Technical Memorandum
Chalk Creek Treatment Feasibility Assessment

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EXECUTIVE SUMMARY

Background

Chalk Creek is located in northwest Reno and is one of several small creeks that flow into the Truckee River. Within the past 30 years, much of the watershed has been covered in single family dwellings. Prior to urbanization, Chalk Creek was generally dry, with little evidence of an established waterway. Water quality monitoring indicates that the creek contains relatively high levels of total dissolved solids (at approximately 2,600 mg/L) and flows year-round at approximately 240 gallons per minute. The concentration of total dissolved solids (TDS) in the Truckee River is of significance since the loading affects long term water quality at Pyramid Lake. By itself, Chalk Creek is not a major contributor of TDS to the Truckee River, but control of TDS here and elsewhere would have positive implications throughout the watershed.

Presented in this memo is a simple analysis of structural and non-structural treatment alternatives to reduce TDS (and nitrogen and phosphorus to a lesser extent) in Chalk Creek water ultimately to reduce the burden on the Truckee River. Technologies were evaluated on a cursory basis appropriate for planning purposes.

Approach

Initially, a list of technologies, methods, and ideas (for TDS mitigation) was assembled through research and discussion with local experts. Next, the alternatives were broken down into advanced, biological or non-treatment type alternatives and the utility and efficacy of each was investigated. Altogether, 12 different treatment alternatives were identified (Table ES-1). A full description of each alternative is presented in Section 2 of this memorandum.

To evaluate the treatment alternatives, five different assessments falling within three general categories (treatment efficiency, facility requirements and feasibility) were used. Fifty percent of the points were issued based on whether the proposed alternative would work (will it remove TDS from this water?) and how reliable it is. Twenty five percent of the points were issued based on facility size, capital, O&M and waste disposal costs. The remaining 25 percent of the evaluation matrix points were issued based on environmental, regulatory and aesthetics. Within each ranking category, each alternative was scored between 1 and 10 points (1 = poor, 10 = excellent) and then multiplied by the ranking criteria weighting factor. Lastly, the points were summarized. If the solution was viable only in the summer or for some fraction of the year, points were adjusted in proportion to the estimated months of service.

Table ES-1
Treatment Alternatives for the Mitigation of TDS in Chalk Creek

Advanced	Biological	Non-Treatment
Reverse Osmosis	Sulfate Reducing Wetland	Source Control
VSEP Membrane	Sulfate Reducing Bioreactor	Pump to the North Valleys
Ion Exchange		Export via Ditch
Chemical Precipitation		Blend with Chalk Bluff Supply
Evaporation		Deep Well Injection

Results

The advanced treatment alternatives (ion exchange, membrane treatment, chemical precipitation, etc.) all utilize “high-technology” type water treatment equipment. These systems, while very effective in removing TDS, are spectacularly expensive to build and operate. All of these advanced systems generate tons of waste per day, so operation and disposal would be on-going issues. These systems would return the water into the Truckee River and would most certainly be granted pollution trading credits for each pound of regulated contaminant removed.

Of the two different biological treatment alternatives, one was an industrial type process with tanks and reactors (sulfate reducing bioreactor) and the other a specialized wetland system. Both rely on the bacterial conversion of sulfate. Sulfate accounts for approximately one-half of the TDS. Therefore, even if these processes are 100 percent efficient in removing sulfate, half of the TDS (1,250 mg/L) would remain in the creek water. The bioreactor would require a facility similar to the advanced processes and would operate year-round. The wetland would require considerable acreage, function only seasonally and perhaps emit odors as sulfide is produced.

Several non-treatment type options were evaluated that did not remove any TDS from the Chalk Creek water, but rather transported water away from the Truckee River. One scenario involved pumping the Chalk Creek water to the North Valleys and into a playa lake. Another non-treatment alternative was to blend the water with the Chalk Bluff raw water supply and transform it into drinking water. Other alternatives considered included putting the Chalk Creek water into Highland or Orr Ditch and using the water for agricultural applications.

After identifying, analyzing and scoring the treatment alternatives, the three ranked treatment alternatives were:

1) Source Control (5.75 pts)
2) VSEP Membrane Treatment (5.60 pts)
3) Export via Ditch (also 5.60 pts)

Export via Ditch. Diverting the outfall of Chalk Creek into the Orr Ditch and away from directly entering the Truckee River is perhaps the easiest of any of the alternatives to implement. The flow rates are such that Chalk Creek water would be diluted over 30 times, and the sulfate and calcium in the water would actually improve the ditch water quality from an agricultural standpoint. The costs associated with this alternative are piping, pumping and diversion costs, estimated to be approximately $750,000. The limitations of this solution are that it is a seasonal solution and the TDS is not actually removed from the watershed. Although the Orr Ditch is privately held, it is likely that this scenario would be permitted; however, it is unknown if TDS removal credits would be issued.

VSEP Membrane Treatment Plant. The advanced membrane process (VSEP) tied for second (with the Orr Ditch alternative) in the treatment alternative analysis because of its ability to remove TDS and some improvements over IX or RO. A VSEP plant would be capable of removing a high degree (98%) of TDS on a year-round basis. Such a plant would most certainly be eligible for pollutant trading credits but would be expensive to build (~$9 million) and operate (estimated $1.5 million/yr). Second only to cost, the largest obstacle of this type of process is the volume of solids generated (~8,000 to 16,000 lbs/day).

Source Control. Source control ranked the highest of all of the treatment alternatives because of the low capital, O&M and disposal costs as well as being the most environmentally friendly and easy to permit. Although source control is potentially a year-round solution, it did not score high marks in the efficiency / “will it work?” category. A source control program may or may not work, but economically, it is the first treatment alternative that should be attempted. A source control program would likely target the reduction of flow in Chalk Creek, but alternatively it might attempt to reduce contamination in the water (TDS, nitrogen and phosphorus).

It is recommended that a pilot source control program be developed and implemented for Chalk Creek. Since the flow (and elevated TDS) in Chalk Creek has been attributed to homeowner irrigation seepage and local geology, it is conceivable that an isolated neighborhood should be selected for such a pilot program. Public awareness of water usage, water schedules, mulching and xeriscape conversion are just some of the possibilities for a source control effort. If the flow in Chalk Creek can be reduced or halted, an important source of TDS to the Truckee River can be mitigated.

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1.0 INTRODUCTION

Chalk Creek is one of several small, perennial (year-round) tributaries to the Truckee River located in northwest Reno that drain foothill watersheds with appreciable residential urbanization. Most of the residential growth has occurred in the last 2 to 20 years. Prior to this growth, these creeks were at best, ephemeral (intermittent). Recent water quality monitoring of Chalk Creek revealed that the runoff contained high levels of total dissolved solids (TDS, at approximately 2,600 mg/L). Monitoring data indicate that Chalk Creek flows year-round at an average flow rate of approximately 240 gallons per minute (gpm, rounded to 250 for design estimations). The concentration of TDS in the Truckee River is of significance since the loading affects long-term water quality at Pyramid Lake. By itself, Chalk Creek is not a major contributor of TDS to the Truckee River, but control of TDS here and elsewhere would have positive implications throughout the watershed.

Presented in this memo is a planning level analysis of alternatives to reduce the TDS in Chalk Creek water and ultimately reduce the load on the Truckee River. In this memo, our understanding of contributing sources of salts (making up the TDS) is discussed as well as possible technologies and approaches to mitigate the effects. Technologies were evaluated on a cursory basis appropriate for planning purposes.

1.1 BACKGROUND AND LOCATION

Chalk Creek transmits water from the south slope of Peavine Mountain, through various drainages east of Sierra Highlands Drive and west of Northgate Golf Course (Townships 19 and 20 North, Range 19 East). The Chalk Creek drainage and associated tributaries run through most neighborhoods in the Mae Anne Avenue, Robb Drive and Aveneda de Landa area of Northwest Reno. Chalk Creek enters the Truckee River about 1 mile upstream of the intersection of West McCarran Boulevard and East 4th Street.

The geology of the area is primarily quaternary pediment gravels, silt, clay, and sand interbedded and draped over the bedrock. Dominant units include the Hunter Creek tertiary sandstone and the cemented diatomaceous siltstone (Chalk formation). Surface soils are primarily fluvial sediments and alluvium. Soils in the watershed are primarily silty and sandy loams over an expansive clay layer. This clay layer can be up to 3 feet in thickness and present problems with building foundations and septic system leaching if not properly mitigated (USDA, 1983).

1.2 UNDERSTANDING (SOURCE OF TDS)

Prior to residential development (1980), infrared aerial photography shows no riparian growth in the drainage. In 1989, when the watershed was being populated with residential dwellings, riparian growth was starting to be evident in the lower reaches of the Chalk Creek watershed. Aerial infrared photographs from 2006 show extensive riparian and adjacent plant growth in the watershed, indicative of the formation of a perennial stream. Recent monitoring shows that two tributaries contribute approximately 90 percent of the flow.

The source of perennial flow is thought to be seeps that occur between the contact of the soil profile and the hardpan (clay layers) or bed rock (diatomaceous silt bedrock). Surface water percolates down through the shallow soils, hits the confining layer and flows laterally, ultimately appearing as springs and seeps along the gullies and washes of Chalk Creek. The primary source of surface water within this urbanized watershed is most likely a result of residential lawn and landscape irrigation.

1.3 WATER QUANTITY AND QUALITY

Water quality data for Chalk Creek and the Truckee River are summarized in Table 1-1. Most of the Chalk Creek values listed are from a single grab sample collected on 1/9/07. Data for average TDS (calculated), electrical conductivity (EC) and pH are from semi-continuous (15 minute interval) sonde readings collected over a one year period (3/21/07 through 4/29/08).

