# HOLLISTER URBAN AREA WATER AND WASTEWATER MASTER PLAN

## APPENDIX F - CENTRALIZED LIME SOFTENING FACILITY TO REDUCE TOTAL DISSOLVED SOLIDS IN DRINKING WATER AND WASTEWATER TREATMENT PLANT INFLUENT

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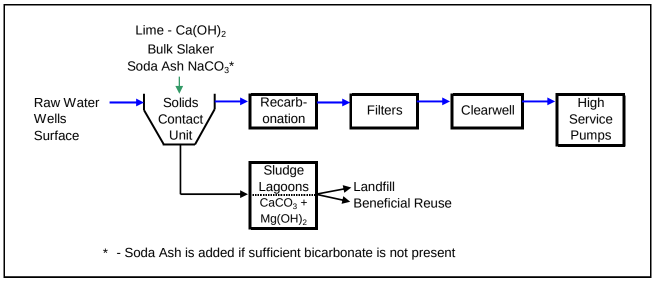
### Summary

Many utilities throughout the United States utilize the lime softening process to reduce the hardness of their waters. This treatment process was originally performed to reduce the amount of scaling that occurred in the utilities water systems. It also provided their customers water which did not rapidly scale their water heaters or commercial air conditioning systems. A current additional benefit of the lime softening process is the ability to allow a relatively small increase in wastewater influent total dissolved solids (TDS) compared to the water systems' TDS. This is partially because softened water will remove the hardness ions which are part of a water's TDS. However, the largest wastewater TDS reduction is by negating the need for water softeners in homes or commercial complexes. Home and commercial softeners are typically ion exchange units which contribute significant amounts of sodium and chloride ions to a wastewater system's TDS. A schematic of a typical single stage lime softening process is shown to the left.



* - Soda Ash is added if sufficient bicarbonate is not present

Hollister and Sunnyslope have set the goals of reducing TDS in the drinking water to 500 mg/L, and to 500 or 700 mg/L in the WWTP's influent. Desktop analysis of the water quality for the Hollister and Sunnyslope water systems, and the Hollister wastewater treatment plant (WWTP) influent, indicates these goals may be within reach by utilizing a centralized lime softening process for treating the utilities' raw water. Softening of the raw water will likely result in a finished water TDS concentration ranging from 485 to 555 mg/L, depending on the blending of the raw water sources and sources to be softened. Blending and treatment options are presented in detail within this Technical Memorandum. The hardness concentration is likely to vary from 55 to 70 mg/L in the softened finished water compared to a maximum goal of 120 mg/L in the MOU. Additionally, softening of the raw water may result in WWTP influent concentrations ranging from 735 to 759 mg/L. The WWTP influent TDS concentrations could be potentially reduced to these levels if home and commercial ion exchange softening units were no longer needed and removed from service.

Cost for a centralized lime softening facility will vary depending on many factors, however a generalized total project cost estimate for a 7 million gallon per day (MGD) facility, which will have a maximum day treatment requirement of 14 MGD, is $2.46 per peak flow gallon or approximately $34.4 million. Since this desktop study indicates a centralized softening facility may allow the TDS goals to be within reach further analysis of this concept may be warranted. Additional items recommended for determining the feasibility of this concept are:

- Jar testing of the raw water;
- Pipeloop analysis of the system due to changing the system's water chemistry;
- Implementing a program to remove home/commercial ion exchange softeners;
- Determining raw and finished water piping to and from the centralized facility; and
- Determining feasible ultimate disposal of solids from the facility.

## Lime Softening Background & TDS Reduction Implications

The lime softening process is a technology that has been used to reduce the hardness of drinking water throughout the United States and the world. The lime softening process mainly removes the dissolved divalent ions of calcium and magnesium as a precipitate from the water. Dissolved calcium and magnesium are also part of a water's total dissolved solids (TDS) concentration. Other dissolved ions that contribute to hardness and TDS are the metal elements of iron, manganese, and strontium. The lime softening process has been shown to reduce the concentrations of these hard ions, as well as silica and arsenic concentrations, and the heavy metals barium, beryllium, cadmium, chromium, mercury and nickel. Additionally, lime softening has been shown to reduce total organic carbon and color in drinking water sources. All of these additional dissolved elements and compounds, if present, contribute to a water's TDS concentration.

Table 10. 4 of the *AWWA Water Quality and Treatment; A Handbook of Community Water Supplies, 4th addition* book classifies the hardness of water as follows:

| Hardness Range, mg/L as $CaCO_3$ | Hardness Description |
|---|---|
| 0 - 75 | Soft |
| 75 - 150 | Moderately Soft |
| 150 - 300 | Hard |
| >300 | Very Hard |

Hard water can lead to excessive scaling within distribution system piping if the treated water's Langlier Saturation Index (LSI) is not closely monitored, and it can create scaling within hot water heaters and commercial air conditioning systems causing premature failure. Thus, if hard water is not softened, many homes and businesses will utilize ion exchange softening units to prevent the scaling in their water heaters and commercial air conditioning units. The ion exchange units soften water by typically exchanging two ions of sodium for a single ion of calcium or magnesium, the two divalent ions that are most prominent in determining water hardness. However, even though magnesium and calcium are removed from water via the ion exchange units, they are returned to the utility's wastewater system when the ion exchange units regenerate their resin beds.

Additionally, when the ion exchange resin is regenerated, a supersaturated solution of sodium chloride is typically used. The supersaturated sodium chloride solution causes the exchange resin to replace the calcium and magnesium ions with sodium ions so the resin can again soften water. But not all of the sodium ions in the supersaturated solution are exchanged with the resin, and none of the chloride ions are exchanged with the resin. Thus, the excess sodium and chloride ions that are not exchanged during the regeneration process are discharged as waste to the sanitary sewer system, as are the exchanged calcium and magnesium ions.

This causes the wastewater system to typically receive the following TDS ions when a relatively hard drinking water is not softened when compared to utilities utilizing lime softening:

- calcium and magnesium ions which are removed by home/commercial ion exchange softening units but are released to the wastewater system when the ion exchange resin bed is regenerated,
- sodium ions that are exchanged for the calcium and magnesium ions during the home and commercial ion exchange process to soften the water, and
- the excess sodium and chloride ions discharged from the supersaturated solution used to regenerate the home and commercial ion exchange resin bed.

These three sources typically result in a significant increase of TDS to the wastewater stream over the dissolved solids concentration of the raw water source or a typical lime softened drinking water.

