ECO:LOGIC

Consulting Engineers

Regional Integrated Wastewater System Planning

Prepared for:
Western Regional Water Commission

Prepared by:
ECO:LOGIC Engineering

February 2010

Contents

Regional Integrated Wastewater System Planning

APPENDICES

SECTION 1: INTRODUCTION

To support the development of the 2011 Regional Water Management Plan, evaluation of a number of regional wastewater issues was initiated in conjunction with the Staff Working Group. The efforts focused on the preparation of a regional water balance and quantifying the aquifer storage potential throughout southern Washoe County to help evaluate the feasibility of direct recharge of highly treated wastewater. Each of these efforts is presented in more detail below.

Using the recent Truckee Meadows Service Area (TMSA) projections and other available work products, a regional water balance was prepared. The water balance includes regional water demands, wastewater flows, wastewater disposal and reclaimed water demand forecasts. The water balance was divided into several subareas including Cold Springs, Reno Stead and Lemmon Valley, Spanish Springs and Sparks, Central Truckee Meadows, and South Truckee Meadows. The main water purveyors included are Washoe County, Truckee Meadows Water Authority (TMWA), Sun Valley General Improvement District (SVGID) and South Truckee Meadows General Improvement District (STMGID). The wastewater treatment facilities include Cold Springs Water Reclamation Facility (CSWRF), Reno Stead Water Reclamation Facility (RSWRF), Lemmon Valley Wastewater Treatment Plant (LVWWTP), Truckee Meadows Water Reclamation Facility (TMWRF), and South Truckee Meadows Water Reclamation Facility (STMWRF).

A graphical representation of the water balance, or flow diagram, is presented in Section 2. The flow diagram includes water supply, wastewater treatment, reclaimed water and wastewater disposal requirements for each of the four major planning areas, and is useful to understand the following:

- How much potable water is used today, and in what locations?
- Where does the potable water come from, and once used, where does it go for treatment?
- Following treatment, how much of the water is reused, and where is the balance disposed of?

Each valley bottom contains alluvial or lake bed sediments in which storage or disposal of treated wastewater may be possible. To help evaluate the feasibility of direct recharge of highly treated wastewater, a summary of the geologic framework and the estimated recharge volume in portions of the alluvial aquifers in Lemmon Valley, Cold Springs, Bedell Flat, Spanish Springs, Warm Springs Valley, and the South Truckee Meadows is presented. Working with the hydrogeology staff from Washoe County Department of Water Resources, a more detailed analysis of the volume of recharge and estimated time it may take for the total dissolved solids (TDS) of the water in the Lemmon Valley aquifer to reach a target concentration was also evaluated.

SECTION 2: REGIONAL WATER BALANCE

A regional water demand and wastewater flow balance was developed for the areas of Cold Springs, Reno-Stead and Lemmon Valley, Sparks and Spanish Springs, Central Truckee

Meadows and South Truckee Meadows. The balance includes existing water resources, water demands, wastewater flows and disposal capacity by area.

Most of the data are from the following sources:

- City of Reno and Washoe County TMSA/FSA Water, Wastewater, and Flood Management Facility Plan, November 2007
- City of Sparks TMSA/FSA Conceptual Facility Master Plan, January 2008
- Amendment to the Washoe County Comprehensive Regional Water Management Plan, January 9, 2009

Washoe County, Reno, Sparks, and TMWA provided some limited updated information, such as reclaimed water usage, and well recharge amounts. The existing water balance is based on an estimated 2006 population 409,085 as stated by the State Demographer.

A summary of the existing water and wastewater balance by area is listed in Tables 2-1 and 2-2, respectively. Information has also been compiled to prepare a future conditions water balance. However, to be consistent with ongoing work, the future conditions water balance will not be presented until the population projections for the 2011 Regional Water Management Plan are agreed upon by the Western Regional Water Commission (WRWC).

Based on the water balance, a graphical representation of the existing conditions for water supply, wastewater treatment, reclaimed water and wastewater disposal requirements was prepared. The existing water balance flow diagram is presented in Plate 1, included in Appendix A.

Table 2-1 - Existing Water Balance by Area

Area	Commitment (AFA)	Demand (AFA)	Estimate of Difference between Commitment Versus Demand (AFA)
Cold Springs	1,417	1,417	0
South Truckee Meadows TMSA	8,961	6,939	2,022
Stead and Lemmon Valley	5,293	5,205	88
Spanish Springs TMSA and Sparks TMSA (Priority Areas 1-4)			
Spanish Springs TMSA	*3,983*	*3,159*	*824*
Sparks TMSA (Priority Areas 1-4)	*35,000*	*30,279*	*4,721*
Subtotal	38,983	33,438	5,545
Central Truckee Meadows Subtotal			
Truckee Meadows TMSA (includes Verdi)	*56,561*	*52,096*	*4,465*
Sun Valley TMSA	*2,375*	*2,375*	*0*
Subtotal	58,936	54,471	4,465
Total	113,590 *	101,470	12,120

Table 2-2 - Existing Wastewater Balance by Area

Wastewater Service Area	2006 Flows (AFA)	Identified Disposal Capacity (AFA)	Available Disposal Capacity (AFA)
Cold Springs WRF	290	1,340	1,050
South Truckee Meadows WRF	2,910	3,270	360
Reno Stead WRF (including Lemmon Valley WWTP)	1,840	3,300	1,460
Truckee Meadows WRF	37,830	40,300	2,470
Total	42,870	48,210	5,340

* This is the will-serve commitment, rather than the amount of water rights dedicated to provide for that commitment (John Enloe)

SECTION 3: TREATED EFFLUENT RECHARGE / TDS ESTIMATES

A planning-level assessment of the volume of high-quality treated effluent that might be stored and/or disposed of in the alluvial deposits of select hydrographic areas of Washoe County was prepared. In addition, a water/TDS mass balance was developed to examine long-term changes in water quality in the alluvial aquifer of Lemmon Valley arising from effluent storage and reuse. The studies rely heavily on data, information and results of previous hydrogeologic investigations of the study areas available through the Washoe County Department of Water Resources (DWR). The intent was not to develop a fully calibrated solute transport model for the basins, but to develop an awareness of the volume of effluent that might be disposed of and recycled; to determine if there is a need for blending water or eventual TDS removal from the system to prevent an unacceptable increase in TDS; and to obtain a sense of the time it may take for any unacceptable water quality conditions to occur.

For comparison purposes, ECO:LOGIC prepared estimates of effluent that can potentially be used to recharge portions of the alluvial aquifers in Lemmon Valley, Cold Springs, Bedell Flat, Spanish Springs, Warm Springs Valley, and the South Truckee Meadows (see Figure 1). The valley bottom of these areas contains alluvial or lake bed sediments in which storage or disposal of treated effluent may locally be feasible. However, the thickness and composition of these sediments, and their ability to accept treated effluent, is highly variable. In some valleys, the materials exhibit very low permeability, while in others the characteristics are largely unknown. The amount of groundwater development by existing domestic and municipal wells also varies between the valleys, and is a constraint on where effluent storage is possible.

The valleys of Cold Springs, Stead (west Lemmon Valley) and Lemmon Valley are structurally-closed basins with similar geomorphology. They are internally-drained, north-south-trending basins, separated by bedrock hills, which step downward to the east and which drain to either the White Lake Playa (Cold Springs Valley), Silver Lake Playa (Stead Valley), or Swan Lake Playa (Lemmon Valley). There is no direct evidence of groundwater discharge from these closed basins, although some may occur through subsurface fracture zones in the underlying bedrock. The Spanish Springs Valley has some similarities to the above basins, but it is not structurally closed and groundwater discharges both southward through fractured bedrock and the North Truckee Drain, and northward towards Warm Springs Valley.

Bedell Flat and Warm Springs Valley are also not structurally closed, and are northwest-trending valleys formed along major fault zones. Warm Springs Valley drains to Pyramid Lake, while Bedell Flat drains northwesterly to Long Valley Creek and ultimately to Honey Lake. Groundwater in the South Truckee Meadows is derived from both the Mt. Rose Fan complex and a shallow aquifer underlying the valley floor. Groundwater from both areas ultimately flows northward to the Truckee River.

Prior to preparing the volume estimates, the hydrogeologic characteristics of each valley were reviewed using existing, available data to evaluate the overall geology, depth to groundwater, and well locations. This information was then used to approximate the thickness and aerial extent of areas where effluent storage seemed most reasonable.

The results of the study are summarized in Table 3, where the various areas are ranked with respect to potential to recharge the aquifer with effluent. The ranking number is qualitative, and is based both on estimated aquifer/vadose zone characteristics, and on potential infrastructure requirements to convey effluent to likely recharge sites. Because of the region's complex and variable geology, none of the sites have been thoroughly characterized, and additional drilling, aquifer testing and/or groundwater modeling will be required prior to implementation. Areas without extensive groundwater development are most favorable for effluent disposal; however, these same areas tend to have the least available subsurface information.

The estimates are for comparative purposes, and assume that no injected water leaves the site, which is both conservative and unlikely. If the effluent dispersed over a wider area, potential storage volumes could be much larger. As a result of all these factors, the rankings and quantities provided represent first approximations. Additional field studies, including long-term infiltration testing, will be required to better quantify each area's recharge potential.

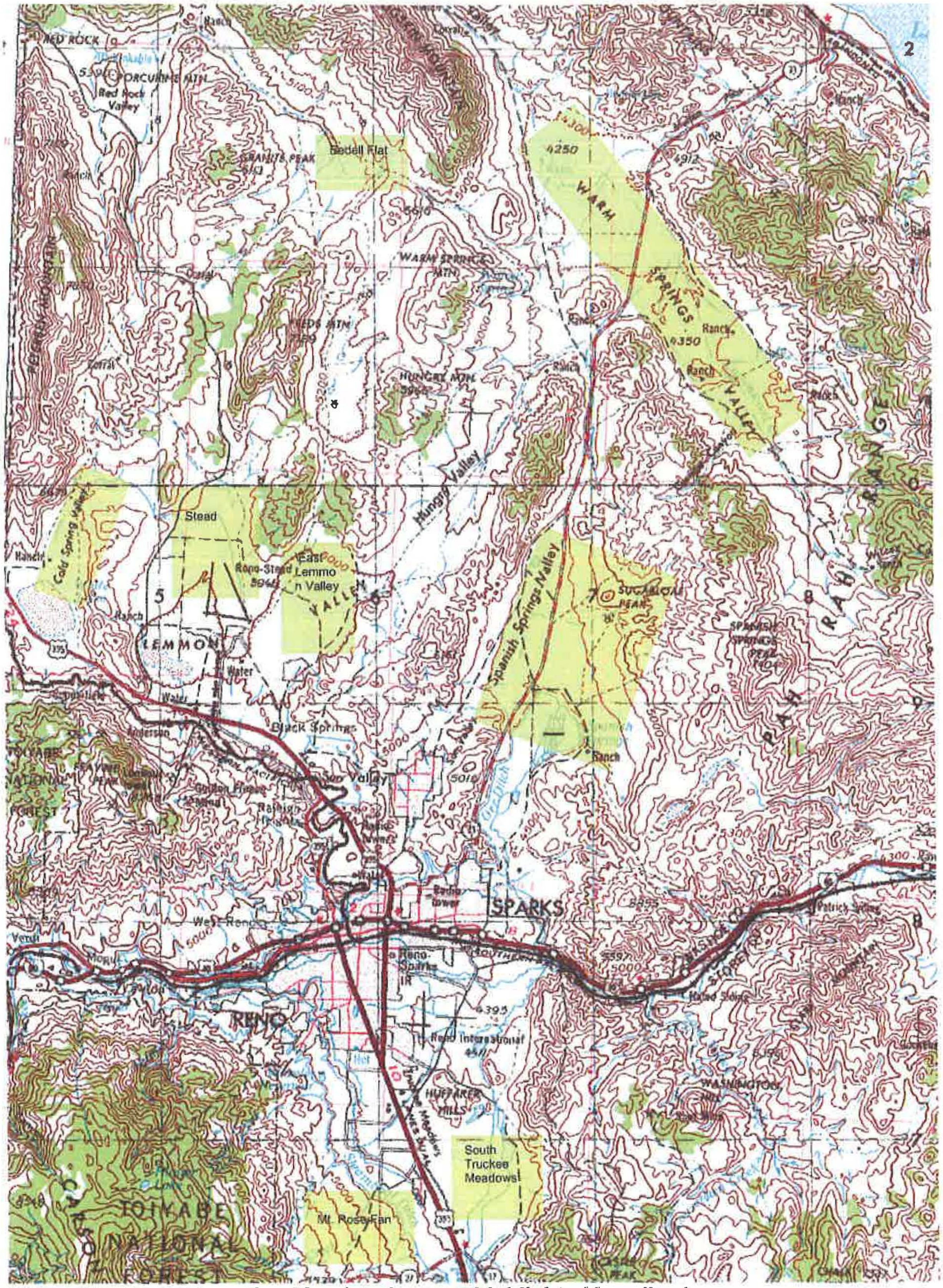


Figure 1: General Location Map (study areas highlighted in yellow).

Table 3: First Approximation of Recharge Storage Volumes

Valley	Estimated effluent storage capacity (Acre-feet)	Potential for salt buildup[1]	Rank[2]	Advantages	Disadvantages
Cold Springs	500	Moderate	6	Few wells in area. Permeable sand horizon may be present. Cold Springs Wastewater Treatment Facility infiltration has not impacted municipal wells.	Limited capacity. Located very close to existing WWTF. Imported effluent may interfere with WWTF rapid infiltration basins (RIBs).
Stead (west Lemmon Valley)	9,300 to 21,000	Moderate	1	Site has been partially characterized. Large undeveloped area with permeable and thick vadose zone and upper aquifer. Located reasonably close to RSWRF. Recharge would help restore declining water levels. Preliminary studies indicate favorable infiltration using wells. Effluent can be recaptured downgradient.	Pipeline required from RSWRF to recharge site. At least eight injection wells may be required. Possible compartmentalization of aquifer from numerous faults in area may limit volume. RIBs may not be feasible, and injection wells would likely be required.
East Lemmon Valley	900	Moderate	7	Proposed disposal area is moderately large, undeveloped area with few existing municipal wells, but near many domestic wells. Recharge would help restore declining water levels in domestic wells.	Geology has not been characterized, but is likely to be unfavorable for significant recharge. Located close to Heppner subdivision with many remaining domestic wells. Located reasonably close to RSWRF.
Bedell Flat	20,700 +	Low	5	Very large undeveloped area with no residents to impact. Possibly very large recharge potential. Effluent could be recovered by downgradient wells.	Remote site would require very lengthy pipeline. Largely unknown geology. Significant amounts of low permeability clay may be present.
Spanish Springs	3,300+	Low	3	Previous studies indicate permeable materials and support infiltration potential near gravel pits on northern side of valley. Inexpensive RIBs possible. Recharge may help support declining water table.	Possible impacts to downgradient wells. Treated effluent pipelines from TMWRF are present nearby.
Warm Springs Valley	26,000	Low-mod	4	Wells near agricultural areas east of Pyramid highway have permeable materials. Recharge would help correct declining water table. Effluent could be beneficial to grass/hay growers.	Clay near surface could limit infiltration and require injection wells. Lengthy pipeline required to bring effluent to site from TMWRF and Spanish Springs.
South Truckee Meadows (Mt. Rose Fan aquifer)	15,000 to 25,000	Low	2	Aquifer has high permeability for easy injection. Injection possible to both vadose zone and aquifer. Large area of water table declines from pumping could be restored. Treated effluent pipelines are present nearby.	High quality aquifer with many municipal and domestic well users. Moderate lift required to pump to upper well sites. Area of drawdown under Wolf Run Golf Course (STMGID #3) may be better site because of lower pumping costs.

[1] Based on assumption that closed basins will have more salt buildup than basins that drain.
[2] 1 = best, 7 = worst

The highest-ranked effluent disposal site (West Lemmon Valley) is located on a Washoe County-owned parcel north of the Stead Airport. Based on preliminary data, effluent storage could be accomplished via combined vadose zone and deeper injection wells. The site is favorable for the following reasons:

1. Undeveloped, publicly-owned land is available.
2. The site is reasonably close to the existing Reno-Stead Water Reclamation Facility (RSWRF). Proposed area development could provide additional effluent users in the future.
3. The site has been partially characterized by three monitoring wells of various depths, and one vadose zone well. Preliminary infiltration testing was completed on these wells, with reasonably favorable results.
4. The water table is relatively deep, and permeable sand horizons exist in both the vadose zone and upper several hundred feet of the aquifer.
5. Washoe County DWR groundwater modeling indicated that recharge and recovery of 2 million gallons per day (mgd) of treated effluent is feasible and that recharge would restore declining water levels in the aquifer. Modeling also indicated no impact to the chemical quality of groundwater of the closest municipal well even after more than 60 years of recharge.
6. Potable-water Aquifer Storage and Recovery (ASR) has been successfully performed on other area municipal wells located a few miles to the south for several years.
7. The closest existing water supply well is about 1.6 miles to the south. This well is not in operation and could potentially be used as a recovery well. Additional airport property is present where other down-gradient recovery wells could be installed.

Other sites with favorable geology and large storage capacity due to declining water tables include the Mt. Rose Fan and Spanish Springs aquifers. Recharge would likely be technically feasible at the Mt. Rose fan, because of favorable aquifer characteristics and existing nearby treated effluent pipelines.

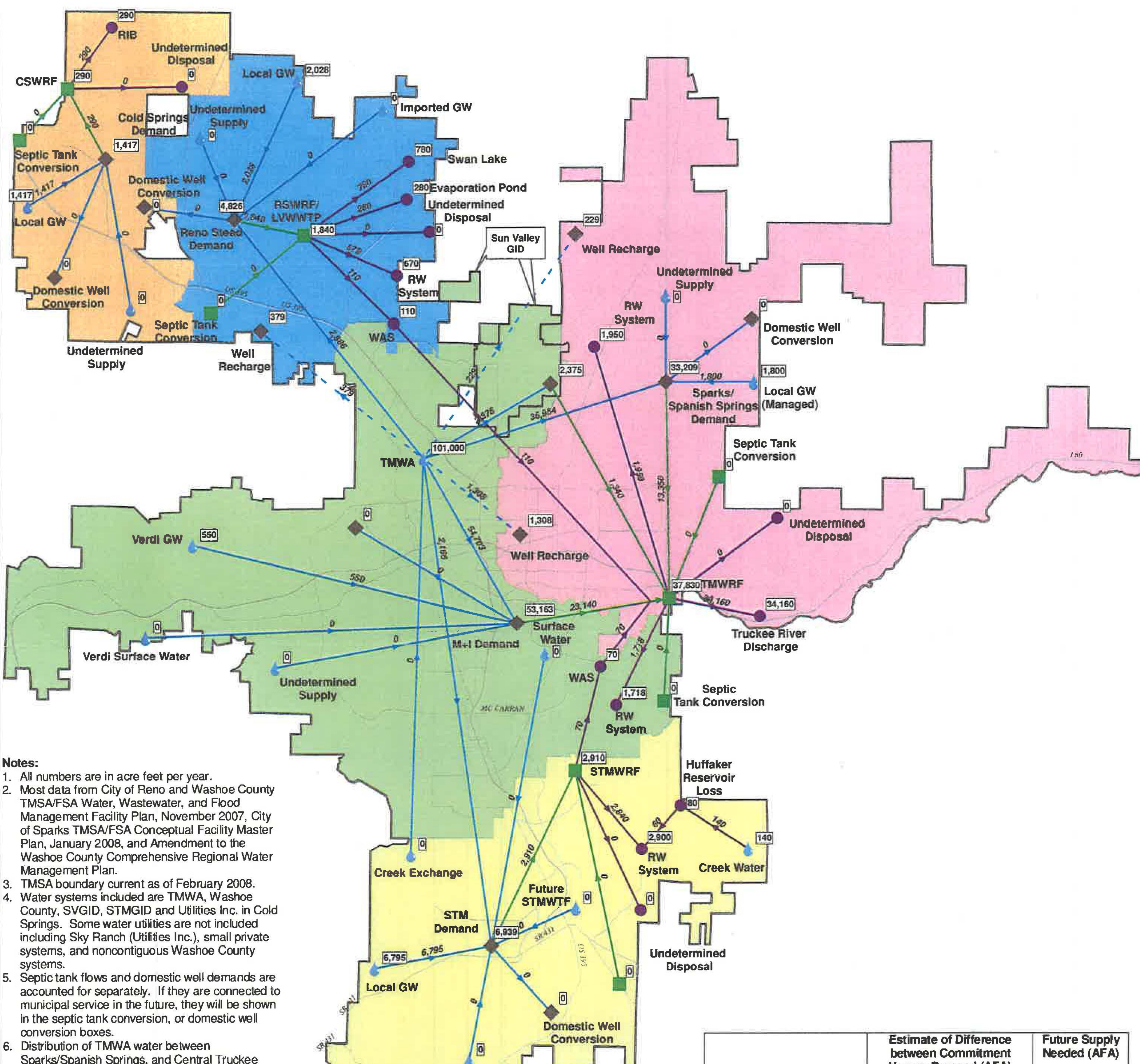
ECO:LOGIC examined the accumulation of total dissolved solids (TDS or salts) in a valley over time if effluent is stored and reused. Because the TDS of effluent will be greater than that of native groundwater or imported Truckee River water, TDS will locally increase where effluent is placed into the aquifer. In structurally-closed basins, the TDS is retained within the valley. Effluent disposal and down-gradient recovery and reuse would eventually recirculate the salts. In valleys that are not closed basins, there may be less long-term TDS accumulation if not all groundwater is recycled.