Table 1-1
Summary of Average Water Quality for Chalk Creek and the Truckee River

Parameter	Unit	Chalk Creek[a]	Truckee River[c]
Total Dissolved Solids (TDS)	mg/L	2,660[b]	88[d]
Electrical Conductivity (EC)	µS	3,001[b]	130[d]
Turbidity (Turb)	NTU	1.5	0.2
pH	Std. Units	8.0[b]	7.8[d]
Alkalinity (Alk)	mg-$CaCO_3$/L	275	44[d]
Calcium (Ca)	mg/L	300	15
Magnesium (Mg)	mg/L	190	5
Hardness (Hard)	mg-$CaCO_3$/L	1,500	58
Sodium (Na)	mg/L	170	20
Potassium (K)	mg/L	<5	<5
Chloride (Cl)	mg/L	110	11
Sulfate (SO4)	mg/L	1,400	20
Nitrate + Nitrite (NO3+NO2)	mg-N/L	2.66[e]	<0.10
Total Kjeldahl Nitrogen (TKN)	mg-N/L	0.63[e]	0.37[d]
Total Nitrogen (calculated)	mg-N/L	3.28[e]	0.37
Total Phosphorus (Tot-P)	mg-P/L	0.37[e]	0.07[d]
Ortho-Phosphorus (O-P)	mg-P/L	-	0.02[d]
Arsenic (As)	µg/L	15	<1
Manganese (Mn)	mg/L	0.27	<0.01
Boron (B)	mg/L	<0.1	-

[a] Values from a grab sample collected 1/9/07, NV State Health Department Report #195518, unless noted
[b] Average values from TRIG website, semi-continuous sonde data collected every 15 minutes, 3/21/07 through 4/29/08
[c] Average of grab samples collected 2/4/08 and 1/26/09, TMWA Chalk Bluff, unless noted
[d] TRIG data for the Truckee River at McCarran, from 1985 to 2008, number of observations > 400.
[e] City of Reno grab samples collected May 2006 through Nov. 2007, number of observations > 75.

As can be seen from the water quality data listed in Table 1-1, the water in Chalk Creek is considerably different than the water in the Truckee River. The most significant difference is the

TDS, which is approximately 20 times higher in Chalk Creek than in the Truckee River. Sulfate (SO_4^{2-}) makes up the largest component of the TDS, followed by calcium, sodium and chloride. The high levels of divalent cations (calcium and magnesium) in the Chalk Creek water result in a very hard water (hardness of 1,500 mg-$CaCO_3$/L). Parameters over the primary and secondary maximum contaminant level (MCL) standards for drinking water are arsenic (MCL=10 μg/L), manganese (MCL=0.1 mg/L), sulfate (MCL=500 mg/L) and TDS (MCL=1,000 mg/L). Assuming the water does not need to be treated to drinking water standards, it is the high levels of TDS and sulfate that pose the largest potential impact to the Truckee River (nitrogen and phosphorus are a secondary concern).

The Chalk Creek stream flow rate was monitored semi-continuously (every 15 minutes) for over one year (from 3/21/07 through 4/29/08). The average recorded flow rate in Chalk Creek at the entrance to the Truckee River was 236 gpm. The typical flow rate in Chalk Creek ranged between 150 to 275 gpm (note: over 90 percent of the observations were within this range). The minimum recorded flow rate was 131 gpm (8/5/07) and the maximum was 780 gpm (1/4/08 storm event flow, TRIG Website, 2009). Wintertime flow rates (from November to April) are generally are near the average of 240 gpm.

1.4 ACTION, MOTIVATION AND POLLUTION TRADING CREDITS

Aside from being an asset to the neighborhoods, there are two primary reasons that the quality of the water in Chalk Creek is of concern. First, Chalk Creek is listed on the State of Nevada's "303(d) List" as being impaired. Secondly, Chalk Creek is a tributary to the Truckee River, in which there are existing Total Maximum Daily Loads (TMDLs) for several contaminants.

The 1974 Clean Water Act (CWA), under Section 303(d), required the states to develop a listing of impaired water bodies that need work beyond existing controls to achieve or maintain water quality standards. Nevada Division of Environmental Protection (NDEP) has submitted to EPA such a list, with the latest "final" version dated 2006 (as submitted February 2009). Chalk Creek was listed as being impaired with respect to high concentrations of sulfate, ortho-phosphorus, TDS, and selenium. The 303(d) listing is generally the first step in targeting a water body for a TMDL type regulation. If Chalk Creek ever becomes a priority to the State of Nevada, NDEP will first model the stream to determine load carrying capacities and the pollutant levels in which beneficial uses can be maintained. Next, load allocations (in lbs/day) are allocated to the various non-point sources, and point source, waste load allocations are assigned to the responsible parties. Recently, waste load allocations have been assigned to storm water runoff in some communities.

Chalk Creek is a tributary to the Truckee River. Following the 303(d) listing process described above, NDEP listed the Truckee River as impaired (in 1988) and subsequently developed TMDLs for nitrogen, phosphorous and TDS in 1994. As the major point source to the river, the Truckee Meadow Water Reclamation Facility (TMWRF) has waste loads incorporated into its National Pollutant Discharge Elimination System (NPDES) discharge permit. To manage the TMWRF discharge limits and constraints, several stakeholders (i.e., Reno, Sparks, Washoe

County, Tribe, etc.) within the Truckee River watershed have implemented various programs to collect data, develop models, and provide technical assistance related to water quality management efforts.

A provision in the CWA provides the framework for the establishment of a pollution credit trading program. Water quality trading can take many forms but usually involves the trading of pollutant loads by two or more parties to help solve regional water quality problems. These credits can be traded in such manner as to minimize economic hardship and maximize load reduction to the river. In this application, any load reduction in Chalk Creek could potentially be transferred to TMWRF and be credited toward its discharge rather than having to construct additional unit processes to comply with the TMDL. The reduction of nonpoint sources and the associated credits that TMWRF could receive is one means to enable TMWRF to comply with the TMDLs in the future.

The Washoe County Regional Water Planning Commission (RWPC) issued a report pertaining to the analysis of non-point source pollution trading for the mitigation of TDS in the Truckee River. In this report, several projects were identified and ranked for their potential to reduce TDS loading (Non-Point Source Pollution Trading Analysis Report, August 2004, Prepared for the Washoe County Regional Water Planning Commission, by Tetra Tech EM Inc., ECO:LOGIC, Desert Research Institute and Sue Oldham, Esq.). The highest ranked project with respect to cost and load reduction was the Mud Lake Slough wetland restoration project, near Pyramid Lake. Chalk Creek was also identified as a highly rated alternative.

This report also contains an analysis of a potential pollution trading credit program for the Truckee River Basin and the benefit to the region and TMWRF. Seven trading program elements were listed. They are:

Trading Program Elements (RWPC, 2004)

A. Legal Authority

B. Clearly Defined Units of Trade

C. Creation and Duration of Credits

D. Quantifying Credits and Uncertainty

E. Compliance and Enforcement

F. Public Participation

G. Periodic Evaluations of Environmental and Economic Effectiveness

For this application, the Clean Water Act provides the legal authority for Environmental Protection Agency (EPA), NDEP and the Pyramid Lake Paiute Tribe (Tribe) to develop a trading program. To generate TDS pollution trading credits for TMWRF, the facility's NPDES permit would be the regulatory mechanism by which trading would occur (RWPC, 2004). Units of trade must be pollutant specific using definable and reliable methodology. The credits should be generated before or during the period being applied. Credits are earned only if expected reductions are quantifiable. Procedures for the determination of this (TDS reduction) must be in place prior to the onset of the program.

With reductions in TDS coming from mostly non-point sources, there will be uncertainty in treatment performance, effectiveness and utility. The EPA has provided for some alternate approaches that can be used to compensate for uncertainty, such as using and applying trading ratios, performance values, conservative assumptions, discount factors and credit pools. These approaches are situational and project specific. Additional detail can be found in various EPA documents (see USEPA 1991, 1996, 2004, and 2007).

Public support, progress monitoring and record keeping are essential components of any pollution trading program. Monitoring, record keeping, reporting and inspections are vital to document success. As with most complex environmental endeavors, public participation and acceptance is critical to a workable solution. Lastly, the trading program should be subjected to continued evaluation to ensure that it is protecting the resource, maintaining beneficial use and making sense environmentally and economically.

1.5 SCOPE OF THIS ANALYSIS

The scope of this analysis was to determine the alternatives and feasibility for treating Chalk Creek water to reduce TDS as the primary contaminant, with potential secondary reductions of total nitrogen and total phosphorous. The level of detail investigated was limited to the determination of technical feasibility (i.e. will it work?), the track record, estimated costs, regulatory and implementation considerations. Additional analysis, pilot studies, permitting and design work would be required to identify all of the issues, considerations and costs associated with the actual implementation of the alternatives presented in this feasibility assessment.

1.6 ORGANIZATION OF THIS MEMORANDUM

The focus of this memo is the identification and analysis of alternatives for the mitigation of Chalk Creek TDS loading to the Truckee River. The treatment alternatives for TDS mitigation are the subject of Section 2 of this memo. Alternatives considered are broken down into advanced systems, biological treatment alternatives and non-treatment alternatives. It is assumed that pollution trading credits could be obtained for any net removal of nutrients and TDS under the existing Truckee River TMDL framework. Therefore, a primary consideration in this evaluation was that the treatment alternatives actually remove TDS (and nutrients) from the system, rather than simply transport them to another location within the Truckee River watershed. At the end of Section 2, a simple ranking system was devised and used to identify the "best" approaches for mitigating the TDS impacts on the Truckee River. Maximum points were issued to year-round solutions.

As will be seen from the ranking in Section 2, there are no easy solutions. Many of the treatment alternatives score about the same. In Section 3, the top ranked approaches are presented in more detail. Summarized in Section 4 are some recommendations and conclusions pertaining to the overall feasibility of treating the water from Chalk Creek. This analysis and associated memo is only a planning level investigation. Additional scrutiny is required before any of these recommendations and/or alternatives can be advanced.

2.0 TREATMENT ALTERNATIVES (FOR TDS MITIGATION)

Loading of TDS (and nutrients) to the Truckee River can be reduced by decreasing their concentration in Chalk Creek or by reducing the volume of water flowing in the creek. Treatment alternatives considered include advanced and biological treatment systems that are capable of reducing the concentration of TDS in the creek. Non-treatment options, which don't remove TDS but do reduce the flow, include export and source reduction. Each of the treatment alternatives are briefly discussed in the following subsections.

2.1 ADVANCED TREATMENT ALTERNATIVES

So-called advanced treatment technologies are those used for the purification of water in industrial or municipal applications. These systems require equipment, land, electrical power and operator attention and remove dissolved solids by some physical means. The technologies presented here are all capable of substantial (or near complete) removal of TDS, but the level of plant sophistication is high and they require considerable capital and O&M costs.