The typical lime softening process includes rapid mix, flocculation and sedimentation (these three processes can be provided in a single solids contact unit), as well as recarbonation, filtration, filter backwash facilities, and chemical feed systems. The lime softening process uses a lime slaker or a batch slaking process to convert hydrated lime (calcium oxide, [$CaO$]) to quicklime (calcium hydroxide, or [$Ca(OH)_2$]) which is added to the source water to produce calcium carbonate [$CaCO_3$] and magnesium hydroxide [$Mg(OH)_2$] precipitates Other precipitates typically include silica dioxide and magnesium silicate, which may precipitate with magnesium hydroxide, iron salts, and other metal salts.

The chemical equations which apply to the lime softening process for forming calcium carbonate and magnesium hydroxide precipitates, and to stabilize the finished water are as follows:

$$H_2CO_3 + Ca(OH)_2 \rightarrow CaCO_3\downarrow + 2H_2O$$

$$Ca^{2+} + 2HCO_3^- + Ca(OH)_2 \rightarrow 2CaCO_3\downarrow + 2H_2O$$

$$Ca^{2+} + Na_2CO_3 \rightarrow CaCO_3\downarrow + 2Na^+$$

$$Mg^{2+} + 2HCO_3^- + 2Ca(OH)_2 \rightarrow 2CaCO_3\downarrow + Mg(OH)_2\downarrow + 2H_2O$$

$$Mg^{2+} + Ca(OH)_2 \rightarrow Mg(OH)_2\downarrow + Ca^{2+}$$

$$Ca^{2+} + 2OH^- + CO2 \rightarrow CaCO_3\downarrow + H_2O$$

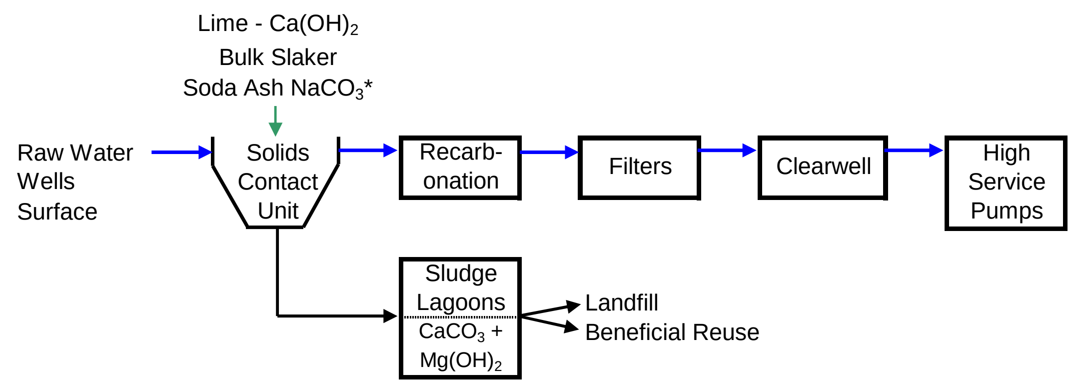
$$2OH^- + 2CO_2 \rightarrow 2HCO_3^-$$

As these equations show, bicarbonate [$HCO_3^-$] is an essential part of the softening process. If sufficient bicarbonate is not present in the raw water, then soda ash [$Na_2CO_3$] is needed to provide sufficient alkalinity for the chemical reactions to occur and the precipitates to form. In general, if the carbonate hardness (i.e., alkalinity and bicarbonate) of the raw water is greater than the total hardness of the water, soda ash will not be required for the softening process and the TDS in the finished water will be lower than the raw water. When the water's carbonate hardness is less than the water's total calcium and magnesium hardness, then most softening plants add soda ash to meet the finished water softening goals. However, a two stage recarbonation system with intermediate settling between the recarbonation units will negate the need for soda ash if the carbonate hardness is between the calcium hardness and total hardness concentrations. The two stage recarbonation process for this occurrence of carbonate hardness will also provide minimal TDS in the finished water.

If soda ash is needed for the softening process then the finished water TDS may actually increase above the raw water's TDS as sodium will be added to the water. However, even in this case it is likely the TDS in the wastewater would be significantly reduced as the salts from the home/commercial ion exchange softening units would no longer be discharged to the wastewater system.

The type of lime softening process (i.e., single stage, two stage, or three stage with two stage recarbonation) depends on the raw water chemistry, the softening goals for the water, and if recalcination of the calcium carbonate precipitates to calcium oxide is used for regenerating the hydrated lime source. A schematic of a typical single stage lime softening process is shown in Figure 1.

*Figure 1 – Typical Single Stage Lime Softening Process Schematic*



* - Soda Ash is added if sufficient bicarbonate is not present

In most softening processes where the pH is elevated (to 10.5 or higher) to remove magnesium from the water, some reduction of total organic carbon occurs. However, activated carbon (powdered or granular carbon) or nanofiltration may also be needed for organics reduction to meet safe drinking water act (SDWA) requirements. The lime softening process will produce a minimal residual amount of calcium and magnesium in the drinking water, typically varying from 30 to 60 mg/L as $CaCO_3$ for calcium, and 10 to 20 mg/L as $CaCO_3$ for magnesium. The residual calcium and magnesium concentrations are typically acceptable for use in home water heaters and commercial air conditioning units.

Lime softening precipitates have been utilized for beneficial reuse through soil conditioning of agricultural fields, road base stabilization, and soil stabilizers for cattle feed lots to reduce hoof disease. Some utilities have recalcined their solids from the process, transforming the $CaCO_3$ to calcium oxide [CaO], as the recalcination process drives off the bound carbon dioxide [$CO_2$]. The resulting CaO is then used to create the hydrated lime and quicklime needed for the lime softening process. The recalcined $CO_2$ gas can also be recovered and reused for recarbonation as part of the lime softening process. Recalcination is generally most cost effective for large plants in areas of the country where lime is more expensive and disposal cost for the residuals generated in the process is problematic.

An advantage of the lime softening process when compared to the reverse osmosis (RO) membrane process is that it will not produce a concentrated brine stream. Disposal of the RO concentrated brine stream is typically very costly, as there are limited options for its use or disposal. Typical brine disposal methods include evaporation ponds, and evaporators and crystallizers. Evaporation ponds are land intensive, and the evaporator/crystallizer systems are energy intensive. The lime softening process will produce side streams, mainly from filter backwashing and the retention of water with solids removal. Depending on state regulations, filter backwash water may be recycled to the head of the plant after settling and solids removal.

However, these side streams are minimal when compared to the amount of concentrate water produced from the membrane process.