Because Stead (west Lemmon Valley) is a likely candidate for effluent disposal, and is more or less a closed basin, a mass balance-TDS spreadsheet was developed to estimate the basin-wide impacts. Detailed results may be found in Appendix B. The results show that the aquifer-wide TDS increase would be less than a 1% per year. With a beginning TDS content of about 220 milligrams per liter (mg/L), a future effluent TDS content of about 585 mg/L based on full utilization of the Fish Springs water supply, and a secondary drinking water standard of 1,000 mg/L, there would be no exceedance of drinking water standards in the "overall" aquifer for decades into the future. The impacts will be greater at locations in close proximity to the injection site.

Consequently, based on the likely injection site, and the location of existing municipal water supply wells, the Washoe County Department of Water Resources modeled the breakthrough of effluent to the nearest wells using MODPATH (a particle tracking code) used in conjunction with the County's existing three-dimensional model of Lemmon Valley. These results indicate that the increase in TDS from the effluent would not reach existing municipal wells for more than 60 years. Even when it did, it would be diluted and partially attenuated by that time and no exceedance of TDS water quality standards would be expected in the recovery well for many years thereafter.

EXISTING REGIONAL WATER BALANCE

2006 POPULATION — 409,085
STATE OF NEVADA DEMOGRAPHER'S OFFICE



Notes:

1. All numbers are in acre feet per year.
2. Most data from City of Reno and Washoe County TMSA/FSA Water, Wastewater, and Flood Management Facility Plan, November 2007, City of Sparks TMSA/FSA Conceptual Facility Master Plan, January 2008, and Amendment to the Washoe County Comprehensive Regional Water Management Plan.
3. TMSA boundary current as of February 2008.
4. Water systems included are TMWA, Washoe County, SVGID, STMGID and Utilities Inc. in Cold Springs. Some water utilities are not included including Sky Ranch (Utilities Inc.), small private systems, and noncontiguous Washoe County systems.
5. Septic tank flows and domestic well demands are accounted for separately. If they are connected to municipal service in the future, they will be shown in the septic tank conversion, or domestic well conversion boxes.
6. Distribution of TMWA water between Sparks/Spanish Springs, and Central Truckee Meadows is assumed.
7. Water supplies are based on an estimate of water rights and/or pumping policy. For example, Washoe County local groundwater pumping in Spanish Springs is limited to 1,800 AFA. The actual water demand from one year to another is less than the water supply shown.
8. TMWA supply is both surface water and groundwater. Approximately 16,950 acre feet are from groundwater, and 84,050 acre feet are from surface water.
9. The ratio of water demand to wastewater flow is higher than the typical of 0.5 ratio due to the comparison of committed water demands to actual wastewater flows.

	Estimate of Difference between Commitment Versus Demand (AFA)	Future Supply Needed (AFA)
Cold Springs	0	0
Reno Stead/Lemmon Valley	88	0
Sparks/Spanish Springs	5,545	0
Central Truckee Meadows	4,465	0
South Truckee Meadows	2,022	0

Service Areas	Available Disposal Capacity (AFA)	Future Disposal Needed (AFA)
CSWRF	1,050	0
RSWRF/LVWWTP	1,480	0
TMWRF	2,470	0
STMWRF	360	0

LEGEND

SUPPLY — DEMAND — FLOW — DISPOSAL — GW RECHARGE — RECLAIMED — WASTEWATER — WATER — TMSA BOUNDARY — COLD SPRINGS — SPARKS/SPANISH SPRINGS — RENO STEAD LEMMON VALLEY — SOUTH TRUCKEE MEADOWS — CENTRAL TRUCKEE MEADOWS

0 1 2 3 MILES NORTH

ECO:LOGIC ENGINEERS · CONSULTANTS
10381 DOUBLE R BLVD RENO, NV 89521
PHONE: 775.827.2311 FAX: 775.827.2316

PLATE 1
EXISTING REGIONAL WATER BALANCE
COUNTY OF WASHOE, NEVADA

REV NO.	REVISION	BY

JOB#	RENO09-001	DESIGNED	CVB
DATE	JAN. 2009	DRAWN	RJG
SCALE	NONE	CHECKED	JPE

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Appx A

APPENDIX B

ECO:LOGIC

Consulting Engineers

Treated Effluent Recharge Estimates

Lemmon, Cold Springs, Spanish Springs, Warm Springs, and South Truckee Meadows Valleys

Prepared for:

Western Regional Water Commission

Prepared by:

ECO:LOGIC Engineering

February 2010

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1.0 Tasks 5 and 6 Introduction and Summary

In April 2009, ECO:LOGIC was retained by the City of Reno to prepare a planning-level assessment of the volume of high-quality treated effluent that might be stored and/or disposed of in the alluvial deposits of select hydrographic areas of Washoe County. ECO:LOGIC also prepared a water/total dissolved solids (TDS) mass balance to examine long term changes in water quality in the alluvial aquifer of Lemmon Valley arising from effluent storage/disposal/reuse. The studies were to rely heavily on data, information and results of previous hydrogeologic investigations of the study areas available through the Washoe County Department of Water Resources (DWR). The intent was not to develop a fully calibrated solute transport model for the basins; but rather to develop an awareness of the volume of effluent that might be disposed of and recycled; to determine if there is a need for blending water or eventual TDS removal from the system to prevent an unacceptable increase in TDS; and to obtain a sense of the time it may take for any unacceptable water quality conditions to occur.

For comparison purposes, ECO:LOGIC prepared estimates of effluent that can potentially be used to recharge portions of the alluvial aquifers in Lemmon Valley, Cold Springs, Bedell Flat, Spanish Springs, Warm Springs Valley, and the South Truckee Meadows (see Figure 1). The valley bottom of these areas contains alluvial or lake bed sediments in which storage or disposal of treated effluent may locally be feasible. However, the thickness and composition of these sediments, and their ability to accept treated effluent, is highly variable. In some valleys, the materials exhibit very low permeability, while in others the characteristics are largely unknown. The amount of groundwater development by existing domestic and municipal wells also varies between the valleys, and is a constraint on where effluent storage is possible.

The valleys of Cold Springs, Stead (west Lemmon Valley) and Lemmon Valley are structurally-closed basins with similar geomorphology. They are internally-drained, north-south-trending basins, separated by bedrock hills, which step downward to the east and which drain to either the White Lake Playa (Cold Springs Valley), Silver Lake Playa (Stead Valley), or Swan Lake Playa (Lemmon Valley). There is no direct evidence of groundwater discharge from these closed basins, although some may occur through subsurface fracture zones in the underlying bedrock.

The Spanish Springs Valley has some similarities to the above basins, but it is not structurally closed and groundwater discharges both southward through fractured bedrock and the North Truckee Drain, and northward towards Warm Springs Valley.

Bedell Flat and Warm Springs Valley are also not structurally closed, and are northwest-trending valleys formed along major fault zones. Warm Springs Valley drains to Pyramid Lake, while Bedell Flat drains northwesterly to Long Valley Creek and ultimately to Honey Lake.

Groundwater in the South Truckee Meadows is derived from both the Mt. Rose Fan complex and a shallow aquifer underlying the valley floor. Groundwater from both areas ultimately flows northward to the Truckee River.

Prior to preparing the volume estimates, the hydrogeologic characteristics of each valley were reviewed using existing, available data to evaluate the overall geology, depth to groundwater, and well locations. This information was then used to approximate the thickness and aerial extent of areas where effluent storage seemed most reasonable.

The results of the study are summarized in Table 1, where the various areas are ranked with respect to potential to recharge the aquifer with effluent. The ranking number is qualitative, and is based both on estimated aquifer/vadose zone characteristics, and on potential infrastructure requirements to convey effluent to likely recharge sites. Public perception and permitting requirements will be more difficult in areas where extensive groundwater development occurs and were considered in the ranking. Because of the region's complex and variable geology, none of the sites have been thoroughly characterized, and additional drilling, aquifer testing and groundwater modeling will be required prior to any implementation. Because areas without extensive groundwater development are most favorable for effluent disposal, these same areas tend to have the least available subsurface information. As a result of all these factors, the rankings and quantities provided herein represent first approximations and additional field studies, including long-term infiltration testing, will be required to better quantify each area's recharge potential.

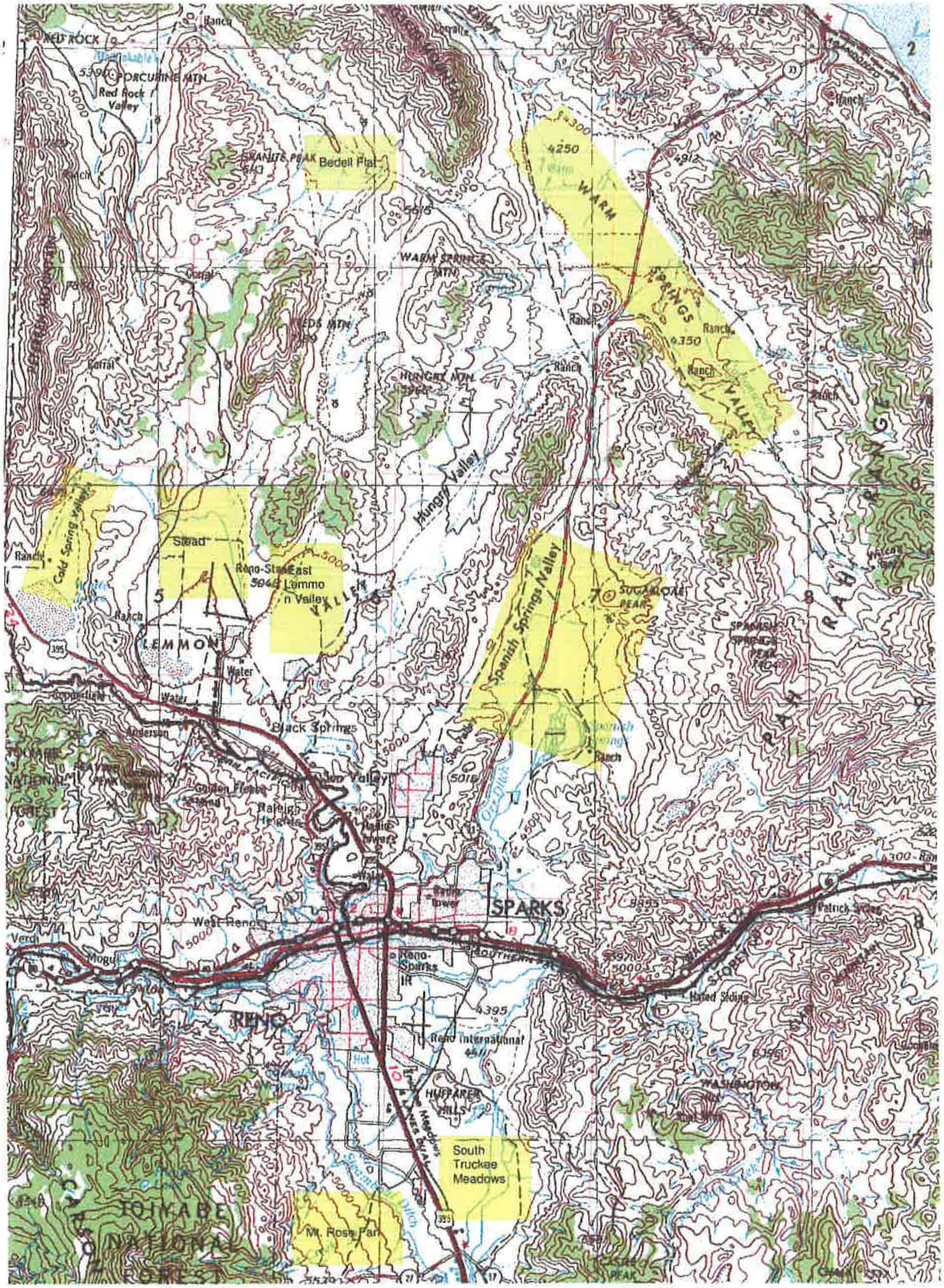

Figure 1: General Location Map (study areas highlighted in yellow).

Table 1: Summary of Findings

Valley	Estimated effluent storage capacity (acre-feet)	Potential for salt buildup[1]	Rank[2]	Advantages	Disadvantages
Cold Springs	500	Moderate	6	Few wells in area. Permeable sand horizon may be present. Cold Springs Wastewater Treatment Facility infiltration has not impacted municipal wells.	Limited capacity. Located very close to existing WWTF. Imported effluent may interfere with WWTF rapid infiltration basins (RIBs).
Stead (west Lemmon Valley)	9,300 to 21,000	Moderate	1	Site has been partially characterized. Large undeveloped area with permeable and thick vadose zone and upper aquifer. Located reasonably close to RSWRF. Recharge would help restore declining water levels. Preliminary studies indicate favorable infiltration using wells. Effluent can be recaptured downgradient.	Pipeline required from RSWRF to recharge site. At least eight injection wells may be required. Possible compartmentalization of aquifer from numerous faults in area may limit volume. RIBs may not be feasible, and injection wells would likely be required.
East Lemmon Valley	900	Moderate	7	Proposed disposal area is moderately large, undeveloped area with few existing municipal wells, but near many domestic wells. Recharge would help restore declining water levels in domestic wells.	Geology has not been characterized, but is likely to be unfavorable for significant recharge. Located close to Heppner subdivision with many remaining domestic wells. Located reasonably close to RSWRF.
Bedell Flat	20,700+	Low	5	Very large undeveloped area with no residents to impact. Possibly very large recharge potential. Effluent could be recovered by downgradient wells.	Remote site would require very lengthy pipeline. Largely unknown geology. Significant amounts of low permeability clay may be present.
Spanish Springs	3,300+	Low	3	Previous studies indicate permeable materials and support infiltration potential near gravel pits on northern side of valley. Inexpensive RIBs possible. Recharge may help support declining water table.	Possible impacts to downgradient wells. Treated effluent pipelines from TMWRF are present nearby.
Warm Springs Valley	26,000	Low-mod	4	Wells near agricultural areas east of Pyramid Highway have permeable materials. Recharge would help correct declining water table. Effluent could be beneficial to grass/hay growers.	Clay near surface could limit infiltration and require injection wells. Lengthy pipeline required to bring effluent to site from TMWRF and Spanish Springs.
South Truckee Meadows (Mt. Rose Fan aquifer)	15,000 to 25,000	Low	2	Aquifer has high permeability for easy injection. Injection possible to both vadose zone and aquifer. Large area of water table declines from pumping could be restored. Treated effluent pipelines are present nearby.	High quality aquifer with many municipal and domestic well users. Moderate lift required to pump to upper well sites. Area of drawdown under Wolf Creek Golf Course (STMGID #3) may be better site because of lower pumping costs.

[1] Based on assumption that closed basins will have more salt buildup than basins that drain.

[2] 1 = best, 7 = worst

The highest-ranked effluent disposal site (West Lemmon Valley) is located on a Washoe County-owned parcel north of the Stead Airport. Based on preliminary data, effluent storage could be accomplished via combined vadose zone and deeper injection wells. The site is favorable for the following reasons:

1. Undeveloped, publicly-owned land is available.
2. The site is reasonably close to the existing Reno Stead Water Reclamation Facility (RSWRF). Proposed area development could provide additional effluent users in the future.
3. The site has been partially characterized by three monitoring wells of various depths, and one vadose zone well. Preliminary infiltration testing was completed on these wells, with reasonably favorable results.
4. The water table is relatively deep, and permeable sand horizons exist in both the vadose zone and upper several hundred feet of the aquifer.
5. Washoe County DWR groundwater modeling indicated that recharge and recovery of 2 million gallons per day (mgd) of treated effluent is feasible and that recharge would restore declining water levels in the aquifer. Modeling also indicated no impact to the chemical quality of groundwater from the closest municipal well even after more than 60 years of recharge.
6. Potable-water Aquifer Storage and Recovery (ASR) has been successfully performed on other area municipal wells located a few miles to the south for several years.
7. The closest existing water supply well is about 1.6 miles to the south. This well is not in operation and could potentially be used as an effluent recovery well. Additional airport property is present where other down-gradient recovery wells could be installed.

Other sites with favorable geology and large storage capacity due to declining water tables include the Mt. Rose Fan and Spanish Springs aquifers. Recharge would likely be technically feasible at the Mt. Rose fan, both because of favorable aquifer characteristics and existing nearby treated effluent pipelines.

ECO:LOGIC examined the accumulation of TDS (or salts) in a valley over time if effluent is stored and reused. Because the TDS of effluent will be greater than that of native groundwater or imported Truckee River water, TDS will locally increase where effluent is placed into the aquifer. In structurally-closed basins, the TDS is retained within the valley. Effluent disposal and down-gradient recovery and reuse would eventually recirculate the salts. In valleys that are not closed basins, there may be less long-term TDS accumulation if not all groundwater is recycled.

Because Stead (west Lemmon Valley) is a likely candidate for effluent disposal, and is more or less a closed basin, a mass balance-TDS spreadsheet was developed to estimate the basin-wide impacts. The results show that the aquifer-wide TDS increase would be less than a 1% per year. With a beginning TDS content of about 220 milligrams per liter (mg/L), a future effluent TDS content of about 585 mg/L based on full utilization of the Fish Springs water supply, and a secondary drinking water standard of 1000 mg/L, there would be no exceedance of TDS drinking water standards in the "overall" aquifer for decades into the future. The impacts will be greater at locations in close proximity to the injection site.

Consequently, based on the likely injection site, and the location of existing municipal water supply wells, the Washoe County Department of Water Resources modeled the breakthrough of effluent to the nearest wells using MODPATH (a particle tracking code) used in conjunction with the County's existing three-dimensional model of Lemmon Valley. These results indicate that the increased TDS in effluent would not reach existing municipal wells for more than 60 years. Even so, it would be diluted and partially attenuated by that time and no exceedances of TDS water quality standards would be expected in the recovery well for many years thereafter.

1.1 Methods

Two main methods were used to estimate recharge potentials, depending on the amount of available hydrologic information for each valley. For the Mt. Rose Fan, Spanish Springs, and West Lemmon Valley, where groundwater flow models or other detailed groundwater investigations illustrating groundwater declines due to pumping exist, the modeled area of dewatering was used to estimate the amount of effluent recharge needed to restore original aquifer conditions. In the remaining valleys, detailed geologic or pumping test data are sparse and aquifer characteristics are either largely unknown or highly variable, and therefore very difficult to estimate. In these valleys, the recharge and storage estimate was made by simply measuring the surface area of a likely recharge site, and using the approximate depth to groundwater and likely aquifer/vadose zone characteristics to calculate a possible volume of available vadose zone that could potentially be filled by treated effluent. A 50% fill height was used (i.e. only 50% of the available vadose zone space was filled) to account for injection mounds that would develop around the wells. This calculation only evaluates the size of the potential recharge area and does not account for migration of effluent away from the recharge site over time, which may or may not be significant depending on the aquifer's hydrologic parameters. It does, however, provide a quantity that can be used to compare the relative storage capacity of each of the valleys.

2.0 Task 5 – Effluent Storage Volumes

A description of each valley, the rationale for selecting a given area within a valley for storing effluent, and the comparative storage volume estimates for each area are provided in the following sections.

2.1 Cold Springs Valley

2.1.1 Hydrogeologic Setting

Cold Springs Valley is a fault-bounded, closed basin. White Lake playa is present towards the south end of the valley where it abuts the lower slope of Peavine Mountain. About two miles north of the playa the valley necks down in an area where the Petersen Mountains and Granite Hills merge. Granitic or older metamorphic rocks form the surrounding hills, while Tertiary lakebed sediments, consisting of semi-consolidated sand, sandstone, siltstone and diatomite fill the valley. Layers of younger alluvium, beach sands, and playa sediments comprised of silt, clay and very fine sand overlie the Tertiary sediments.

Extensive residential development is present mostly on the north and southwest sides of the playa. Groundwater supply wells and some domestic wells exist in the same areas. Groundwater moves toward the playa from all directions with some entering Cold Springs Valley from the adjacent Long Valley drainage.

Groundwater levels are typically 4 to 8 feet below the playa surface, but are shallowest on the north side, where groundwater seeps onto the playa surface. North of the playa, the water table remains shallow and relatively flat. Steeper gradients towards the playa exist from the south and west. Upward vertical gradients measured in wells near the playa margin support the concept of the playa as a groundwater discharge area. Little or no groundwater is thought to leave the valley by subsurface leakage to adjacent basins, although a small amount conceivably flows through fractured bedrock towards Lemmon Valley.

Groundwater levels throughout the valley fluctuate in response to precipitation. During wet climatic periods a shallow playa lake forms. Most water in the valley is good quality (up to 260 mg/L TDS) and dominated by calcium bicarbonate, except directly under the playa where salts accumulate from evaporation of surface water and upwelling groundwater, and TDS locally exceeds 20,000 mg/L.

Area wastewater is treated at the Cold Springs Wastewater Treatment Facility (CSWWTF) located north of the playa and treated effluent is infiltrated into a series of rapid infiltration basins (RIBs, see Figure 2). As of 2007, the CSWWTF infiltrated approximately 250,000 gallons per day (gpd, or 0.77 acre-feet per day). The facility has three shallow monitoring wells (MW-2S to 4S) that are screened across the water table, and four other monitoring wells screened in a deeper, semi-confined part of the aquifer (MW-2D to 4D).

Infiltrated effluent from the CSWWTF appears to move horizontally towards the playa, rather than vertically to deeper permeable strata tapped by the deeper municipal wells located near the playa. To date, the monitoring wells indicate that the shallow water table aquifer is rising in response to RIB infiltration, but that the piezometric level in the deep aquifer is declining in response to groundwater pumping by the municipal wells (see Figure 3). The shallow and deeper aquifers appear to be isolated from each other by a clayey aquitard.

