difficult to acquire.

Section 5: Managing Salts in Central Arizona

Analysis for Section 5.1: Water Treatment Plants

The following assumptions have been made for potable water treatment alternatives:

1. For the purposes of this study, three different sizes of water treatment plants were analyzed for costs of salinity reduction: small (10 MGD); medium (50 MGD); and large (100 MGD). These sizes were selected because they reflect the range of average sizes of water treatment plants in central Arizona.

2. Source water is assumed to have a TDS concentration of 650 mg/L, regardless of whether it was actually CAP water or other surface water, with reductions in salinity evaluated at 100 mg/L increments to a minimum TDS concentration of 450 mg/L.

3 Evaporation ponds are the assumed concentrate management approach for all enhanced treatment options under consideration in this set of salinity control evaluations. The associated length of pipelines to transport concentrate to required evaporation ponds is assumed, for purposes of these evaluations, to be 20 miles in the Phoenix metropolitan area and 10 miles in the Tucson metropolitan area. Using the categories defined in the cost model developed by the Reclamation (see Assumption No. 4 below), land type is assumed to be "Ag lands, undeveloped land, desert near City" for the Phoenix area with brush ground cover. Pipeline construction through the Phoenix area is assumed to be in a congested area. The City of Tucson currently owns a considerable amount of land (approximately 22,000 acres in Avra Valley) that could be potentially available for evaporation pond construction; therefore, no additional land costs are assumed in the Tucson area cost projections. Ground cover on the Tucson lands is assumed to be brush and pipeline construction is assumed to be in a sparsely populated area.

4. Costs included in these evaluations result primarily from the cost model developed in 2004 by the U.S. Department of Interior Bureau of Reclamation (Reclamation). This cost model utilizes cost curves developed in the Reclamation's 2004 *Appraisal Evaluation* entitled <u>Reverse Osmosis Treatment of Central Arizona Project Water for the City of Tucson</u> .

5. Efficiency is assumed to be 85 percent on all RO applications.

6. Replacement of water resources lost in the brine reject stream (concentrate) is assumed to be Indian Lease (IL) water at $1,700 per acre-foot.

5.1.1 One-Stage Microfiltration (MF) Pretreatment Followed by RO

Description: This option would consist of utilizing MF pretreatment and RO filtering. The brine concentrate would be discharged to evaporation ponds. The overall treatment process is shown below in Figure 1.

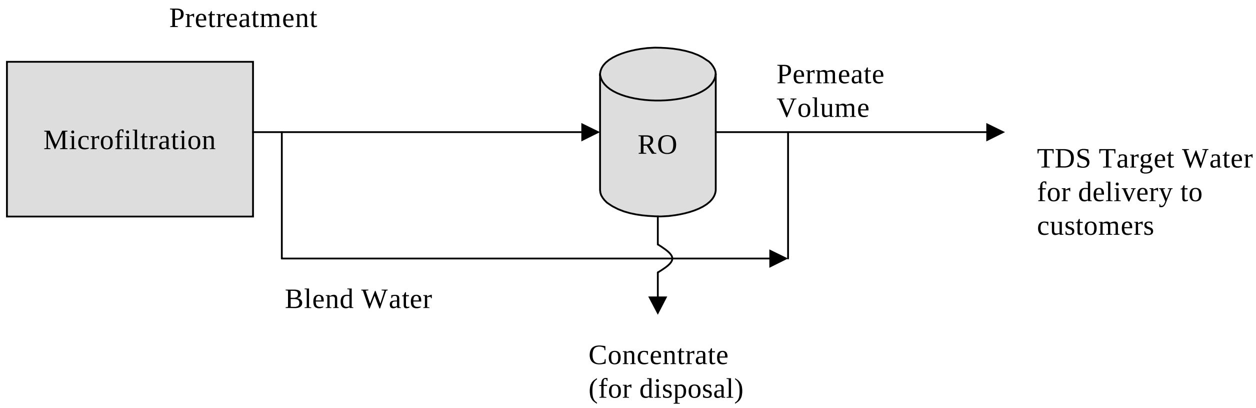

Figure 1: MF Pretreatment Followed by RO

Institutional Considerations: An APP would be required for the construction and operation of the evaporation ponds.

Water Resource Utilization: The MF pretreatment followed by RO option results in a high quality of water with 95 percent removal of salts. The volume of water treated and level of treatment (i.e. TDS target) result in varying water resource losses. However, this evaluation assumes 85 percent efficiency with significant water loss (15 percent) to concentrate through the RO process. The projected loss of water could potentially be decreased through enhancements to the RO process, such as the DewVaporation process or HERO™ technology, or application of other new technology. Table 1 reports the range of water volume and TDS targets for small, medium and large potable water treatment plants. The volume of water required to be treated through RO is shown in the column labeled "RO Plant Size", which is derived by adding the permeate and concentrate volumetric flow rates. "Blend Volume" refers to that volume of water that would not be treated through the RO process but would be blended back with the "Permeate Volume" to achieve the desired TDS target. (See Figure 1.) These volumes are consistent for treatment plants regardless of whether they are located in Phoenix or Tucson. However, due to differences in average rainfall and evaporation rates, the size requirement for the evaporation pond area may vary between these locations and is reported separately in Table 6.

Overall Plant Capacity and TDS (in mg/L)	RO Plant Capacity (MGD)	Blend Volume (MGD)	Permeate Volume (MGD)	Concentrate Volume (MGD)	Pond Area (acres)	
					Phoenix	Tucson
10 MGD/ 550	2.07	7.93	1.76	0.31	72	78
10 MGD/ 450	4.02	5.98	3.42	0.60	140	151
50 MGD/ 550	10.36	39.64	8.81	1.55	362	388
50 MGD/ 450	20.10	29.90	17.09	3.02	701	753
100MGD/ 550	20.73	79.27	17.62	3.11	723	777
100MGD/ 450	40.20	59.80	34.17	6.03	1,402	1,507

Table 6: Target TDS

Technical and Operational Feasibility: With MF pretreatment, the water would have high reliability and consistency with the needs of RO. This approach could also have the flexibility needed to address other treatment concerns that might emerge over time. Such flexibility would depend on a modular treatment train design where treatment components could be added to address water quality concerns as needed.

Environmental/Public Acceptability: While environmental impacts and public acceptability of modifications at existing plants for purposes of adding RO treatment will vary by specific site, the primary potential concern with this option will more likely relate to concentrate management. Construction of larger facilities, through modification of existing plants, may cause various neighborhood and environmental concerns relative to the specifics of existing facilities. Those concerns might include potential or perceived impacts on neighboring properties (buffering potential), land availability, if expansion is required, associated costs, and such operational issues as noise, traffic, and chemical storage. Potential public concerns with concentrate management issues include conveyance pipeline construction and prospective evaporation pond locations. These concerns will likely focus on cost and disturbance of habitat and/or loss of panoramic view, or viewshed. The size and costs of such facilities will vary on a case-by-case basis. Also, costs associated with final disposal could add considerable expense to cradle-to-grave concentrate management.

Benefits/Risks of Salinity Control/Reduction Option: This evaluation categorized the various risks and benefits of the salinity control option in terms of positives and negatives as follows:

+ A high degree of salinity control would be achieved providing better quality water.
+ This option would provide better reliability than conventional treatment processes that rely on either conventional filtration or cartridge filters as RO pretreatment.
- Raw water quality with variable high turbidity would require extra operational vigilance using MF.

Economic/Financial Feasibility: Cost estimates vary for the Phoenix and Tucson metropolitan areas due to a number of factors, including land costs and location of treatment facilities in relation to potential concentrate disposal sites. Table 7 provides the estimated total construction costs for the range of treatment facilities evaluated for both the Phoenix and Tucson areas.

Overall Plant Capacity / TDS Target (in mg/L)	Phoenix Area	Tucson Area
	$ Millions	
10 MGD/ 550	25.24	18.05
10 MGD/ 450	36.89	28.10
50 MGD/ 550	75.01	59.73
50 MGD/ 450	129.55	104.98
100 MGD/ 550	132.83	107.74
100 MGD/ 450	239.26	194.93

Table 7: Estimated Total Construction Costs

Table 8 provides a 20-year annualized total of capital and operational costs assuming a 6 percent interest. Figure 2 displays these costs in graphical format.

Overall Plant Capacity / TDS Target (in mg/L)	Phoenix Area	Tucson Area
	$ Millions	
10 MGD/ 550	3.07	2.41
10 MGD/ 450	4.71	3.9
50 MGD/ 550	9.95	8.54
50 MGD/ 450	17.51	15.24
100 MGD/ 550	17.97	15.65
100 MGD/ 450	32.67	28.59

Table 8. Total Annualized Capital and Operational Costs

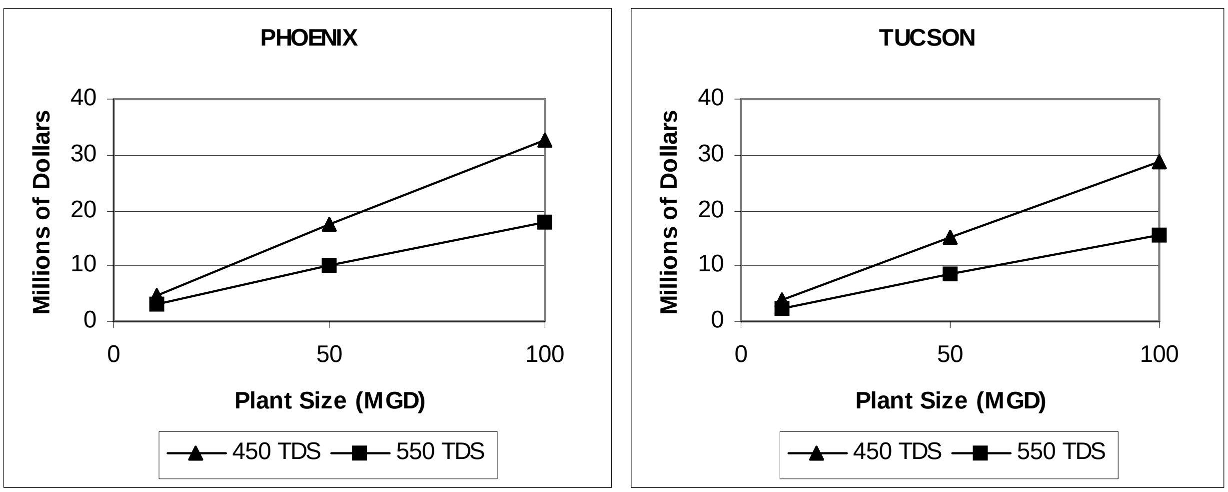

Figure 2. Annualized Costs MF-RO Option for Phoenix and Tucson

Table 9 lists the 20-year annualized capital and operational costs related to each phase of this treatment option, which consists of MF pretreatment followed by RO treatment with concentrate disposal to evaporation ponds. MF and RO costs, plus evaporation ponds and replacement of concentrate reject water, are based on inputs to the cost model assembled by the Reclamation for this project.

	Phoenix Area		Tucson Area	
Overall Plant Size/ TDS Target:	MF	RO, Evap & Water (IL)	MF	RO, Evap & Water (IL)
	$ Millions			
10 MGD/550	0.39	2.68	0.39	2.02
10 MGD/450	0.67	4.04	0.67	3.23
50 MGD/550	1.43	8.52	1.43	7.11
50 MGD/450	2.48	15.03	2.48	12.76
100 MGD/550	2.54	15.43	2.54	13.11
100 MGD/450	4.45	28.22	4.45	24.14

Table 9. Annualized Capital and Operational Costs by Pretreatment and Treatment Phase

Conclusion: This option analyzed the feasibility of potable water treatment utilizing MF as pretreatment for RO with concentrate discharged via pipeline to evaporation ponds. RO requires very low suspended particulate concentrations to avoid fouling the membrane surfaces. MF as a one-stage pretreatment step provides the reliability needed to meet the operational needs of RO.