A disadvantage of the lime softening process is that feeding lime solutions requires significant maintenance and the operators of the lime softening plant will need to have a sound understanding of the process. However, a recent advance in lime slaking technology, the batch slaking process, has been found to be more operator and maintenance friendly than the older lime slaker process (paste slakers). Another disadvantage of the lime softening process is the generation of substantial solids quantities which must be handled and ultimately land applied or landfilled.  Additionally, lime softening will not remove dissolved anions (nitrates or sulfates) or monovalent ions (sodium and potassium) from source waters which RO membranes will remove. These anions and monovalent ions contribute to a water's TDS concentration. Operation and maintenance costs are typically lower for a lime softening plant, as the lime softening system's cost for chemicals and energy is typically lower than required for an RO plant when coupled with the cost to periodically replace the facility's membranes and to maintain an evaporation pond system.

## Centralized Lime Softening Applications to the City of Hollister and Sunnyslope County Water District

The City of Hollister (Hollister) and the Sunnyslope County Water District (Sunnyslope) obtain their drinking water from two sources.  The first source is from deep groundwater wells, and the second source of water is imported San Felipe surface water.  The groundwater is typically over 300 mg/L as $CaCO_3$, which is considered as very hard water.  The surface water is treated at the LESSALT Water Treatment Plant, and has a hardness around 100 mg/L as $CaCO_3$, which is considered as moderately soft water.  The amount of groundwater and surface water varies for both Hollister and Sunnyslope.  For Hollister and Sunnyslope, the groundwater makes up approximately 75% and 71% of the drinking water source, respectively.

The constituents for each of the water sources are important parameters in determining if the hardness and TDS in the drinking water can be reduced and result in significant TDS reductions at the wastewater treatment plant (WWTP). Tables 1 and 2 provide a summary of the important hardness and TDS water quality parameters for the Hollister and Sunnyslope water systems respectively.  These water quality parameters are from the City of Hollister and Sunnyslope County Water District 2004 Annual Drinking Water Quality Reports.

### *Table 1 – Hollister Water Quality*

| Parameters/Water Source | COH (Wells) | LESSALT (Surface Water) | SSCWD (Wells) | All Waters Blended | Only Well Water Blended |
|---|---|---|---|---|---|
| % of Total Water Source | 69% | 24% | 7% | | |
| TDS (ppm) | 627 | 300 | 775 | 558.88 | 640.63 |
| Total Hardness (ppm as CaCO3) | 334 | 100 | 393 | 281.97 | 339.43 |
| Calcium (ppm) | 51 | 21 | 70 | 45.13 | 52.75 |
| Calcium (ppm as CaCO3) | 127.36 | 52.44 | 174.81 | 112.70 | 131.73 |
| Magnesium (ppm) | 50 | 12 | 53 | 41.09 | 50.28 |
| Magnesium (ppm as CaCO3) | 205.84 | 49.40 | 218.20 | 169.16 | 206.98 |
| Sodium (ppm) | 98 | 48 | 84 | 85.02 | 96.71 |
| Potassium (ppm) | 2.4 | 2.9 | 1.1 | 2.43 | 2.28 |
| Chloride (ppm) | 83 | 76 | 96 | 82.23 | 84.20 |
| Sulfate (ppm) | 179 | 43 | 240 | 150.63 | 184.62 |
| Total Alkalinity (ppm as CaCO3) | 264 | 80 | 295 | 222.01 | 266.86 |
| Bicarbonate (ppm) | 323 | 80 | 295 | 262.72 | 320.42 |
| pH | 7.5 | 8.3 | 7.8 | 7.6174 | 7.5204 |

### *Table 2 – Sunnyslope Water Quality*

| Parameters/Water Source | SSCWD (Wells) | LESSALT (Surface Water) | COH (Wells) | All Waters Blended | Only Well Water Blended |
|---|---|---|---|---|---|
| % of Total Water Source | 68% | 29% | 3% | | |
| TDS (ppm) | 775 | 300 | 627 | 632.81 | 768.75 |
| Total Hardness (ppm as CaCO3) | 393 | 100 | 334 | 306.26 | 390.51 |
| Calcium (ppm) | 70 | 21 | 51 | 55.22 | 69.20 |
| Calcium (ppm as CaCO3) | 174.81 | 52.44 | 127.36 | 137.90 | 172.80 |
| Magnesium (ppm) | 53 | 12 | 50 | 41.02 | 52.87 |
| Magnesium (ppm as CaCO3) | 218.20 | 49.40 | 205.84 | 168.88 | 217.67 |
| Sodium (ppm) | 84 | 48 | 98 | 73.98 | 84.59 |
| Potassium (ppm) | 1.10 | 2.90 | 2.40 | 1.661 | 1.15 |
| Chloride (ppm) | 96 | 76 | 83 | 89.81 | 95.45 |
| Sulfate (ppm) | 340.00 | 43.00 | 179.00 | 249.04 | 333.20 |
| Total Alkalinity (ppm as CaCO3) | 295 | 80 | 264 | 231.72 | 293.69 |
| Bicarbonate (ppm) | 295 | 80 | 323 | 233.49 | 296.18 |
| pH | 7.8 | 8.3 | 7.5 | 7.8801 | 7.7821 |

Hollister and Sunnyslope have set the goals of reducing TDS in the drinking water to 500 mg/L, and to 500 or 700 mg/L in the WWTP's effluent. When reviewing the water quality parameters for both Hollister and Sunnyslope, it became apparent that there may be two alternatives for softening the water sources. The first alternative is to soften all waters, and the second alternative is to soften only the well water and blend it with unsoftened surface water. It should be noted that while the alkalinity for these blended waters is less than the total hardness of the blended water, it is higher than the blended waters' calcium hardness. Thus, since the goal of this study is to reduce TDS as much as possible, it was assumed for this analysis that a dual stage recarbonation system with intermediate settling would likely be utilized. This would minimize the need for soda ash addition, as well as the hardness and TDS in the finished softened water.

## Drinking Water TDS Reduction Evaluation

The TDS in the drinking water for all waters blended together and softened was theoretically determined to be approximately 485 mg/L and 550 mg/L for the Hollister and Sunnyslope drinking waters, respectively. The TDS in the drinking water for when only the well waters are blended and softened, and then blended with unsoftened surface water, was theoretically determined to be approximately 490 mg/L and 555 mg/L for the Hollister and Sunnyslope drinking waters, respectively. These calculations reflect a residual hardness of approximately 55 mg/L as $CaCO_3$ in the finished drinking water when all waters are softened for both Hollister and Sunnyslope. The residual hardness in the drinking water for softening only well waters is estimated to be around 66 to 68 mg/L as $CaCO_3$ for Hollister and Sunnyslope, respectively.