2.1.1 Conventional Reverse Osmosis

In reverse osmosis (RO), contaminated water is forced through a membrane using pressure. Clean water passes through while salts and particles remain on the other side. A common application of RO is the desalinization of sea water. System pressure and treatment efficiency are a function of the membrane selected and the water being treated.

A typical RO treatment facility has three major components: a pretreatment unit, the actual RO modules and a tank to store (or further concentrate) the reject water (containing the removed material). The pretreatment step is critical because RO membranes can quickly foul with large particles. Conventional treatment (i.e., coagulation, flocculation, sedimentation, and filtration) processes can be used for RO pretreatment; however, integrated membrane systems (e.g., pretreatment with micro (or ultra) filtration before RO) are becoming the industry standard.

Reverse osmosis is capable of a very high degree of TDS removal. Removal of TDS and nutrients (nitrogen and phosphorus) can be expected to exceed 80 percent. Reverse osmosis systems have been in use for decades and have a proven track record. New advances in membrane formulation allow for even greater efficiencies at lower operating pressures.

The byproduct produced by RO is a liquid waste stream (reject water) that contains all of the materials removed. Depending on the pressure, the membranes used, and the effectiveness of the pretreatment step, the waste stream can be 5 to 30 percent of the water being treated. In other words, in treating Chalk Creek with an average flow rate of 250 gpm, the volume of liquid waste from the RO membranes alone would be between 18,000 and 108,000 gallons per day (gpd). The pretreatment system will also generate a residual (solid or liquid depending on the system).

A RO-type treatment facility would require land, power and easy access (for waste hauling trucks to dispose of the liquid waste on a daily basis). Buildings to house the pretreatment and RO modules would be required along with tanks to hold the liquid waste stream. Some creek diversion structure and equilibration basin would also be necessary. A full time operator and waste hauler would likely be required. Routine maintenance includes cleaning of the pretreatment modules and RO membrane replacement. Operation and maintenance (O&M) costs for an RO facility of this size, including brine disposal, could be over a million dollars per year.

Such a facility can operate year-round, as long as there is flow in the creek. Operation (the number of modules in service) is flexible and can vary with flow rate. The treated water could be returned to the Truckee River, or potentially used to supplement potable supplies. Since salts are removed from the system, full pollution trading credits could be expected with this type of facility. Permits required would be similar to a drinking water treatment plant. On-site chemical storage would be required for membrane cleaning solutions, pH adjustment, etc. With land acquisition, earthwork, creek diversion, equipment, buildings and solids handling, this facility may cost somewhere between 6 to 10 million dollars to construct. Aside from the cost, the largest obstacle is the disposal of the salt laden reject water.

2.1.2 VSEP Membrane Filtration

The Vibratory Shear Enhanced Process (VSEP) process is an enhancement on the traditional membrane filtration process and perhaps well suited for this application. The VSEP is a propriety process marketed by New Logic Research, Emeryville California. With VSEP, a vibrating membrane mechanism and cross-flow dynamics allow for high throughput (membrane flux) and minimal pretreatment requirements.

A VSEP treatment facility may only have two components: the VSEP modules, and a small tank to store the reject water. Reportedly, the pretreatment step is non-critical because of the self-cleaning aspect of the VSEP process. Continuous backwashing is accomplished by the vibration and tangential flow path. The VSEP membrane system is a vertical plate and frame type construction where membrane leafs are stacked by the hundreds on top of each other. The result is that the horizontal footprint of the units is comparatively small.

The VSEP system is reportedly capable of even higher TDS removal than conventional RO. Removal of TDS and nutrients (nitrogen and phosphorus) is reportedly around 99 percent. The VSEP process is new and the track record for this type of application is somewhat uncertain.

As with RO, the byproduct produced by VSEP is a liquid waste stream (reject water) that contains all of the materials removed. Along with minimal pretreatment requirements, the major advantage of the VSEP process is the high flux rate. Reportedly, the waste stream is around 0.5 to 3 percent of the water being treated. For this application (Chalk Creek at 250 gpm), the volume of liquid waste generated from the VSEP process would be between 1,800 and 10,800 gpd. Because of the high salt content of this waste stream, the product may be a slurry of liquid and solid material.

A VSEP treatment facility would have nearly the same requirements as outlined for an RO facility (land, power and easy access for waste hauling). Because of the lack of a pretreatment system and the smaller footprint of the membranes, the building may be somewhat smaller. Tanks or vessels would still be required to contain and store the liquid waste stream, but they would be smaller in size than those required for a similar sized RO facility. Again, some creek diversion structure and equilibration basin would be necessary. O&M and waste disposal costs would be significant.

As with the RO facility, a VSEP plant can operate year-round, as long as there is flow in the creek. Operation (the number of modules in service) can vary with flow rate. The treated water could be returned to the Truckee River, or potentially used to supplement potable supplies. Since salts are removed from the system, full pollution trading credits could be expected. Permits are the same as with the RO plant. The cost of a VSEP facility can be expected to be more expensive than a traditional RO plant. A VSEP facility may cost around $9 million to build (see Section 3.2.4). Aside from the cost, the largest obstacle is the disposal of the salt laden reject water/slurry. A secondary consideration is the proprietary nature of the process and its limited track record.

2.1.3 Ion Exchange

Ion exchange (IX) systems use specially designed resin beds to swap (exchange) undesirable ions in the water being treated for desirable ones. Pretreated water is passed through columns of exchange resins and the ions contributing to TDS are preferentially removed. One bed will exchange anions (chloride, sulfate and phosphate) for hydroxide ions (OH^-). A second bed will exchange cations (calcium and magnesium) for hydrogen ions (H^+). Exhausted resin beds are regenerated by soaking in acid or base solutions. It is these regeneration solutions that are the primary waste streams associated with ion exchange facilities.

An IX type facility for this application would have about six essential process components. First, some type of pretreatment (likely microscreens) would be required to remove large materials that might foul the resin beds. Two different sets of resin beds (anion and cation) are required to remove the TDS and allow for one of each type to be in-service while the other is being backwashed or regenerated. Upon exhaustion, the resin beds are regenerated by filling the beds with a concentrated acid or base solution. This solution remains in contact with the resin until all of the sorbed materials (salts from the creek water) are displaced. Therefore, tanks containing the regeneration solutions, necessary pumps and a second set of tanks for the spent regenerant solution are required. Since the process is exchanging H^+ and OH^-, some adjustment of finished water pH may be required (effluent for the IX process is likely not pH neutral).

A properly operated IX treatment facility can be expected to remove about 90 percent of the TDS (effectively removing chloride, sulfate, calcium and magnesium). Lesser removals for ions with smaller charges or lower preference for the resins (like some nitrogen and phosphorus complexes) can be expected. Therefore, depending on the form, the removal of nitrogen and phosphorus from the creek water may be 40 to 60 percent. The IX process has been around for years and the track record is proven.

As with the membrane processes, the byproduct produced by IX is a liquid waste stream (waste regeneration solution) that contains all of the materials removed as well as some of the regenerant material. The volume of the waste stream is a function of the number of times per day that the IX tanks need to be regenerated and the tank volumes. A conservative estimation of the volume of waste solution is between 4,000 and 12,000 gpd. It is possible that the solutions can be combined to precipitate solid salts (calcium sulfate, i.e., gypsum), but piloting would be required to verify the efficacy.

An IX treatment facility would have nearly the same requirements as outlined for the membrane plants (land, power and easy access for waste hauling) with the addition of several more tanks for holding the regenerant solutions. Tanks, vessels or concentrators would be required to contain and store and process the liquid waste stream. As with the other options, some creek diversion structure and equilibration basin would be necessary. Routine maintenance would include cleaning and resin replacement. Most O&M costs would center around processing chemicals and disposing of the waste regenerant solutions.

As with the membrane type facilities, an IX plant can operate year-round, as long as there is flow in the creek. Operation can vary with flow rate. The treated water could be returned to the Truckee River, or potentially used to supplement potable supplies. Since salts are removed from the system, full pollution trading credits could be expected. The required permits for such a facility would be a bit more complicated because of the tanks of acid and base required for resin regeneration. The cost of an IX facility is likely similar to the other high-tech plants (somewhere between $6 to 8 million to construct). Again, aside from the cost, the largest obstacle is the disposal of the wastewater generated (regeneration solutions) and the large quantity of chemicals required.

2.1.4 Chemical Precipitation

Sulfate makes up the largest component of the Chalk Creek TDS. In mining and industrial wastewaters, chemical precipitation using lime is the most common method for the removal of sulfate. However, precipitation effectiveness is limited by the solution pH and the solubility of gypsum (calcium sulfate). With pH adjustment and additional chemicals beyond lime, it is possible to reduce the sulfate concentration down to around 250 mg/L (an 82 percent removal of SO_4^{2-}, or approximately a 60 percent reduction in TDS). Precipitation of sulfate by adding hydrated lime [$Ca(OH)_2$] to an acidic solution results in production of calcium sulfate according to the following reaction:

$$H_2SO_4 + Ca(OH)_2 \leftrightarrow CaSO_4 + 2H_2O$$

Calcium sulfate (gypsum) is soluble in water at a concentration around 1,400 mg-SO_4/L (at 20 °C, similar to the Chalk Creek sulfate concentration). Sulfate reduction below this level using hydrated lime is not possible. However, sulfate can be removed by the addition of calcium aluminate or aluminum hydroxide in the presences of quicklime (CaO). Either of these compounds precipitate sulfate ions as the mineral ettringite [$(CaO)_6(Al_2O_3)(SO_4)_3 \cdot 32\ H_2O$]. Precipitation of sulfate by adding quicklime and monocalcium aluminate to a sulfate containing water (Chalk Creek) results in production of ettringite (an insoluble precipitate) according to the following reaction:

$$5CaO + CaOAl_2O_3 \ + \ 3SO_4 \ \leftrightarrow \ (CaO)_6(Al_2O_3)(SO_4)_3$$

With gypsum at its limit of solubility, a chemical precipitation facility for the removal of sulfate from Chalk Creek can likely skip the initial lime precipitation step and progress to ettringite formation via quicklime and monocalcium aluminate addition (a single unit process). Calcium aluminate is dosed at the rate of approximately one pound of reagent per pound of sulfate. During ettringite precipitation, contaminants such as nitrate, chloride, fluoride, boron and metals may be removed (incorporated into the precipitate). Kinetically, this process takes 30 to 300 minutes, depending on the amount of reagent added, water temperature and level of sulfate removal required.