5.1.2 Conventional Filtration Plus Cartridge Filter Pretreatment Followed by RO

Description: This option consists of a two-stage pretreatment, using conventional filtration as the first stage then feeding the water through cartridge filtration as a second stage. Conventional filtration consists of a series of processes including coagulation, flocculation, sedimentation, and filtration. The pretreated water would then be fed into an RO plant for desalination with the concentrate discharged via pipeline to an evaporation pond. The overall treatment train is portrayed schematically in Figure 3. This alternative seeks to take advantage of existing treatment facilities with modifications for adding RO treatment for salinity control. While this option may not be feasible for a new plant, it may be reasonably incorporated into existing potable water treatment plant facilities being modified for enhanced treatment.

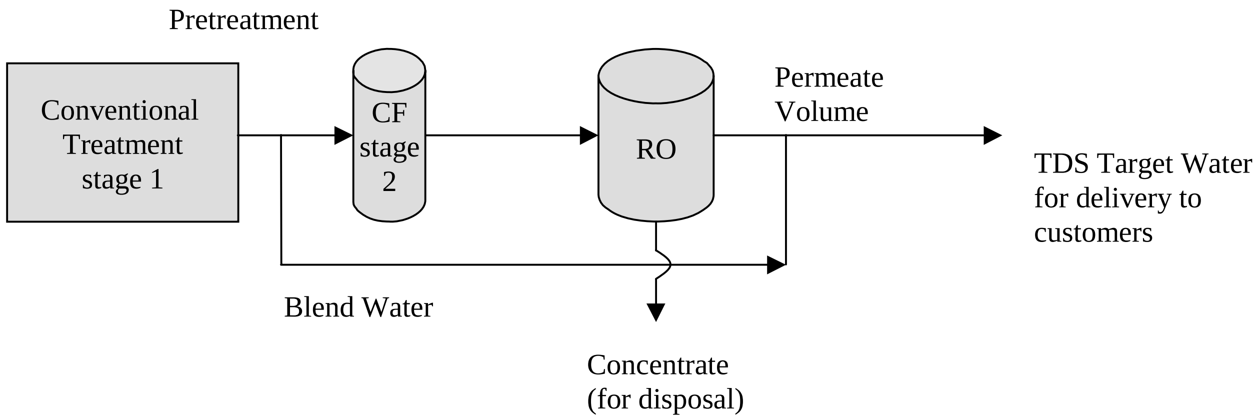

Figure 3: Conventional Filtration Treatment/ Cartridge Filtration Pretreatment Followed By RO

Institutional Considerations: This option, using conventional filtration treatment followed by cartridge filtration, then RO, is generally acceptable within the Institutional Considerations criteria with no significant issues. As stated previously, an APP would need to be obtained for the construction and operation of evaporation ponds. If the land for the evaporation ponds, or any pipelines or conveyances, were to be located on federal lands, or the construction of this facility is federally-funded, NEPA regulations would have to be followed.

Water Resource Utilization: This option results in a high quality product water with 95 percent removal of salts. The volume of water treated and level of treatment (i.e. TDS target) result in varying water resource losses; however, this evaluation assumes 85 percent efficiency with significant water loss (15 percent) to concentrate through the RO process. The projected loss of water could potentially be decreased through enhancements to the RO process such as the new DewVaporation™ or HERO™ technology, or other new technology. Table 1 lists the range of water volume and TDS targets for small, medium and large potable water treatment plants with the volume required to be treated through RO shown in the second column. “Blend Volume” refers to that volume of water that would not be treated through the RO process but would be blended back with the “Permeate Volume” to achieve the desired TDS target. *See Figure 3.* These volumes are consistent for potable treatment plants regardless of whether they are located in Phoenix or Tucson. However, due to differences in average rainfall and evaporation rates, the sizing requirements for the evaporation ponds will vary between locations and is shown separately in Table 10.

Overall Plant Capacity and TDS Target (mg/L)	RO Plant Capacity (MGD)	Blend Volume (MGD	Permeate Volume (MGD)	Concentrate Volume (MGD)	Pond Area (acres)	
					Phoenix	Tucson
10 MGD/ 550	2.07	7.93	1.76	0.31	72	78
10 MGD/ 450	4.02	5.98	3.42	0.60	140	151
50 MGD/ 550	10.36	39.64	8.81	1.55	362	388
50 MGD/ 450	20.10	29.90	17.09	3.02	701	753
100MGD/ 550	20.73	79.27	17.62	3.11	723	777
100MGD/ 450	40.20	59.80	34.17	6.03	1,402	1,507

Table 10: Potential Pond Size and Effluent Volume Treated Based on Plant Capacity and Target TDS

Technical and Operational Feasibility: This option, using conventional filtration and cartridge filter pretreatment followed by RO, may have the flexibility needed to address other treatment concerns that might emerge over time. This flexibility would depend on a modular treatment train design where treatment components can be added to address water-quality concerns as needed.

Technical and Operational Feasibility: Using only conventional filtration treatment as roughing filters would not provide water of sufficient quality for RO. Even following the first stage with cartridge filtration may not provide desired results on a consistent basis. Some conventional treatment plants may not be able to consistently provide product water that would be suitable for efficient RO treatment even if the cartridge component is added to the treatment train. It may be that the cartridges have to be replaced so frequently to avoid membrane fouling that the operational efficiency of this option would be compromised.

Provided operational issues with filtration prove acceptable, this approach could have the flexibility needed to address other treatment concerns that might emerge over time. This flexibility would depend on a modular treatment train design where treatment components can be added to address water-quality concerns as may be required.

While unlikely to be the design choice for a new plant, this approach is technologically feasible and allows utilization of existing facilities by adding treatment trains to meet additional water quality concerns such as salinity control.

Environmental/Public Acceptability: While environmental impacts and public acceptability of modifications on existing plants for purposes of adding RO treatment will vary by site, the primary potential concern with this option will more likely relate to concentrate management. Construction of larger facilities, through modification of existing plants, may cause various neighborhood and environmental concerns relative to the specifics of existing facilities. Those concerns might include potential or perceived impacts on neighboring properties (buffering potential), land availability, if expansion is required, associated costs, and such operational issues as noise, traffic, and chemical storage. Potential public concerns with concentrate management issues include the construction of conveyance pipelines and evaporation ponds. These concerns will likely focus on cost and disturbance of habitat and/or viewshed. The size and cost of these facilities will vary on a case by case basis. Also, costs associated with final disposal could add considerable expense to cradle-to-grave concentrate management.

Benefits/Risks of Salinity Control/Reduction Option: This criteria was used to evaluate and categorize the various risks and benefits of each salinity control option in terms of positives and negatives. For this specific option, the positive and negative issues are as follows:

+ This option would utilize existing treatment facilities as part of the treatment process.
+ A high degree of salinity control would be achieved providing better quality water.
- If a new plant were to be designed to accomplish salinity reductions, this option would not be chosen.
- This may be an inefficient process since it seeks to salvage existing infrastructure at the potential cost of treatment efficiency.

Economic/Financial Feasibility: Cost estimates vary between the Phoenix and Tucson metropolitan areas due to a number of factors including land costs and location of treatment facilities in relation to potential concentrate disposal sites. This option allows utilization of existing facilities, which are assumed to already be using conventional filtration treatment, being modified to add RO treatment. Because of that, in this option, capital construction costs would primarily consist of the addition of cartridge filters, the RO plant, pipeline and evaporation pond construction, with minor capital costs related to modification of the existing facility. Modification costs could vary considerably based on the specific facility and are not included in the cost estimation. Table 11 provides the total capital cost for construction of the cartridge filtration, RO system, evaporation pond, and associated pipelines and conveyances for the range of treatment facilities evaluated for both the Phoenix and Tucson areas.

As discussed in the Technical and Operational Feasibility criteria, some conventional treatment plants may not be able to consistently provide product water that would be suitable for efficient RO treatment even if the cartridge component is added to the treatment train. It may be that the cartridges have to be replaced so frequently to avoid membrane fouling that the cost effectiveness (Economic Feasibility) of this option would be compromised.

Overall Plant Size / TDS Target (mg/L)	Phoenix Area	Tucson Area
	$ Millions	
10 MGD/550	20.91	13.72
10 MGD/450	29.96	21.17
50 MGD/550	61.76	46.48
50 MGD/450	108.29	83.72
100 MGD/550	111.43	86.35
100 MGD/450	204.84	160.52

Table 11: Estimated Total Construction Costs

Table 12 provides an estimate of 20-year annualized total capital and operational costs assuming a 6 percent interest. Figure 4 portrays these same costs in graphical format.

Overall Size Plant / TDS Target (mg/L)	Phoenix Area	Tucson Area
	$ Millions	
10 MGD/550	2.99	2.33
10 MGD/450	4.62	3.81
50 MGD/550	10.03	8.62
50 MGD/450	17.96	15.69
100 MGD/550	18.45	16.13
100 MGD/450	34.09	30.01

Table 12: 20-Year Annualized Estimated Total Capital and Operational Costs

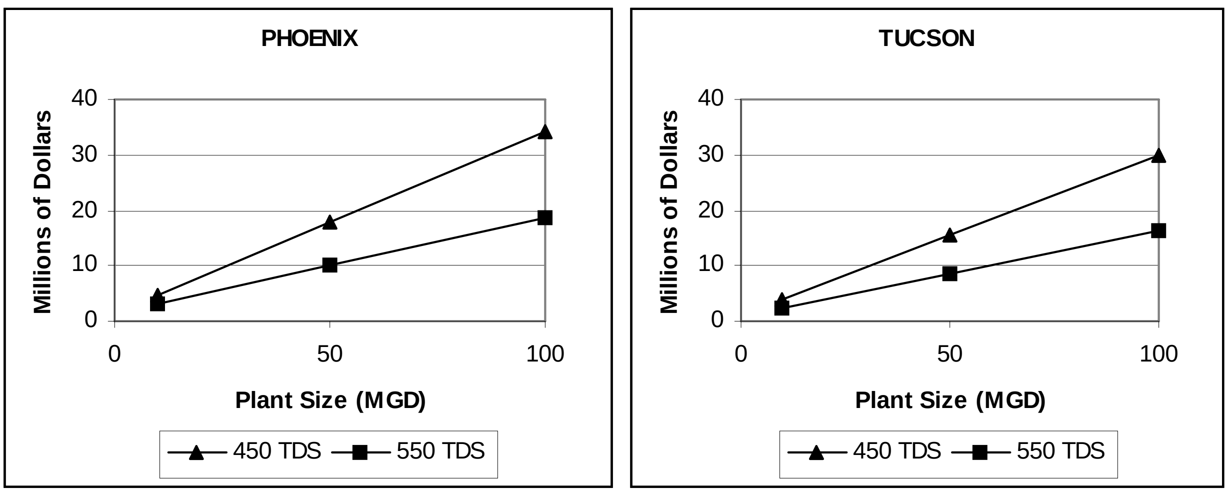

Figure 4: Annualized Costs for the Conventional Filtration Treatment/Cartridge Filtration/RO Option for Phoenix and Tucson

Table 13 below separates out the 20-year annualized capital and operational costs related to each phase of this treatment option, i.e. Stage 1 conventional filtration, Stage 2 cartridge filtration, and followed by RO, with the resultant concentrate being disposed of in evaporation ponds. The operational costs and minor capital modification costs for conventional treatment facilities were based on the Reclamation's *Appraisal Evaluation* report (2004); industry cost curves were modified by Tucson Water. Estimated costs for the RO system, evaporation ponds, and replacement of concentrate reject water are based on inputs to the cost model assembled by Reclamation for this project. Assumed interest rate is six percent and costs include the replacement of lost water resource as well. Replacement of cartridge filters was assumed to be five times per year.