While the estimated TDS from the lime softening process is slightly higher than the goal of 500 mg/L for the Sunnyslope water, the goal of 500 mg/L may actually be realized through the lime softening process as this process will typically reduce other TDS contributing elements such as iron, manganese, strontium, arsenic, and when high pH softening is used for magnesium removal, silica will also typically be reduced. This additional TDS reduction will also be achieved for the Hollister softened water, which is estimated to be less than the 500 mg/L goal through the precipitation and removal of just the calcium and magnesium ions.

Appendix A provides the summary of the TDS reduction evaluations for the Hollister and Sunnyslope drinking waters from the lime softening process.

## WWTP Influent TDS Reduction Evaluation

The existing TDS in the influent to the Hollister WWTP is approximately 1220 mg/L. The TDS in the blended drinking waters for Hollister and Sunnyslope is 559 and 633 mg/L, respectively. Thus the TDS essentially doubles from the drinking water to the Hollister WWTP. The 1220 mg/L TDS is not readily removed through typical WWTP processes. One method to reduce TDS at WWTPs is to utilize RO processes after treatment, however the RO process typically produces a reject stream of 15 to 20 percent. The reject stream, which is also called a concentrate stream, contains the ions which cannot pass through the RO membranes, and currently can only be disposed of through two methods. One method is through evaporation ponds, which require relatively large areas and will need to be lined and routinely cleaned. The other method is through evaporators and crystallizers, also known as zero liquid discharge systems, and these devices require significant amounts of energy.

In comparing the TDS parameters for the Hollister WWTP with the Hollister drinking water, it is apparent that a large amount of the additional TDS is from sodium and chloride. The sodium increases from 85 to 258 mg/L and the chloride increases from 82 to 316 mg/L. These increases are likely from the home and commercial ion exchange softening units that are estimated to be used by half of the utility's customers.

To estimate the amount of TDS reduction that may result at the Hollister WWTP by utilizing a central lime softening process for the drinking water, the following assumptions were made:

- The ongoing public education process would continue to ensure that home and commercial ion exchange softening units are no longer used;
- Calcium and magnesium ions will be removed at the central drinking water lime softening facility to the residual amount previously mentioned and these ions will not be returned to the wastewater stream as they will be precipitates and removed to sludge lagoons and ultimately to landfills or for beneficial reuse;
- The sodium ions that are exchanged for the calcium and magnesium divalent ions in the home and commercial ion exchange softening process will no longer be added because the water is already softened and these divalent ions have been removed to an acceptable level (i.e., their residual amounts as previously mentioned); and ,
- The excess sodium and chloride ions discharged from the supersaturated solution which is used to regenerate the home and commercial ion exchange resin bed will no longer occur as the water is already softened to an acceptable level.

The amount of TDS that will be removed from the drinking water and wastewater by softening the water to the 55 mg/L residual amount will be approximately 67 mg/l for the Hollister drinking water and 76 mg/L for the Sunnyslope drinking water.  This is the amount of magnesium and calcium removed by the lime softening process.  Since the magnesium and calcium ions will no longer need to be exchanged in ion exchange softeners, then a further reduction of sodium and associated chloride ions will result in another reduction in TDS of approximately 265 mg/L for the Hollister drinking water, and approximately 294 mg/L for the Sunnyslope drinking water.  Additionally, if it is assumed the additional sodium and chloride ion concentrations which result from the supersaturated sodium chloride solution used to regenerate the ion exchange resin bed, is the difference between the theoretical reductions in sodium and chloride aforementioned and the increased amount of sodium and chloride seen in the WWTP's influent, then an approximate 142 mg/L and 116 mg/L TDS reduction could also be realized for the Hollister and Sunnyslope drinking waters, respectively.  When these aforementioned results are combined, TDS reductions of 473 to 487 mg/L are likely to occur, giving a TDS concentration in the WWTP's influent of approximately 738 and 750 mg/L for the Hollister and Sunnyslope drinking waters, respectively.  Table 3 provides a summary of this overall potential of TDS reduction at the WWTP.

*Table 3 – Potential WWTP TDS Reductions Utilizing Lime Softening*

| Potential TDS Reduction Items | Potential WWTP TDS Reduction By Softening All Waters (mg/L) | |
|---|---|---|
| | Hollister | Sunnyslope |
| (1) Removing Ca & Mg to Residual of 55 mg/L as $CaCO_3$ | 67 | 76 |
| (2) Eliminating Na (& Cl) Exchange for Ca & Mg | 265 | 294 |
| (3) Eliminating Excess Salt Contributed from Supersaturated Ion Exchange Regeneration Process | 142 | 116 |
| (4) Total TDS Potential Reduction Amount, mg/L (1+2+3) | 474 | 486 |
| (5) Existing WWTP Influent TDS, mg/L | 1224 | 1224 |
| Potential WWTP Influent TDS Concentrations, mg/L (5-4) | 750 | 738 |

While the estimated WWTP influent TDS from a centralized lime softening process for the Hollister and Sunnyslope drinking waters is higher than the goal of 500 or 700 mg/L, the lime softening process may still allow the upper end of this goal to be met. This is because the lime softening process will typically reduce other TDS contributing elements such as iron, manganese, strontium, arsenic, and when high pH softening is used for magnesium removal, silica will also typically be reduced.

Attachment B provides the summary of the TDS reduction evaluations for the WWTP's influent which will likely result from a centralized lime softening facility for the Hollister and Sunnyslope drinking waters.

## Lime Softening Probable Capital Costs

Costs for water treatment plants, including a lime softening plant, will vary depending on a number of factors, including land acquisition costs, solids handling and disposal requirements, the level of instrumentation and control, administration and maintenance building area needs, process units covering and building needs, buildings and process units architectural finishes, aesthetic site landscaping and screening requirements, level of site security, costs of construction materials which currently are experiencing a high rate of escalation, and other factors.  For a lime softening process the cost will also vary depending on whether a single stage, two stage, or three stage system will be needed, and if blending of non-softened water is possible.

While all of these factors will affect the overall cost for a lime softening treatment plant, there are generalized cost references which can be used for estimating the probable capital cost of lime softening facilities.  For this study the EPA publication titled "1999 Infrastructure Drinking Water Needs Survey, Modeling the Cost of Infrastructure" was used as the basis for estimating the probable capital cost for a centralized Hollister and Sunnyslope lime softening plant. This equation also compares favorably with HDR's experience with lime softening facilities.  The 1999 EPA publication gave an equation for determining an average total project cost (e.g., design, construction, permits, administration and legal fees, and contingencies) for a new lime softening plant as follows:

WTP Cost = $e^{(14.660+0.465^2/2)}*D^{0.884}$

where D = the design capacity in million gallons per day (MGD).