As a result of the quicklime addition, the solution pH of the water being treated will be high (approximately 11.5). Therefore, a second unit process, pH adjustment via acid addition or recarbonation (i.e., CO_2 addition), will be required. The sludge formed in ettringite precipitation and the recarbonation step will need to be dewatered separately in a centrifuge/filter press.

A chemical precipitation type process for this application will have four essential process components. Initially, quicklime and calcium aluminate are mixed with the creek water and transferred to a chemical clarifier. The settled precipitate is removed from the bottom of the clarifier and sent to a solids processing unit (centrifuge, filter press, drying bed). The treated water is then pH adjusted via acid addition or recarbonation. The solids are sent to a sludge press or similar unit process for the concentration of chemical solids.

A chemical precipitation system for sulfate removal can be expected to remove about 60 percent of the TDS (effectively removing sulfate to about 250 mg/L only). Lesser removals of nitrogen and phosphorus are possible via co-precipitation. The precipitation process for the removal of low levels of sulfate is somewhat uncommon, although precedented.

The byproduct of this process is a solid waste (the stable mineral ettringite) that can be disposed of in a sanitary landfill. The ettringite precipitate will need to be concentrated and dewatered, likely via conventional plate and press type system. The mass of solids produced per day is estimated at 8,000 to 10,000 pounds/per day.

A sulfate precipitation plant would require a series of mixers, clarifiers, chemical storage and solids handling facilities. Like the other advanced systems, land, power and easy access for waste hauling are required. Depending on the reaction kinetics, 7,500 to 75,000 gallon clarifiers are required to treat a Chalk Creek average flow rate of 250 gpm. A full-time operator and waste hauler would likely be required. Routine operation and maintenance would include replenishing chemicals, cleaning and solids handling.

As with the other advanced treatment plants, a precipitation plant can operate year-round, as long as there is flow in the creek. Operation will vary with flow rate and efficiency can be expected to decrease with water temperatures. The treated water would likely be returned to the Truckee River and TDS removal credits be issued depending on the net removal. The required permits for such a facility would need to include chemical handling and storage facilities. Construction costs are estimated to be similar to the other high-tech plants (around $7 to 9 million). Again, aside from the cost, significant obstacles are the chemical requirements and the ongoing disposal of the solids generated (this process will generate the largest amount of solids of any process).

2.1.5 Evaporation

Classified somewhere between a treatment and non-treatment option, salts and solids (along with all of the Chalk Creek flow) could be removed from the Truckee River system via diversion to an evaporation basin (the so-called "zero discharge" approach). In order for an evaporation basin to be capable of disposing of all of the water from Chalk Creek, it must be of sufficient size to store water during the winter months (when evaporation rates are low), and evaporate the entire stored volume during the summer months. Published average annual rainfall and average evaporation rates at specific locations can be used to estimate the area needed to evaporate a known volume of water. Using historic meteorological data from the Stead Area (the closest location of relative land) from the years 1985-2000, it was estimated that over 160 acres would be needed to dispose of 250 gpm from Chalk Creek. This disposal method is mechanically simple; it requires a pipeline to transport the creek water, and an area of land suitable to act as an evaporation pond.

The capital costs associated with this disposal method would be acquisition of land for the disposal pond, liner, excavation and earthwork to contain the water and construction of the pipeline and associated works. Comparatively (to IX or RO), annual operating and maintenance costs are low. Evaporation of the high TDS creek water would form solids and precipitates that accumulate in the evaporation basin over time. Proper design would require solids removal after 5 to 15 years. Solids would be removed with a front loader or other such equipment. Dust control would be required in the summer months (spray application of the new creek water to wet the entire basin surface). The primary limitation of evaporation as a disposal method is the large area of land needed for evaporation to take place and the pumping and piping system to convey the water to the disposal area. An area on the order of one quarter of a square mile would be needed to evaporate the Chalk Creek water.

2.2 BIOLOGICAL TREATMENT ALTERNATIVES

Biological processes under anaerobic conditions can reduce some of the sulfate in the water to insoluble sulfide precipitates, ultimately lowering the TDS content. Sulfate reducing bacteria may be an alternative to the physico-chemical treatment systems. Biological treatment systems include sulfate reducing wetlands and sulfate reducing bioreactors and may represent a low energy (near-passive) treatment alternative for the reduction of sulfate and nutrients.

2.2.1 Sulfate Reducing Wetlands

Sulfate reducing wetlands (SRW) have been used for decades in the mining industry for the control of sulfate and dissolved metals in acidic wastewaters. For this application, subsurface flow wetlands could be constructed in a portion of the lower drainage and the creek flow diverted through a series of lined basins filled with support media and wetland vegetation. Typically, subsurface type wetlands (water surface below the surface of the wetland) have increased anaerobic removal efficiencies because of their depth and quiescent conditions. The removal mechanism is the anaerobic conversion of sulfate to sulfide and perhaps even to elemental sulfur. Dissolved metals (like iron) and decaying vegetation facilitate the process. In order to function, the lower portion of the wetland must be anaerobic. How well the process will work with pH neutral water and low metal content of Chalk Creek is largely unknown. Assuming 50 percent removal of sulfate, the TDS of Chalk Creek could be reduced from 2,700 to around 1,700 mg/L. With this type of a wetland, some removal of nutrients (via uptake) can be expected.

The size of the required wetland for this application is unknown. Certainly, a longer hydraulic residence time is required to force anaerobic conditions in the lower most part of the wetland. Assuming an average creek flow of 250 gpm, a 10 day HRT, 30% void volume and a water depth of 3 feet, the wetland would need to be around 50 acres in area to treat all of the flow. Operation of the wetland may be seasonal, depending on temperature and flow through hydraulics. Once constructed, the operational and maintenance activities would be minimal. Required maintenance may be limited to summer vegetation harvest. This process should generate no liquid or solid waste, but may have an odor. Wetland longevity is unknown, but it is likely on the order of several decades.

2.2.2 Sulfate Reducing Bioreactors

Similar to a sulfate reducing wetland, a sulfate reducing bioreactor (SRB) uses an acclimated biological community to convert sulfate to sulfide which then precipitates out of solution (or gets further reduced to insoluble elemental sulfur). Unlike a wetland, where sulfate conversion occurs in only the lowermost anaerobic zone, a bioreactor can utilize the entire volume, thus requiring less area. Required elements are a tank (or tanks) with some sort of interior substrate for the attached growth (wood chips, plastic balls, etc.) and a carbon source (typically ethanol) to provide energy to the microbes. Raw water and carbon enter the tank, progress through a series of baffles, and exit in a fully reduced form. Re-aeration would be required to replenish the dissolved oxygen prior to being released back to the creek. As with the wetland, how well the process will work with pH neutral water is unknown. Since the process can be managed and automated, sulfate reduction can be assumed to be higher. Assuming 90 percent removal of sulfate, the TDS of Chalk Creek would be reduced from 2,700 to around 1,000 mg/L. Some anaerobic conversion/removal of nutrients can be expected with a SRB.

The size and general design of a SRB to treat Chalk Creek water is largely unknown. Such a system would require piloting to define the design elements. Miller (2005) reports a successful SRB system for the reduction of sulfate in acidic wastewater from the Leviathan Mine. Reportedly, good reduction of sulfate was observed in a pond that contained wood chips (50 percent void volume) with a hydraulic residence time (HRT) between 12 to 24 hours. Water was introduced from the bottom (upflow direction) and ethanol was fed at a rate of 0.4 mL/L. Based on this, to treat Chalk Creek (at 250 gpm) a tank size between 360,000 and 720,000 gallons would be required (50% voids, HRT between 12 and 24 hrs). At 250 gpm, approximately 144 gallons of ethanol would be required per day. The operation will likely need scrubbers to remove any hydrogen sulfide gas generated. Periodic flushing would be required to remove precipitated material. The permitting of such a recovery system may be difficult in residential or streamside locations.

2.3 NON-TREATMENT OPTIONS

Non-treatment alternatives are designed to eliminate (or reduce) the amount of Chalk Creek flow that directly enters the Truckee River. This reduction in flow will generally be in the form of some sort of diversion, where the creek water is transported out of the watershed. Alternatively, a source reduction program that simply reduces the flow in Chalk Creek would qualify as a non-treatment option. A few selected non-treatment options are described in the subsequent sections.

2.3.1 Export via Orr or Highland Ditch for use as Irrigation Water

The lower reach of Chalk Creek crosses (or nearly so) two different ditches (Orr and Highland). For decades, these two ditches have supported various agricultural endeavors throughout the valley, but currently are typically operated from May through August (optimistically) each year. Under this alternative, the creek water would be diverted into one of the ditches, diluted with Truckee River water, and used to irrigate fields, pastures and golf courses. The flow rates in the ditches are such that the Chalk Creek water would be diluted with river water at a ratio between 1:12 to 1:32. An analysis of water quality requirements for agricultural use show that the quality of the ditch water would actually improve with the addition of the high calcium and sulfate component of the Chalk Creek water.

To get water from the creek into the Highland Ditch, approximately 2,000 feet of piping would be required to get water from the creek bottom to a point past the intake of the Chalk Bluff WTP. Some sort of collection structure/pond and a small pump would be required to lift the water up approximately 100 ft. Total installation costs would likely be less than $250,000. It may be possible to introduce Chalk Creek water into the Orr Ditch by gravity; however, this would need to be confirmed by a detailed survey of the alignment. For comparison, a small pump station and approximately 5,000 feet of piping would be necessary to discharge the water beyond a ditch flow control structure which returns excess water to the river. Total installation costs would be about $750,000 assuming the piping could follow the ditch alignment. Because of the lower head, the operating costs for the Orr Ditch option would be less than the Highland Ditch option.

This non-treatment scenario has both benefits and shortfalls. Ultimately, the high TDS flow of Chalk Creek would not directly enter the Truckee River. Although the TDS is not removed from the Truckee River system, most of the solids and TDS can be expected to be retained in the soil matrix. Any Chalk Creek water added to either ditch would proportionally decrease the amount of Truckee River water diverted, thus leaving more water in the river. The largest shortfall of this scenario is that it is a seasonal solution, viable during the six to eight-month irrigation season.