	Phoenix Area			Tucson Area		
Overall Plant Size /TDS Target (mg/L)	Conventional Treatment	Cartridge Filtration	RO System, Evaporation Ponds, and Water Replacement (IL)	Conventional Treatment	Cartridge Filtration	RO, Evap & Water
	$ Millions					
10 MGD/550	0.17	0.14	2.68	0.17	0.14	2.02
10 MGD/450	0.32	0.26	4.04	0.32	0.26	3.23
50 MGD/550	0.83	0.68	8.52	0.83	0.68	7.11
50 MGD/450	1.61	1.32	15.03	1.61	1.32	12.76
100 MGD/550	1.66	1.36	15.43	1.66	1.36	13.11
100 MGD/450	3.23	2.64	28.22	3.23	2.64	24.14

Table 13: Annualized Capital and Operational Costs by Pretreatment and Treatment Phase

Conclusion: This option consisted of utilizing conventional filtration techniques, including sand and coagulation, followed by cartridge filtration as pretreatment for RO. The RO process requires very low suspended particulate concentrations to avoid fouling the membrane surfaces. As direct feed to RO, conventional filtration alone will likely not provide water of sufficient quality to guarantee efficient operation of RO treatment on a consistent basis. The choices made in pretreatment greatly impact the operational costs and effectiveness of RO treatment and may impact the concentrate stream as well.

5.1.3 Potable Treatment with Salinity Control: Conventional Filtration/Coagulation Plus MF Pretreatment Followed by RO

Description: This option evaluated the pretreatment process in which conventional direct filtration treatment were used as the first stage , an MF system would be used for the second stage filtering, then the pretreated water would be sent through an RO plant for desalinization. The brine concentrate would be discharged via pipeline to an evaporation pond. While it is doubtful that this option would be a design feature in a new plant, it may be reasonably incorporated into existing potable water treatment plant facilities being modified for enhanced treatment. The treatment process for this option is shown below in Figure 5.

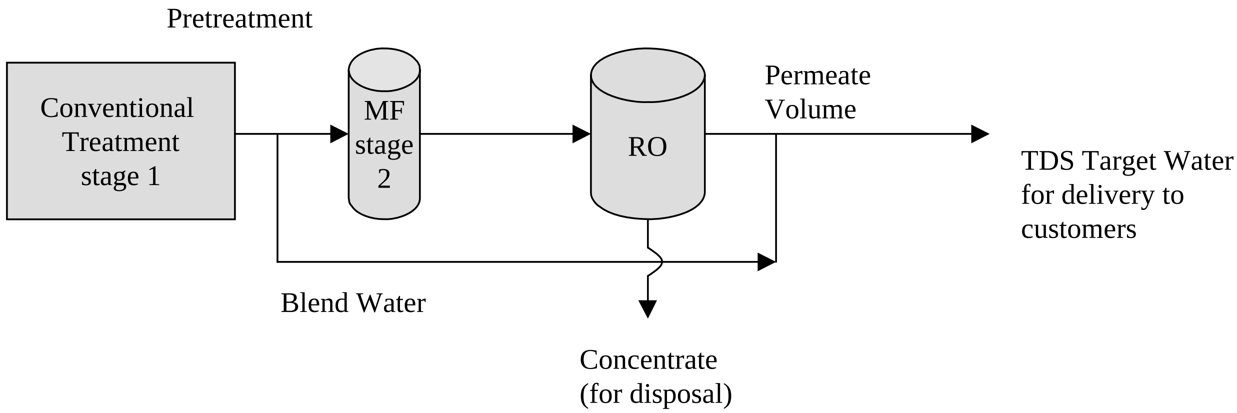

Figure 5: Conventional Filtration / MF Pretreatment Followed By RO

Institutional Considerations: An APP would need to be obtained for the construction and operation of evaporation ponds. If the land for the evaporation ponds, or any pipelines or conveyances, were to be located on federal lands, or the construction of this facility is federally-funded, NEPA regulations would have to be followed.

Water Resource Utilization: This option would result in a high quality water with 95 percent removal of salts. The volume of water treated and level of treatment (i.e. TDS target) would result in varying water resource losses, however, this evaluation assumes 85 percent efficiency with significant water loss (15 percent) to concentrate through the RO process. The projected loss of water could potentially be decreased through enhancements to the RO process, such as the DewVaporation process or HERO™ technology, or other new technology. Table 14 reports the range of water volume and TDS targets for small, medium and large potable water treatment plants with the volume required to be treated through RO shown in the column labeled "RO Plant Size" derived by adding the permeate and concentrate volume rates. "Blend Volume" refers to that volume of water that would not be treated through the RO process but would be blended back with the "Permeate Volume" to achieve the desired TDS target. *See Figure 5.* These volumes are consistent for treatment plants regardless of whether they are located in Phoenix or Tucson. Due to differences in average rainfall and evaporation rates, requirements for pond area may vary between these locations and is reported separately in Table 14.

Overall Plant Size and TDS Target (mg/L)	RO Plant Capacity (MGD)	Blend Volume (MGD)	Permeate Volume (MGD)	Concentrate Volume (MGD)	Pond Area (acres)	
					Phoenix	Tucson
10 MGD/550	2.07	7.93	1.76	0.31	72	78
10 MGD/450	4.02	5.98	3.42	0.60	140	151
50 MGD/550	10.36	39.64	8.81	1.55	362	388
50 MGD/450	20.10	29.90	17.09	3.02	701	753
100MGD/550	20.73	79.27	17.62	3.11	723	777
100MGD/450	40.20	59.80	34.17	6.03	1,402	1,507

Table 14: Targeted Water Qualities

Technical and Operational Feasibility: Adding MF as a second stage pretreatment provides water that will have a high degree of consistency and quality to operate RO efficiently.

This approach could have the flexibility needed to address other treatment concerns that might emerge over time. This flexibility would depend on a modular treatment process design where treatment components can be added to address water quality concerns as needed.

Environmental/Public Acceptability While environmental impacts and public acceptability of modifications on existing plants for purposes of adding RO treatment will vary by specific site, the primary potential concern with this option will more likely relate to concentrate management. Construction of larger facilities, through modification of existing plants, may cause various neighborhood and environmental concerns relative to the specifics of existing facilities. Those concerns might include potential or perceived impacts on neighboring properties (buffering potential), land availability if expansion is required, associated costs, and such operational issues as noise, traffic, chemical storage and the like. Potential public concerns with concentrate management issues include conveyance pipeline construction and prospective evaporation pond locations. These concerns will likely focus on cost and disturbance of habitat and/or viewshed, and the size and costs of such facilities will vary on a case by case basis. Also, costs associated with final disposal could add considerable expense to cradle-to-grave concentrate management.

Benefits/Risks of salinity control/reduction option

This salinity control option was evaluated in terms of positives and negatives. The positives and negatives for this option are as follows:

+ This option would utilize existing treatment facilities as part of the treatment train process.
+ A high degree of salinity control would be achieved providing better quality water.
+ This option would provide better reliability than conventional treatment train which relies on cartridge filters as stage 2 pretreatment
- If a new plant were to be designed to accomplish salinity reductions, this option would not be chosen.
- This option may be an inefficient process since the treatment process seeks to salvage existing infrastructure at the potential cost of treatment efficiency.

Economic/Financial Feasibility Cost estimates vary between the Phoenix and Tucson metropolitan areas due to a number of factors including land costs and location of treatment facilities in relation to potential concentrate disposal sites. This option seeks to utilize existing facilities being modified to add RO treatment and would not be a design feature in a new facility. Therefore, capital construction costs would primarily consist of the addition of MF, the RO plant, pipeline and evaporation pond construction, with minor capital costs related to modification of the existing facility. Modification costs could vary considerably based on the specific facility and are not included in the cost estimate. Table 15 provides only the total capital cost for the MF, the RO, the pipeline, and evaporation pond elements of this option for the range of treatment facilities evaluated for both the Phoenix and Tucson areas.

Overall Plant Size / TDS Target (mg/L):	Phoenix Area	Tucson Area
	$ Millions	
10 MGD/550	25.24	18.05
10 MGD/450	36.89	28.10
50 MGD/550	75.01	59.73
50 MGD/450	129.55	104.98
100 MGD/550	132.83	107.74
100 MGD/450	239.26	194.93

Table 15: Estimated Total Construction Costs

Table 16 provides a 20-year annualized total cost of capital and operational costs assuming a 6 percent interest.   Figure 6 shows these same costs in graphical format.

Size Plant and TDS Target (mg/L)	Phoenix Area	Tucson Area
	$ Millions	
10 MGD/550	3.24	2.58
10 MGD/450	5.03	4.22
50 MGD/550	10.78	9.37
50 MGD/450	19.12	16.85
100 MGD/550	19.63	17.31
100 MGD/450	35.9	31.82

Table 16: Total 20-Year Annualized Capital and Operational Costs

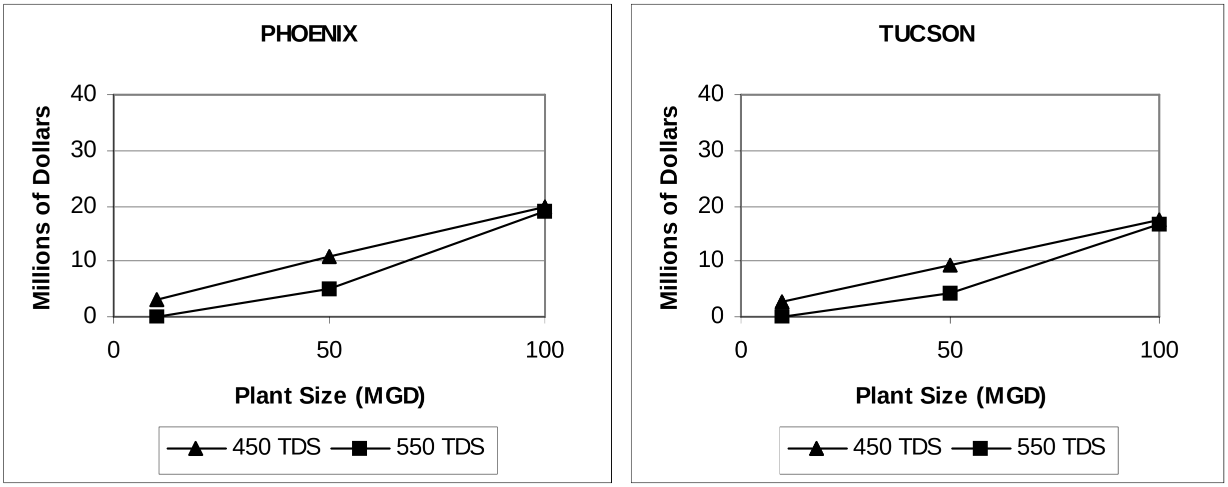

Figure 6: Annualized Costs for Conventional Filtration/MF Pretreatment Followed By RO Option for Phoenix and Tucson.