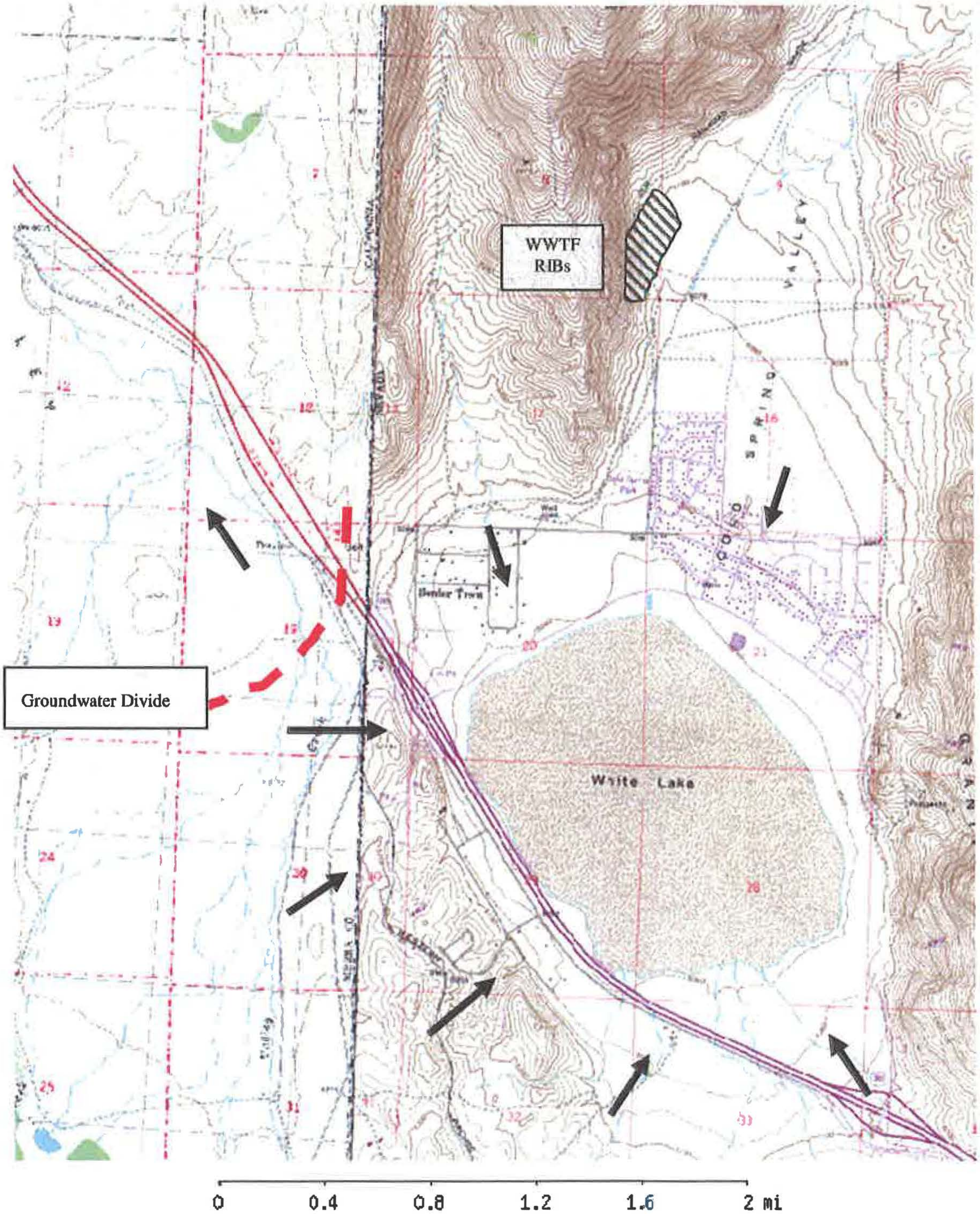

Figure 2: Topographic map of Cold Springs and White Lake.
Black arrows show generalized groundwater flow direction. Red dashed line represents approximate boundary between groundwater flow systems of Cold Springs and Long Valley. Data from Van Denburgh (1981).

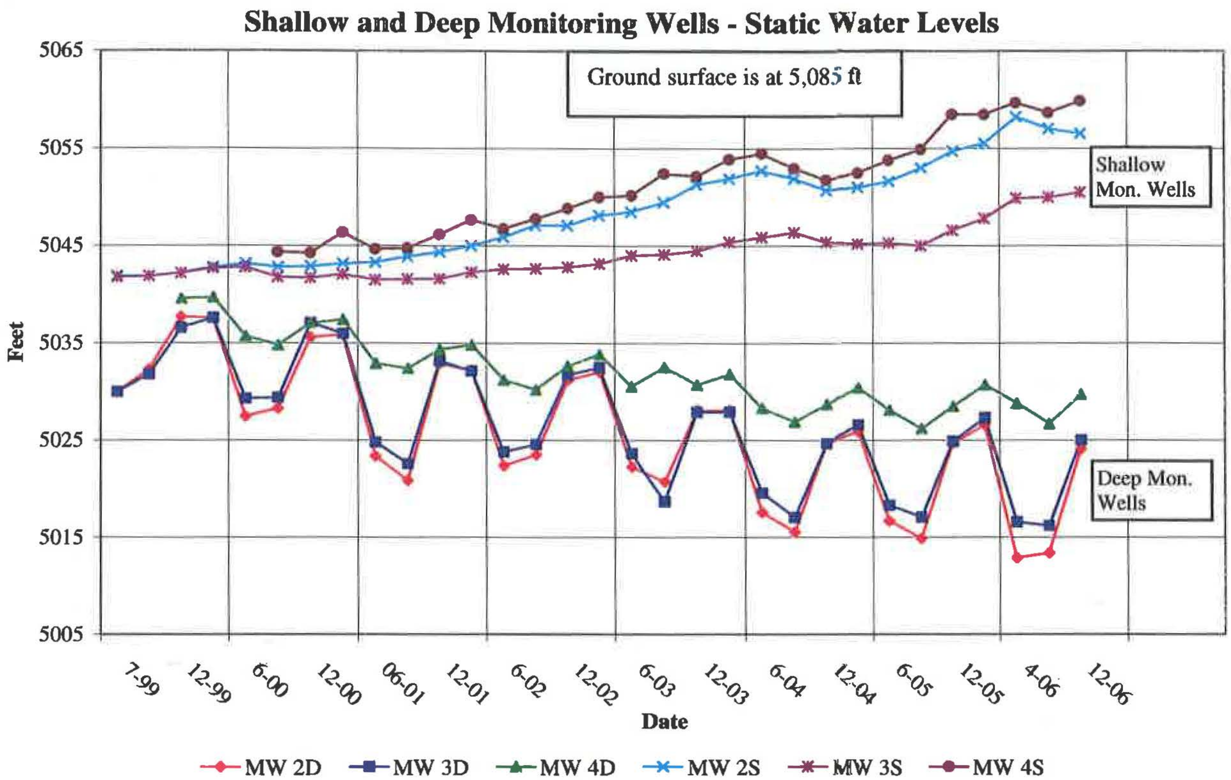

Figure 3: Cold Springs WWTF, Combined Plot of Groundwater Elevations for both Deep and Shallow Wells

The effluent migrates away from the CSWWTF site at a slower rate than it is being infiltrated, and an effluent mound is rising at a rate of about two feet per year. If RIB discharge increases are maintained into the future, the RIBs will reach their design capacity of 700,000 gpd in about 10 years. At about the same time, a flooded condition from the rising water table could necessitate construction of additional infiltration basins.

Any effluent imported into the valley to recharge the shallow aquifer could exacerbate the RIB condition. Instead, additional effluent could be disposed by evaporation on the playa surface. In 2007, ECO:LOGIC evaluated potential impacts from playa disposal by reviewing existing data for the valley and playa, and collecting core samples from bore holes throughout the playa. The cores indicate that the playa is comprised mostly of silty, micaceous clay and lesser very-fine sand, and that highly saline water exists under most of the playa surface. Additional studies would be required to quantify the evaporation potential.

2.1.2 Potential Effluent Recharge Areas

Because of the valley's terrain and shallow groundwater near the playa, there is only a limited space north of the playa where groundwater could be recharged with treated effluent. A potential recharge site is shown in Figure 4. The land is privately owned, and may have development plans. However, because of its proximity to the CSWWTF RIBs, recharge there would have an effect similar to increasing the size of the existing RIBs, and would likely interfere with the RIBs by raising the shallow water table. This would likely decrease the lifespan of the RIBs, and could increase the potential for flooded conditions at either the CSWWTF, or near the north end of the playa where the shallow groundwater ultimately discharges.

2.1.3 Comparative Recharge Volume

The amount of effluent that could be recharged into the vadose zone, based on the area shown in Figure 3, is calculated in Table 2. As previously discussed, this quantity only evaluates the size of the recharge area and does not account for migration of effluent away from the recharge site over time, which may or may not be significant depending on the local aquifer conditions. The value is shown only for comparative purposes with the other valleys. The depth to groundwater is also based on relatively old well logs, and it is possible that groundwater levels are higher due to RIB operations.

Figure 4: Cold Springs – Potential effluent disposal area

Table 2: Cold Springs - Potential Recharge Capacity

Scenario	Area (ft^2)	Area (acres)	DTW (ft)	50% Fill Height (ft) or thickness	% Permeable sand	Porosity of sand	Volume (A-FT)
1	4,800,000	110	60	30	50	0.30	**500**
Notes: Depth to water (DTW) is the estimated, average depth to groundwater taken from well logs, where available. Fill height assumes half the DTW can be used for storage over the measured map area.							

2.2 West Lemmon Valley (Stead)

2.2.1 Hydrogeologic Setting

West Lemmon Valley (Stead) is bounded on the south by Peavine Mountain, and is separated from adjacent valleys by north-south trending faults, or fault-bounded bedrock hills. The center of the valley has a thick accumulation of Tertiary-age lakebed sediments (more than 1,600 feet thick north of the Stead airport) overlain by a thin layer of younger alluvium.

The Tertiary lakebed sediments that fill the valley are variable in composition and include unconsolidated to moderately well-consolidated layers of clay, muddy sands, coarse sand, and minor gravel. The permeability of these sediments is extremely variable both vertically and laterally. The dip of tilted bedding and/or fault surfaces may also locally influence groundwater movement.

Thicker layers of sand and/or gravel may have moderate to high permeability, produce significant groundwater, and (in areas where groundwater is sufficiently deep) have significant storage capacity in the vadose zone. Coarser, permeable materials have been identified in wells drilled along the western side of the valley, but their areal distribution is not well documented.

Overlying the Tertiary sediments, mostly in the valley bottom, are younger alluvial or playa deposits. Although the alluvium may have high permeability, the deposits are very thin and have minimal storage potential. The playa deposits are fine-grained and have similar low storage potential.

The Stead valley contains numerous municipal and domestic groundwater wells in the southern and western portions of the valley that produce groundwater mostly from the Tertiary lakebed sediments. The northern portion of the valley contains widely-spaced domestic wells, while the central and northeast portions of the valley are undeveloped because the land is owned by the Reno-Stead airport. Wastewater from the southern, densely developed part of the basin is treated at the RSWRF, while lower density development on the west and far northern portions of the valley use septic systems.

Depth to groundwater is generally deepest on the north end of the valley (more than 200 feet deep) and along the valley margins, and is shallowest towards the center and south end of the valley, near the Silver Lake playa (less than 20 feet).

2.2.2 Potential Effluent Recharge Areas

Several areas in west Lemmon Valley have previously been investigated for their use either in aquifer recharge, or aquifer storage and recovery (ASR). The Truckee Meadows Water Authority (TMWA) has annually injected water into two municipal wells, Air Guard #1 and Silver Lake #4 located west and southwest of the airport, at rates of up to 365 gpm per well for 60 consecutive days. Well logs for these sites indicate that the geology contains a significant aggregate thickness of relatively permeable sand.

In 2001, Washoe County DWR installed three groundwater monitoring wells about 2 miles north of the airport to various depths, including one to 1,630 feet below ground surface (bgs) (see Figures 5 and 6). Groundwater was present at about 190 feet bgs. Layers of permeable, coarse-grained sand, similar to that found in the TMWA wells, were identified in each borehole, both above and below the water table, but pumping tests were not completed on the wells.

In 2006, ECO:LOGIC completed a 170-foot-deep vadose zone well at the Washoe County site and performed short-term (3,000 gallon) infiltration tests on all four wells. Results of the infiltration testing are provided in Table 3. The vadose zone and shallow portion of the aquifer (Layer 1) appeared to be sufficiently permeable to accept and store relatively large volumes of water.

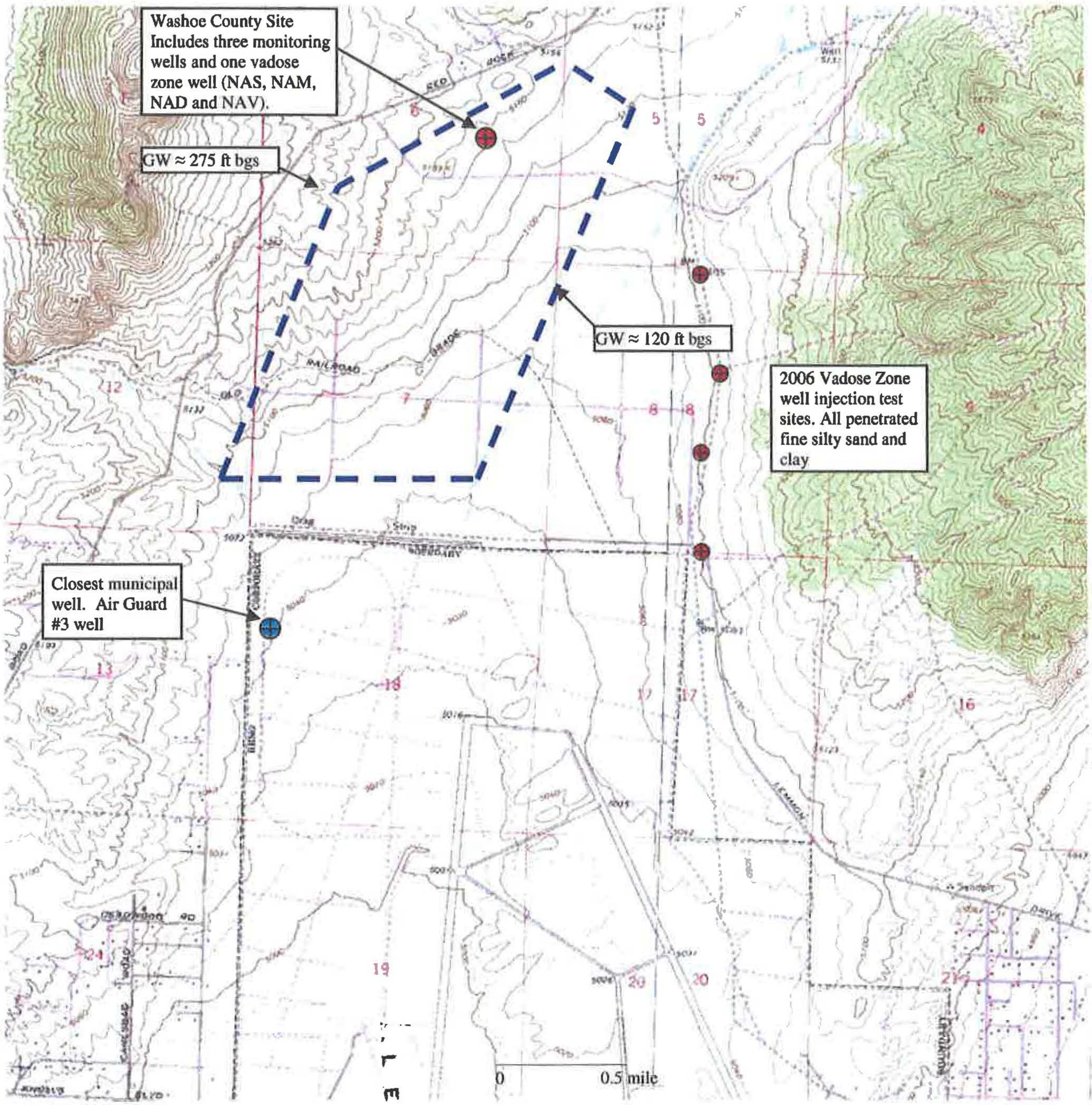

Figure 5: Proposed West Lemmon Valley recharge site.
Topographic map of the northern Stead Valley and Washoe County Well Site.

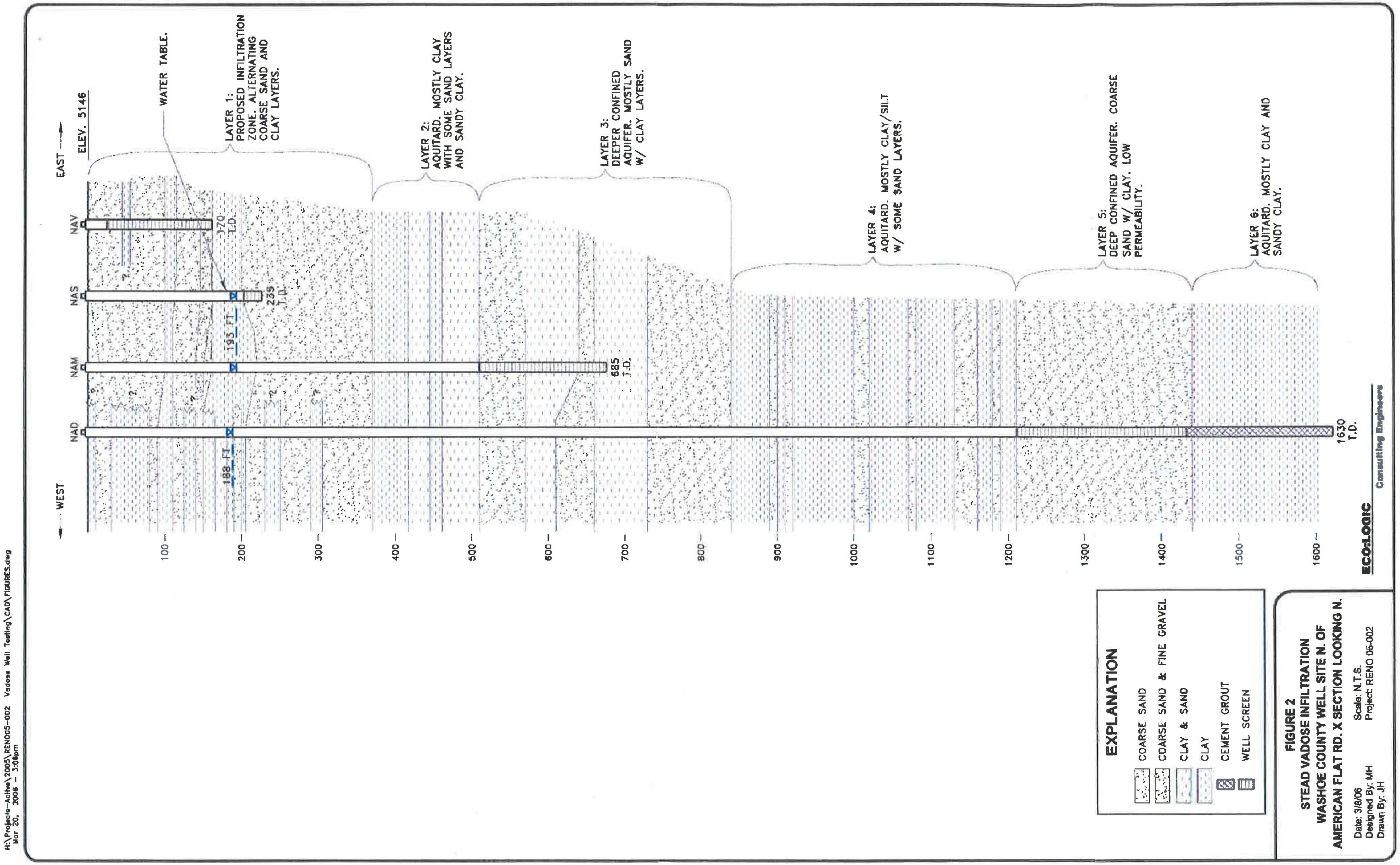

Figure 6: Geologic Cross Section of Washoe County Well Site.

Table 3: Stead, North Airport / Washoe County Site Injection Test Results

Well	Average injection Rate (gpm)	End of injection Water Level (ft bgs)	Maximum Water Level Rise (ft)	End of Test Specific Capacity (gpm/ft of WL rise)	Projected water level rise at end of 70 days	Specific Capacity at 70 days	Transmis. (gpd/ft)	Hyd. Cond. $(gpd/ft^2)^1$	Potential max. injection rate at 70 days (gpm)[2]
NAV Test #1	110	111.3	48.7	2.26	84	1.31	2904	35	177
NAV Test #2	113	103.5	56.5	2.00	93	1.22	2983	32	164
NAS	16.5	185.2	8.89	1.86	14	1.18	2722	136	159
NAM	102	157	36	2.83	72	1.42	2992	19	191
NAD	53	8.5	180	0.29	NA[3]	NA	209	1	10?

[1] For comparison purposes only to show injection over a given screen length. Equal to the estimated transmissivity divided by the well screen length for the groundwater wells, or by the projected water level rise for the vadose well. Well screen length assumed equal to aquifer thickness due to presumed horizontal layering in aquifer.

[2] Assumes water level maintained at 25 ft below the ground surface and no interference from injection into other zones. Injection rate may or may not be less, but cannot be determined without doing longer term injection testing. Larger, developed ASR wells are expected to allow injection at greater rates.

[3] Test was performed at too high a rate to project beyond one day. The maximum injection rate shown is a rough approximation.

Also in 2006, four vadose zone infiltration wells were installed northeast of the Stead airport in an area that had no previous drilling to assess that area's effluent infiltration potential (see Figure 5). The lake bed sediments in that area were found to consist of dense, fine-grained silty sand. Although the site was favorably located with respect to other area groundwater users, infiltration testing indicated that the vadose zone materials had relatively low permeability. The wells were only drilled to the water table at about 120 feet bgs, and the permeability of deeper strata was not determined.