Based on this equation, and updating the cost to current dollars, the following costs were developed for lime softening treatment facilities ranging from 1 to 100 MGD.

| Design | Year 2006 | |
|---|---|---|
| MGD | $ Million | $/gallon |
| 1 | $3.34 | $3.34 |
| 2.5 | $7.50 | $3.00 |
| 5 | $13.84 | $2.77 |
| 7.5 | $19.81 | $2.64 |
| 10 | $25.54 | $2.55 |
| 25 | $57.42 | $2.30 |
| 50 | $105.97 | $2.12 |
| 75 | $151.65 | $2.02 |
| 100 | $195.56 | $1.96 |

In planning for a centralized lime softening facility for Hollister and Sunnyslope, the softening facility will need to be designed to treat the service area's maximum day flows. The average flow for the service area's planning period is 7 MGD and the maximum day flow is approximately 2 times the average flow. Thus, the size of the centralized softening treatment plant needs to be designed for a flow of approximately 14 MGD. Based on the updated costs from the 1999 EPA report, the probable total project cost for a 14 MGD lime softening facility would be approximately $34,393,000, or $2.46/gallon. Estimated operations and maintenance costs for this size facility are estimated at $415 per million gallons provided.

This cost analysis is only for the probable construction cost of a centralized lime softening water treatment plant. It does not include the cost for routing the surface water supplies and well water to a central location for treatment, or for finished water connections to the water distribution systems. Nor does it take into account the disposal costs associated with the sludge produced from the process; however it does include sludge lagoons for the facility.

## Recommended Actions

This analysis for a centralized lime softening facility, and the estimated TDS reductions in the drinking water and the WWTP's influent, is based on data from the 2004 Annual Drinking Water Quality Reports for Hollister and Sunnyslope, as well as reported TDS at the WWTP. While these reports serve as a sound basis for this desktop softening and TDS desktop analysis, additional analysis is warranted to determine if further reduction of the TDS is obtainable by a centralized lime softening treatment plant. This analysis indicates that the TDS goals of 500 mg/L and 700 mg/L in the drinking water and wastewater are within reach through a centralized lime softening facility.

The most cost effective method to determine the feasibility of the lime softening process for lowering the TDS in the drinking water and the WWTP influent is to perform jar testing of waters which would be representative for a centralized softening facility. In this case, since the two scenarios of softening all waters and softening just the well water compared favorably, then both of these alternatives should be simulated in the jar testing program. The jar testing would assist in determining the actual hardness and TDS that will result in the drinking water. This can then be used to determine how the WWTP TDS would be affected using the same desktop analysis as currently performed.

The jar testing will also assist in verifying the following items for the softening process:

- is sufficient bicarbonate present in the water so soda ash is not needed for the softening process (current data indicates soda ash could be minimize or avoided depending on the process used to soften the water);
- whether a single stage, two stage or three stage process with a two stage recarbonation system will be needed;
- chemical amounts required to adjust the water to an appropriate LSI; and,
- volumes of sludge which are likely to result from the process (theoretical calculations for calcium and magnesium carbonate sludges indicate around 7 to 8 tons per day; however this does not include magnesium non-carbonate, coagulants, or suspended solids which will also be removed with the process).

Additional analysis should also include identifying appropriate disposal methods for the sludge and their costs, the cost to bring all waters to a centralized location for treatment, and the cost to distribute the water appropriately to the existing distribution systems. Additionally, the lime softening process will result in a change of water chemistry in the existing distribution system. Thus, a study of what will happen to the existing scale in the distribution system through a pipeloop study is recommended to be performed.

Finally, it should be noted that for the lime softening process to have a significant affect on the WWTP TDS concentrations, an effective campaign to curtail the use of home and commercial ion exchange softening systems will be needed. Thus, the utilities working with their respective municipal governments will continue their ongoing efforts to implement effective public awareness program and/or home softening removal program, so that current softeners are no longer used. Thus, future cost estimates should include the cost for this public awareness program, as well as a potential home/commercial ion exchange removal program.

# Attachment A

## Summary of TDS Reductions in the Drinking Water Utilizing a Centralized Lime Softening Facility

# Softening Hollister Well Water & Blending with Non-softened Surface Water
# Compared with Softening All Hollister Waters

**Hollister Water Quality Data**

| Parameters/Water Source | COH (Wells) | LESSALT (Surf Water) | SSCWD (Wells) | All Waters Blended | Only Well Water Blended | |
|---|---|---|---|---|---|---|
| % of Total Water Source | 69% | 24% | 7% | | | |
| TDS | 627 | 300 | 775 | 558.88 | 640.63 | mg/l |
| Total Hardness (CaCO3) | 334 | 100 | 393 | 281.97 | 339.43 | mg/l as CaCO3 |
| Calcium (Ca) | 51 | 21 | 70 | 45.13 | 52.75 | mg/l |
| Calcium (CaCO3) | 127.36 | 52.44 | 174.81 | 112.70 | 131.73 | mg/l as CaCO3 |
| Magnesium (Mg) | 50 | 12 | 53 | 41.09 | 50.28 | mg/l |
| Magnesium (CaCO3) | 205.84 | 49.40 | 218.20 | 169.16 | 206.98 | mg/l as CaCO3 |
| Sodium (Na) | 98 | 48 | 84 | 85.02 | 96.71 | mg/l |
| Potassium (K) | 2.4 | 2.9 | 1.1 | 2.43 | 2.28 | mg/l |
| Chloride (Cl) | 83 | 76 | 96 | 82.23 | 84.20 | mg/l |
| Sulfate (SO4) | 179 | 43 | 240 | 150.63 | 184.62 | mg/l |
| Total Alkalinity (CaCO3) | 264 | 80 | 295 | 222.01 | 266.86 | mg/l as CaCO3 |
| Bicarbonate (HCO3) | 323 | 80 | 295 | 262.72 | 320.42 | mg/l |
| pH | 7.5 | 8.3 | 7.8 | 7.6174 | 7.5204 | |

| Atomic & Compound Weights | | |
|---|---|---|
| Ca | 40.08 | mg/mole |
| Mg | 24.312 | mg/mole |
| Na | 22.9898 | mg/mole |
| K | 39.102 | mg/mole |
| Cl | 35.453 | mg/mole |
| C | 12.011 | mg/mole |
| SO4 | 96.0616 | mg/mole |
| CaCO3 | 100.09 | mg/mole |

Notes:
1) according to Table 10.4 from AWWA Water Quality & Treatment, when Total Hardness > 300 mg/l as CaCO3 the water is considered to be very hard.
2) Values for Total Alkalinity and Bicarbonate are approximated base on blending ratios; actual concentrations will vary as they are dependent on the final pH of the blended water.