2.3.2 Pump to North Valleys

Under this scenario, Chalk Creek water would be pumped out of the hydrographic basin and into the North Valleys where it would be released into one of the existing saline playas and allowed to percolate or evaporate. Initially, Silver Lake (west Lemmon Valley), Swan Lake (east Lemmon Valley) and White Lake (Cold Springs Valley) were considered. Silver and Swan Lakes would be preferable, since they are located closer to Reno; however, both were eliminated from further consideration due to existing flooding issues. Only White Lake has sufficient size and capacity to contain and evaporate the creek flows (approximately 400 AFA would discharge to the playa and evaporate).

If the flow from Chalk Creek were pumped north from the Truckee Meadows, a new pipeline and pump station(s) would be required to transport the water to the North Valleys. After the water is collected at the mouth of the creek, it could be piped along North McCarran Blvd. to an abandoned 14-inch Truckee Meadows Water Authority (TMWA) water main located in the vicinity of Rancho San Rafael Park. This abandoned main could potentially be used as a conduit to run the new, smaller diameter pipeline to Raleigh Heights. From there, a new pipeline would be needed to move the water to the final location for disposal. Roughly 17 miles of pipe and two pump stations would be needed.

The largest problem with pumping the water from the Truckee Meadows is the large capital cost of constructing a new pipeline to transport the water such a distance. If a 6-inch pipeline were required to transport the water to Cold Springs Valley, the cost to install pipe alone would be around 7 million dollars. The issue of water rights is also uncertain with this option, since there would be no return flow to the Truckee River.

2.3.3 Blending with Chalk Bluff Potable Source Water

In this non-treatment scenario, the water from Chalk Creek could be pumped into the Highland Ditch, diluted with river water and used as source water at the Chalk Bluff Water Treatment Plant (WTP). The dilution ratio would be over 100:1 (Truckee River to Chalk Creek) with a negligible decrease in water quality. The net result of this treatment scenario is that the Chalk Creek, with its TDS load, would not flow directly into the Truckee River. Furthermore, the equivalent flow could remain in the Truckee River (and not be used to make drinking water). Some piping and a small pump station would be necessary to lift the water from the creek outlet to the Highland Ditch.

This scenario is potentially a year-round solution, since Chalk Bluff WTP processes water all year long. However, there are several considerations that make this alternative undesirable. First, it is unlikely the Truckee Meadows Water Authority would allow the intentional degradation of their source water, no matter how negligible. Secondly, because the drinking water used in the Truckee Meadows ultimately returns to the Truckee River via the TMWRF plant, limited pollution trading credits for TDS would be achieved. Because of these significant concerns, this alternative was eliminated from further consideration.

2.3.4 Deep Well Injection

One method used by the petrochemical industry for the disposal of brine wastewaters is deep well injection. In this scenario, the flow from Chalk Creek would be collected and pumped into some underground formation on a perpetual basis. At an average flow of 250 gpm, the subsurface formation must be able to accommodate 360,000 gallons of water per day. In order for an injection well to function, the underlying strata must be capable of accepting and dispersing the injected fluid.

The subsurface conditions dictate the feasibility of disposal using an injection well. An examination of the geology and nearby well logs indicates the absence of a suitable subsurface formation that is capable of accommodating the required volume of water. Test borings 1,000 to 5,000 feet would need to be performed to fully characterize the formations and to ensure that nearby groundwater resources would not be degraded. This well would be classified as a Class V injection well and be subject to federal and state permits. Because of the proximity to a large population center and a state boundary, permitting is unlikely.

Should the water first be treated with RO or some other method that reduces the volume of water requiring disposal, an injection well becomes more feasible. It may perhaps be easier to find a geological formation capable of accepting a reduced flow, but permitting and cost are still significant obstacles.

2.3.5 Source Control

The most obvious objective of a source control program would be to lessen the flow in Chalk Creek, provided that the concentration of TDS, nitrogen and phosphorus remain the same when the flow is reduced. If this is the case, a 60 percent reduction in creek flow would translate to 60 percent less loading from Chalk Creek into the Truckee River. Indications are that the flow in Chalk Creek is directly attributable to urbanization (before the roads and houses, there was no flow). Therefore, if specific aspects of urbanization can be reversed, it may be feasible to lessen the flow in Chalk Creek and decrease the loading to the Truckee River. Critical to the success of a source control program is to develop an understanding of the problem. The two biggest questions are: where does the creek flow originate and from where does the sulfate come?

As an example, a source control program might target selected neighborhoods for a flow reduction program. Neighborhoods could potentially be selected based on parameters such as housing density, local geology or water use. For example, it may be possible to reduce or modify lawn irrigation practices to reduce seepage and salt leaching, and subsequent salt loading to the creek (lawn to xeriscape conversion). Currently, residential watering schedules are twice per week. People have a tendency to water heavily on their assigned days, which results in soil saturation, runoff and/or irrigation infiltration. More frequent watering for shorter periods may reduce infiltration and subsequent down-gradient seepage. Alternatively, a source control program may include watershed-wide programs to increase plant water and nutrient uptake, reduced infiltration, decrease erosion, promote a sulfate reducing environment, amend soils to minimize the leaching of salts, or simply promote plantings for increased evapo-transpiration.

2.4 TREATMENT ALTERNATIVES EVALUATION MATRIX

Presented in Table 2-1 is an evaluation matrix for the various treatment and non-treatment options for mitigating Chalk Creek TDS. Five different criteria were used falling under three general categories (treatment efficiency, facility requirements and feasibility). Fifty percent of the points were issued based on how well the proposed treatment system would work and how reliable it is. Twenty five percent of the points were issued based on facility size, capital, O&M and waste disposal costs. The remaining 25 percent of the evaluation matrix points were issued based on environmental, regulatory and public acceptance considerations. Within each ranking category, each alternative was scored between 1 and 10 points (1 = poor, 10 = excellent) and then multiplied by the ranking criteria weighting factor. Lastly, the points were summarized. If the solution was seasonal (functionality limited to non-winter months), points were deducted in proportion to the estimated months of service.

As can be seen from the final score row in Table 2-1, points ranged from a low of 4.13 (export and evaporate) to a high of 5.75 (source control). The final scores were clustered fairly closely together, indicating no clear and obvious solution. The top three ranked treatment alternatives were:

1) Source Control (5.75 pts)
2) VSEP Membrane Treatment (5.60 pts)
3) Export via Ditch (5.60 pts, seasonal solution only)

Each of these three alternatives is developed in greater detail in the following section.

Table 2-1. Chalk Creek Treatment Option Evaluation Matrix

Ranking Criteria	Scoring (high= good, low= bad)	Wt.	RO		VSEP		IX		Wetland		SRB		Export and Evap		Source Control		Export via Ditch		Pump to North Val.		Blend with Chalk Bluff	
			S.	Pts	S.	Pts	S.	Pts	S.	Pts	S.	Pts	S.	Pts	S.	Pts	S.	Pts	S.	Pts	S.	Pts
Treatment Efficiency (50%)																						
Will it Work? Will it Reduce TDS in the River?	1=No, 10=Absolutely, it Will Lower TDS	0.300	9	2.70	9	2.70	9	2.70	6	1.80	7	2.10	9	2.70	2	0.60	9	2.70	7	2.10	2	1.50
Track Record (Certainty of Function)	1=Uncertain, 10=No Question - It Will Work	0.200	8	1.60	7	1.40	8	1.60	6	1.20	7	1.40	9	1.80	2	0.40	10	2.00	8	1.60	9	2.00
Facility and Process Requirements (25%)																						
Facility Size and Capital Cost	1=Big and Expensive, 10=Small & Inexpensive	0.125	3	0.38	3	0.38	3	0.38	6	0.75	4	0.50	3	0.38	9	1.13	9	1.13	3	0.38	9	0.25
O&M and Waste Disposal Costs	1=Costly to Operate, Large Amounts of Waste 10=Inexpensive to Operate, Low Waste Generation	0.125	1	0.13	3	0.38	1	0.13	10	1.25	6	0.75	6	0.75	9	1.13	10	1.25	4	0.50	10	1.25
Feasibility (25%)																						
Environmental, Regulatory, and Public Acceptance	1=Unpopular, Difficult to Permit 10=Favorable, Easy to Permit	0.250	3	0.75	3	0.75	3	0.75	10	2.50	3	0.75	5	1.25	10	2.50	9	2.25	3	0.75	1	0.25
	Sum	1.00		5.55		5.60		5.55		7.50		5.50		6.88		5.75		9.33		5.33		5.25
	Seasonal Solution Only? (Y/N, if Y, then Assume Operation/Pts. for 7/12 months)			N		N		N		Y		N		Y		N		Y		N		N
	FINAL SCORE (adjust for season)			**5.55**		**5.60**		**5.55**		**4.50**		**5.50**		**4.13**		**5.75**		**5.60**		**5.33**		**5.03**
	FINAL RANK			**4,5**		**2,3**		**4,5**		**9**		**6**		**10**		**1**		**2,3**		**7**		**8**

Notes:
RO = Reverse Osmosis; VSEP= Vibratory Shear Enhanced Process membrane system; IX = Ion Exchange; Wetland = Sulfate Reducing Wetland; SRB = Sulfate Reducing Bioreactor; Export and Evap = Export and Evaporation.
Wt. = Weighting Factor: More important features have a higher point value. Score (1-10) multiplied by the weighting factor to determine the points assigned.
S. = Score. The score (1-10) assigned to the treatment option (see scoring).
Pts. = Points: Equal to the sum of the points times the weighting factor.
Seasonal Solution: If yes, then multiply sum by 0.6 since the treatment solution is only viable 60% (7/12 months = 0.58) of the year (at best).
Final Rank: Value separated by commas means shared rank with other treatment option.

3.0 EVALUATION OF TOP ALTERNATIVES

Presented in this section is a more detailed discussion of the alternatives for mitigating TDS in Chalk Creek as identified in Section 2.4. Each of the three highest ranked treatment alternatives (i.e., Source Control, VSEP and Export via Ditch) is evaluated in this Section with respect to process, feasibility and cost.

3.1 SOURCE CONTROL

Source control ranked the highest of all of the alternatives because of the low capital, O&M and disposal costs as well as being the most environmentally friendly and relatively easy to implement. Although source control is potentially a year-round solution, it did not score high marks in the efficiency category. A source control program may or may not work, but it is the first mitigation alternative that should be attempted. As previously stated, a source control program would likely target the reduction of flow in Chalk Creek, but alternatively it might attempt to reduce contamination in the water (TDS, nitrogen and phosphorus). Both approaches will be developed in this section.