Based on these investigations, the Washoe County-owned property and surrounding area located north of the airport and west of the valley center appears to be favorable for both effluent storage and recovery. This large undeveloped area is located reasonably close to the RSWRF, there are no nearby down-gradient wells, and a thick section of permeable vadose zone and upper aquifer exists into which effluent could be recharged.

The closest municipal groundwater supply well to the Washoe County site is approximately 1.5 miles to the southwest (TMWA Air Guard #3 Well). That well was constructed with screened intervals extending from 310 feet bgs to 838 feet bgs and produced 1,200 gpm with 25 feet of drawdown. The Washoe County DWR ran computer simulations of the effects of effluent recharge and groundwater pumping on this well, which is discussed in Section 2.2.4, while a discussion of possible salt accumulation in the overall aquifer is provided in Chapter 3.0.

2.2.3 Comparative Recharge Volume

Using the methods previously described, ECO:LOGIC estimated the amount of effluent that could be recharged within the vadose zone at the Washoe County site north of the airport (see Figure 6 and Table 2). Only the area west of the center of the valley was included, to account for the fine-grained sediments identified in bore holes on the east side of the valley. As in the other valleys, the estimate is for comparative purposes, and assumes that no injected water leaves the site, which is both conservative and unlikely. If the effluent dispersed over a wider area, potential storage volumes could be much larger.

Table 4: Stead, North Airport / Washoe County injection Site - Potential Injection Capacity

Scenario	Area (ft^2)	Average Depth to Water	Average Fill Height (50% of depth to water)	% Coarse Sands	Sand porosity	Sand volume (ft^3)	Sand volume (A-FT)
1	34,376,357	197.5	99	0.40	0.30	407,359,830	**9,351**
Entire alluvial aquifer	609,840,000		20[a]	25	.30	914,760,000	**21,000**

Estimate assumes that injected water does not leave the injection "area", but simply fills the coarse sand layers within the vadose zone. Assumes even dispersion of water and complete filling of measured area.

Scenario 1 - area measured from Figure 1. Assumes no significant boundaries exist within the area identified, that coarse sands make up 50% of vadose zone and that the sands contain few fines.

Entire alluvial aquifer defined by Harrill, p. 80, as 14,000 acres.

[a] Average fill height based on total estimated drawdown in aquifer by 2043, as determined by Washoe County DWR.

2.2.4 DWR Model Results

Because of the favorable recharge characteristics identified at the Washoe County site, the Washoe County DWR used their existing Lemmon Valley groundwater model to simulate: 1) the effects of recharging two million gallons per day (mgd) of treated effluent; 2) if the treated effluent could be recovered using down-gradient TMWA wells; and, 3) how far the injected effluent would migrate in a reasonable period using particle tracking functions. Their complete report is provided as Attachment A.

Three scenarios were modeled. Select model results are illustrated in Figures 7 through 9. Figure 7 shows that an average of 2 mgd can be injected at the Washoe County site, in multiple wells, without resulting in "flooded cells", or essentially pumping more water into the aquifer than it can accept. However, a large groundwater mound would form through much of the valley by the end of simulated injection in 2043. Figure 8 shows the anticipated effects if the same quantity of water were removed from the aquifer at existing TMWA wells beginning five years after initiation of injection (2013). In this case, the groundwater mound would be much reduced, and the current groundwater deficit in the valley would be minimized. Figure 9 demonstrates the radius of influence of both the injection and recovery wells after 62 years of system operation. Note that the effluent would be evenly distributed over all of Layer 2 in their model, which is quite thick. As shown, despite the increased water levels, individual particles barely migrate beyond the Washoe County property boundary. There would thus be a very lengthy residence time in the aquifer before the recharged effluent would be recovered by other wells for reuse.

Because faults have been mapped in the proposed recharge area, boundaries leading to aquifer compartmentalization may exist, which could effect recharge distribution. Multiple injection sites would help reduce this potential. Additional site investigations and recharge testing are recommended to confirm the model results.

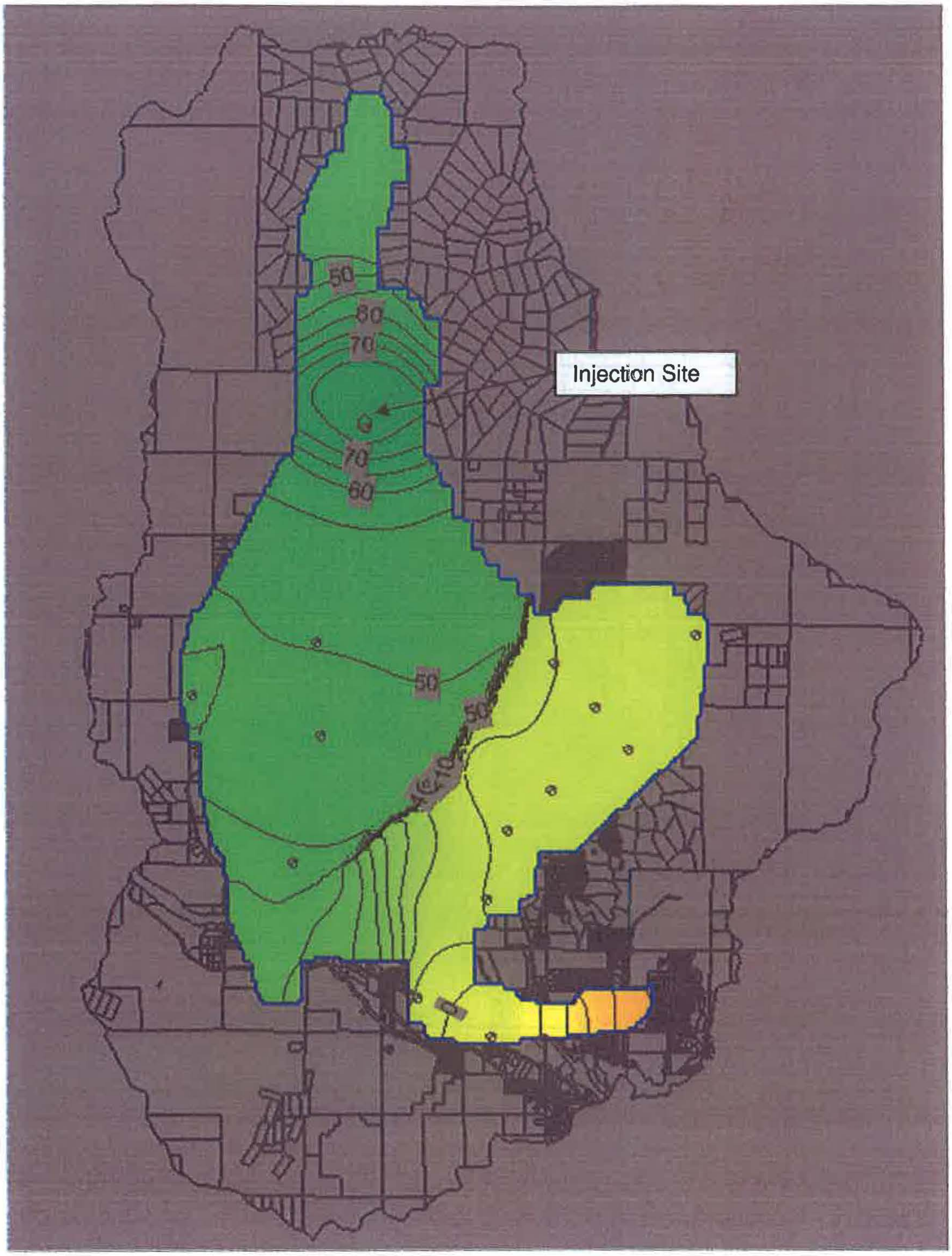

Figure 7: Alternative 2: Injection well recharging 2 MGD and 2007 pumping rates. Head change after 62 years of 2 MGD injection & 2007 pumping rates.

Modeling completed by Christian Kropf, Washoe County Department of Water Resources (December 2009).

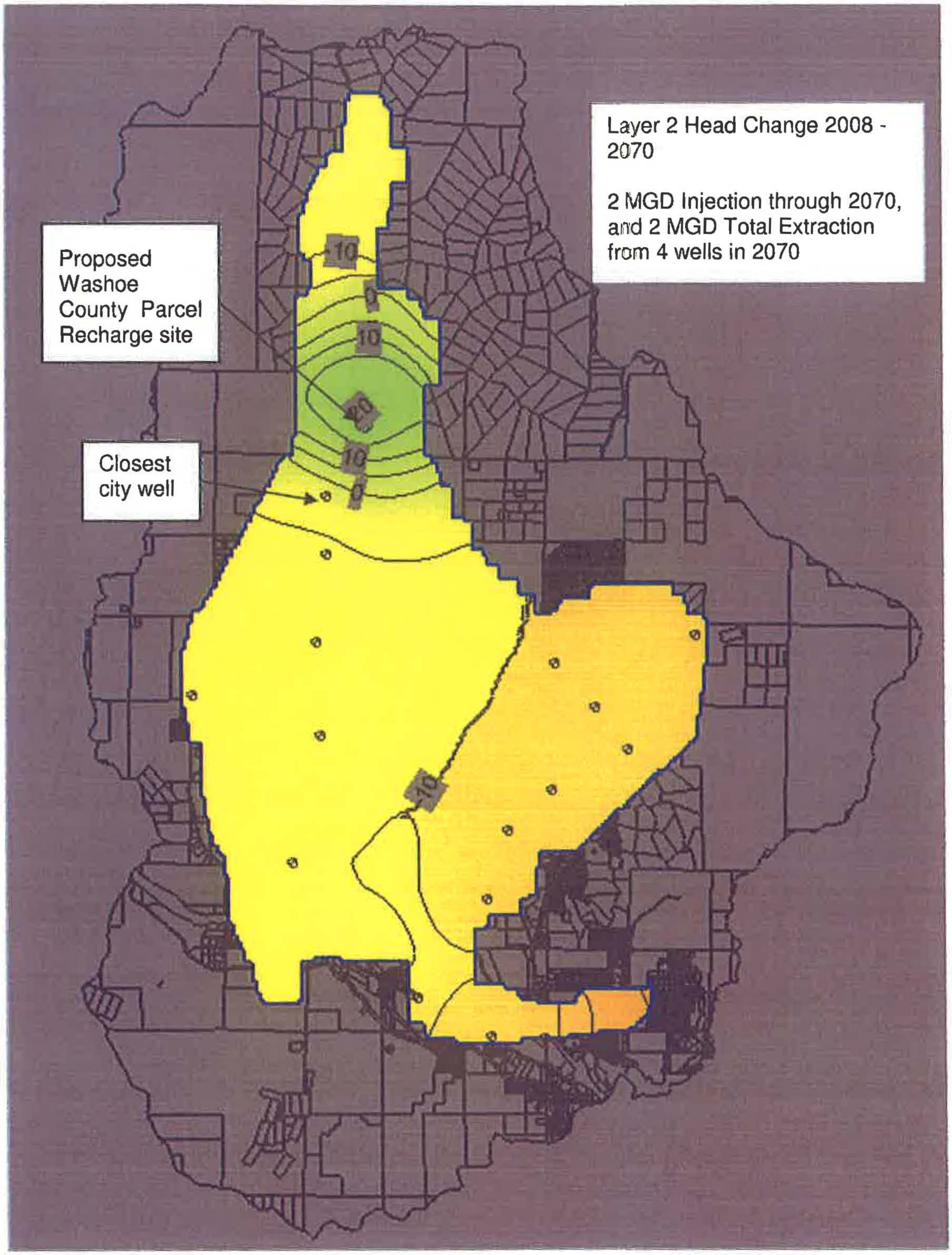

Figure 8: Alternative 3: 2 MGD injection & 2 MGD pumping from 4 municipal wells. Groundwater head change after 62 years.

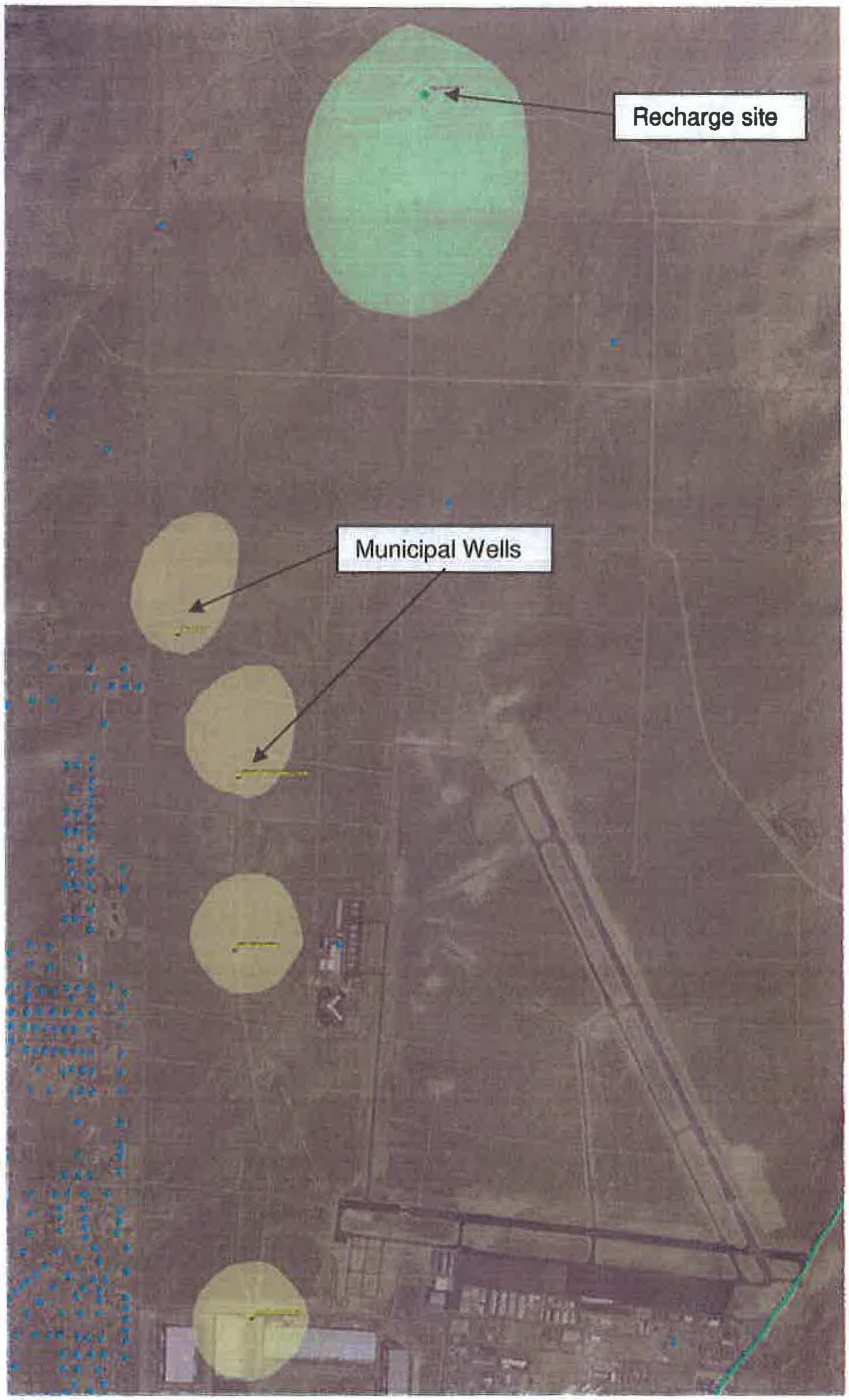

Figure 9: Alternative 3: 2 MGD injection & 2 MGD pumping from 4 municipal wells. Injection and municipal well influence after 62 years.

Modeling completed by Christian Kropf, Washoe County Department of Water Resources (September 2009).

2.3 East Lemmon Valley

2.3.1 Hydrogeologic Setting

East Lemmon Valley is separated from West Lemmon Valley by a north-northeast trending bluff formed along the airport fault zone (see Figure 10). Swan Lake, an ephemeral playa lake, is situated in the south-central portion of the valley. As a result of the fault, Swan Lake is about 40 feet lower in elevation than Silver Lake. Swan Lake has wetlands that are maintained by effluent discharged from the nearby RSWRF. Residential development exists around most of the playa, except to the west and southwest, where commercial development exists. Several water supply wells are also present around the playa's perimeter.

The thick section of Tertiary lake bed sediments present in west Lemmon Valley is present only on the south end of the valley. North and northeast of the lake, granitic basement rocks, which have been extensively "decomposed" are prevalent at shallow depth. Large, shallow pits exist east of the Heppner subdivision where decomposed granite has been mined. Groundwater is shallow throughout the area, but deepens away from Swan Lake to the north and northeast. At the north end of the Heppner subdivision, groundwater is typically present at a depth of about 150 feet bgs.

Residential water in the Heppner area is supplied by individual, low-capacity domestic wells, but because of excessive groundwater pumping, a dropping water table and nitrate pollution, the wells are gradually being replaced by a municipal water system.

2.3.2 Potential Effluent Recharge Areas

An undeveloped area is present north and northeast of the Heppner subdivision in Sections 10 and 14 (T21N, R19E) that may be suitable for effluent recharge, particularly if a municipal water supply replaces the existing domestic wells. Recharge closer to Swan Lake, or on the south side, would be less likely because of the very shallow water table, seasonal flooded conditions that occur near the playa, or other development.

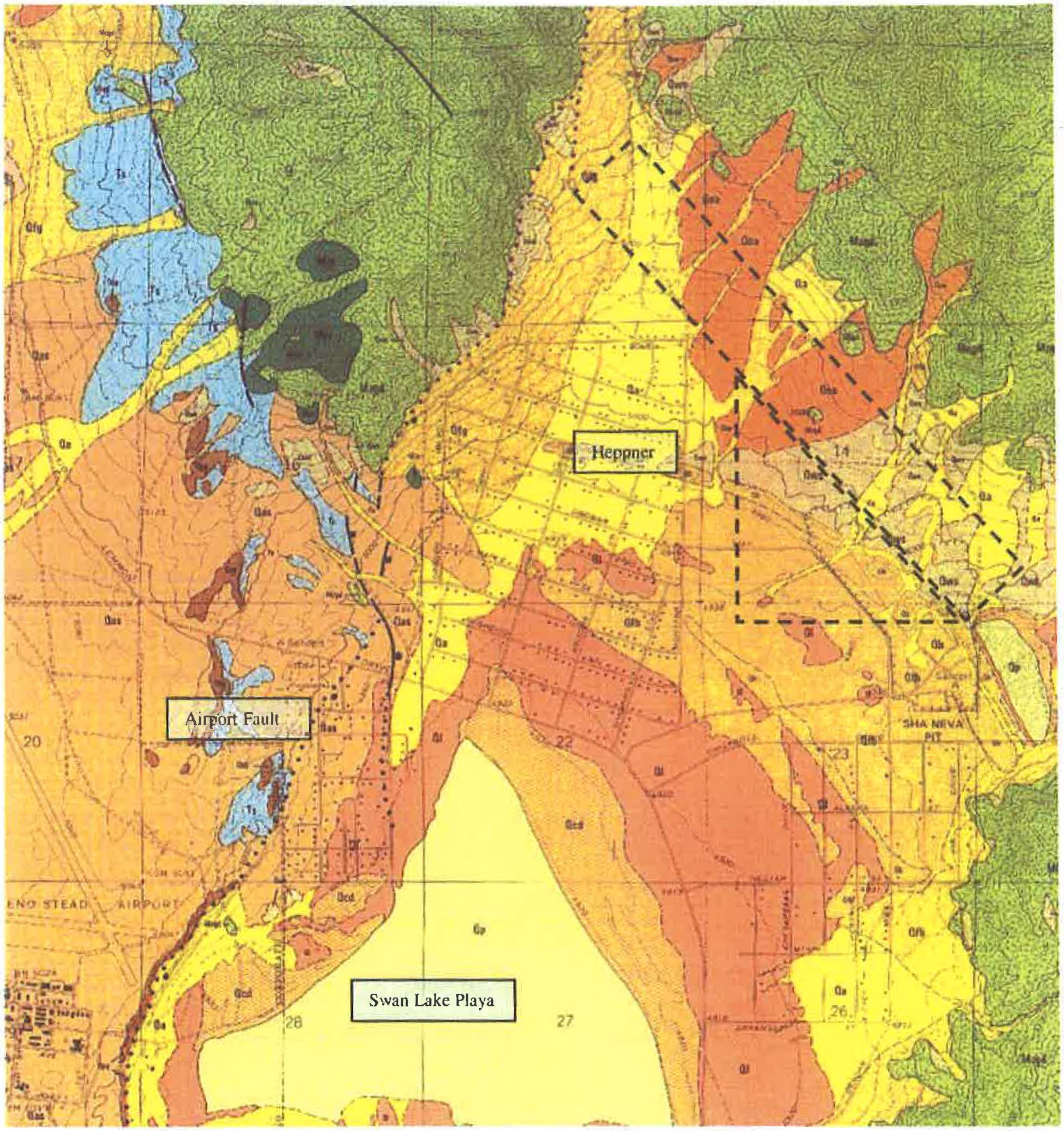

Figure 10: Geologic map of East Lemmon Valley showing potential disposal area.

2.3.3 Comparative Recharge Volume

The valley area directly north of Heppner in Section 10 is BLM land that is a wedge shape that narrows to the north and is bounded on both the west and east by granitic bedrock. There are no well logs or other subsurface information available that document the depth to bedrock. Based on a review of driller's logs for wells installed along the northern edge of the Heppner subdivision in Section 15, the alluvial materials in Section 10 are likely to be less than 20 feet thick and underlain by 100 or more feet of decomposed granite, underlain by fractured granite.

There are also no available well logs for Section 14, but several decomposed granite mine pits are present, and well logs from the eastern edge of the Heppner subdivision indicate shallow decomposed granite underlain by granite.