**<u>TDS Concentration Reduction By Lime Softening (1) All Waters, & (2) Well Waters then Blend with Non-softened Surface Water</u>**

Lime softened water will have the following Ca & Mg concentrations:
Softened water Ca will be between 30 & 50 mg/l as CaCO3, use 40
Softened water Mg will be between 10 & 20 mg/l as CaCO3, use 15

40 mg/l of Ca as CaCO3 = 9.72 mg/l of Ca
15 mg/l of Mg as CaCO3 = 3.45 mg/l of Mg

| | **Softened Well & Surface Waters (mg/l)** | **Softened Well Water Only (mg/l)** |
|---|---|---|
| Amount of Ca that could be removed by lime softening = | 35.41 | 43.03 |
| Amount of Mg that could be removed by lime softening = | 37.64 | 46.83 |
| Combined amount of Ca & Mg that could be removed by lime softening = | 73.06 | 89.86 |
| TDS of Well Water after softening (just Ca & Mg reduction) = | | 550.77 |
| **TDS of Softened Well Water blended with Non-softened Surface Water (just Ca & Mg reduction) =** | | **490.58** |
| **TDS when all waters (well & surface) are blended and softened (just Ca & Mg reduction) =** | **485.82** | |
| **Total Hardness when only well waters are softened and blended with non-softened surface water (as CaCO3) =** | | **65.80** |
| **Total Hardness when all waters are blended and then softened (as CaCO3) =** | **55.00** | |

**The actual resulting TDS may be less as the softening process will likely precipitate other TDS elements also, such as iron, silica and arsenic, and alkalinity will be removed. Jar testing will give best results to determine actual TDS after softening.**

# Softening Sunnyslope Well Water & Blending with Non-softened Surface Water
# Compared with Softening All Sunnyslope Waters

## Sunnyslope Water Quality Data

| Parameters/Water Source | SSCWD (Wells) | LESSALT (Surf Water) | COH (Wells) | All Waters Blended | Only Well Water Blended | |
|---|---|---|---|---|---|---|
| % of Total Water Source | 68% | 29% | 3% | | | |
| TDS | 775 | 300 | 627 | 632.81 | 768.75 | mg/l |
| Total Hardness (CaCO3) | 393 | 100 | 334 | 306.26 | 390.51 | mg/l as CaCO3 |
| Calcium (Ca) | 70 | 21 | 51 | 55.22 | 69.20 | mg/l |
| Calcium (CaCO3) | 174.81 | 52.44 | 127.36 | 137.90 | 172.80 | mg/l as CaCO3 |
| Magnesium (Mg) | 53 | 12 | 50 | 41.02 | 52.87 | mg/l |
| Magnesium (CaCO3) | 218.20 | 49.40 | 205.84 | 168.88 | 217.67 | mg/l as CaCO3 |
| Sodium (Na) | 84 | 48 | 98 | 73.98 | 84.59 | mg/l |
| Potassium (K) | 1.10 | 2.90 | 2.40 | 1.661 | 1.15 | mg/l |
| Chloride (Cl) | 96 | 76 | 83 | 89.81 | 95.45 | mg/l |
| Sulfate (SO4) | 340.00 | 43.00 | 179.00 | 249.04 | 333.20 | mg/l |
| Total Alkalinity (CaCO3) | 295 | 80 | 264 | 231.72 | 293.69 | mg/l as CaCO3 |
| Bicarbonate (HCO3) | 295 | 80 | 323 | 233.49 | 296.18 | mg/l |
| pH | 7.8 | 8.3 | 7.5 | 7.8801 | 7.7821 | |

| Atomic & Compound Weights | | |
|---|---|---|
| Ca | 40.08 | mg/mole |
| Mg | 24.312 | mg/mole |
| Na | 22.9898 | mg/mole |
| K | 39.102 | mg/mole |
| Cl | 35.453 | mg/mole |
| C | 12.011 | mg/mole |
| SO4 | 96.0616 | mg/mole |
| CaCO3 | 100.09 | mg/mole |

Notes
1) according to Table 10.4 from AWWA Water Quality & Treatment, when Total Hardness > 300 mg/l as CaCO3 the water is considered to be very hard.
2) Values for Total Alkalinity and Bicarbonate are approximated base on blending ratios; actual concentrations will vary as they are dependent on the final pH of the blended water.

## TDS Concentration Reduction By Lime Softening (1) All Waters, & (2) Well Waters then Blend with Non-softened Surface Water

Lime softened water will have the following Ca & Mg concentrations:
Softened water Ca will be between 30 & 50 mg/l as CaCO3, use 40
Softened water Mg will be between 10 & 20 mg/l as CaCO3, use 15

40 mg/l of Ca as CaCO3 = 9.72 mg/l of Ca
15 mg/l of Mg as CaCO3 = 3.45 mg/l of Mg

| | **Softened Well & Surface Waters (mg/l)** | **Softened Well Water Only (mg/l)** |
|---|---|---|
| Amount of Ca that could be removed by lime softening = | 45.50 | 59.48 |
| Amount of Mg that could be removed by lime softening = | 37.57 | 49.43 |
| Combined amount of Ca & Mg that could be removed by lime softening = | 83.08 | 108.91 |
| TDS of Well Water after softening (just Ca & Mg reduction) = | | 659.84 |
| **TDS of Softened Well Water blended with Non-softened Surface Water (just Ca & Mg reduction) =** | | **555.48** |
| **TDS when all waters (well & surface) are blended and softened (just Ca & Mg reduction) =** | **549.73** | |
| **Total Hardness when only well waters are softened and blended with non-softened surface water (as CaCO3) =** | | **68.05** |
| **Total Hardness when all waters are blended and then softened (as CaCO3) =** | **55.00** | |

**The actual resulting TDS may be less as the softening process will likely precipitate other TDS elements also, such as iron, silica and arsenic, and alkalinity will be removed. Jar testing will give best results to determine actual TDS after softening.**