The 20-year annualized capital and operational costs related to each phase of this treatment option, which includes conventional filtration, followed by MF pretreatment, final RO treatment, and the construction costs for the evaporation ponds, are broken out in Table 3b. For this evaluation, operational costs and minor capital modification costs for conventional treatment facilities were based on the January, 2004 Reclamation *Appraisal Evaluation* entitled Reverse Osmosis Treatment of Central Arizona Project Water for the City of Tucson and industry cost curves as modified by Tucson Water. MF and RO costs including evaporation ponds and replacement of concentrate reject water are based on inputs to the cost model assembled by Reclamation for this project.

	Phoenix Area			Tucson Area		
Overall Plant Size / TDS Target (mg/L):	Conventional Treatment	MF	RO, Evap & Water	Conventional Treatment	MF	RO, Evap & Water
	$ Millions					
10 MGD/550	0.17	0.39	2.68	0.17	0.39	2.02
10 MGD/450	0.32	0.67	4.04	0.32	0.67	3.23
50 MGD/550	0.83	1.43	8.52	0.83	1.43	7.11
50 MGD/450	1.61	2.48	15.03	1.61	2.48	12.76
100 MGD/550	1.66	2.54	15.43	1.66	2.54	13.11
100 MGD/450	3.23	4.45	28.22	3.23	4.45	24.14

Table 17: Annualized Capital and Operational Costs by Pretreatment and Treatment Phase

Conclusion: This option seeks to take advantage of existing potable water treatment facilities with the addition of RO treatment for salinity control. To maximize RO treatment efficiency, use of direct filtration as a "roughing filter" followed by MF for pretreatment was analyzed. This option has higher costs but has the reliability of MF as a pretreatment for RO.

5.1.4 Soil Aquifer Treatment (SAT) Plus Cartridge Filtration as Pretreatment Followed by RO

Description: This option is composed of three filtering stages: Stage 1 utilizes the natural filtering effects of a soil aquifer treatment, perhaps via surface spreading recharge basins. Soil aquifer treatment is a process whereby partially-treated effluent is allowed to infiltrate through the soil, or vadose zone, to the groundwater. The vadose zone acts as a natural filter and removes essentially all suspended solids, biodegradable materials, bacteria, viruses, and other microorganisms. Significant reductions in nitrogen, phosphorus, and heavy metals concentrations can also be achieved. Stage 2 of this option would consist of subsequent recovery of the SAT-treated waters followed by cartridge filtration to ensure water of sufficient quality for RO treatment. The brine would be discharged to evaporation ponds.

The overall treatment process for this option is shown below in Figure 7 where the RO plant is but one component of the treatment process.

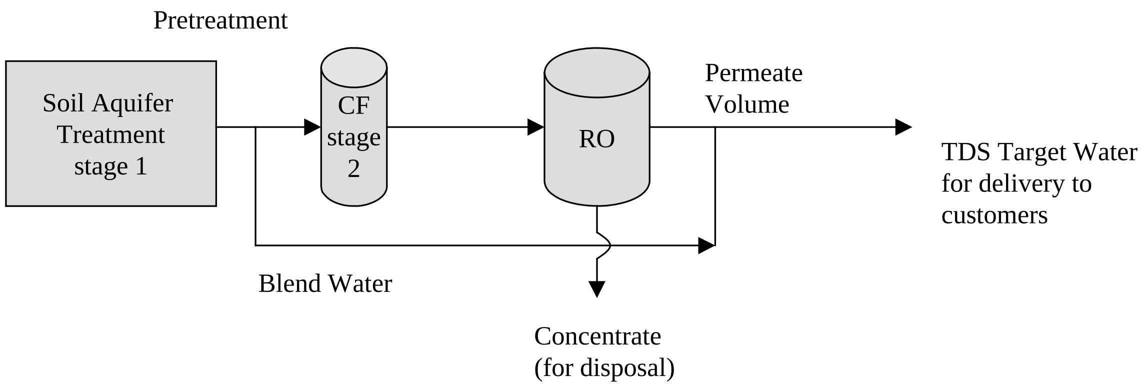

Figure 7: SAT Followed by Cartridge Filtration and RO

Institutional Considerations: An APP would be required for the construction and operation of the SAT infiltration basins, in addition to the brine concentrate evaporation ponds. If the land for the SAT basins and/or the evaporation ponds, or any pipelines or conveyances, were to be located on federal lands, or the construction of this facility is federally-funded, NEPA regulations would have to be followed.

Water Resource Utilization SAT has the potential to enhance resource reliability through sub-surface storage water banking) thereby increasing operational flexibility during potential shortages, maintenance considerations with the CAP, or other potentially vulnerable sources of surface water supply. Volume of water treated and level of treatment (i.e. TDS target) result in varying water resource losses; however, this evaluation assumes 85% efficiency with significant water loss (15%) to concentrate through the RO process. The projected loss of water could potentially be decreased through enhancements to the RO process such as DewVap or HERO, or other new technology. Table 18 reports the range of water volume and TDS targets for small, medium and large potable water treatment plants with the volume required to be treated through RO shown in the column labeled “RO Plant Size” which is calculated by adding the permeate and concentrate volume rates. “Blend Volume” refers to that volume of water that would not be treated through the RO process but would be blended back with the “Permeate Volume” to achieve the desired TDS target. *See Figure 7.* These volumes are consistent for treatment plants regardless of whether they are located in Phoenix or Tucson. However, due to differences in average rainfall and evaporation rates, requirements for pond area may vary between these locations and is reported separately in Table 18.

Overall Plant Size / TDS (mg/L)	RO Plant Capacity (MGD)	Blend Volume (MGD)	Permeate Volume (MGD)	Concentrate Volume (MGD)	Pond Area (acres)	
					Phoenix	Tucson
10 MGD/550	2.07	7.93	1.76	0.31	72	78
10 MGD/450	4.02	5.98	3.42	0.60	140	151
50 MGD/550	10.36	39.64	8.81	1.55	362	388
50 MGD/450	20.10	29.90	17.09	3.02	701	753
100MGD/550	20.73	79.27	17.62	3.11	723	777
100MGD/450	40.20	59.80	34.17	6.03	1,402	1,507

Table 18. Potential Pond Size and Effluent Volume Treated Based on Plant Capacity and Target TDS

Technical and Operational Feasibility: Effective SAT depends primarily on permeable soils that provide high infiltration rates and a sufficiently deep aquifer. Vadose zones containing little or no clay layers and transmissive aquifers are also requirements for effective SAT. Available land with suitable SAT conditions would be critical for this option. If the vadose zone is suitable, SAT can offer considerable flexibility and adaptability to changing effluent conditions, such as water quality buffering and/or treatment of emerging contaminants. SAT has also been demonstrated to significantly reduce dissolved organic carbon in recharged surface waters, which in turn reduces the potential formation of trihalomethanes (THMs) and other disinfection byproducts. The ability of SAT to reduce the organic carbon in surface water sources may also prove instrumental in determining the method of secondary disinfection that would be required. SAT would provide a high level of technical reliability for providing a chemically stable source water to the RO component for final treatment.

If the hydraulic parameters of the aquifer and/or recovery well construction produces occasional slugs of highly turbid or sandy water, then the post-SAT recovered water could adversely impact RO membranes. Therefore, it would be prudent to add the option of cartridge filtration as a secondary pretreatment to protect the RO membranes from the occasional slugs of turbid/sandy water.

If salinity control was the only objective of a water treatment plant, SAT could potentially be too expensive of a pretreatment option to pursue. SAT as a pretreatment step is viable only if other water resource and operational objectives are important factors in providing potable supply.

Environmental/Public Acceptability: Due to the potential land requirements, public concerns could be raised with regard to environmental/cultural resource impacts or visual impacts. Those concerns might include potential or perceived impacts on neighboring properties (buffering potential), land availability if expansion is required, associated costs, and such operational issues as noise, traffic, and the like. Potential public concerns with concentrate management issues include conveyance pipeline construction and prospective evaporation pond locations. These concerns will likely focus on cost and disturbance of habitat and/or viewshed, and the size and costs of such facilities will vary on a case by case basis. Also, costs associated with final disposal could add considerable expense to cradle-to-grave concentrate management.

Benefits/Risks of salinity control/reduction option: This salinity control option was evaluated in terms of positives and negatives. The positives and negatives for this option are as follows:

+ SAT provides a flexible, reliable Stage 1 pretreatment option to RO.
- Water must be recharged only in areas where there are no contaminants in the soil profile or aquifer.
- To reduce potential for fouling RO membranes, cartridge pretreatment after well recovery would be necessary.

Economic/Financial Feasibility: Cost estimates vary for the Phoenix and Tucson metropolitan areas due to a number of factors including land costs and location of treatment facilities in relation to potential concentrate disposal sites. Estimated construction costs for an SAT facility with recovery capability is approximately $1 million per 1,000 AF of recharge capacity per year, excluding land costs. If salinity control was the only objective, SAT could potentially be too expensive of a pretreatment option to pursue, especially if the purchase of land for recharge facilities is required. SAT as a pretreatment step is viable if other water-resource and operational objectives are important factors in providing potable supply. Potentially high costs may accompany this option depending on land availability and proximity of recharge site to raw water source and to the treatment plant.

Table 19 provides a 20-year annualized total cost of capital and operational costs assuming a 6 percent interest and the SAT estimated capital costs described above. Figure 8 portrays these costs in graphical format.

Overall Plant Capacity/ TDS Target (in mg/L):	Phoenix Area	Tucson Area
	$ Millions	
10 MGD/550	2.00	1.48
10 MGD/450	3.10	2.45
50 MGD/550	6.84	5.66
50 MGD/450	12.46	10.52
100 MGD/550	12.81	10.82
100 MGD/450	24.08	20.51

Table 19: Total Annualized Capital and Operational Costs for SAT / Cartridge Filtration Pretreatment Followed by RO Option for Phoenix and Tucson

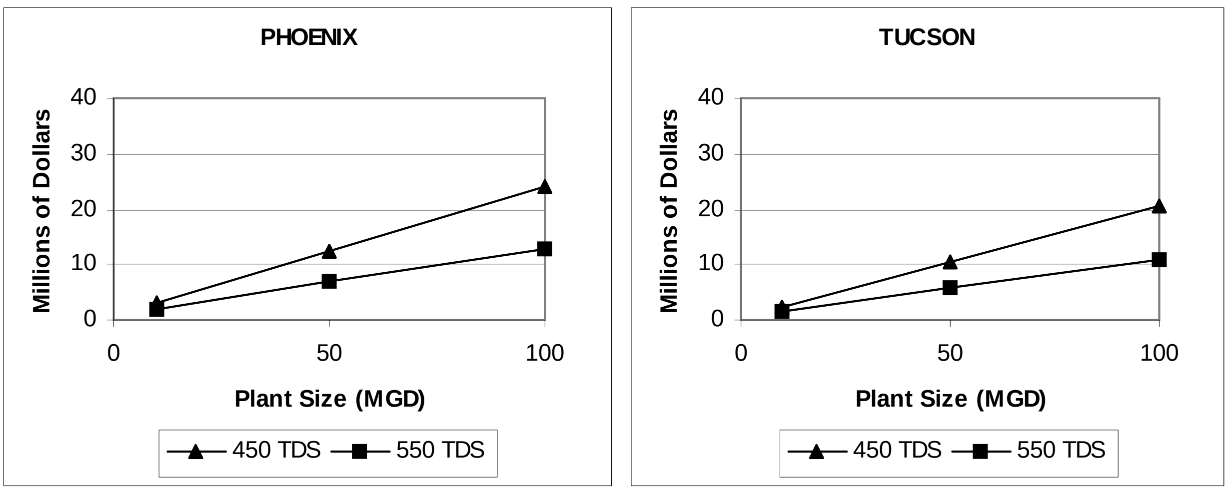

Figure 8: Annualized Costs for SAT / Cartridge Filtration Followed By RO Option for Phoenix and Tucson

Table 20 provides the 20-year annualized costs by each phase of this treatment option, which includes pretreatment consisting of SAT and cartridge filtration followed by RO. The brine concentrate would be sent to evaporation ponds for disposal. RO costs including evaporation ponds and replacement of concentrate reject water are based on inputs to the cost model assembled by Reclamation for this project. In this evaluation, operational costs and capital costs for construction of SAT and CF facilities were based on the January, 2004 Reclamation *Appraisal Evaluation* entitled Reverse Osmosis Treatment of Central Arizona Project Water for the City of Tucson and industry cost curves as modified by Tucson Water. Replacement of cartridge filters was assumed to be 5 times per year.