The decomposed granite is known to be relatively dense when in-place and has low permeability. According to Washoe County DWR, there are two County injection wells located in nearby Golden Valley that are constructed in similar decomposed granite and fractured granite. The purpose of the wells is to recharge the area aquifer, but the wells have injection rates of only 5 gpm and 35 gpm when injected under about 25 psi of pressure.

In summary, although a relatively large undeveloped area exists in the northern part of the valley, it appears that there is limited potential for effluent recharge due to the low permeability of decomposed and fractured granite. A large number of injection wells, or large area of rapid infiltration basins would be required. Our comparative estimate of the potential storage volume for the area shown in Figure 10 is provided in Table 5.

Table 5: East Lemmon Valley - Potential Recharge Capacity

Scenario	Area (ft^2)	Area (acres)	DTW (ft)	50% Fill Height (ft) or thickness	% Permeable materials	Porosity of permeable materials	Available Volume (ft^3)	Volume (A-FT)
1	25,200,000	580	150	75	20	0.1	38,000,000	**900**

Notes: All values are estimated. DTW is the estimated, average depth to groundwater taken from well logs, where available. Fill height assumes half the DTW can be used for storage over the measured map area.
All numbers are approximate and rounded to nearest significant digit.

2.4 Bedell Flat

2.4.1 Hydrogeologic Setting

Bedell Flat is a large and virtually undeveloped northwest-trending valley located along the Honey Lake fault zone. The valley is bounded on the north by Dogskin Mountain and on the southwest by the Sand Hills. Dogskin Mountain is comprised mostly of granitic rock with volcanic tuffs on its west end. The Sand Hills are comprised mostly of uplifted Tertiary lakebed sandstone.

The valley is filled with alluvium and lakebed sediments and slopes downward to the northwest. Geophysical surveys indicate the maximum thickness of alluvial and lakebed deposits is about 2,500 feet beneath the south-central part of the valley.

Only a few wells exist in the valley (see Figure 11). At an old BLM well near the south side of the valley, groundwater was reported at 207 feet below the ground surface (bgs). The well log indicates clay and sandy-clay were dominant to 224 feet bgs, and the yield was only 5 gpm. Further to the northwest and at a slightly lower elevation, two wells exist that have static water levels of 46 feet bgs and 63 ft bgs. One has a reported yield of 700 gpm, but had silt and silty sand to a depth of 165 feet. In the far northwest corner of the valley, two well logs are available for residential wells. Both were drilled in volcanic tuffs and clay, and were about 550 feet deep. Static water levels were 26 ft and 40 ft bgs, but the wells only produced 30 gpm and 8 gpm, with drawdown to the well bottom after a few hours of pumping.

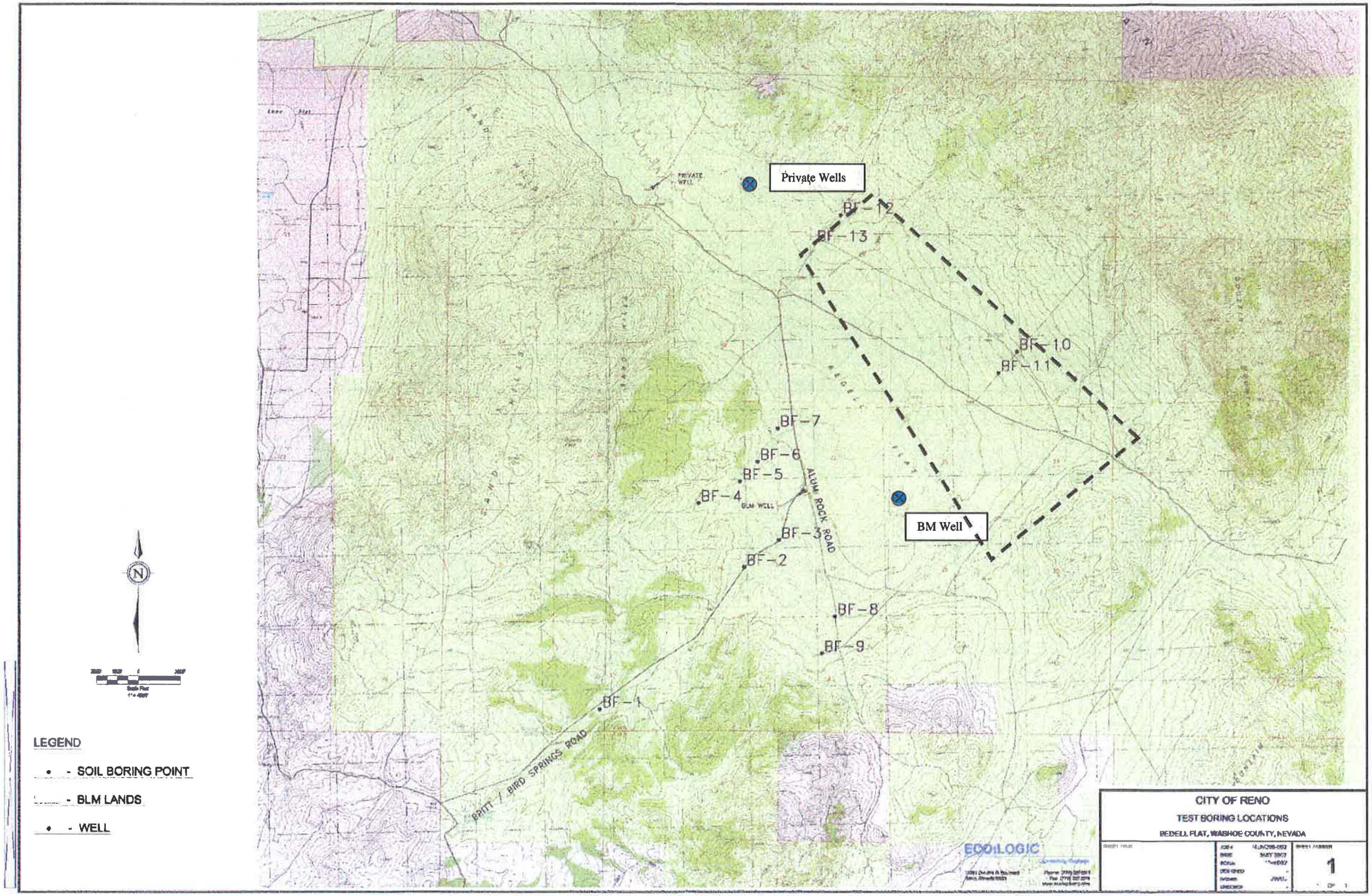

Figure 11: Location of Wells and Soil Borings in Bedell Flat

The well data indicate groundwater flow is from the southeast to the northwest and that groundwater is deepest at the head of the valley to the southeast. The shallow groundwater in the northwest corner of Bedell Flat occurs where the valley necks-down, and low-permeability volcanic bedrock is present near the surface.

The Fish Springs Ranch pipeline was installed through the northern and eastern portions of Bedell Flat in 2007, and an ECO:LOGIC inspection of the trench and excavated materials indicated a prevalence of dense, well-graded, muddy sand, silty sand and sandy silt (see Figure 12). Portions of the trench along the northwest side of the valley, in an area that drains volcanic rock to the north, appeared to contain a greater amount of clay.

Figure 12: Typical muddy, silty sand present in Fish Springs pipeline trench in Bedell Flat.

Also in 2007, ECO:LOGIC completed thirteen shallow soil borings in the valley to evaluate select areas for their potential as rapid infiltration basin sites (see Figure 11). In general, all of the holes encountered a thin topsoil layer overlying Tertiary lake bed sediments consisting of dense to very dense, well-graded, angular, non-plastic, very-fine to very-coarse grained, silty sands with local gravel layers. Clean sands lacking silt were uncommon, and in many areas the amount of very fine sand and silt was significant. Very little clay was encountered.

Cleaner sand was present in boreholes BF-3 and BF-7 along the southwest side of the valley. Sieve analyses of samples collected from these holes indicated a D10 size (10% passing the size listed) of greater than 0.1 mm. Infiltration rates of more than 2.0 inches per hour are possible in soils of this grain size, although the sieve samples did not reflect the high in-place density of the materials. No in-situ testing was performed to confirm the infiltration estimates.

2.4.2 Potential Effluent Recharge Areas

Although Bedell Flat is undeveloped and the basin contains a thick sequence of alluvial or lake bed sediments, dense silty sand appears to be prevalent and the permeability of these materials is likely low to moderate. Trench exposures, soils borings, and the few available well logs indicate that dense, fine-grained, poorly sorted materials are dominant near surface and in the vadose zone. Typically it is difficult to inject or infiltrate significant volumes of water into such materials.

Despite this drawback, because the valley is so large and unexplored, significant storage potential likely exists, unless a predominance of silt or clay is present that reduces permeability and limits injection potential. The head of the valley has not been explored by any drilling, and may have very large recharge capacity.

Recharged effluent would gradually migrate to the northwest, where it could be recovered by the existing private wells, or new down-gradient wells. If not recovered, effluent would, after a very long time, surface as seepage in the Red Rock area and drain to Long Valley.

2.4.3 Comparative Recharge Volume

The potential storage volume was estimated for the area shown in Figure 11, using the same methods as the other valleys. Due to the large percentage of anticipated clay, it is assumed that only about 25% of the vadose zone will be sufficiently permeable to store water.

Table 6: Bedell Flat - Potential Recharge Capacity

Scenario	Area (ft^2)	Area (acres)	DTW (ft)	50% Fill Height (ft) or thickness	% Permeable sand	Porosity of sand	Available Volume (ft^3)	Volume (A-FT)
1	120,000,000	2,750	300	150	25	0.20	900,000,000	**20,700**
Notes: DTW is the estimated, average depth to groundwater taken from well logs, where available. Fill height assumes half the DTW can be used for storage over the measured map area.								

2.5 Spanish Springs Valley

2.5.1 Hydrogeologic Setting

Spanish Springs Valley is a broad, north-south trending valley bounded on the east by the Pah Rah Range, comprised largely of volcanic rocks, and on the west by Hungry Ridge, comprised largely of Mesozoic granitic and metamorphic rocks. Younger basin-fill sediments in the valley consist of interbedded deposits of sand, gravel, clay and silt. These sediments are thickest to the west along Hungry Ridge, where they are up to 1,000 feet thick (Scheafer, et. al., 2007). Bedrock is less than 100 feet bgs in the southern part of the valley.

Washoe County produces municipal water from ten groundwater wells that have a combined maximum capacity of 8,020 gpm. Six of these wells are present in the west-central portion of the valley near the Pyramid Lake highway, (Desert Springs Wells DS #1 through DS #4, and Spring Creek Wells SC #2 and SC #3), and four wells are in the southeastern foothills (Spring Creek Wells SC #4 through SC #7). Geology in the wells varies from alluvial sand, gravel and clays in the western wells, to both alluvium and volcanic bedrock in the southeastern wells.

In 2004, ECO:LOGIC prepared a groundwater budget analysis for the Spanish Springs Valley. Groundwater levels were dropping because of the valley's conversion from agricultural to urban land uses, and the resultant increase in groundwater pumping and decrease in irrigation water delivered via the Orr Ditch. Due to groundwater overdrafts, it was estimated that a minimum of 2,800 AFA of additional valley recharge would be required to bring the basin into balance by 2020. If additional domestic wells were installed, the amount would be increased an additional 319 AFA. It was estimated that the groundwater declines could be alleviated, and basin water levels balanced, by infiltrating 2,200 AFA of treated effluent using RIBs in the northern portion of the valley, and injecting 605 AFA of potable water into the Spring Creek wells.

Additional studies indicated that effluent could be piped from either the Truckee Meadows Water Reclamation Facility or the Reno Stead Water Reclamation Facility to Spanish Springs, where it would be delivered to an RIB site. Kennedy Jenks (2001) and Stantec (2004) studied locations for RIBs and identified feasible sites in the vicinity of the Martin Marietta quarry and Donovan Pit located in the northwestern part of the valley. Field hydraulic conductivities up to 11.4 ft/day were measured in those areas.

In 2009, Washoe County DWR estimated recharge potential for existing municipal wells in the valley. Estimates were performed using half their specific capacities and by computer modeling. They concluded the wells could accept up to 2,000 AFA in recharge water.

2.5.2 Potential Effluent Recharge Areas

Gravel quarries on the northwest side of the valley (see Figure 13) have been evaluated for their infiltration potential, with favorable results. Depth to groundwater in that area ranges from about 200 feet bgs on the western flanks of the valley, to 80 to 100 feet on the valley floor. Because of its distance from existing water supply wells, this area appears to have the most potential for effluent infiltration using the gravel pits for infiltration sites. Stored effluent could be recovered downgradient to the south via wells.

Figure 13: Aerial photograph of the northern portion of Spanish Springs Valley and potential recharge site.

2.5.3 Comparative Recharge Volume

As shown in Table 7, potential effluent storage volumes were estimated for the area shown in Figure 9, using the methods previously described. In this case, the volume for the identified area is 3,300 acre-feet. The 2004 groundwater model for the valley, indicated that recharge of 3,119 AFA was required to correct the valley's overdraft situation. Water would be recharged both via basins in the north half of the valley and via wells in the southeast corner.

Table 7: Spanish Spring Valley

Scenario	Area (ft^2)	Area (acres)	DTW (ft)	50% Fill Height (ft) or thickness	% Permeable sand	Sand Porosity	Available Volume (ft^3)	Volume (A-FT)
1	45,000,000	1,040	100	50	25	0.25	142,000,000	**3,300**
Annual overdraft based on GW model								**3,119 per year**
Notes: DTW is the estimated, average depth to groundwater taken from well logs, where available. Fill height assumes half the DTW can be used for storage over the measured map area.								

2.6 Warm Springs Valley

2.6.1 Hydrogeologic Setting

Warm Springs Valley is a northwest trending valley created along the Warm Springs fault zone. The valley is bordered on the northeast by the Virginia Range, and on the southwest by Dogskin Mountain and the Pah Rah Range (see Figure 14). The valley is roughly bisected by the Pyramid Highway, with the portion of the valley northwest of the highway known as Winnemucca Valley, while Palomino Valley is to the southeast. Both valleys drain towards the highway and form Mullen Creek, which flows northeast through a gap in the Virginia Range to Pyramid Lake.

The Pah Rah and Virginia Ranges are mostly comprised of volcanic flows and tuffs, while Dogskin Mountain is mostly granitic rock. Warm Springs valley is dominantly filled with alluvial and lacustrine deposits comprised of silt, clay, sand and minor gravel. Near the valley center, the alluvial materials may be 1,000 or more feet thick, but away from the center, bedrock is present at shallower depth beneath a thin alluvial cover.

Warm Springs Valley has wide-spread, but low-density residential development, particularly near the Pyramid Highway. Irrigated agricultural areas are present to the southeast of the highway (see Figures 14 and 15). Groundwater is present at relatively shallow depth throughout the central and western parts of the valley (30 feet or less just west of the highway), but is deeper in the agricultural areas southeast of the highway (typically 160 to 180 ft bgs) and away from the valley floor. Well logs indicate alternating thin layers of sand, clay and local gravel in all areas. Well yields near the agricultural areas are variable, but some are capable of producing more than 1,000 gpm. Over the years, many wells have been deepened in response to aquifer dewatering.

The valley's name is derived from low- to moderate-temperature geothermal springs (up to 68°C) that are present along the west boundary of Warm Springs Valley, and are controlled by several northwest-striking faults (Garside, et. al., 2003). Groundwater temperatures appear to be hottest near the springs.

In 2007, Black Eagle Consulting completed soil borings to evaluate a site in the center of the valley for effluent RIBs. Their logs showed primarily silty sand to a depth of about 40 feet bgs, well-graded sand with silt from 40 to 50 feet, and clay and silty clay to depths of more than 130 feet. Hydraulic conductivity measurements were made of the silty sand. Black Eagle suggested the clay and silty clay were essentially impermeable and estimated the hydraulic conductivity of the well graded sand with silt to be in the range of 1 to 5 feet per day. ECO:LOGIC estimated that infiltration basins would require a very large area to dispose of 200,000 gpd without causing a mound to reach the land surface. Additional field investigations were recommended.

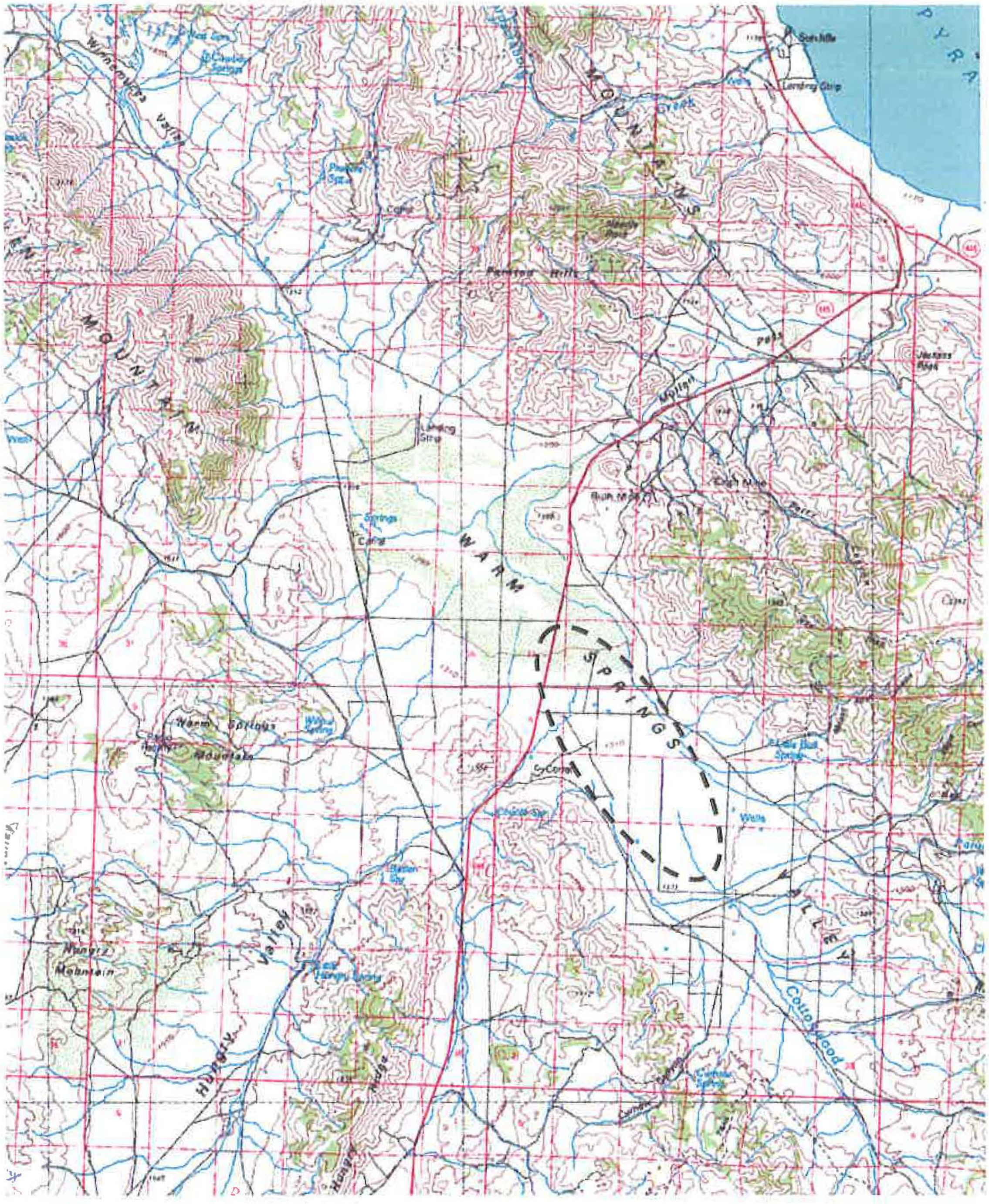

Figure 14: Topographic Map of Warm Springs Valley and potential recharge site

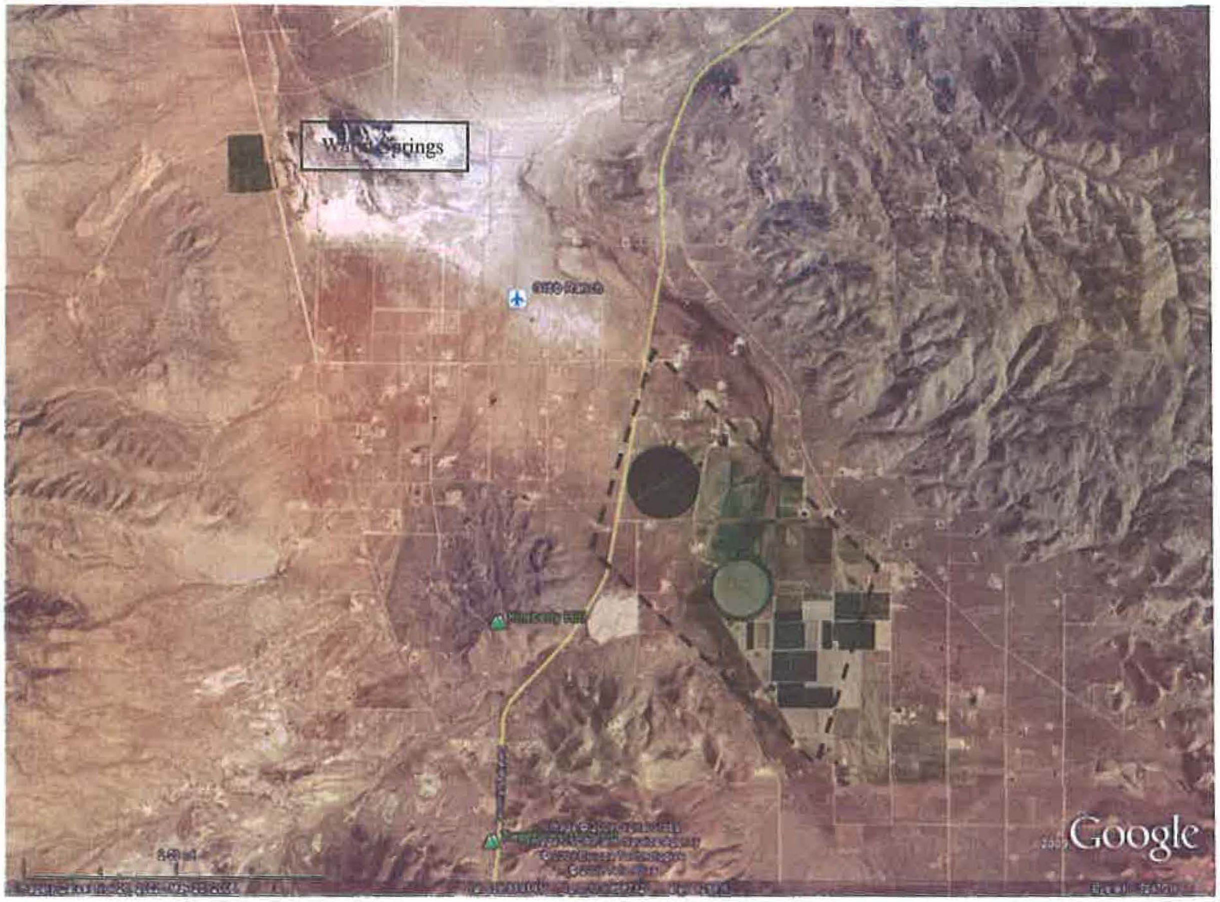

Figure 15: Aerial photograph of Warm Springs Valley and potential recharge site

2.6.2 Potential Effluent Recharge Areas

The combination of numerous domestic wells, shallow geothermal areas, and shallow static water levels in parts of the valley floor limit both the location and volume of treated effluent that can be recharged within the valley. Outward from the center of the valley, the thickness of alluvial deposits decreases and bedrock becomes shallow. For instance, most of Winnemucca Valley has both shallow bedrock and groundwater that would limit recharge potential. However, some water table drawdown has been reported east of the Pyramid Highway from agricultural pumping, and this area may have potential for effluent recharge or effluent ASR wells (see Figure 15). These agricultural areas, which grow alfalfa or sod, could also possibly replace some of their groundwater usage with treated effluent. The site is located a considerable distance from a WWTF, and a lengthy pipeline would be required to deliver effluent to the site.