Critical to the success is to first fully understand the problem. From where does the flow originate? Where does the TDS/sulfate originate? Are there any hot spots? Assuming the problem can be sufficiently understood, a plan can be formulated and an implementation strategy devised. Once the source control plan has been put in place, the results should be carefully monitored for several years. While the plan would be an on-going, evolving approach, some maintenance (physical or social) may be necessary. After several years of the program, the results should be critically reviewed and the program revised as necessary.

A pilot source control program could be targeted to a few residences, a localized area or the entire watershed. Two potential programs for flow reduction include revising a lawn irrigation schedule and/or lawn conversion. As discussed earlier, it may be possible to reduce or modify lawn irrigation practices to reduce seepage and salt leaching, and subsequent salt loading to the creek. Twice-a-week watering encourages soil saturation. It is possible that more frequent watering for shorter periods may reduce infiltration and subsequent down-gradient seepage. Residential sprinkler systems can be fitted with weather-based evapo-transpiration (ET) irrigation controllers that apply only the amount of water required for growth and maintenance. A traditional water conservation approach may be all that is required to substantially decrease overwatering and lateral movement of the excess water to the creek. If the results from such a pilot program show promise, the next step would be to develop and implement a broader source control program in targeted areas to reduce seepage and salt leaching.

Watershed-wide programs may be effective in decreasing flow in Chalk Creek. It is conceivable that the flow in the creek could be substantially reduced by terracing and selective planting to retain water that facilitates evaporation and uptake. It is possible that with a larger understanding of the geology, there may be areas in the watershed where infiltration (into deeper strata) should be encouraged.

It is possible that a watershed-wide source control program can be developed specifically to reduce TDS (the largest component being sulfate). The success of such a program depends on a fundamental understanding of the source of dissolved solids. If certain soil horizons, types or formations are significant contributors, a source control program can be developed to perhaps mitigate salt mobilization. As an example, a mulching program may retain the applied water on the surface, thus reducing infiltration into a particular formation and subsequent salt mobilization. If hot spots are identified, Chalk Creek could be channelized or piped past or around them. If all formations within the watershed contribute salts, a program to reduce erosion and stabilize the stream bank may reduce TDS levels in the creek. Lastly, slowing and spreading the creek may encourage sulfate reduction via anaerobic conversion.

All-in-all, there are a wide variety of source control type programs that could be implemented to reduce flow or reduce the TDS concentration in Chalk Creek. A solid understanding of hydrology, geology and sociology is required to identify the appropriate source control measures. Depending on the mechanisms responsible, a small, localized pilot program might be most implementable. Depending on its success, a regional source control strategy may then become evident.

3.2 VSEP Membrane Treatment

The VSEP treatment process tied for second in the treatment alternative matrix (Table 2-1) because of its ability to remove TDS without extensive pretreatment and the smaller, more concentrated waste stream (compared to similar processes IX or RO). Like the other large treatment facilities, a VSEP plant would be very expensive to construct and operate. A VSEP plant would be capable of removing TDS and would generate waste products on a year-round basis. In this section, the VSEP process is discussed in greater detail and additional considerations and complexities of building and operating this type of a treatment facility is presented.

3.2.1 Process Overview

The Vibratory Shear Enhanced Process (VSEP) is an enhancement of the traditional membrane filtration process that provides for improved contaminant removal (95-98 percent reduction of TDS) and less reject water while requiring a simple level of pretreatment. The VSEP system uses conventional RO stacked plate membranes coupled with a vibrating mechanism and cross-flow dynamics that allow for high throughput and less fouling. The configuration depends upon the quality of the water to be treated, desired effluent quality and target water recovery. To facilitate this planning level analysis, the manufacturer (New Logic Research, Emeryville California) was contacted and some preliminary design and performance information was obtained.

3.2.1 Facility Description

A conceptual VSEP process flow diagram for a facility to treat Chalk Creek water is shown in Figure 3-1. To reduce the TDS to below 100 mg/L, the manufacturer recommends a single treatment train consisting of two VSEP RO units and two regular RO units. Settled creek water would be pumped into the first of four process “storage” tanks. These storage (equilibration) tanks would be 15,000 to 30,000 gallons in size, providing 1-2 hours of feed water to the process train. The storage tanks may contain internal heaters (the warmer the water, the higher the treatment efficiency). From the Stage 1 Feed Tank (see Figure 3-1), the water would pass through a 150 µm microscreen and then enter the first VSEP membrane unit. Permeate (treated water that passes the membrane) from the first VSEP unit would then be passed through a second, conventional spiral RO unit producing the majority of the finished water. A second set of VSEP-RO and Spiral-RO units would treat water from Storage Tanks 3 and 4 to further improve water production and decrease the volume of the reject water.

Assuming the feed tanks can be situated outside, a VSEP plant similar to that shown in Figure 3-1 would require a building of about 2,500 ft^2 in size to house the pre-filters, pumps and VSEP/RO units. A collection structure, equilibration basin and feed pump would be required to get water from Chalk Creek into the building. Ideally, creek water would be pre-settled (in an outside basin) to lessen the load on the lead microscreen. Improved access to the creek diversion and the pre-settling/equilibration basin would be required for maintenance activities.

The byproduct produced by the VSEP process is a highly concentrated liquid waste stream containing all of the TDS and other solids removed from the creek water. For this application (Chalk Creek at 250 gpm), the estimated volume of liquid waste generated from the VSEP process would be around 17,000 gpd (assuming 5 percent reject rate). The reject would theoretically have a TDS concentration around 57,500 mg/L, but much of the salts would precipitate and fall out of solution. Because of the volume of solids and wastewater produced, some concentration step would be necessary to facilitate disposal. There are several different types of brine concentrators and crystallizers, most of which employ falling film evaporators and heat exchangers. At best, these systems are capable of producing a solid product with 50 percent moisture content. Assuming the production rates listed above, 50 percent moisture content, approximately 16,200 lbs/day of solid waste would be produced. Assuming bulk density between salt and gypsum, approximately 9 cubic yards of solid waste would be generated per day. As a result, a second solids handling building would be required.

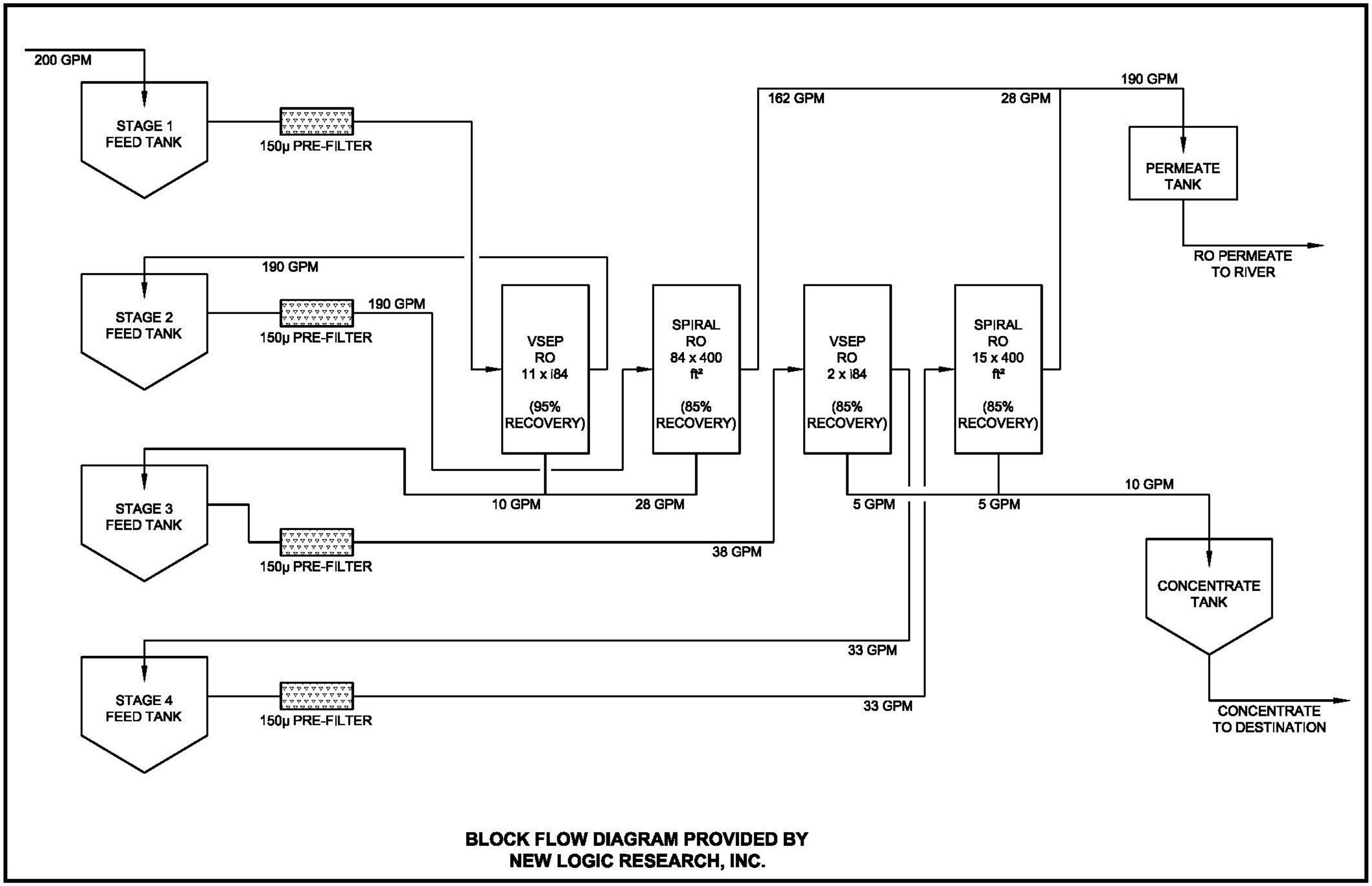

Figure 3-1 VSEP Process Flow Diagram for Treating Chalk Creek Water

3.2.3 Process Efficiency

The proposed VSEP system claims to be 95 percent efficient in water production. Presented in Table 3-1 is the estimated finished water quality as provided by the VSEP manufacturer (New Logic Research, Inc.). Piloting would be required to verify that both water quality and production can be attained. The treated water would likely be piped directly to the Truckee River; however, the quality would be high enough for potable use if so desired.