	Phoenix Area			Tucson Area		
Overall Plant Size/ TDS Target:	SAT	CF	RO,Evap & Water (IL)	SAT	CF	RO,Evap & Water (IL)
	$ Millions					
10 MGD/550	0.25	0.14	2.68	0.25	0.14	2.02
10 MGD/450	0.48	0.26	4.04	0.48	0.26	3.23
50 MGD/550	1.25	0.68	8.52	1.25	0.68	7.11
50 MGD/450	2.42	1.32	15.03	2.42	1.32	12.76
100 MGD/550	2.50	1.36	15.43	2.50	1.36	3.11
100 MGD/450	4.84	2.64	28.22	4.84	2.64	24.14

Table 20: Annualized Capital and Operational Costs by Pre-Treatment and Treatment

Conclusion: This option analyzed the feasibility of potable water treatment utilizing SAT and cartridge filtration as pretreatment for RO. RO requires very low suspended particulate concentrations to avoid fouling the membrane surfaces. SAT alone will provide highly reliable pretreatment filtration. Although, recovery wells could potentially produce slugs of highly turbid/sandy water which could adversely impact RO membranes. To mitigate against this possibility, it is considered prudent to add the option of cartridge filtration to protect the RO membranes.

5.1.5 Slow Sand Filter (SSF) Plus Cartridge Filtration as Pretreatment Followed by RO

Description: This option substitutes SAT with SSF for pretreatment followed by RO desalinization. A slow sand filter is comprised of a bed of fine sand that is supported by a layer of gravel. This filter media is confined in a box with openings at both ends allowing water to flow in and out, while operating on a top-down, gravity basis. The filtration process removes solids, precipitates, turbidity and in some cases bacterial particles that produce bad taste and odor.

The overall treatment process is shown in Figure 9 . Similar to the previous options, the brine concentrate is discharged via pipeline to evaporation ponds.

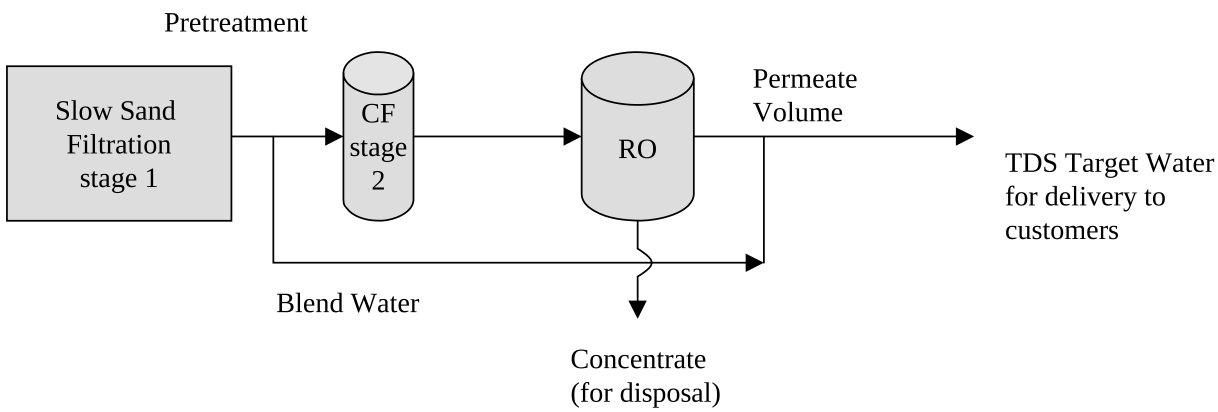

Figure 9: **SSF Pretreatment Followed By RO**

Institutional Considerations: An APP would be required for the construction and operation of the brine concentrate evaporation ponds. If the land for the evaporation ponds, or any pipelines or conveyances, were to be located on federal lands, or the construction of this facility is federally-funded, NEPA regulations would have to be followed.

Water Resource Utilization: Slow sand filtration, coupled with second stage cartridge filters and RO, results in a high quality of water with 95% removal of salts similar to other direct treatment options. Volume of water treated and level of treatment (ie TDS target) result in varying water resource losses; however this evaluation assumed 85% efficiency with significant water loss (15%) to concentrate through the RO process. The projected loss of water could potentially be decreased through enhancements to the RO process such as DewVap or HERO, or other new technology. Table 21 reports the range of water volume and TDS targets for small, medium and large potable water treatment plants with the volume required to be treated through RO shown in the column labeled "RO Plant Size" which is derived by adding permeate and concentrate volume rates. "Blend Volume" refers to that volume of water that would not be treated through the RO process but would be blended back with the treated "Permeate Volume" to achieve the desired TDS target. *See Figure 9.* These volumes are consistent for treatment plants regardless of whether they are located in Phoenix or Tucson. However, due to differences in average rainfall and evaporation rates, requirements for pond area may vary between these locations and is reported separately in Table 21.

Overall Plant Capacity / TDS (mg/L)	RO Plant Capacity (MGD)	Blend Volume (MGD)	Permeate Volume (MGD)	Concentrate Volume (MGD)	Pond Area (acres)	
					Phoenix	Tucson
10 MGD/550	2.07	7.93	1.76	0.31	72	78
10 MGD/450	4.02	5.98	3.42	0.60	140	151
50 MGD/550	10.36	39.64	8.81	1.55	362	388
50 MGD/450	20.10	29.90	17.09	3.02	701	753
100MGD/550	20.73	79.27	17.62	3.11	723	777
100MGD/450	40.20	59.80	34.17	6.03	1,402	1,507

Table 21. Target TDS

Technical and Operational Feasibility: SSF is considered applicable primarily for relatively high quality water supplies with low turbidity. Operation of SSF requires only the adjustment of water flow, the monitoring of head loss and turbidity, and periodic removing of a thick layer of particulates that forms on top of the filter. SSF provides only statistical removal of particles, based on particle size, allowing for some pass-through. Therefore, it is recommended that a cartridge filter follow the SSF.

SSF may require significant area if a large volume of water is to be pretreated. Hence, land availability may be a constraint when locating and sizing facilities.

Environmental/Public Acceptability: Due to the potential land requirements, public concerns could be raised with regard to environmental/cultural resource impacts or visual impacts. Those concerns might include potential or perceived impacts on neighboring properties (buffering potential), land availability if expansion is required, associated costs, and such operational issues as noise, traffic, and the like. Potential public concerns with concentrate management issues include conveyance pipeline construction and prospective evaporation pond locations. These concerns will likely focus on cost and disturbance of habitat and/or viewshed, and the size and costs of such facilities will vary on a case by case basis. Also, costs associated with final disposal could add considerable expense to cradle-to-grave concentrate management.

Benefits/Risks of salinity control/reduction option

This salinity control option was evaluated in terms of positives and negatives. The positives and negatives for this option are as follows:

+ This option provides a relatively low cost pretreatment alternative.
- The effectiveness of pretreatment depends on raw water quality.
- Because particulate removal is statistically based, this option will have some particulate pass-through, which can be reduced with second stage cartridge pretreatment prior to RO.

Economic/Financial Feasibility: Table 22 provides estimated total construction costs for the range of treatment plant sizes evaluated by the Sub-Committee for both the Phoenix and Tucson areas under the above-listed assumptions. Land purchase requirements may result in additional costs.

Reclamation Report 90 found that because of its relatively low capital and operating costs and low requirements for operator attention, SSF may be attractive to small water treatment plants, if adequate land is available and source waters are of sufficiently good quality.

Overall Plant Capacity/ TDS Target (in mg/L):	Phoenix Area	Tucson Area
	$ Millions	
10 MGD/550	23.94	16.75
10 MGD/450	32.99	24.2
50 MGD/550	76.93	61.65
50 MGD/450	123.46	98.89
100 MGD/550	141.77	116.69
100 MGD/450	235.18	190.86

Table 22: Estimated Total Construction Costs

Table 23 provides the 20-year annualized total costs including both capital and operational costs assuming a 6% interest. Figure 2 displays this information graphically. Figure 2 portrays these costs in graphical format.

Plant Size/ TDS Target (mg/L):	Phoenix Area	Tucson Area
	$ Millions	
10 MGD/550	2.92	2.26
10 MGD/450	4.49	3.68
50 MGD/550	9.69	8.28
50 MGD/450	17.30	15.03
100 MGD/550	17.77	15.45
100 MGD/450	32.77	28.69

Table 23: Total Annualized Capital and Operational Costs

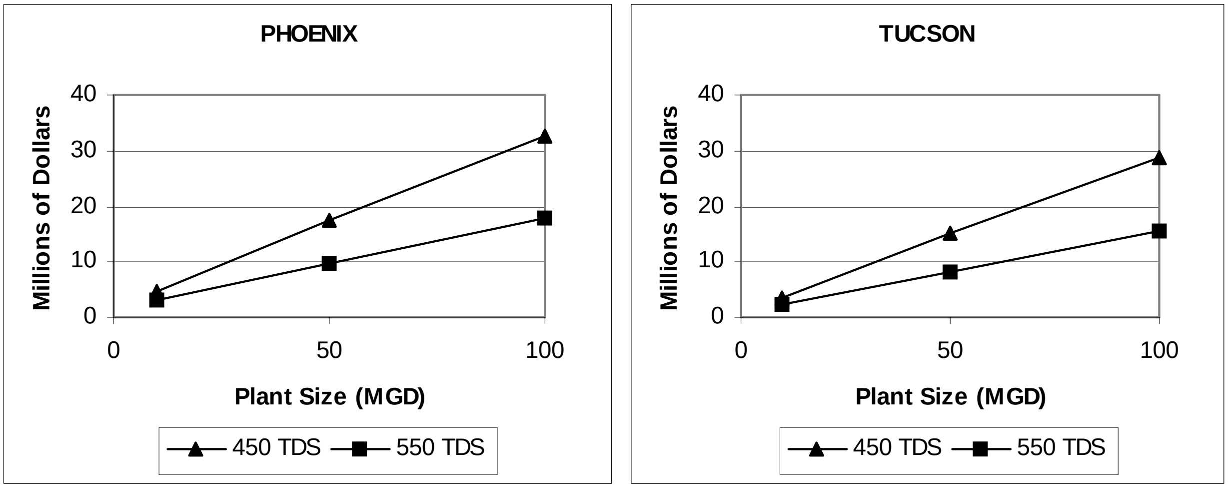

Figure 10: Annualized Costs for SSF and Cartridge Filtration Pretreatment Followed By RO

	Phoenix Area			Tucson Area		
Overall Plant Size/ TDS Target:	SSF	CF	RO,Evap & Water	SSF	CF	RO,Evap & Water
	$ Millions					
10 MGD/550	0.10	0.14	2.68	0.10	0.14	2.02
10 MGD/450	0.19	0.26	4.04	0.19	0.26	3.23
50 MGD/550	0.49	0.68	8.52	0.49	0.68	7.11
50 MGD/450	0.95	1.32	15.03	0.95	1.32	12.76
100 MGD/550	0.98	1.36	15.43	0.98	1.36	13.11
100 MGD/450	1.91	2.64	28.22	1.91	2.64	24.14

Table 24: Potential Pond Size and Effluent Volume Treated Based on Plant Capacity and Target TDS

Conclusion: This option analyzed the feasibility of potable water treatment utilizing SSF and cartridge filtration as a pretreatment option for RO to control salinity. The Sub-Committee evaluated a range of water treatment facilities with the basic characteristics of SSF as Stage 1 pretreatment with recovered water fed through cartridge filtration prior to the RO treatment.