2.6.3 Comparative Recharge Volume

The volume estimate for the area identified in Figure 15 is shown in Table 8.

Table 8: Warm Springs Valley - Potential Recharge Capacity

Scenario	Area (ft^2)	Area (acres)	DTW (ft)	50% Fill Height (ft) or thickness	% Permeable sand	Porosity of sand	Volume (A-FT)
1	132,000,000	3,000	100	50	70	0.25	**26,500**

Notes: DTW is the estimated, average depth to groundwater taken from well logs, where available. Fill height assumes half the DTW can be used for storage over the measured map area.

2.7 South Truckee Meadows

2.7.1 Hydrogeologic Setting

The South Truckee Meadows has more than a dozen municipal wells that produce groundwater from two main areas: the Mt. Rose Fan, and the lower Truckee Meadows proper. The Mt. Rose Fan aquifer underlies faulted and uplifted glacial outwash deposits. The deposits are up to 500 feet thick and form a boulder and cobble-strewn land surface. The aquifer geology is comprised of these coarse bouldery outwash deposits, and also (locally) the underlying lake bed sediments and volcanic rocks. The distribution, thickness, and depth of these units in relation to the water table and the proximity of fault blocks, impacts groundwater production at any given site. Groundwater is present at depths of 250 to 350 feet bgs in the upper part of the fan, and less than 100 feet bgs towards the toe of the fan.

Groundwater pumping has resulted in an area of drawdown centered on South Truckee Meadows General Improvement District (STMGID) and Washoe County wells (see Figure 16). Drawdown may be exacerbated locally by the numerous faults, some of which appear to restrict groundwater flow and compartmentalize the aquifer. Water quality is generally very good, except near areas of geothermal fluid input and/or hydrothermally-altered volcanic rocks near Steamboat Springs and near the far northwest corner of the fan.

The lower Truckee Meadows aquifer is present under the flat valley floor. Geology consists of a thinner layer of glacial outwash overlying a thick sequence of alluvial or lacustrine sand, silt and clay. Locally the sand contains some gravel. Groundwater is present at shallow depth (less than 10 feet bgs), and artesian conditions exist. Water quality is mostly good, but is poor on the south end of the valley, due to the input of geothermal fluids containing elevated arsenic and other deleterious elements. Groundwater discharges to Steamboat Creek, which flows north to the Truckee River.

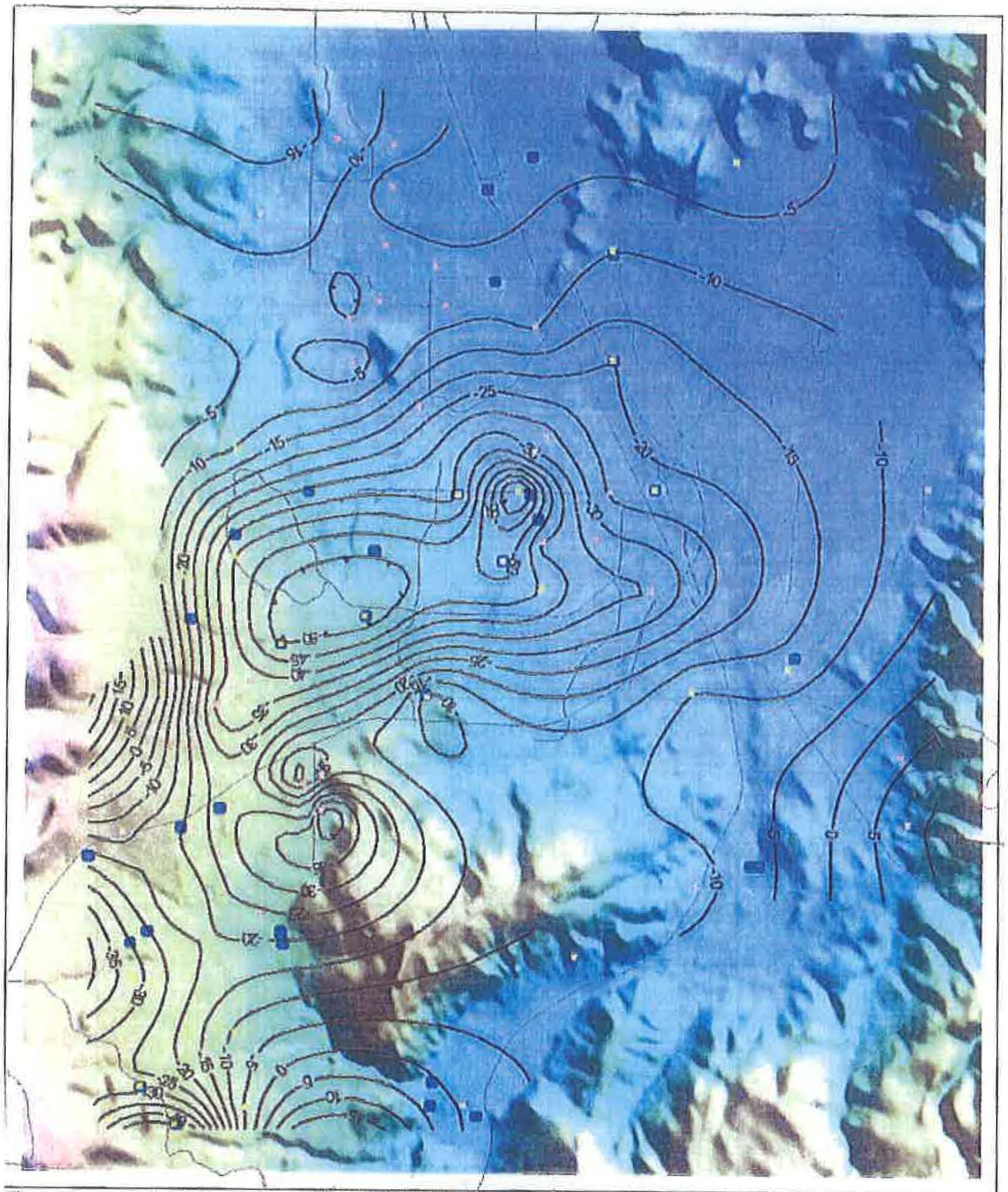

Figure 5. Water level changes from 1982 to 2007. Blue points indicate QM wells, red points indicate measured data, yellow points indicate estimated data (one end point known), and green points indicate dummy data (approximated). Contour interval is 5 feet. See Figure 1 for well and road names.

Department of Water Resources

Figure 16: Mt. Rose fan map of water level changes (DWR, 2007).

2.7.2 Potential Effluent Recharge Areas

Because of the shallow groundwater on the valley floor and local artesian conditions, it is not feasible to infiltrate significant amounts of effluent in that area. A small quantity of effluent could be discharged to wetlands, but unless impounded, it would discharge to Steamboat Creek, which flows to the Truckee River.

The large drawdown cones that have occurred at the STMGID and Washoe County wells are technically feasible areas to store water, since the aquifer has high permeability, a thick vadose zone, and well defined cones of depression. Further, the aquifer is locally compartmentalized by faults, creating essentially large containers available for water storage.

2.7.3 Comparative Recharge Volume

Storage volumes were calculated from a contour map showing estimated drawdown cones that was drawn for the Mt. Rose Fan aquifer by the Washoe County DWR (Groundwater Level Status South Truckee Meadows, Washoe County, Nevada, 2007 Update). The map, which shows the change in water levels from 1982 to 2007, indicates drawdown ranges from 10 feet to more than 55 feet throughout much of the aquifer (see Figure 16). To provide a conservative estimate of the total amount of drawdown that has occurred in the aquifer, ECO:LOGIC calculated the change in volume within the -20 foot drawdown contour (i.e. the area with more than 20 feet of drawdown). The total volume within the -20 foot contour was about 4,395,000,000 cubic feet. Assuming the porosity of this volume is only 15%, it has the capacity to hold 15,128 acre-feet of water. Twenty-five percent porosity would result in about 25,000 acre-feet of water storage capacity. Likewise, increasing the area to the -15 foot drawdown cone would also result in larger available volume.

Table 9: Mt. Rose Fan - Potential Recharge Capacity

Scenario	Area (ft^3)	Porosity	Volume (A-FT)
Area within -20 ft drawdown cone	4,395,000,000	0.15	**15,100**
Area within -20 ft drawdown cone	4,395,000,000	0.25	**25,200**
Notes: Area is equal to the cone of depression found within the -20 ft contour map.			

3.0 Task 6: TDS Balance

After completing the review of potential recharge areas, a water/TDS Mass Balance spreadsheet was prepared for the Stead (West Lemmon Valley) area to provide an initial assessment of the long-term, basin-wide changes in water levels and quality that could occur in the alluvial aquifer. The spreadsheet was prepared for the Stead sub-basin, since it is favorable for effluent storage/disposal/reuse, and relatively detailed information on water use and effluent generation is available for that area.

Projections of future growth and associated water uses are based on effects that would occur at completion of area build-out, and assume use of imported water from the Fish Springs Ranch system. Water and TDS sources and sinks incorporated into the spreadsheet include: TMWA and Fish Springs Ranch municipal water supplies; estimates of potable water consumption, irrigation and wastewater return flows to RSWRF; current reuse sites; and consideration of future disposal options of excess effluent by aquifer storage and recovery (ASR) well injection and pumping.

The intent of the spreadsheet method was to: 1) develop an awareness of the volume of effluent that might be disposed of and recycled; 2) determine if there is a need for blending water or eventual TDS removal from the system to prevent an unacceptable increase in TDS; and 3) obtain a sense of the time it may take for any unacceptable water quality conditions to occur. A description of the methods and assumptions used in the spreadsheet is provided in the following section. Following completion of the spreadsheet, the Washoe County DWR was requested to further evaluate the area using the capabilities of their groundwater flow model, previously described in Section 2.2. That model provides a more accurate estimate of localized groundwater impacts.

3.1.1 Methods

As in any groundwater model where the aquifer geology is variable and hydrogeologic data are sparse, a large number of simplifying assumptions are required. In this case, because a spreadsheet is not a particularly sophisticated method of assessing impacts, the largest assumption is that the hydrologic head and the salt content of the recharged effluent is evenly distributed across the entire aquifer, even if the treated effluent is only recharged to a small portion of the aquifer. Although these assumptions are unrealistic (because of the known geologic complexity of the alluvial aquifer, which includes both lateral variations in the strata and numerous faults which likely act as boundaries to groundwater flow), they allow a initial assessment prior to completing more detailed modeling and site characterization.

According to Harrill (1973), the alluvial aquifer within the Stead or Silver Lake sub-basin underlies an area of 14,000 acres. The amount of water level rise that would occur from imported effluent is reasonably easy to calculate, if one assumes a constant porosity to the vadose zone throughout the aquifer. For instance, if the porosity is 0.10 and 1,400 acre-feet of water are added to the unconfined aquifer, the water level should rise one foot over the entire area. Table 10 uses this method to estimate water level rise after calculating a water budget for the valley.

The TDS impact of recharged effluent to the overall aquifer is much harder to assess, even though the TDS content from all potential sources was carefully calculated. This occurs for at least three reasons. First, groundwater closest to the recharge area will obviously be impacted faster than groundwater located at a further distance. Secondly, the method of recharge will determine how, and what portion of, the aquifer that will be impacted. For instance, if vadose zone wells are used to infiltrate the effluent, the shallow groundwater would be impacted to a larger extent, but deeper groundwater zones may not be affected at all if that water is isolated by overlying aquitards (see Section 2.1 as an example at Cold Springs). If injection wells are used, which distribute the water over a larger vertical section of the aquifer and vadose zone, impacts will have greater vertical distribution but will be more diluted over the larger volume. Thirdly, as groundwater levels rise from imports, the total volume of water in the aquifer will increase, which will result in a relative dilution of the effluent's impacts.

The DWR model described previously uses a large aquifer thickness (Layer 2), which extends from about 150 feet bgs to the underlying bedrock surface. For our model, the thickness of aquifer to be impacted by the recharged effluent was only the upper 40 feet of the water table distributed across the entire basin. This is the same value Harrill selected for calculating the aquifer's transitional storage reserve. If a greater aquifer thickness is used, the anticipated TDS impacts will decrease correspondingly. The spreadsheet also looks at the total amount of water in the aquifer or open space of the vadose zone, which is assumed to be 30%.

3.1.2 Results

The spreadsheet in Table 10 was run iteratively for a 25-year period. The results of the study are shown in Figure 17. Over the selected time period, groundwater levels rose about 0.5 feet per year from the input of an additional 2 mgd of reclaimed water. The average TDS value for the upper 40 feet of the aquifer within the basin increases about 3 mg/L per year, but the rate of increase slows over time, since aquifer volume increases each year. At this rate of increase, a very long time period would be required before average TDS content increased to above the secondary drinking water standard of 1000 mg/L.

To more accurately assess the local impacts to nearby wells, the Washoe County DWR simulated the aquifer response using their MODFLOW groundwater model for the basin. Results of the evaluation were provided in Section 2.2.4.

Table 10: TDS Balance – Silver Lake Subarea – West Lemmon Valley

	A	B	C	D	E	F	G	H
1		**NORTH VALLEYS EFFLUENT DISPOSAL PROJECT**						
2		**STEAD - LEMMON VALLEY TDS BALANCE**						
3		**SILVER LAKE SUBAREA (SLSA)**						
4		Red cells contain variables subject to change - see explanation						
5		Cells in yellow were updated for each following year, using results calculated in row 78						
6	**A**	**SILVER LAKE SUBBASIN AQUIFER CHARACTERISTICS**						
7		**AQUIFER STORAGE VOLUME***						
8		Equals area x thickness to be dewatered x average porosity						
9		Area of subbasin (14,000 acres), average porosity of 30%, and thickness to be impacted of (40 feet) from USGS, 1973.						
10			**Acres**	**Ft**	**Porosity**	**AF**		
11			**14,000**	**40**	**0.3**	**168,000**		
12		* The entire Silver Lake subarea (SLSA) comprises 14,000 acres. Impacts to a smaller area can be estimated by decreasing size. TDS impacts were estimated to the "Transitional Storage Reserve". This is not equal to total volume of water, only what can be produced - defined as 40 ft thickness using specific yield of 16%. Water level Impacts, however, were to the total volume of water, using a porosity of 30%. Spreadsheet runs start with 40 ft in cell D11 and 220 mg/L in cell E34, which gives results shown in row 73.						
13	**B**	**GROUNDWATER IMPORTS**						
14	**b1**	**FISH SPRINGS RANCH (FSR) WELLS**	**AF/Year**	**Litres**	**TDS**			**Total Salts (pounds)**
15		A #1	2,000	2.47E+09	240	mg/L		1,305,292
16		B #2	1,500	1.85E+09	170			693,436
17		C #3	1,500	1.85E+09	190			775,017
18		D #4	1,500	1.85E+09	240			978,969
19		E #5	1,500	1.85E+09	240			978,969
20		F #6	0	0.00E+00	210			0
21		TOTAL FOR FSR TO ALL LEMMON Valley	8,000	9.87E+09	**218**	weighted average TDS		4,731,683
22		Note: only a portion of this water will go to the Silver Lake SubArea						
23		Percentage to Silver Lake SubArea	36%					
24		**Volume to Silver Lake SubArea**	**2,880**	3.55E+09	**218**			**1,703,406**
25								
26	**b2**	**TRUCKEE RIVER IMPORTS**						
27		All Silver Lake SubArea	0	0	90	mg/L		**0**
28								
29		**TOTAL IMPORTS TO SILVER LAKE Subarea**	**2,880**	3.55E+09	**218**	weighted average TDS		**1,703,406**
30		Equals Groundwater Imports plus Truckee						

	A	B	C	D	E	F	G	H
31	C	**WELL PRODUCTION - WATER REMOVED FROM AQUIFER**						
32	c1	**MUNICIPAL WATER SUPPLY WELLS**						
33		ASR Average Input since 2001		0.00E+00	190	mg/L		0
34		Additional Pumpage (Stead Only)	635	7.83E+08	220			379,894
35		All Silver Lake Subarea	**635**	7.83E+08	**220**	weighted average TDS		**379,894**
36		Total water requirement for SLSA is about 3,515 AFA at buildout. The above value was used to balance Fish Springs Ranch (FSR) water. Assume no more ASR wells after FSR imports begin. Initial TDS of 220 mg/L used in cell E34.						
37		**TOTAL WATER SUPPLY FOR SLSA**	**3,515**		**218**	weighted average TDS		**2,083,300**
38		Equals Imports plus municipal wells						
39	c2	**RESIDENTIAL WELLS**	352	4.34E+08	250	mg/L		239,304
40		not included in effluent return						
41	c3	**NATURAL OUTFLOW (ET)**	760	9.37E+08	0	mg/L		0
42		Outflow calc'd by Harrill (p. 46). An imbalance exists between recharge and discharge of about 200 AFA. All salts remain in basin. Value could be increased to 960 AF/yr to account for leakage on airport fault, or other imbalances.						
43		**TOTAL WATER REMOVED FROM AQUIFER**	**1,747**					
44	D	**SUBBASIN RECHARGE**						
45	d1	**RECHARGE DUE TO EXCESS IRRIGATION INFILTRATION**						
46		Total secondary recharge =20% of total water supply	**AF/Year**	20%	**TDS**			Total Salts (pounds)
47		as per USGS 1973, p. 62	**703**	8.67E+08	654			**1,249,980**
48		Salt content of infiltration due to evapoconcentration is 3 times original TDS.						
49	d2	**RECHARGE DUE TO SEPTIC INFILTRATION**						
50		Total secondary recharge	**AF/Year**	45%	**TDS**			
51		= % of residential wells	**158**	1.95E+08	750			**323,060**
52		Does not include irrigation infiltration. TDS assumed to be 3X initial quality						
53	d3	**PRECIPITATION RECHARGE**	**AF/Year**		**TDS**			
54		Lemmon valley west (AFA)	900	1.11E+09	25	mg/L		**61,186**
55		*1,500 AF/YR value from Washoe County DWR. Harrill estimated 1,000 AF/YR but only used 900 AF/YR in calculations. To be conservative, 900 AF/YR is used in this spreadsheet.						
56	d4	**SEWAGE TREATMENT PLANT EFFLUENT RECHARGE** - Equals total flow to plant minus effluent used for irrigation						
57		**Average Daily flow to WTP**	5	mgd				
58		**Amount used for irrigation and Swan Lake**	3	mgd				
59		Million gallons per day discharged from WTP	**2**					
60		Weighted average of supply water TDS	**218**	**Final TDS**				
61		Anticipated TDS increase	340	**558**				
62								**Total Salt**
63			**AF/Year**	**litres**	**TDS**			**(pounds)**
64		discharge mgd in AFA	**2,240**	2.76E+09	**558**			**3,399,112**
65		USGS 1973, measured Stead effluent TDS of 420, or 340 greater than Truckee River source water, which had TDS of 80. Sample on 3/25/05 was 422 mg/L. In 1973, flow through sewer plant was about 40% of volume of imported water						

	A	B	C	D	E	F	G	H
66		**SUBTOTAL - RECHARGE TO SLSA**	3,843		482	weighted average TDS		5,033,337
67		**SUBTRACT WATER REMOVED BY WELLS and ET**	1,747					619,198
68		**TOTAL RECHARGE**	2,096		482			4,414,139
69	E	**CHANGE IN TOTAL GROUNDWATER DUE TO PROJECT - SILVER LAKE SUBAREA ONLY**						
70			**AF**	**Litres**	**TDS**			**Total Salts (lbs)**
71		SUBBASIN INTITIAL AQUIFER VOLUME*	168,000	2.07E+11	220			100,507,475
72		RECHARGE PER YEAR	**2,096**		**482**	weighted average TDS		4,414,139
73		**TOTAL VOLUME AFTER ONE YEAR**	**170,096**		223.2	TDS weighted		**104,921,614**
74	e1	**Percent increase per annum - assumes all recharge is evenly distributed throughout sub-area**	**1.2%**		**1.5%**			
75		* Volume of top 40 ft of aquifer, plus any yearly increases. TDS increases each year along with volume.						
76			**Area (acres)**	**Acre ft added**	**ft of water**	**Porosity**		**Annual WT Increase (ft)**
77	e2	**CHANGE IN AQUIFER WATER TABLE ELEVATION**	14,000	2,096	0.149734	0.3		**0.50**
78		Porosity for silty sand - linked to cell E11.						
79		Assumes water is evenly distributed throughout the aquifer, which is unlikely due to recharge locations, variable geology and other discharge components, which are not accounted for.						