Table 3-1
Estimated Finished Water Quality using the VSEP Process

Parameter	Unit	Chalk Creek[a]	VSEP[b]	Estimated %R
Total Dissolved Solids (TDS)	mg/L	2,660[b]	59	97.8
Turbidity (Turb)	NTU	1.5	<0.01	99.7
Calcium (Ca)	mg/L	300	1.6	99.5
Magnesium (Mg)	mg/L	190	0.6	99.7
Hardness (Hard)	mg-$CaCO_3$/L	1,500	6.3	99.6
Sodium (Na)	mg/L	170	4.1	97.6
Chloride (Cl)	mg/L	110	0.2	99.8
Sulfate (SO4)	mg/L	1,400	<1	99.9

[a] See Table 1-1 for data source; [b] New Logic Research, Inc.

3.2.4 Estimated Construction and O&M Costs

Planning level estimated costs for constructing and operating a VSEP membrane facility for treating Chalk Creek are provided in Table 3-2. These costs are rough estimates of the required land, buildings and processes required to support such a facility. As can be seen from the estimated values in Table 3-2, a VSEP facility may cost around $9 million dollars to build and about $1.5 million per year to operate.

Table 3-2
Estimated Capital and O&M Costs for the VSEP Treatment Alternative

Capital Expenditure	Estimated Cost (Dollars)
Land, Grading and Pavement	$1,100,000
Buildings (two)	$550,000
VSEP Process Equipment	$3,900,000
Tanks, Pumps and Piping	$75,000
Intake, Diversion, Equilibration Basin	$275,000
Brine Concentrator	$500,000
Solids Handling Equipment	$150,000
Electrical, SCADA, Controls, Fixtures, Finishing	$2,600,000
Estimated Cost	$9,150,000
O&M Expenditure	**Estimated Cost (Dollars)**
VSEP Operation	$250,000
Solids Processing	$500,000
Solids Disposal	$450,000
Power Costs	$300,000
Estimated Annual	$1,500,000

3.2.5 Technical Feasibility

A VSEP type membrane treatment facility can be operated year-round to treat the water in Chalk Creek to reduce the TDS load to the Truckee River. Second only to cost, the largest obstacle is the volume of solids generated (8,000 to 16,000 lbs/day).

3.3 EXPORT VIA DITCH

The concept of diverting the outfall of Chalk Creek into one of two ditches and away from directly entering the Truckee River was introduced in Section 2.3.1. The ditch export alternative tied for second in the treatment alternative matrix (Table 2-1) because of the low cost and overall feasibility. The limitations are that it is a seasonal solution and that the TDS is not actually removed from the watershed. In this section, the export via ditch alternative is outlined and discussed in more detail.

3.3.1 Overview

The lower reach of Chalk Creek has two nearby ditches, Orr and Highland. Using the Highland Ditch is a less attractive alternative because Chalk Creek is lower in elevation and would require pumping. Secondly, Highland Ditch supplies raw Truckee River water to the Chalk Bluff WTP, so the entry point would need to be past the WTP takeoff (requiring approximately 2,000 ft of piping). Chalk Creek actually flows in two culvert pipes over the top of the Orr Ditch.

The water in Orr Ditch is used primarily for agricultural use (see next section for the only possible exception). Orr ditch was constructed in the late 1800s to provide irrigation and stock watering to farm and ranch properties in the north part of the Truckee Meadows and the Spanish Springs area (TMWA, 2008). The ditch originates (takes off from the Truckee River) about 800 feet upstream of where Chalk Creek enters the river (see Figure 3-2). The ditch travels along the northern foothills of the Truckee Meadows in a northeasterly direction for approximately 30 miles, eventually ending in the northeast part of the Spanish Springs Valley. Drainage and return flow from the Orr Ditch is conveyed back to the Truckee River via the North Truckee Drain (Figure 3-3).

According to TWMA, over the years, most of the historical diversions and water rights associated with the Orr Ditch have been converted to municipal and industrial use. Currently, the ditch is in use (flowing) from May to September each year, with an average flow of about 18 cubic feet per second (8,080 gpm). The significant users are the Red Hawk Golf Course, University of Nevada, City of Reno (Paradise and Oxbow Parks) and the Wildcreek Golf Course. At best, diverting Chalk Creek into the Orr Ditch is a seasonal solution.