Analysis for Section 5.2: Wastewater Treatment Plants (WWTPs)

The following assumptions were used for analyzing the Options discussed in Section 5.2:.

1. No microfiltration pretreatment would be required as the effluent is assumed to be filtered from the WWTP. If filtration is not done at the WWTP then microfiltration costs would have to be included.

2. Initial TDS was assumed to be 2,000 mg/L; analyzed at 200 mg/L changes

3. Land type was agricultural lands, undeveloped land, and/or native desert near City.

4. Vegetative ground cover was brush.

5. Pipeline conveying effluent to the evaporation pond was 20 miles in length.

6. Pipeline to the evaporation pond were constructed in a congested area,

5.2.1 Wastewater Treatment Plants

Description: This option looked at using RO membranes to reduce the TDS in WWTP effluent that would be permitted for reuse applications, such as turf irrigation, agricultural irrigation, artificial recharge, etc. The increase in TDS from water treatment plants to WWTPs is approximately 400 mg/L. It is anticipated that as more commercial and residential customers use water softeners, cooling towers, etc., the TDS will continue to increase to a point where reuse applications are infeasible. In addition, traditional wastewater treatment does not remove TDS.

For this option, it was assumed that wastewater would be treated by conventional filtration methods and that only a portion of the filtered effluent would be treated with RO to give a target TDS for specific reuse applications. The resultant RO concentrate would be disposed of in an evaporation pond.

Three plant sizes (small: 5MGD, medium: 25MGD, and large: 50MGD) were evaluated to develop annualized costs for a given change in TDS concentration. It assumed that these plant sizes represent the amount of wastewater treated by conventional methods and a portion treated by RO and blended with non-RO treated water to produce a target TDS for the entire wastewater effluent stream.

It was assumed that this analysis could be applied to both new and existing WWTPs.

Institutional Considerations
There may be no institutional problems with this method of controlling salinity. As in similar options that utilized evaporation ponds, an APP would be required for the construction and operation of the ponds. If the land for the evaporation ponds, or any pipelines or conveyances,

was to be located on federal lands, or the construction of this facility is federally-funded, NEPA regulations would have to be followed.

Water Resource Utilization

A portion of the effluent will be lost to , and consequently, could not be used for reuse applications. The cost to replace this lost water is included in the cost evaluation.

Lower TDS effluent may allow for more reuse applications. For example, higher quality reclaimed water can be used golf course irrigation, landscape impoundments, or even spray irrigation of an orchard or vineyard., In the case of recharge facilities, the lower TDS may allow for more water to be recharged without degrading the groundwater.

Technical and Operational Feasibility

There are several items that need to be closely monitored when using RO at WWTPs, specifically constituents that can cause biofouling, suspended solids, and chlorination. Many of these issues can be remedied during design of a new facility, but for existing facilities changes may need to be completed to operate the RO at acceptable levels.

One drawback to this, or any, option utilizing evaporation ponds, is that the amount of land required for the ponds may not be available near existing WWTPs, and therefore, a pipeline may be required to convey the concentrate to a suitable location for the ponds. This may require the purchase of land and procurement of easements or right-of-way for these added facilities. In addition, existing WWTPs may not have space within the current plant boundaries for the addition of an RO facility.

Environmental/Public Acceptability

There are currently two major water treatment facilities that use this option for indirect potable recharge: the Scottsdale Water Campus (Arizona) and Water Factory 21 (California). In both cases, wastewater effluent is treated with RO membranes and then recharged into the vadose zone and recovered downgradient for potable uses. Based on the existence of these two facilities, it is anticipated that public acceptability of these types of reuse applications will be high.

The use of evaporation ponds may cause some concerns to the public, such as unsightliness of the ponds.

Benefits/Risks of RO Treated Effluent

The major benefit of using RO to treat a portion of effluent from a WWTP is that the treated effluent would have a relatively low TDS and could be used for several types of reuse applications, which would not be the case if the TDS were too high. For example, higher quality reclaimed water can be used golf course irrigation, landscape impoundments, or even spray irrigation of an orchard or vineyard.

Only a portion of the effluent would need to be treated with RO to meet the needs of the reuse application; the remaining effluent, which would be used for less demanding uses, would not be treated. For example, if you have a 5 MGD plant but only 1 MGD is required for recharge purposes, then only a portion of the effluent is treated to give 1 MGD at the target TDS.

Economic/Financial Feasibility
Using the model developed by the Reclamation (2004), the following chart was developed to show cost for incremental decrease of TDS for each of the three assumed plant sizes.

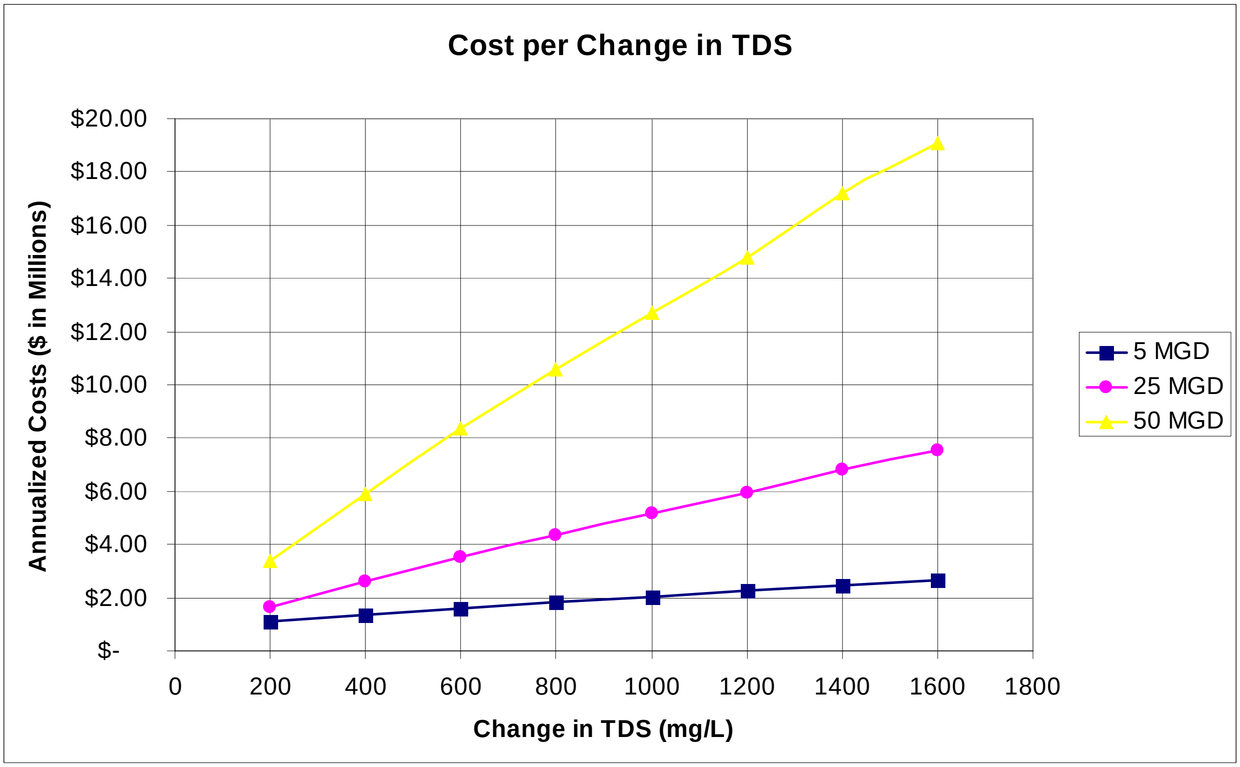

Chart 1

Chart 1 illustrates the following points:

- That annualized costs increase as the change in TDS increases and plant capacity increases. This is mainly due to the increased costs of evap. pond land and liner requirements.
- The annualized cost for smaller plants in relatively flat as TDS change increases.

Table 25 summarizes the capital and O&M costs for the three plant sizes.

Change in TDS	Capital Costs RO	Capital Costs Ponds	Capital Costs Total	O&M Costs RO	O&M Costs Ponds	O&M Costs Total	Annualized Cost
	5 MGD						
200	$ 0.77	$ 13.98	$ 14.75	$ 0.10	$ 0.07	$ 0.17	$ 1.12
400	$ 1.42	$ 16.11	$ 17.54	$ 0.15	$ 0.08	$ 0.23	$ 1.37
600	$ 2.03	$ 18.17	$ 20.20	$ 0.20	$ 0.09	$ 0.29	$ 1.60
800	$ 2.60	$ 20.15	$ 22.76	$ 0.24	$ 0.10	$ 0.34	$ 1.83
1000	$ 3.14	$ 22.07	$ 25.21	$ 0.28	$ 0.11	$ 0.39	$ 2.05
1200	$ 3.66	$ 23.93	$ 27.58	$ 0.32	$ 0.12	$ 0.44	$ 2.26
1400	$ 4.15	$ 25.72	$ 29.87	$ 0.36	$ 0.13	$ 0.49	$ 2.47
1600	$ 4.62	$ 27.45	$ 32.07	$ 0.40	$ 0.14	$ 0.54	$ 2.66
	25 MGD						
200	$ 3.35	$ 21.99	$ 25.35	$ 0.30	$ 0.11	$ 0.41	$ 1.64
400	$ 6.22	$ 33.48	$ 39.70	$ 0.54	$ 0.17	$ 0.71	$ 2.59
600	$ 8.88	$ 45.42	$ 54.30	$ 0.77	$ 0.23	$ 1.00	$ 3.55
800	$ 11.38	$ 55.35	$ 66.73	$ 0.99	$ 0.28	$ 1.27	$ 4.37
1000	$ 13.75	$ 64.94	$ 78.68	$ 1.20	$ 0.32	$ 1.53	$ 5.16
1200	$ 16.00	$ 74.20	$ 90.20	$ 1.41	$ 0.37	$ 1.78	$ 5.92
1400	$ 18.15	$ 85.66	$ 103.81	$ 1.61	$ 0.43	$ 2.04	$ 6.81
1600	$ 20.21	$ 94.33	$ 114.54	$ 1.81	$ 0.47	$ 2.28	$ 7.52
	50 MGD						
200	$ 6.33	$ 33.88	$ 40.20	$ 0.55	$ 0.17	$ 0.72	$ 3.39
400	$ 11.75	$ 56.85	$ 68.60	$ 1.02	$ 0.28	$ 1.31	$ 5.90
600	$ 16.77	$ 79.90	$ 96.67	$ 1.48	$ 0.40	$ 1.88	$ 8.37
800	$ 21.49	$ 99.75	$ 121.24	$ 1.93	$ 0.50	$ 2.42	$ 10.58
1000	$ 25.96	$ 118.93	$ 144.89	$ 2.35	$ 0.59	$ 2.95	$ 12.71
1200	$ 30.21	$ 137.47	$ 167.68	$ 2.77	$ 0.69	$ 3.46	$ 14.76
1400	$ 34.27	$ 161.70	$ 195.97	$ 3.17	$ 0.81	$ 3.98	$ 17.18
1600	$ 38.16	$ 179.04	$ 217.20	$ 3.56	$ 0.90	$ 4.45	$ 19.10

Table 25

From Table 25, the following observations can be noted:

- Capital costs are driven by evaporation ponds.