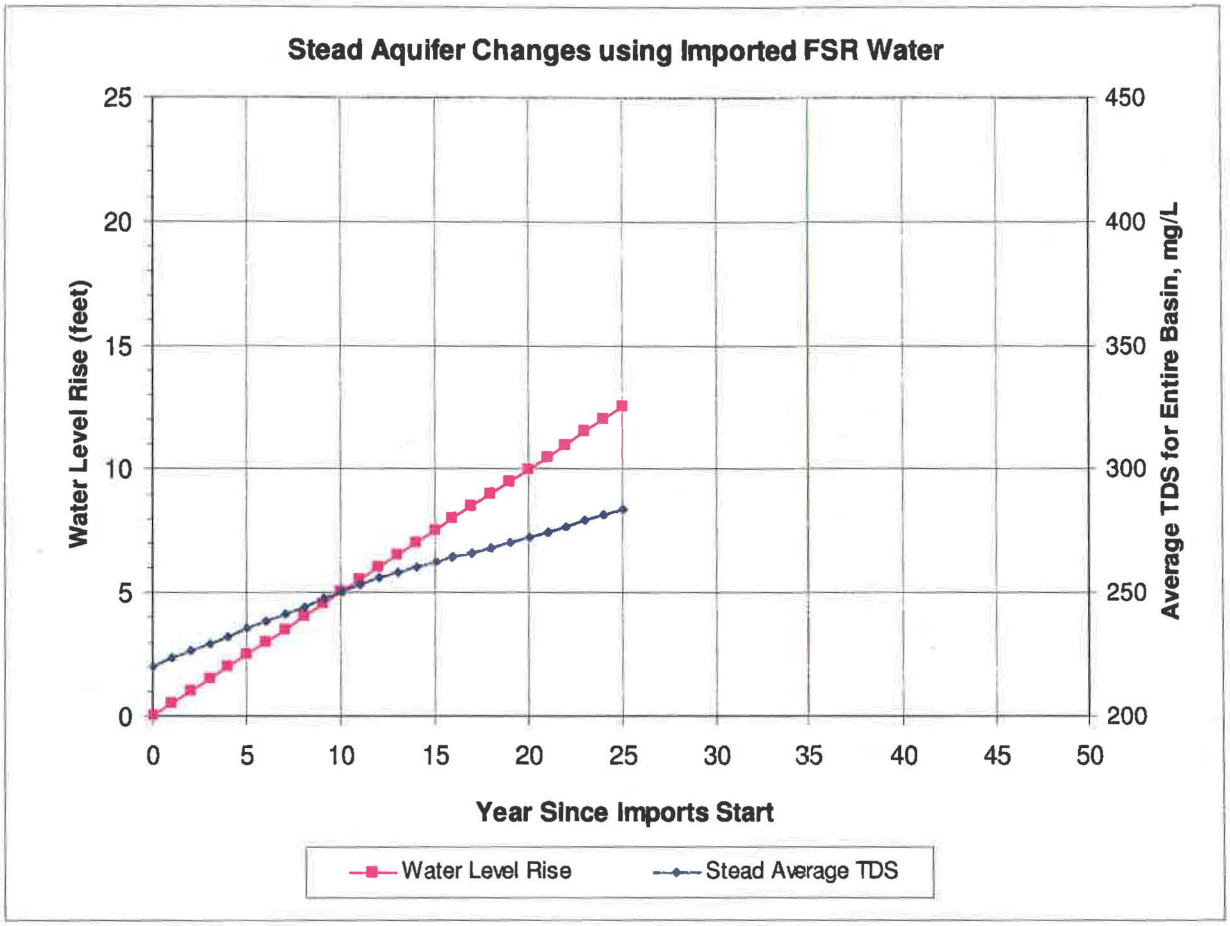

Figure 17: West Lemmon Valley – Estimated TDS and water level increases due to water importation and effluent recharge.

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APPENDIX C

TECHNICAL MEMORANDUM

Groundwater Flow and TDS Transport Modeling
Lemmon Valley, Nevada

Discussion of Modeling Results

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Christian A. Kropf, Washoe County Department of Water Resources
John Buzzone, Washoe County Department of Water Resources

Technical Memorandum

GROUNDWATER FLOW AND TRANSPORT MODELING TO ESTIMATE GROUNDWATER INJECTION WELL INFLUENCE TO THE GROUNDWATER IN LEMMON VALLEY

Introduction

As the driest state in the nation, as well as the fastest growing state in the nation, water planners in Nevada are forced to make critical decisions regarding groundwater management and water supply forecasting. This is especially important since all surface water resources are fully appropriated (Nevada Department of Conservation and Natural Resources, 1999) and Nevada turns to its groundwater resources to meet the needs of its growing population (Lopes, 2006). This project seeks to quantify the relative effects associated with four potential water management alternatives considered for the Lemmon Valley area of Washoe County, Nevada.

Purpose and Scope

This project, initiated by the Northern Nevada Water Planning Commission (NNWPC), is intended to support the NNWPC's investigation into the viability of aquifer storage and recovery in Lemmon Valley as a part of a preliminary region-wide analysis of potential water management alternatives. Specifically, this project is intended to quantify the effects of four Lemmon Valley water management alternatives using groundwater simulation techniques. The four management alternatives are:

- Alternative 1: Continue to extract groundwater at current rates;
- Alternative 2: Incorporate groundwater injection;
- Alternative 3: Incorporate additional municipal supply wells; and
- Alternative 4: Estimate solute transport given flow conditions simulated in Alternative 3.

Background

Hydrogeologic Setting

The Lemmon Valley Hydrographic area, composed of the East and West Lemmon Hydrographic sub-regions, encompasses 96.8 square miles. Figure 1 depicts the location and general features of Lemmon Valley. The following geologic and hydrogeologic information for Lemmon Valley is summarized from

Washoe County's Wellhead Protection Program report (Widmer and VanHoozer, 2000).

Lemmon Valley hydrographic basin is bounded by Peavine Mountain on the south and on the west by the Sierra Nevada range. Lemmon Valley is separated from Sun Valley by Peterson Mountains, the Granite Hills, and the Hungry Hills, which form fault scarps on the eastern side.

The Lemmon Valley basin consists of five geologic units: Quaternary alluvium; Tertiary sediments; Tertiary volcanics; intermediate volcanic extrusives and detritus recently uplifted by the Cretaceous granodiorite; Cretaceous granodiorite; and Mesozoic metasediments and metavolcanics, which have a low groundwater yield. Normal faulting created north-south trending mountain ranges comprised of granodiorite and metavolcanic rocks with sediments and alluvial filled basins. The fault structures mostly trend northeast-southwest. The Airport Fault found in central Lemmon Valley originates in southern Hungry Hills and goes south to Peavine Mountain. The Airport Fault is an east-dipping normal fault interpreted as an impermeable barrier to groundwater flow.

Lemmon Valley is a hydrologically closed basin-fill aquifer, meaning there is no discharge to adjacent groundwater basins. The general trend of groundwater flow is from the southwest towards the northeast with the steepest gradient for the system located in the mid-fan area. Precipitation, mostly from Peavine Mountain, is the primary source of groundwater in the valley. Surface runoff in the east portion of the basin is infrequent due to low precipitation; however, other factors determining runoff in the area also include soil thickness, topography of the area, type and abundance of vegetation, soil moisture content, temperature and humidity. Surface waters in Lemmon Valley flow into the Silver Lake Playa and evaporate. The primary discharge from Lemmon Valley is through evapotranspiration.

The valley floor sediments are well-sorted and fine-grained. The greatest groundwater yield tends to come from valley fill deposits. Lemmon Valley fill deposits are estimated to be thickest in the west playa area at 2,200 feet (VanHoozer, 2009). The thickest areas tend to be under the playa, where the clay layer (abundant to a depth of 200' beneath land surface) thins laterally. There are two hydrostratigraphic units in the east: an upper unconfined aquifer; and two lower confined aquifers. There seems to be little or no connection between deeper pumping wells and shallow monitoring wells as a result of the confining layers. Groundwater recharge to Lemmon Valley is estimated at 1,500 AFY (Harrill, 1973; VanHoozer, 2007).

A study by the WCDWR in 1994 found that concentrations of nitrate in domestic wells in the Lemmon Valley basin were above the MCL of 10 ppm for nitrate-N

(Widmer and McKay, 1994). The two areas most affected by septic effluent were Golden Valley and the Heppner Subdivision. Both areas have experienced groundwater mining resulting in water level declines of as much as 60 feet from 1974 to 1994, with an estimated continued decline of one to three feet per year. Resultant large cones of depression under each area may contribute to concentrating septic effluent in the groundwater (Widmer and McKay, 1994).

At the time of the report published in 1994, groundwater pumpage exceeded recharge by 520 AFY. It is believed that this deficit is made up from septic effluent recharge. This effluent recharge is also believed to be equal to or more than natural recharge in this valley. According to the report, livestock feces appear to be a significant additional contributor to groundwater nitrate concentrations. The report also noted temporal trends depicting a nitrate increase from a maximum of around 4 milligrams per liter (mg/L) in pre-1985 data to around 13 mg/L in post-1985 data (Widmer and McKay, 1994).

Groundwater withdrawals in Golden Valley are even more extreme, with pumpage exceeding natural recharge by as much as 500% at the time of publication in 1994. Maximum concentrations of nitrate in this valley increased from 15 mg/L In 1984 to 19 mg/L in 1993. The study also noted an "increasingly pervasive "spreading" of above background-level nitrate occurrences in Golden Valley" (Widmer and McKay, 1994). The study observed that the septic effluent contamination is largely controlled by soil conditions, especially where fast draining soils exist.

Recent Modeling Efforts

Randy VanHoozer and Greg Pohll, completed a three-dimensional groundwater flow model (3D MODFLOW) for Lemmon Valley in early 2009 (VanHoozer and Pohll, 2009), Attachment A. The model was developed to provide a management tool for addressing water supply issues for Lemmon Valley. The model simulates localized changes in groundwater levels due to domestic wells, municipal supply wells, natural recharge, and evapotranspiration. This model included grid refinement and enhanced estimation of local (parcel specific) sources and sinks.

The model was first calibrated for steady state conditions using 1970 water levels from 17 wells in order to produce modeled water level elevations that are similar to actual water level elevations. The model was then calibrated to transient conditions using observed water elevation data.

Methods

The likely groundwater responses to the four water management alternatives were estimated using the existing 3D MODFLOW groundwater flow model described above. To accomplish this, the model was modified to incorporate the four water management alternatives and adapted to simulate groundwater conditions from 2008 through 2070, using the model's 2007 conditions as the initial state. A complete discussion of model assumptions and hydrogeologic input values are included in the VanHoozer and Pohll (2009) report. Table 1 below lists the well pumping and injection rates for each alternative. Negative numbers signify water withdrawal and positive numbers signify injection.

Table 1. Pumping and injection rates for each alternative.

	Pumping/Injection Rates (gal/day)			
Well	Alternative 1	Alternative 2	Alternative 3	Alternative 4
BS1	-40,146	-40,146	-40,146	-40,146
CMOR1	-14,230	-14,230	-14,230	-14,230
CMOR2	-14,230	-14,230	-14,230	-14,230
Foothill	-5,353	-5,353	-5,353	-5,353
GVPark	-3,569	-3,569	-3,569	-3,569
RS1	-3,122	-3,122	-3,122	-3,122
RS2	-3,122	-3,122	-3,122	-3,122
SKMutual	-53,529	-53,529	-53,529	-53,529
SL1	-6,047	-6,047	-500,040	-500,040
SL4	-58,368	-58,368	-500,040	-500,040
LVP5	-282,206	-282,206	-282,206	-282,206
LVP6	-38,835	-38,835	-38,835	-38,835
LVP7	-157,750	-157,750	-157,750	-157,750
LVP8	-220,147	-220,147	-220,147	-220,147
LVP9	-80,321	-80,321	-80,321	-80,321
WebbEast	-3,792	-3,792	-3,792	-3,792
WebbWest	-3,792	-3,792	-3,792	-3,792
GVI-1	16,237	16,237	16,237	16,237
GVI-3	4,924	4,924	4,924	4,924
GVI-4	34,794	34,794	34,794	34,794
GVI5	4,996	4,996	4,996	4,996
SL3 - Red Rock	0	0	-500,040	-500,040
SL2 - Silver Knolls	0	0	-500,040	-500,040
All Domestics	-625	-625	-625	-625
New Injection Well	0	2,000,000	2,000,000	2,000,000

The alternatives and associated model modifications are described below.

- Alternative 1: Continue to extract groundwater at current rates;
- Alternative 2: Incorporate groundwater injection;
- Alternative 3: Incorporate additional municipal supply wells; and
- Alternative 4: Estimate solute transport given flow conditions simulated in Alternative 3.

Alternative 1: Extract Groundwater at Current Rate:

Before the model was adjusted to simulate the influence of injection, it was first modified to reflect the status quo to establish a base case against which the other alternatives can be compared. To accomplish this, the only modifications necessary to the model were to set the source and sink variables equal to current conditions and set the simulation period to 2008 through 2070. All wells were pumped at a constant rate throughout the simulation period. The 2007 groundwater conditions were used as the initial state for all simulations.

Alternative 2: Incorporate Groundwater Injection

The purpose of Alternative 2 is to asses whether the aquifer can accept 2 million gallons per day (MGD) of recharge. For this analysis, the Alternative 1 model was modified to include an injection well recharging 2 MGD at a constant rate for 62 years (2008-2070). The location of the injection well was selected based on a drilling and injection pilot test completed by Eco:Logic in 2006. The injection site consists of a relatively deep vadose zone (~200 feet) and deep saturated thickness (~1,600 feet) of aquifer materials that allows for flexibility when finalizing the recharge process (vadose recharge well versus confined aquifer injection well). The injection well was assumed to be fully screened within Layer 2, a semi-confined to confined layer of relatively thick alluvium from which the majority of domestic and municipal or quasi-municipal wells extract water. Layer 2 begins at the bottom of Layer 1 (~150 feet below land surface) and extends downward to the bedrock - alluvium contact (up to approximately 2,400 feet below land surface). Particle flow paths were also simulated for water recharged through the injection well for a period of 62 years using MODPATH. MODPATH is a particle (flow path) tracking code that is used in conjunction with MODFLOW. The particles are tracked through time assuming they are transported by advection using the flow field computed by MODFLOW. Particle tracking analyses are useful for delineating areas of influence for wells.

Alternative 3: Incorporate Additional Municipal Supply Wells

There are two additional municipal supply wells in the northern portion of the west basin that are currently inactive, but are likely to be activated in the future. Analysis of this management alternative seeks to determine how these municipal wells might be influenced by the injected water. The Alternative 2 model was modified by adding these two additional wells. The cumulative pumping rate of the two additional wells and the two existing municipal wells was set equal to the injection rate of 2 MGD (0.5 MGD each). All four municipal wells and the injection well were modeled as fully-screened within the thicker portion of Layer 2. Particle flow paths were simulated for water recharged through the injection well and water flowing to the municipal wells for a period of 62 years using MODPATH.

Alternative 4: Estimate Solute Transport Given Flow Conditions Simulated in Alternative 3

The injected water may have concentrations of total dissolved solids (TDS) greater than background concentrations. To determine whether water quality in nearby municipal and domestic wells might be influenced by the injected water the Alternative 3 model was modified by assuming a constant 100 mg/L TDS concentration in the injection water using the solute transport model MT3DMS. MT3DMS is a modular three-dimensional transport model for the simulation of advection, dispersion, and chemical reactions of dissolved constituents in groundwater systems (Zheng, 1990). The background TDS concentrations were assumed to be 0 mg/l. This allows for resultant concentrations found throughout the aquifer to be referenced to a percentage (e.g. a value of 25 mg/L in a well would indicate that 25% of the water at the well is injected water). The MT3DMS model could not be made operational for this analysis despite numerous attempts and consultations with the software technical support team and groundwater modeling experts in the area.

As an alternative, TDS concentrations were estimated using direct analytical methods. For this, advection was assumed to be the major driver for solute transport and as such, the particle path analysis completed in Alternative 3 provides a reasonable representation of solute transport. The two analytical approaches employed were (1) determine travel times from an injection well to a pumping well and (2) determine the resultant TDS concentration at some distance from the injection well using the advection-dispersion equation. Equations, variables, and calculations associated with each approach are described in detail in worksheets 1 and 2 found in Appendix B.

1. From reorganizing the Muskat (1937) formula for determining the shape of the front advancing from a recharging well to a pumping well (Bear, 1979), we can estimate the time it takes for water from an injection well to reach a pumping well.

$$t = (4*pi*n*d^2*B)/3Q$$

In order to provide a worst-case estimate, the pumping rate was set to 2 MGD in the nearest well; identical to the injection well recharge rate of 2 MGD.

2. From the Ogata (1970) advection-dispersion equation the percent concentration of a solute at a specified distance from the source can be estimated. The following equation is from Fetter, 1994 p. 458.

$$C = C_0/2 * [erfc((L-v_x t)/(2\surd(D_L t))) + exp(v_x L/D_L) * erfc((L+vxt)/(2\surd(D_L t)))]$$

Results and Discussion

Alternative 1:

The model predicts that there will be a significant decline in groundwater levels over the next 62, assuming no changes in extraction rates. Figure 2 shows the relative change in groundwater levels throughout model boundaries.

Alternative 2:

With the injection of 2 MGD, the water level decline observed in Alternative 1 is reversed and there is an increase in water levels between 0 and 110 feet (Figure 3). Analysis of the anticipated particle flow paths originating at the injection well indicates that the area of influence, with regard to particle flow, is limited in extent after 62 years of injection. This is mainly due to the saturated thickness over which injection occurs (the thicker the injection layer, the less radial flow over a given time period). As shown in Figure 4, the total distance a particle would travel from the injection well after 62 years of injection is about 2,450 feet, or about half of a mile. While a particle would not travel far from the injection well, the pressure response to injection occurs quickly and improves conditions through out the basin. This could produce more favorable pumping conditions, such as decreased drawdown and less energy required to extract water, at individual wells.

Alternative 3:

Two municipal wells (SL2 and SL3) were added and the pumping rate of the two existing municipal wells was increased to 500,000 gallons per day each. As show in Figure 5, water levels increased near the injection well and decreased with distance from the injection well. Overall, heads remain relatively unchanged due to the injection well, even with the increased pumping at the four municipal wells. Water levels are maintained at higher elevations as compared to Alternative 1 results.

As shown in Figure 6, after 62 years, injected water does not reach the extraction well capture zones. Even if it did reach the extraction well capture zones, it would still take another 50 or more years to reach the well.

Alternative 4:

Although the MT3DMS portion of the model could not be made operational, it is assumed that MODPATH will account for the majority of the transport phenomenon. As stated in Alternative 3, injected water does not reach the extraction wells.

Based on the Muskat (1937) equation, it is estimated that travel time from the injection well to the nearest pumping well (with Q_{in} and Q_{out} equal to 2 MGD) to be somewhere between 60 to 240 years. The high uncertainty is due to the length of screened interval. A longer screened interval may result in a longer travel time, whereas a shorter screened interval may result in a shorter travel time.

Based on the advection-dispersion equation (Ogata, 1970), the concentration of solute (TDS in this case) in the nearest municipal well (SL-3 or Red Rock) is estimated to be 60% of the starting concentration after 100 years of injection. This method takes into account advection and dispersion, but does not account for retardation or the 3D nature of the problem. These two additional factors should decrease the final concentration in the nearest municipal well after 100 years of injection.

Conclusions

Results of the investigation indicate that water from the injection well is unlikely to negatively influence the nearest municipal or domestic wells during the simulation period (2008-2070).

Water levels within the West and East Basins would likely benefit from a groundwater recharge program. This could have direct beneficial effects on municipal and domestic wells by reducing drawdown and pumping costs.

The analysis indicates that TDS is unlikely to reach the municipal supply wells within the simulation period (2008-2070). However, over longer time periods there is likely to be some transport of TDS to the municipal supply wells. .

References

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Widmer, M. C. and R. G. Vanhoozer. 2000. Wellhead Protection Program, Lemmon Valley Water System, Washoe County, Nevada. Washoe County Department of Water Resources, 31 p.