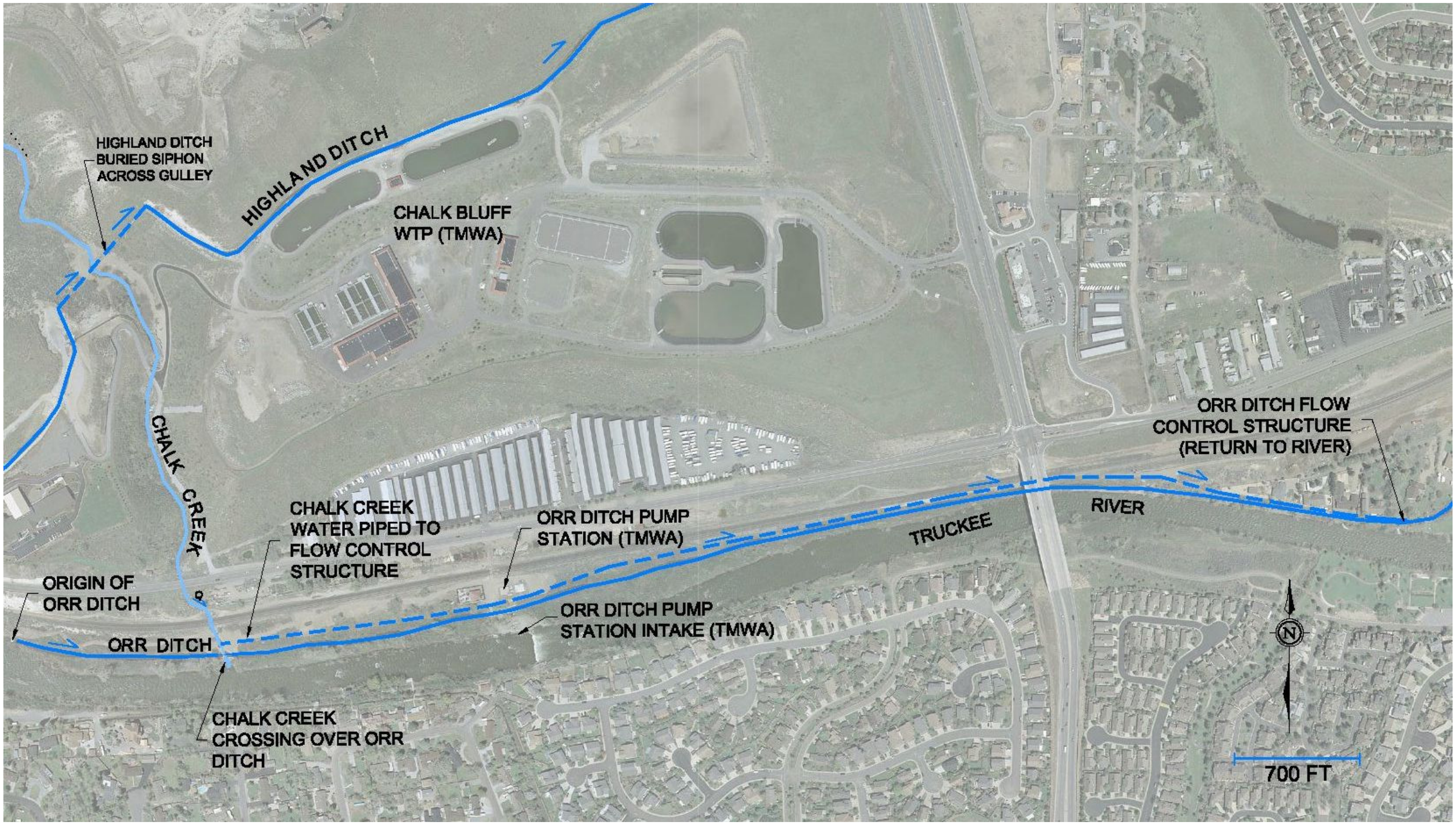

Figure 3-2 Lower Reach of Chalk Creek Showing the Orr and Highland Ditches

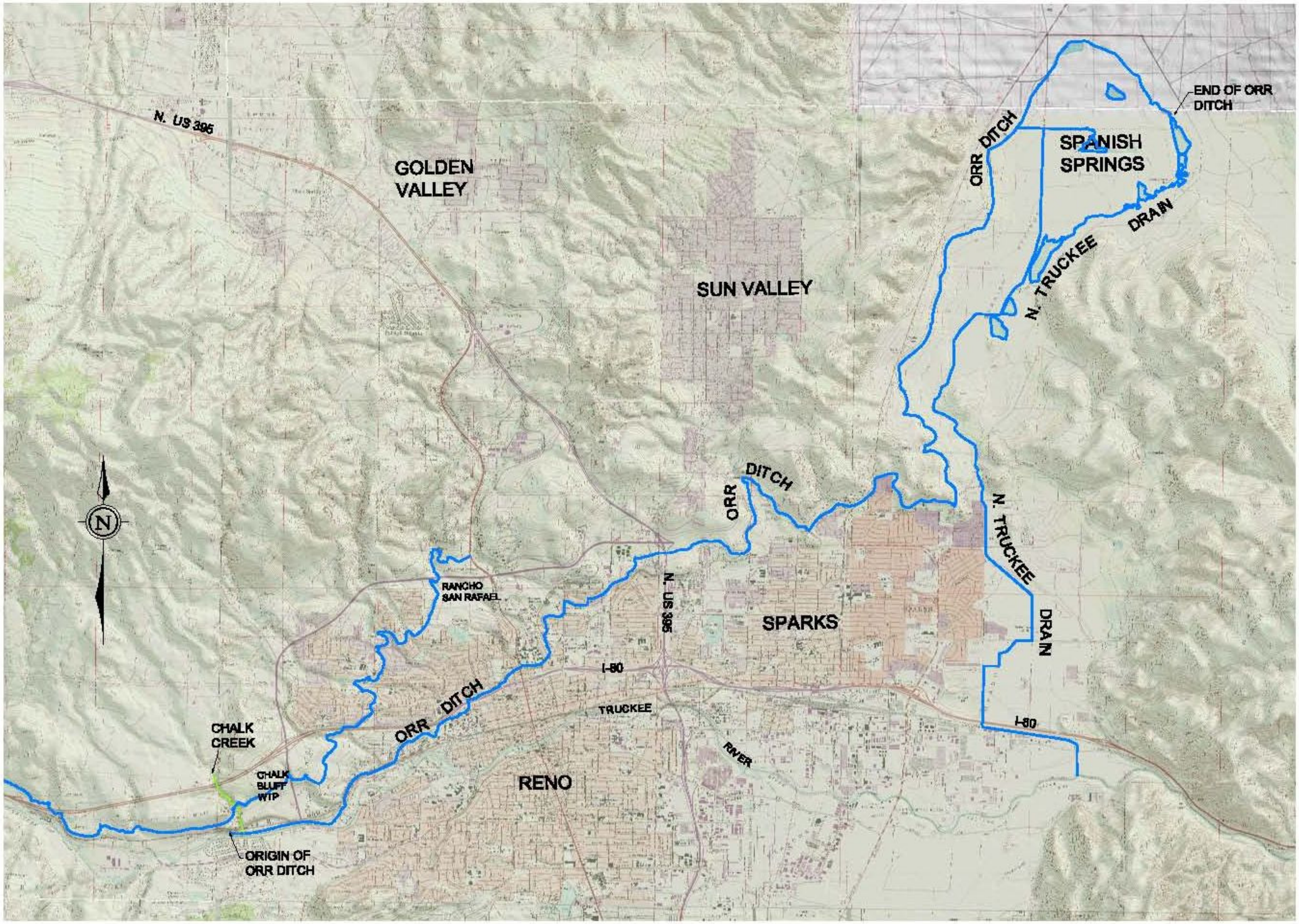

Figure 3-3 Travel and Extent of the Orr Ditch through the Truckee Meadows

The addition of Chalk Creek water (250 gpm) to the Orr Ditch water (8,080 gpm) will not significantly alter the water quality of the ditch (over a 30x dilution). Chalk Creek water has TDS that average about 2,660 mg/L. The water has relatively low concentrations of sodium and chloride (170 and 110 mg/L, respectively) and relatively high concentrations of calcium, magnesium and sulfate (300, 190 and 1,400 mg/L, respectively). In most irrigation water, sodium and chloride are elements of concern, as they enhance clay swelling, soil compaction, and inhibit plant growth. As described below, calcium and sulfate are frequently used as soil amendments to enhance plant growth.

Some plants are less tolerant of irrigation water having elevated TDS. The Western Fertilizer Handbook, 8th edition, California Fertilizer Association, indicates that most fescue and ryegrass varieties are tolerant of irrigation water with approximate TDS values ranging from 1,700 to 2,900 mg/L. Since Chalk Creek water has an average TDS concentration of 2,660 mg/L, the water could be used directly on the more tolerant species, but would require dilution on more sensitive species. Although the TDS is elevated, calcium sulfate (gypsum) is the dominant salt in the creek water. Gypsum is commonly used as a soil amendment to relieve compaction and improve aeration in sodic clay soils, and is generally beneficial to all plant growth when present at moderate levels.

The Sodium Adsorption Ratio (SAR), along with pH, is another method used to characterize salt-affected soils using comparative concentrations of Na+, Ca2+, and Mg2+. The SAR of a soil extract takes into consideration that the adverse effect of sodium is moderated by the presence of calcium and magnesium ions. When the SAR rises above 12 to 15, serious physical soil problems arise and plants have difficulty absorbing water. Elevated Ca and Mg contents produce low SAR values. The estimate of the SAR value for mixed Chalk Creek and Orr Ditch water is 1.3. These results indicate that the raw creek water has overall salinity that is too high for most irrigation, but the blended creek / ditch water would only have an increasing "low salt" problem.

3.3.2 Facilities

A small diversion facility, pump station and approximately 5,000 feet of piping would be necessary to discharge the water beyond a ditch flow control structure, which returns excess water to the river (see Figure 3-2). Evaluation of alignment alternatives is necessary to determine the best location for the pipeline. It may be possible to introduce Chalk Creek water into the Orr Ditch by gravity; however, a detailed comparison should be performed of a gravity versus pressure pipe alternative. The evaluation should consider a detailed survey of the alignment options, and the life cycle costs of a larger diameter gravity pipeline compared to a small diameter pressure pipeline.

3.3.3 Treatment Efficiency

Treatment efficiency and effectiveness of this solution is difficult to ascertain. First off, TDS is not actually removed from the watershed. It would be land-applied well away from the river and trapped in the soil matrix. Some TDS can be expected to return directly back to the Truckee River via agricultural return flow (through the North Truckee Drain). Running some simple calculations - At the average flow of 250 gpm with an average concentration of TDS of 2,660 mg/L, Chalk Creek contributes approximately 8,000 lbs/day (7,984 lbs/day) of dry TDS into the Truckee River. On an annual basis, this is nearly 1,460 tons per year. Assuming that the ditch is 75% efficient in removing TDS, and that the ditch operates for 153 days/year, disposal of the water from Chalk Creek into Orr ditch would reduce the annual TDS load to the Truckee by 31%. Assuming 50% removal and 120 days of operation, the annual TDS removal percentage drops to about 16%.

A secondary benefit of this alternative is that any Chalk Creek water added to the ditch would proportionally decrease the amount of Truckee river water diverted for irrigation, thus leaving more water in the river.

3.3.4 Estimated Construction and O&M costs

Without an alignment survey, it is difficult to estimate the required cost of the necessary facilities. A small diversion structure, pump station and approximately 5,000 feet of piping would be necessary to discharge the water beyond the ditch flow control structure. Total installation costs would be about $750,000 assuming the piping could follow the ditch alignment. The estimated operating cost for the Orr Ditch option would be about $20,000 per year.

Table 3-3
Estimated Capital and O&M Costs for the Orr Ditch Alternative

Capital Expenditure	Estimated Cost (Dollars)
Intake / Diversion Facility	$25,000
Pump Station	$100,000
Pipeline, 5,000 feet, 6 inch	$600,000
Electrical, SCADA, Controls	$25,000
Estimated Cost	$750,000
O&M Expenditure	**Estimated Cost (Dollars)**
Facility O&M	$15,000
Power Costs	$5,000
Estimated Annual	$20,000

3.3.5 Technical Feasibility

This treatment scenario is likely the most feasible of all the alternatives evaluated. The disadvantages are that TDS is not removed from the watershed and that this solution is seasonal. Although the Orr ditch is privately held, it is likely that this scenario could be permitted. It is unknown if any TDS removal credits would be issued.

4.0 SUMMARY AND RECOMMENDATIONS

The scope of this analysis was to determine alternatives and feasibility for treating Chalk Creek water to reduce total dissolved solids as the primary contaminant, with potential secondary reductions of total nitrogen and total phosphorous. Treatment alternatives considered were broken down into advanced, biological or non-treatment type solutions. The level of detail investigated was limited to the determination of technical feasibility (will it work?), operational track record, costs, regulatory and implementation considerations. It was assumed that pollution trading credits could be obtained for any net removal of TDS (or nutrients) under the existing Truckee River TMDL framework. Therefore, a primary consideration in this evaluation was that the treatment alternatives actually remove TDS (and nutrients) from the system, rather than simply transport them to another location within the Truckee River watershed. Treatment alternatives that were seasonal were scored appropriately.

The treatment alternatives evaluated were:

Advanced
1) Reverse Osmosis
2) VSEP Membrane
3) Ion Exchange
4) Chemical Precipitation
5) Evaporation

Biological
6) Sulfate Reducing Wetland
7) Sulfate Reducing Bioreactor

Non-Treatment
8) Source Control
9) Pump to the North Valleys
10) Export via Ditch
11) Blend with Chalk Bluff Supply
12) Deep Well Injection

The numerical ranking used can be found in Table 2-1. The final scores were clustered fairly close together, indicating no clear and obvious solution. The top three ranked alternatives were:

1) Source Control (5.75 pts)
2) VSEP Membrane Treatment (5.60 pts)
3) Export via Ditch (5.60 pts, seasonal solution only)

The concept of diverting the outfall of Chalk Creek into the Orr Ditch and away from directly entering the Truckee River is perhaps the easiest of any of the alternatives to implement. The flow rates are such that Chalk Creek water would be diluted over 30 times, and the sulfate and calcium in the water would actually improve the ditch water quality from an agricultural standpoint. The costs associated with this alternative are estimated to be $750,000. The limitations of this solution are that it is a seasonal solution and that the TDS is not actually removed from the watershed. Although the Orr ditch is privately held, it is likely that this alternative could be permitted. It us unknown if TDS removal credits would be issued.

The advanced membrane process (VSEP) tied for second (with the Orr Ditch alternative) in the treatment alternative matrix (Table 2-1) because of its ability to remove TDS without extensive pretreatment and the smaller, more concentrated waste stream (compared to similar processes IX or RO). A VSEP plant would be capable of removing a high degree (98%) of TDS on a year-round basis. Such a plant would most certainly be eligible for pollutant trading credits but would be expensive to build (9 million dollars) and operate (1.5 million dollars). Second only to cost, the largest obstacle of this type of process is the volume of solids generated (8,000 to 16,000 lbs/day).

Source control ranked the highest of all of the treatment alternatives because of the low capital, O&M and disposal costs as well as being the most environmentally friendly and relatively easy to permit. Although source control is potentially a year-round solution, it did not score high marks in the efficiency category. A source control program may or may not work, but it is the first mitigation alternative that should be attempted. As previously stated, a source control program would likely target the reduction of flow in Chalk Creek, but alternatively it might attempt to reduce contamination in the water (TDS, nitrogen and phosphorus).

It is recommended that a pilot source control program be developed and implemented for Chalk Creek. Since the flow (and elevated TDS) in Chalk Creek may be attributed to homeowner irrigation seepage and local geology, it is conceivable that an isolated neighborhood could be selected for such a pilot program. Public awareness of water usage, water schedules, mulching and xeriscape conversion are just some of the possibilities for a source control effort. If the flow in Chalk Creek can be reduced or halted, an important source of TDS to the Truckee River can be mitigated.

5.0 REFERENCES

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