Conclusion: It may be necessary to use advanced water treatment on a portion of the effluent currently being produced in Arizona's WWTPs. This option evaluated the use of RO treatment of a portion of the effluent prior to recharging the effluent to the vadose zone or aquifer. When the effluent can not be used for the intended purpose then the cost of advanced water treatment will be met because the next source of water to meet those needs will be more expensive. Currently, in the Phoenix metropolitan area, some of the water reclamation plants produce effluent that does not meet the minimum reuse standards.

Analysis for Section 5.3.1 and 5.3.2: RO Wellhead Treatment

The following section discusses the treatment of brackish groundwater using RO. Two options were evaluated . These options consisted of using RO treatment as either: (1) wellhead treatment for a single well or (2) centralized treatment for a number of wells, or well field. The following assumptions were made in analyzing RO treatment at the wellhead or at a centralized facility:

1. Brackish groundwater is assumed to have a TDS of 1,500 mg/L or greater;

2. Efficiency is assumed to be 85 percent on all RO applications;

3 Brine concentrate would be disposed of in evaporation ponds;

4. No MF pretreatment is required, but it is assumed that some sort of sediment removal system, such as cartridge filters, will be used prior to running water through the RO unit to prohibit sediment load on membranes.

5.3.1 RO Wellhead Treatment at One Well

Description: This option consists of treating brackish groundwater at the wellhead with RO and transporting the brine concentrate to a regional evaporation pond for disposal. It is assumed that either a new or existing well can be fitted with the RO unit, although some retrofitting may be required for an existing well.

Design of the wellhead RO treatment will depend on the quantity and quality of the brackish groundwater. For the purposes of this evaluation, the initial TDS concentration in the groundwater was assumed to be 1,500 mg/L and the pumping capacity of each well was 694 gallons per minute (gpm), or 1,120 acre-feet per year (1 MGD). Pretreatment for the groundwater consisted of filtration for sediment removal and pH adjustment, if necessary. It is anticipated that water will be blended to achieve the target TDS concentration; therefore some water will bypass RO treatment. The chart below estimates what quantities of permeate and concentrate would be required based on the above described assumptions to achieve the targeted TDS. Volume of concentrate is listed below and is dependent on the water quality that is targeted.

Target TDS (mg/L)	Bypass Volume (gpm)	Permeate Volume (gpm)	Concentrate Volume (gpm)
400	139	472	83
500	174	442	78
600	222	401	71
700	278	354	62

Table 26

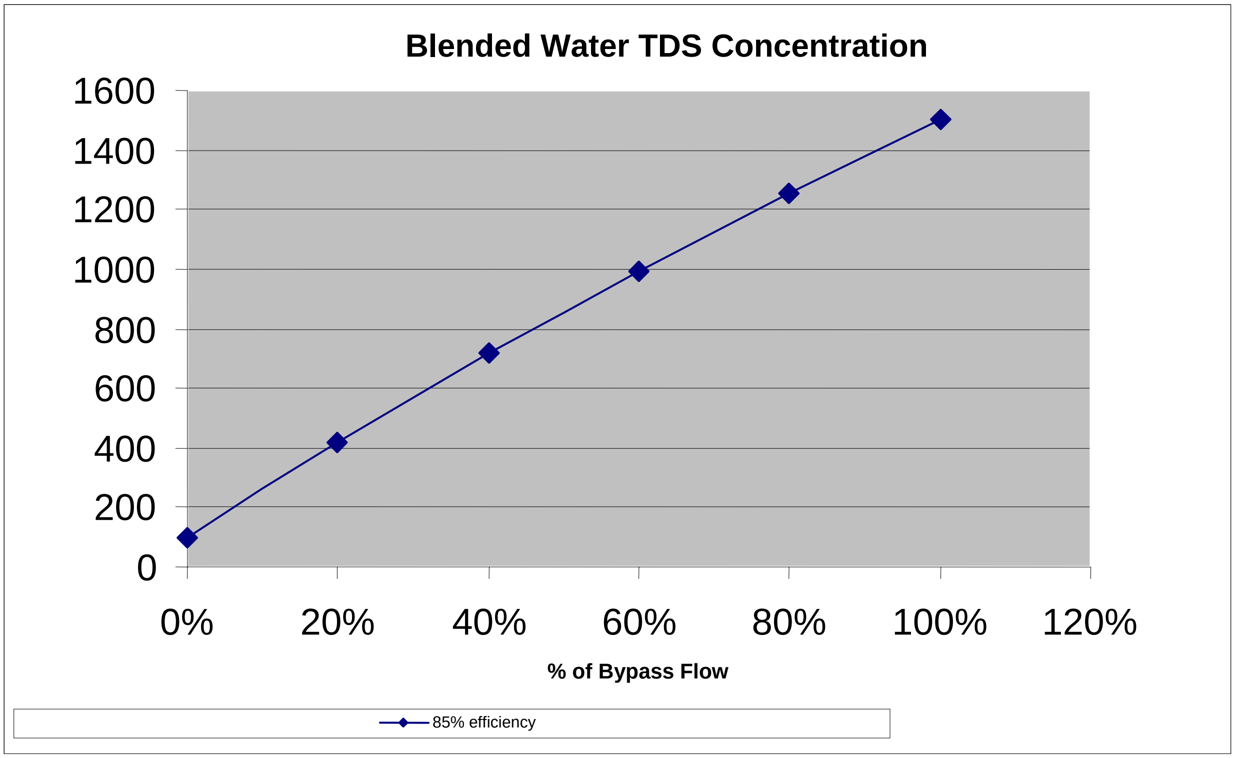

Chart 2

Institutional Considerations

RO treatment at the wellhead would be a feasible option, assuming the water provider has the water rights to pump within an area of brackish groundwater. A blending plan may require the approval of the state or county drinking water regulator and issues could arise with other water quality constituents that are concentrated in the RO process.

An APP would need to be obtained for the construction and operation of evaporation ponds. If the land for the evaporation ponds, or any pipelines or conveyances, were to be located on federal lands, or the construction of this facility is federally-funded, NEPA regulations would have to be followed.

Water Resource Utilization
RO treatment of brackish groundwater would be beneficial to water providers with this resource. This water can not be used without advanced water treatment however, the percentage of water lost to brine concentration is considerable. While all the water treated would count against a water user or providers groundwater pumping.

Technical and Operational Feasibility
Careful evaluation and sizing will be required to retrofit an older well with the discharge piping to accommodate an RO unit. Other operational considerations include that the well site may need to be enlarged in order to accommodate additional equipment; operation of the well may become more difficult because of membrane sensitivities; staff may require specific operational training; operational flexibility is reduced with blending to acquire a specific TDS target.

Environmental/Public Acceptability

Little or no public opposition would be expected from this option based on the number of existing RO treatment plants already in operation.

Little, if any, public opposition would be expected for the construction and operation of evaporation ponds based on the fact that there are many large evaporation ponds in existence in central Arizona. The only issues, of which may receive minor opposition, would include the unsightliness of large ponds, wildlife impacts, and removal of habitat.

Benefits/Risks of salinity control/reduction option

While the consequence of many of the salinity reduction options is the creation of a brine concentrate, the primary benefit of RO treatment at the wellhead for brackish water would be the rehabilitation, or restoration, and beneficial use of a valuable resource, the groundwater.

Economic/Financial Feasibility

The cost of implementing a wellhead RO treatment plant is feasible, especially if the water is necessary for a water provider to meet demands. As is the case with many of the options evaluated in this study, as the volume of brine concentrate increases, the cost of the treatment option also increases due primarily to the increase in land required for evaporation ponds.

Change in TDS	Capital			O&M			Annualized Total (Million $)
	RO Plant (Million $)	Pond (Million $)	Total (Million $)	RO plant (Million $)	Ponds (Million $)	Total (Million $)	
RO Wellhead Treatment							
200	$0.23	$11.54	$12.51	$0.07	$0.06	$0.13	$0.93
400	$1.19	$12.10	$13.72	$0.08	$0.06	$0.16	$1.03
600	$0.60	$12.65	$14.80	$0.09	$0.06	$0.18	$1.13
800	$0.77	$13.16	$15.80	$0.10	$0.07	$0.20	$1.22
1000	$0.92	$13.65	$16.73	$0.11	$0.07	$0.22	$1.30

Table 27

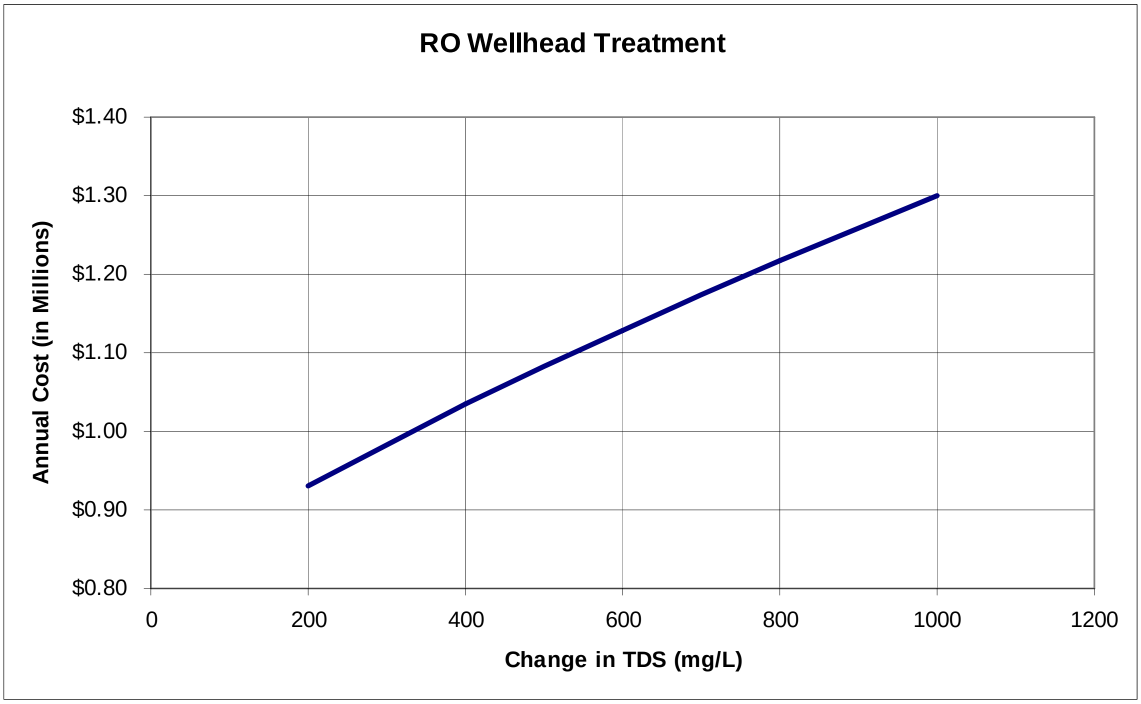

Chart 3

Conclusion: The cost of producing potable water from brackish sources is considerable but the cost of finding another source of water could be higher. If there were incentives to use brackish groundwater, such as not counting against a city's or town's groundwater limits, then the cost of brackish groundwater would be justified.