# Attachment B

## Summary of TDS Reductions at the WWTP by Utilizing a Centralized Lime Softening Facility

### Hollister combined source water has the following characteristics & concentrations

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Ca = | 45.13 | mg/l | 8.08% | of the TDS | Ca = | 112.70 | mg/l as CaCO3 |
| Mg = | 41.09 | mg/l | 7.35% | of the TDS | Mg = | 169.16 | mg/l as CaCO3 |
| Na = | 85.02 | mg/l | 15.21% | of the TDS | | | |
| K = | 2.429 | mg/l | 0.43% | of the TDS | | | |
| Cl = | 82.23 | mg/l | 14.71% | of the TDS | | | |
| SO4 = | 150.63 | mg/l | 26.95% | of the TDS | | | |
| TDS = | 558.88 | mg/l | 72.74% | Sum of the above percentages | | | |
| Undefined = | 152.351 | mg/l | 27.26% | of the TDS | | | |

| Atomic/Compund Weights | | |
|---|---|---|
| Ca | 40.08 | mg/mole |
| Mg | 24.312 | mg/mole |
| Na | 22.9898 | mg/mole |
| K | 39.102 | mg/mole |
| Cl | 35.453 | mg/mole |
| SO4 | 96.0616 | mg/mole |
| CaCO3 | 100.09 | mg/mole |

Ca + Mg = 86.22 mg/l 15.43%

Hardness (Calculated) = 281.86 mg/l as CaCO3 (calculated, using only Ca & Mg)

Hardness (Recorded) = 281.97 mg/l as CaCO3

### Hollister WWTP water characteristics & concentrations

| | | | | |
|---|---|---|---|---|
| Ca = | 45.13 | mg/l | 3.69% | of the TDS, assumes the same as the raw water concentrations |
| Mg = | 41.09 | mg/l | 3.36% | of the TDS, assumes the same as the raw water concentrations |
| Na = | 258 | mg/l | 21.08% | of the TDS |
| Cl = | 316 | mg/l | 25.82% | of the TDS |
| K = | 2.429 | mg/l | 0.20% | of the TDS, assumes the same as the raw water concentrations (likely higher from IX softeners that use KCl) |
| SO4 = | 225 | mg/l | 18.38% | of the TDS |
| TDS = | 1224 | mg/l | 72.52% | Sum of the above percentages |
| Undefined = | 336.351 | mg/l | 27.48% | of the TDS |

### Raw Water & WWTP Water Concentration Comparisons

Total TDS increase = 665.12 mg/l % increase = 119.01% , Close to doubling
WWTP Influent Na increases by = 172.98 mg/l
Moles that Na increased = 7.52 moles
WWTP Influent Cl increases by = 233.77 mg/l
Moles that Cl increased = 6.59 moles
INTERESTING, Cl increase is less than Na increase, I would expect it to be the same or higher as some IX softeners use potassium chloride softening salt
WWTP Influent K increases by = 0 mg/l
Moles that K increased = 0.00 moles
Moles of Na + K = 7.52 moles

### Ion Exchange Softening

Moles Na would increase if all of Ca and Mg were exchanged with Na thru Ion Exchange
Moles of Ca = 1.13 moles
Moles of Mg = 1.69 moles
Total Moles of divalent Ca & Mg = 2.82 moles
For every Ca and Mg ion, 2 Na (or K) ions are added back to the water.
Moles of monovalent Na (or K) exchanged for moles of Ca & Mg = 5.63 moles
Amount of Na in excess of calculated amount = 1.89 moles
likely from excess salt during the ion exchange regeneration process

### TDS Concentration Reduction By Lime Softening the Drinking Water

Lime softened water will have the following Ca & Mg concentrations:
Softened water Ca will be between 30 & 50 mg/l as CaCO3, use 40
Softened water Mg will be between 10 & 20 mg/l as CaCO3, use 15

40 mg/l of Ca as CaCO3 = 16.02 mg/l of Ca
15 mg/l of Mg as CaCO3 = 3.64 mg/l of Mg

Amount of Ca that could be removed by softening blended raw water = 29.11 mg/l
Amount of Mg that could be removed by softening blended raw water = 37.45 mg/l
Combined amount of Ca & Mg that could be removed by softening blended raw water = 66.56 mg/l
% of TDS = 11.91%
**Resulting TDS in raw water from lime softening (Ca & Mg removal only accounted for) = 492.32 mg/l**

**The actual resulting TDS may be less as the softening process will likely precipitate some of the undefined TDS also, such as iron, silica and arsenic.**

**Best way to determine this is to conduct some lime softening jar tests & chemical analysis of the waters before and after softening.**

### Reduction in Wastewater TDS from Lime Softening

Moles of Ca that could be removed by lime softening raw water = 0.73 moles
Moles of Mg that could be removed by lime softening raw water = 1.54 moles
Total moles of Ca & Mg that could be removed by lime softening raw water = 2.27 moles
Total moles of Na that would not be added by lime softening raw water = 4.53 moles
mg/l of Na that would not be added by lime softening raw water = 104.22 mg/l
Total moles of Cl that would not be added by lime softening raw water = same as Na = 4.53 moles
mg/l of Cl that would not be added by lime softening raw water = 160.72 mg/l
Total mg/l (Ca+Mg+Na+Cl) that would be reduced by lime softening raw water = 331.49 mg/l
**Note** - this reduction amount will likely increase as a higher increase in Na results than is calculated above, & there is likely to be a reduction in excess salt from the ion-exchange regeneration process.

**TDS in WWTP water could theoretically be reduced by the amount above making the TDS =** 892.51 mg/l

**IN ACTUALITY THIS REDUCTION WILL LIKELY BE MORE AS IT APPEARS AN ACCESS OF Na, Cl ARE RESULTING FROM THE ION-EXCHANGE SOFTENERS WHEN THEY REGENERATE**

If all water softeners were eliminated, then theoretically the NA & K & CL concentrations would be similar to what they are in the source water. Thus, **a further reduction of approximately 142 mg/l could result** if all home/business ion-exchange softeners were removed. I know that the possibility of this is remote, but a publicity campaign by the City could help to persuade many users to discontinue the use of home softeners.