APPENDIX A

Figures

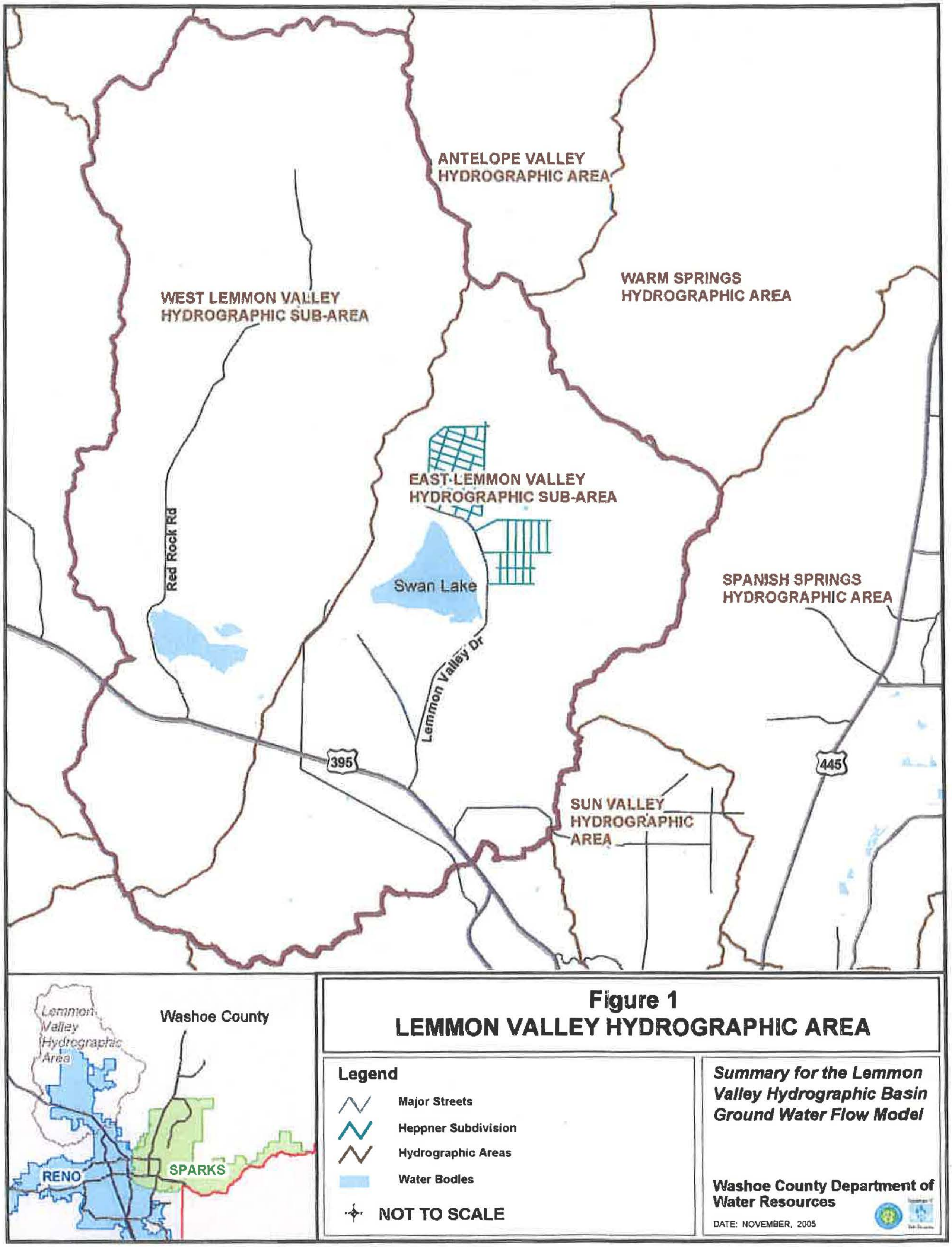

Figure 1
LEMMON VALLEY HYDROGRAPHIC AREA

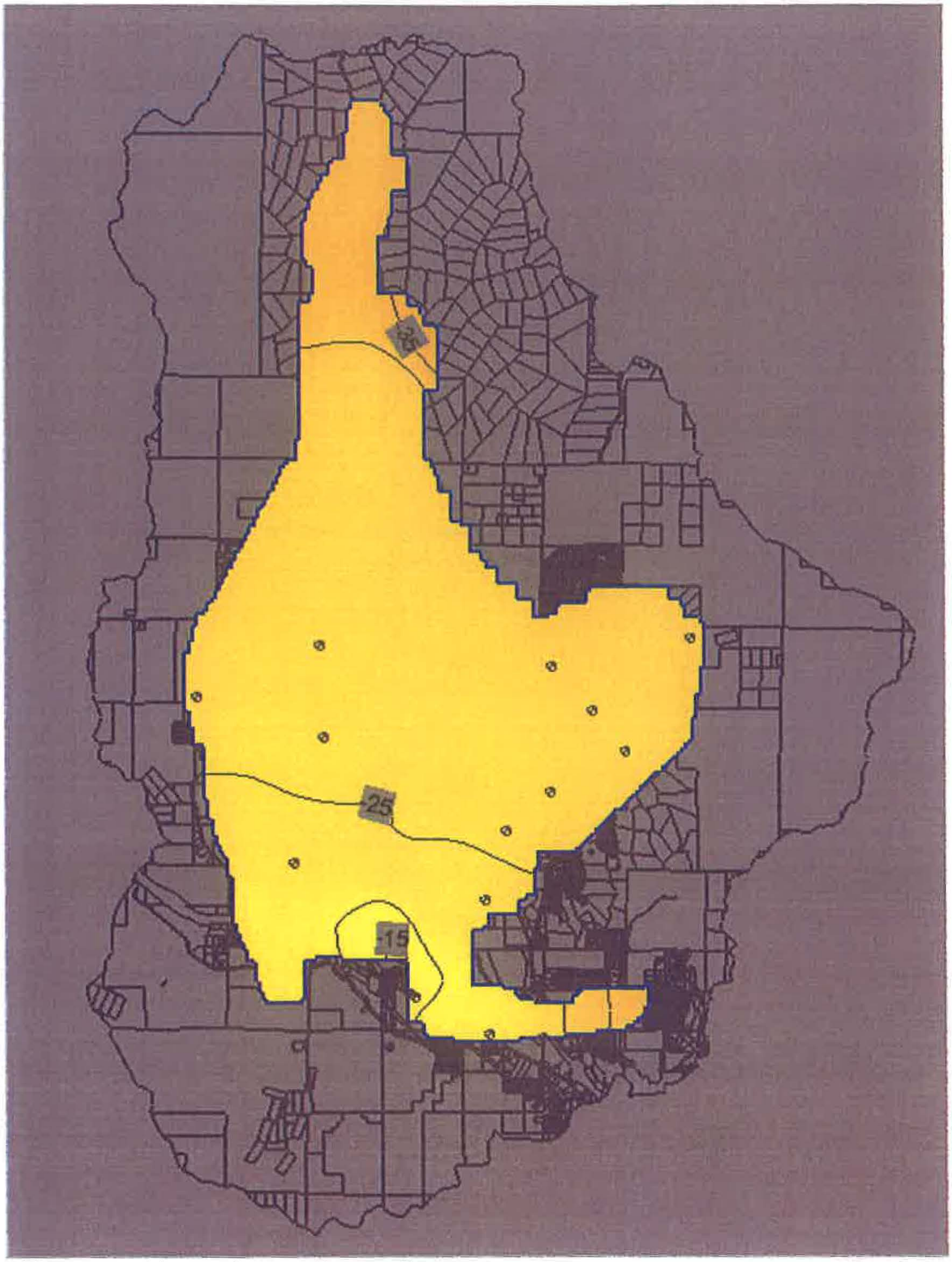

Figure 2. Alternative 1: Status Quo.
Drawdown after 62 years of pumping at 2007 rates.

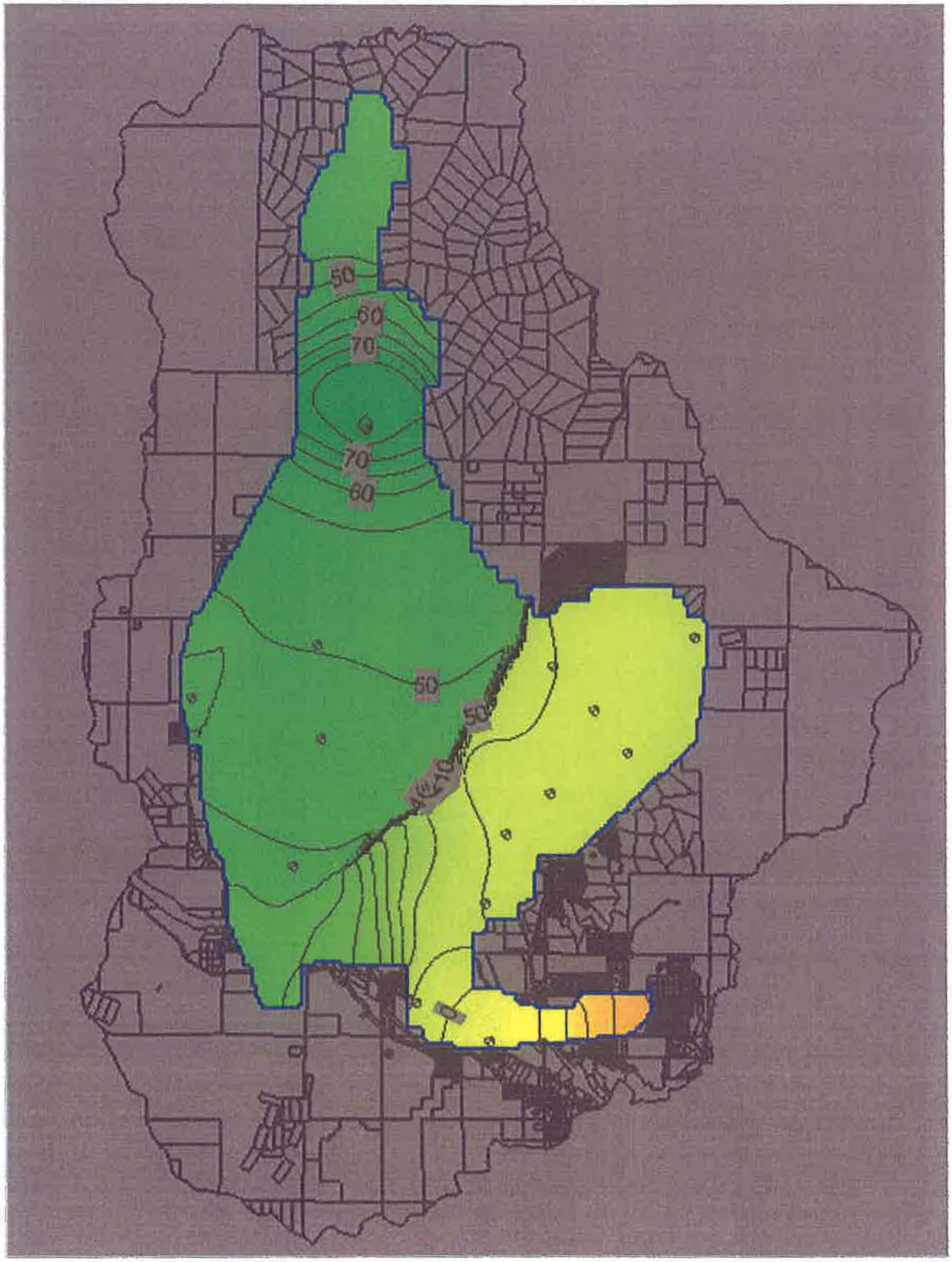

Figure 3. Alternative 2: Injection well recharging 2 MGD and 2007 pumping rates. Head change after 62 years of 2 MGD injection & 2007 pumping rates.

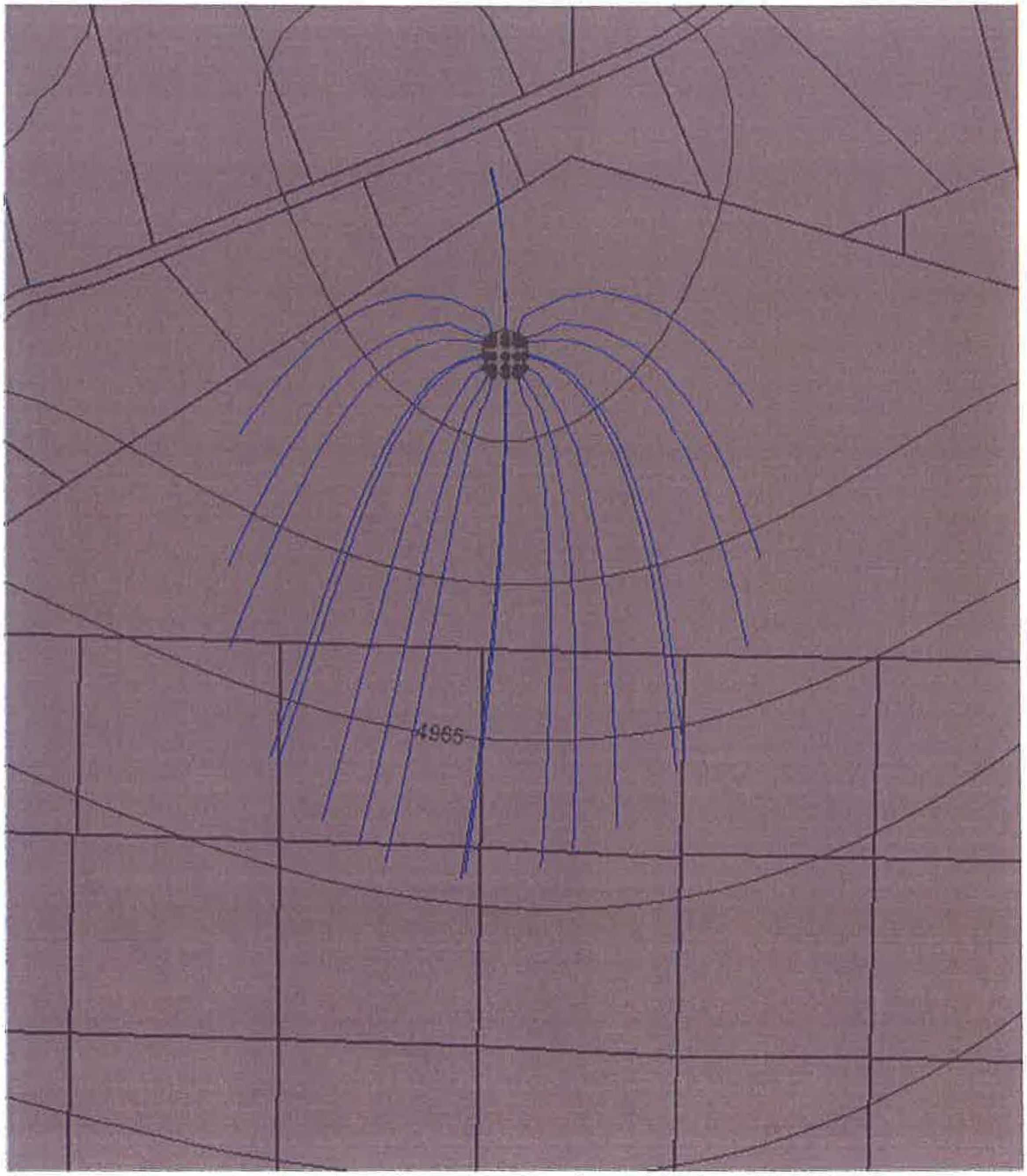

Figure 4. Alternative 2: Injection well recharging 2 MGD and 2007 pumping rates. Injection well influence after 62 years of 2 MGD recharge.

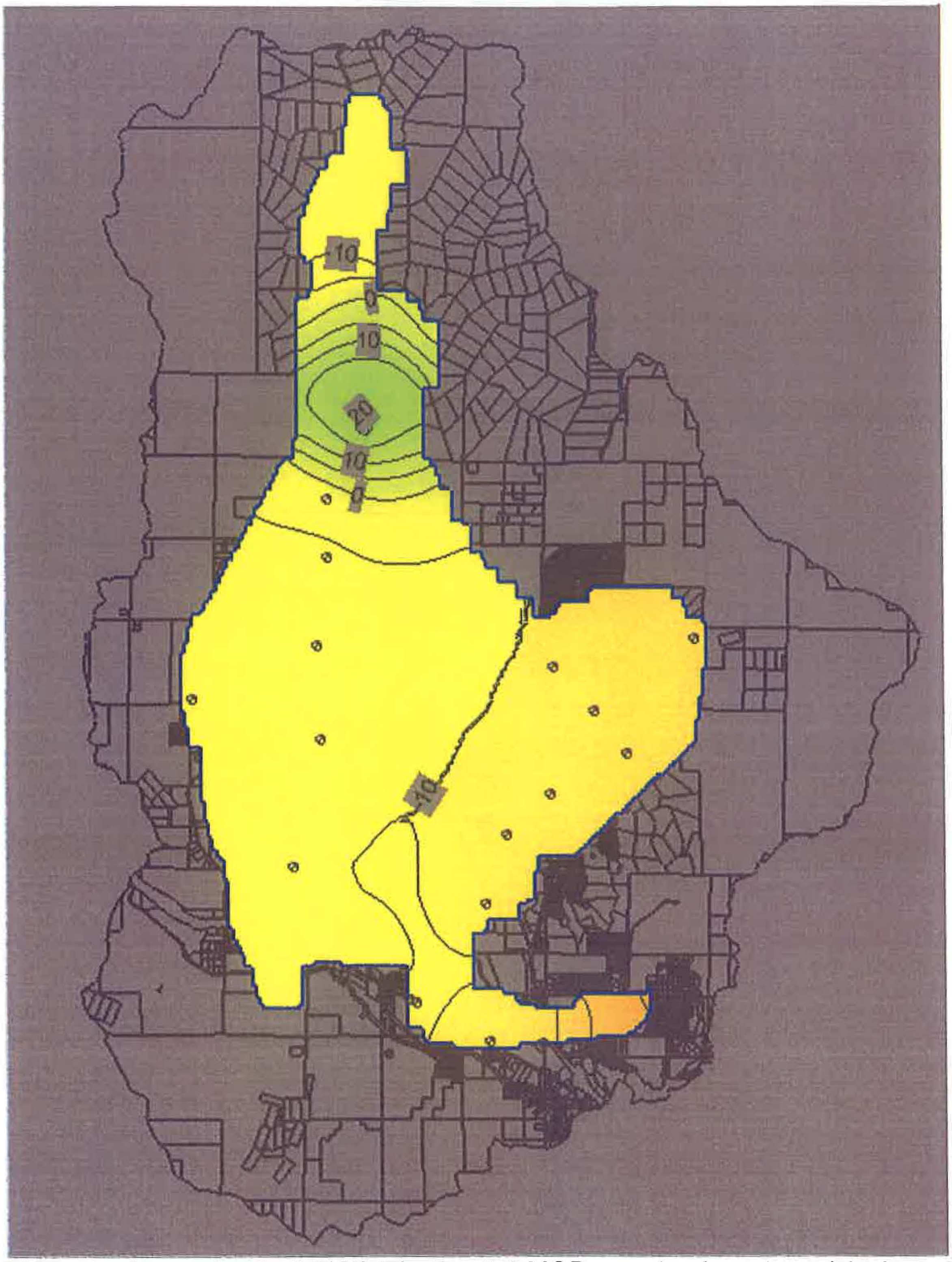

Figure 5. Alternative 3: 2 MGD injection & 2 MGD pumping from 4 municipal wells. Groundwater head change after 62 years.

Figure 6. Alternative 3: 2 MGD injection & 2 MGD pumping from 4 municipal wells. Injection and municipal well influence after 62 years.

APPENDIX B

Worksheets

Worksheet 1

Calculating the travel time from an injection well to a pumping well with the same rate (Qin = Qout).

For a fully-penetrating well of 1600 feet:

Input Parameters

Using the Muskat 1937 equation from Bear p. 281.			
Porosity (n):	0.15	unitless	
Aquifer Thickness (B):	1600	feet	
Halfway point (d):	4785	feet	Halfway point between injection and pumping well
Pumping & Injection rate (Q):	267361	ft^3/day	

$t = (4 * pi * n * d^2 * B) / (3 * Q)$

t =	86093	days
t =	236	years

For a partially-penetrating well of 400 feet:

Input Parameters

Using the Muskat 1937 equation from Bear p. 281.			
Porosity (n):	0.15	unitless	
Aquifer Thickness (B):	400	feet	
Halfway point (d):	4785	feet	Halfway point between injection and pumping well
Pumping & Injection rate (Q):	267361	ft^3/day	

$t = (4 * pi * n * d^2 * B) / (3 * Q)$

t =	21523	days
t =	59	years

Worksheet 2

Calculating the concentration at some distance from a continuous source. From Fetter, pg. 460.

Input Parameters

Using the Ogata, 1970 one-dimensional advection-dispersion equation.

Aquifer Properties					
Hydraulic Conductivity (K):	10	ft/day			
Hydraulic Gradient (dh/dl):	0.00261	unitless			
Effective Porosity (n_e):	0.15	unitless			
Contaminant Properties					
Initial Solute Concentration (C_0):	100	mg/L			
Molecular Diffusion (D*):	1.55E-05	ft^2/day	estimated		
Other Parameters					
Distance to Receptor (L):	9570	ft			
Time since release of solute (t):	36525	days		100.0	years

1. Determine the average linear velocity:

v_x= K(dh/dl)/n_e

v_x= 0.174 ft/day

2. Determine the coefficient of longitudinal hydrodynamic dispersion

a. Find the value of a_L

a_L = 0.0175*L^1.46

a_L = 11354.5 ft

b. Find the value of DL (longitudinal dispersion coefficient)

D_L = a_L*v_x+D*

D_L = 1975.7 ft^2/day

3. Substitute values into Advection-Dispersion equation (Ogata, 1970)

C = $C_0/2$ x [ERFC(A) + EXP(B) x ERFC('C)]

$C_0/2$ =	50		
A =	0.189212238	ERFC(A) =	0.789018
B =	0.842834795	EXP(B) =	2.322943
'C =	0.937355891	ERFC('C) =	0.184965

C = **60.9** Resultant Concentration at 9570 feet away after 36525 days.
or 100 years