When the current water sources are totally allocated then advanced treatment of brackish groundwater will become much more likely to happen.

The biggest drawback is the disposal of the concentrate. Small scale brackish groundwater plants can use evaporative ponds but evaporative ponds get expensive due to large land needs and also the cost of the double liners used to seal the ponds.

A case in point is the City of Goodyear, which is currently treating brackish groundwater by RO which comes from a single well. The City of Goodyear has had to address a couple of problems with the system. For one, the well is an old irrigation well and, due to construction, pulls in high amounts of silt from the formation during pumping; the silt then causes the pretreatment filters to clog. In addition, the concentrate is currently being disposed of into the sewer, however, the City's WWTP is nearing hydraulic capacity and salinity limits, which means the City will have to find an alternative disposal method.

5.3.2 Centralized Groundwater Treatment Plant

Description: This option consists of treating brackish groundwater from several wells at a centralized water treatment plant with RO, prior to adding water into the distribution system.

Similar to the single well treatment, the resulting brine concentrate is assumed to be transported via pipeline to a regional evaporation pond for disposal.

For the purposes of this study, it was assumed that four wells would be used at a water treatment plant for a capacity of 6,000 gpm (9,678 acre-feet per year, or 8.64 MGD), and that the TDS concentration in the groundwater, prior to treatment, is 1,500 mg/L. Pretreatment for the groundwater would include filtration for sediment removal and pH adjustment, if necessary. It is anticipated that water will be blended to achieve the target TDS concentration; therefore some water will bypass RO treatment. The chart below estimates what quantities of permeate and concentrate would be using the above described assumptions to achieve the targeted TDS. Volume of concentrate is listed below and is dependent on the water quality that is targeted.

Targeted Water Qualities

Targeted TDS (mg/l)	Bypass Volume (gpm)	Permeate Volume (gpm)	Concentrate Volume (gpm)
400	1200	4080	720
500	1500	3825	675
600	1920	3468	612
700	2400	3060	540

Table 28

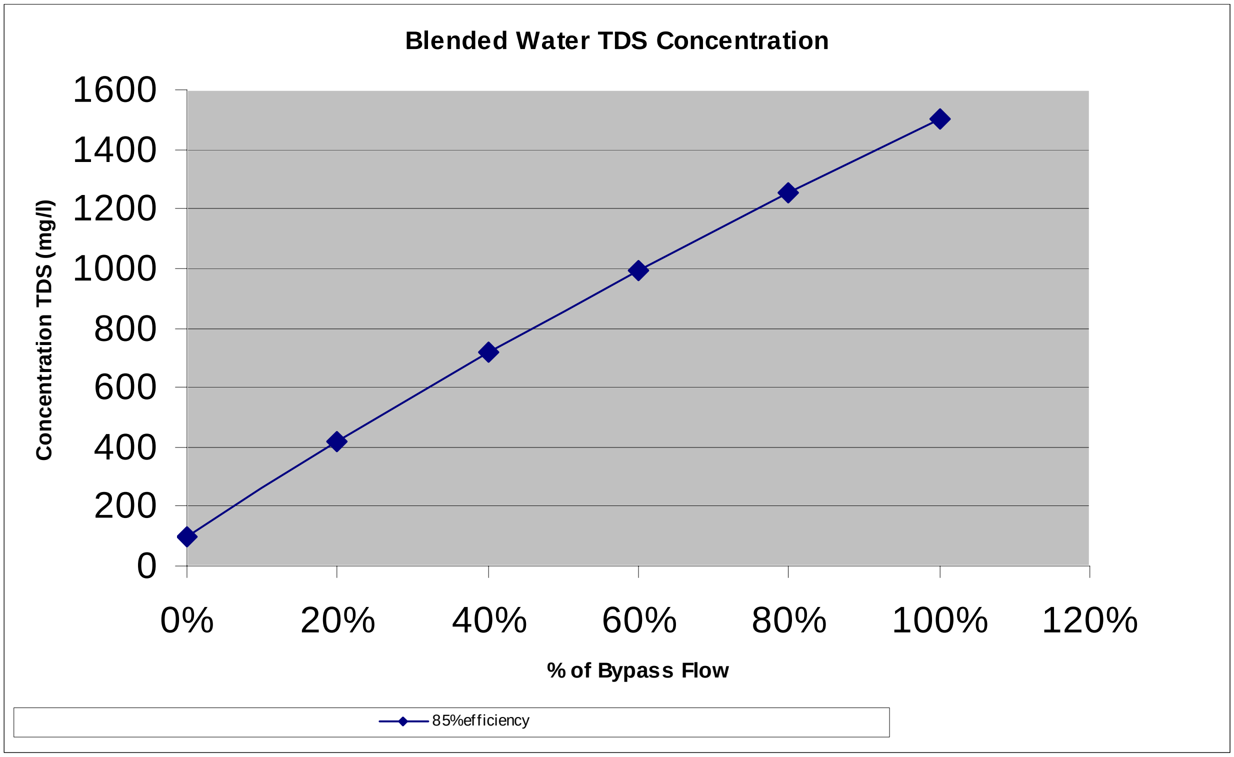

Chart 4

Institutional Considerations
This option would be feasible as long as the water provider has rights to pump within an area of brackish water. Blending plan may require approval through drinking water regulator (state or county), and issues may arise with other water quality constituents that are concentrated in RO process.

The creation of evaporation ponds and pipeline for the disposal of brine concentrate may create the necessity acquisition of easements and possible environmental mitigation. Both of these processes are often lengthy. Additional permits may have to be secured depending on pond liner requirements.

Water Resource Utilization
RO treatment of brackish water is a beneficial to water providers with this resource. The volume of water lost to brine concentration is considerable, especially at lower efficiency rates but this water was not potable.

Technical and Operational Feasibility
RO is a very reliable technology and feasible option, both technically and operationally. The following factors must also be considered prior to implementing this technology: Operation may be more difficult because of membrane sensitivities; Staff may require additional training; operational flexibility is reduced with blending to acquire a specific TDS target.

A brine concentrate pipeline must be made of material resistant to high concentrations of TDS. There is the potential for overloading evaporation basins if they are not properly sized.

Environmental/Public Acceptability
The public will like having better quality water, but may not like the increase in cost associated with acquiring higher quality water.

There are many public issues with evaporation ponds including: Potential for contamination of the area with brine; Unsightliness of large ponds; and wildlife impacts and removal of habitat.

Benefits/Risks of salinity control/reduction option
While the risk of any salinity reduction option is the creation of a brine contaminant stream, the overall benefit of RO wellhead treatment on brackish water is a significant benefit to society because of the beneficial use of a previously unusable source of water.

Economic/Financial Feasibility
The cost of implementing a centralized RO treatment plant is feasible, especially if the water is necessary for a water provider to meet demands. Once again as volumes of concentrate increase, the higher the cost of the alternative because of the amount of land required for evaporation ponds.

Change in TDS	Capital			O&M			Annualized Total
	RO Plant (Million $)	Pond (Million $)	Total (Million $)	RO plant (Million $)	Ponds (Million $)	Total (Million $)	(Million $)
Centralized Well Treatment							
200	$1.67	$16.10	$21.14	$0.17	$0.08	$0.33	$1.70
400	$3.08	$21.01	$29.47	$0.28	$0.11	$0.54	$2.46
600	$4.37	$25.68	$37.09	$0.38	$0.13	$0.74	$3.17
800	$5.56	$30.98	$45.01	$0.48	$0.15	$0.93	$3.89
1000	$6.69	$35.24	$51.68	$0.58	$0.18	$1.11	$4.52

Table 29

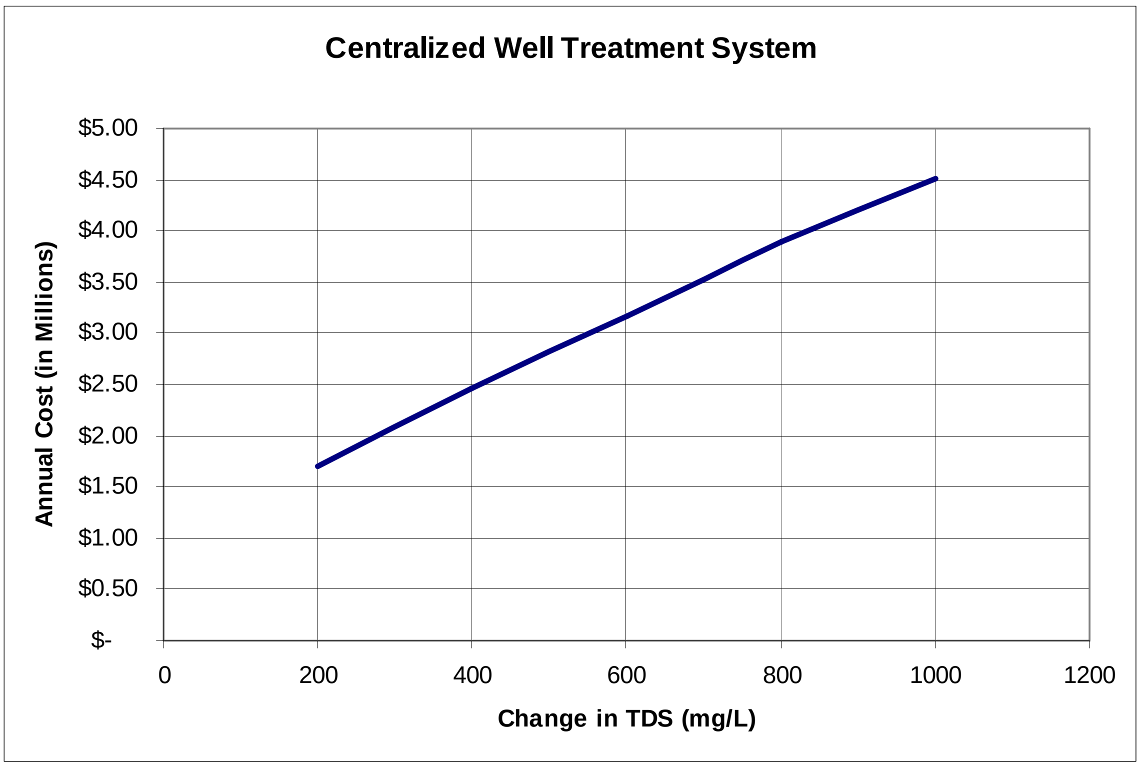

Chart 5

Conclusion: The cost of producing potable water from brackish sources is considerable but the cost of finding another source of water could be higher. If there were incentives to use brackish groundwater, such as not counting against a city's or town's groundwater limits, then the cost of brackish groundwater would be justified.

When the current water sources are totally allocated then advanced treatment of brackish groundwater will become much more likely to happen.

The biggest drawback is the disposal of the concentrate. Small scale brackish groundwater plants can use evaporative ponds but evaporative ponds get expensive due to large land needs and also the cost of the double liners used to seal the ponds.

The Town of Gila Bend currently treats brackish groundwater from multiple wells by sending the water through one RO facility. The brine concentrate is evaporated in ponds, which work well for the Town because the RO facility is small and land is available and relatively inexpensive.