If excess amounts of Na & Cl are eliminated then the TDS could be = 750.69 mg/l

**Additionally, further reduction off TDS would result as lime softening chemical precipitation will typically remove iron, silica and arsenic from the source waters, and which are a percentage of the raw water undefined TDS amount.**

| | | |
|---|---|---|
| Excess amount of Na = | 68.76 | mg/l |
| Excess amount of K = | 0 | mg/l |
| Excess amount of Cl = | 73.05 | mg/l |
| Total | 141.82 | mg/l |

Total TDS Reduction = 473.31 mg/l

### Sunnyslope combined source water has the following characteristics & concentrations

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Ca = | 55.22 | mg/l | 8.73% | of the TDS | Ca = | 137.90 | mg/l as CaCO3 |
| Mg = | 41.02 | mg/l | 6.48% | of the TDS | Mg = | 168.88 | mg/l as CaCO3 |
| Na = | 73.98 | mg/l | 11.69% | of the TDS | | | |
| K = | 1.661 | mg/l | 0.26% | of the TDS | | | |
| Cl = | 89.81 | mg/l | 14.19% | of the TDS | | | |
| SO4 = | 249.04 | mg/l | 39.35% | of the TDS | | | |
| TDS = | 632.81 | mg/l | 80.71% | Sum of the above percentages | | | |
| Undefined = | 122.079 | mg/l | 19.29% | of the TDS | | | |

| Atomic/Compund Weights | | |
|---|---|---|
| Ca | 40.08 | mg/mole |
| Mg | 24.312 | mg/mole |
| Na | 22.9898 | mg/mole |
| K | 39.102 | mg/mole |
| Cl | 35.453 | mg/mole |
| SO4 | 96.0616 | mg/mole |
| CaCO3 | 100.09 | mg/mole |

Ca + Mg = 96.24 mg/l 15.21%
Hardness (Calculated) = 306.77 mg/l as CaCO3 (calculated, using only Ca & Mg)
Hardness (Recorded) = 306.26 mg/l as CaCO3

### Hollister WWTP water characteristics & concentrations

| | | | | |
|---|---|---|---|---|
| Ca = | 55.22 | mg/l | 4.51% | of the TDS, assumes the same as the raw water concentrations |
| Mg = | 41.02 | mg/l | 3.35% | of the TDS, assumes the same as the raw water concentrations |
| Na = | 258 | mg/l | 21.08% | of the TDS |
| Cl = | 316 | mg/l | 25.82% | of the TDS |
| K = | 1.661 | mg/l | 0.14% | of the TDS, assumes the same as the raw water concentrations (likely higher from IX softeners that use KCl) |
| SO4 = | 225 | mg/l | 18.38% | of the TDS |
| TDS = | 1224 | mg/l | 73.28% | Sum of the above percentages |
| Undefined = | 327.099 | mg/l | 26.72% | of the TDS |

### Raw Water & WWTP Water Concentration Comparisons

Total TDS increase = 591.19 mg/l % increase = 93.42% , Nearly doubles
WWTP Influent Na increases by = 184.02 mg/l
Moles that Na increased = 8.00 moles
WWTP Influent Cl increases by = 226.19 mg/l
Moles that Cl increased = 6.38 moles
INTERESTING, Cl increase is less than Na increase, I would expect it to be the same or higher as some IX softeners use potassium chloride softening salt
WWTP Influent K increases by = 0 mg/l
Moles that K increased = 0.00 moles
Moles of Na + K = 8.00 moles

### Ion Exchange Softening

Moles Na would increase if all of Ca and Mg were exchanged with Na thru Ion Exchange
Moles of Ca = 1.38 moles
Moles of Mg = 1.69 moles
Total Moles of divalent Ca & Mg = 3.06 moles
For every Ca and Mg ion, 2 Na (or K) ions are added back to the water.
Moles of monovalent Na (or K) exchanged for moles of Ca & Mg = 6.13 moles
Amount of Na in excess of calculated amount = 1.87 moles
likely from excess salt during the ion exchange regeneration process

### TDS Concentration Reduction By Lime Softening the Drinking Water

Lime softened water will have the following Ca & Mg concentrations:
Softened water Ca will be between 30 & 50 mg/l as CaCO3, use 40
Softened water Mg will be between 10 & 20 mg/l as CaCO3, use 15

40 mg/l of Ca as CaCO3 = 16.02 mg/l of Ca
15 mg/l of Mg as CaCO3 = 3.64 mg/l of Mg

Amount of Ca that could be removed by softening blended raw water = 39.20 mg/l
Amount of Mg that could be removed by softening blended raw water = 37.38 mg/l
Combined amount of Ca & Mg that could be removed by softening blended raw water = 76.58 mg/l
% of TDS = 12.10%
**Resulting TDS in raw water from lime softening (Ca & Mg removal only accounted for) = 556.23 mg/l**

**The actual resulting TDS may be less as the softening process will likely precipitate some of the undefined TDS also, such as iron, silica and arsenic.**

**Best way to determine this is to conduct some lime softening jar tests & chemical analysis of the waters before and after softening.**

### Reduction in Wastewater TDS from Lime Softening

Moles of Ca that could be removed by lime softening raw water = 0.98 moles
Moles of Mg that could be removed by lime softening raw water = 1.54 moles
Total moles of Ca & Mg that could be removed by lime softening raw water = 2.52 moles
Total moles of Na that would not be added by lime softening raw water = 5.03 moles
mg/l of Na that would not be added by lime softening raw water = 115.66 mg/l
Total moles of Cl that would not be added by lime softening raw water = same as Na = 5.03 moles
mg/l of Cl that would not be added by lime softening raw water = 178.36 mg/l
Total mg/l (Ca+Mg+Na+Cl) that would be reduced by lime softening raw water = 370.60 mg/l
**Note** - this reduction amount will likely increase as a higher increase in Na results than is calculated above, & there is likely to be a reduction in excess salt from the ion-exchange regeneration process.

**TDS in WWTP water could theoretically be reduced by the amount above making the TDS =** 853.40 mg/l

**IN ACTUALITY THIS REDUCTION WILL LIKELY BE MORE AS IT APPEARS AN ACCESS OF Na, Cl ARE RESULTING FROM THE ION-EXCHANGE SOFTENERS WHEN THEY REGENERATE**

If all water softeners were eliminated, then theoretically the NA & K & CL concentrations would be similar to what they are in the source water. Thus, **a further reduction of approximately 116 mg/l could result** if all home/business ion-exchange softeners were removed. I know that the possibility of this is remote, but a publicity campaign by the City could help to persuade many users to discontinue the use of home softeners.

If excess amounts of Na & Cl are eliminated then the TDS could be = 737.21 mg/l

**Additionally, further reduction off TDS would result as lime softening chemical precipitation will typically remove iron, silica and arsenic from the source waters, and which are a percentage of the raw water undefined TDS amount.**

| | | |
|---|---|---|
| Excess amount of Na = | 68.36 | mg/l |
| Excess amount of K = | 0 | mg/l |
| Excess amount of Cl = | 47.83 | mg/l |
| Total | 116.19 | mg/l |

Total TDS Reduction = 486.79 mg/l