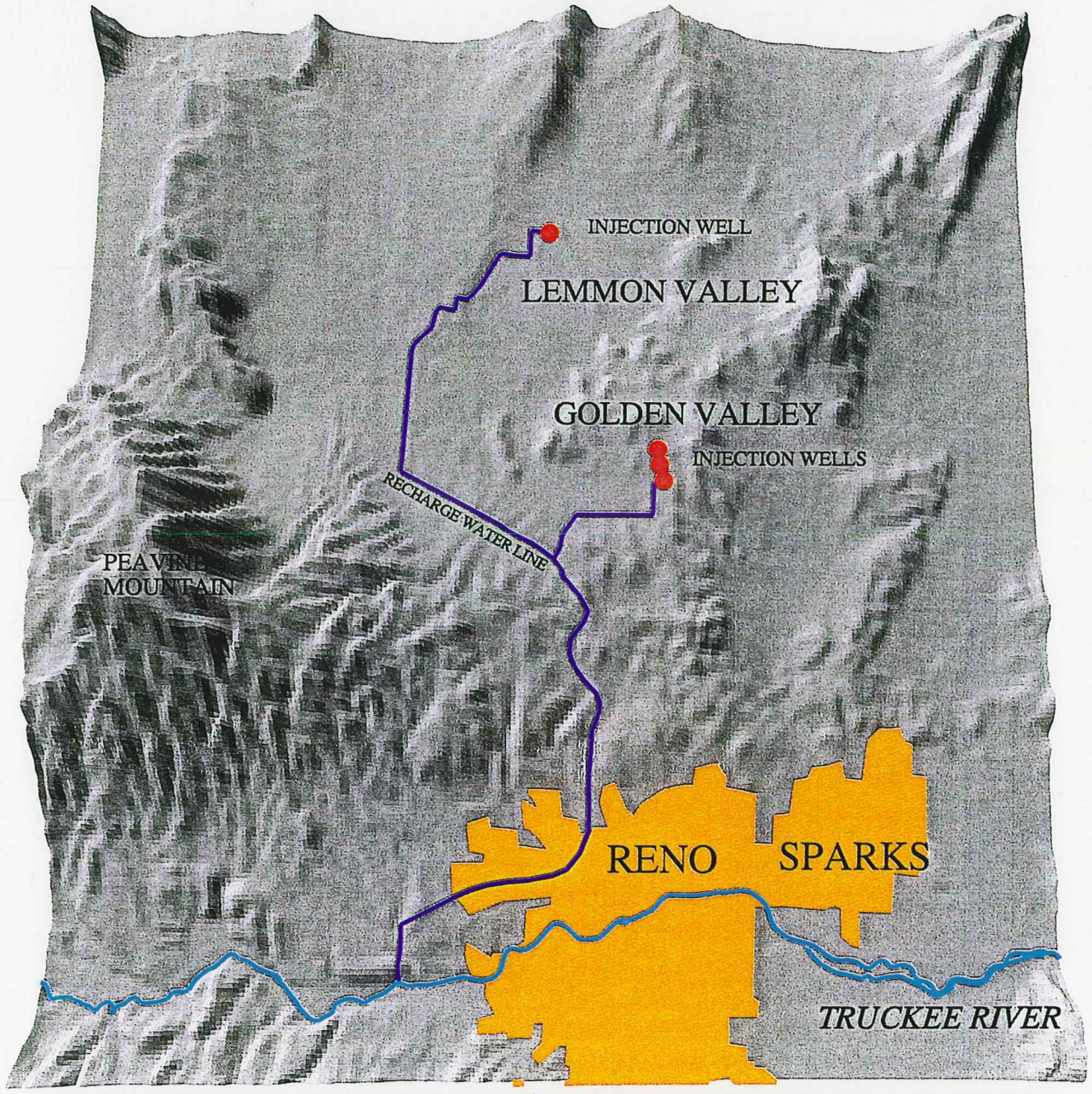
High Plains States Groundwater Demonstration Program



Washoe County Recharge Demonstration Study - Summary Report

A Cooperative Project by:
Washoe County, Nevada
U.S. Department of the Interior
Bureau of Reclamation

In Participation With:
U.S. Environmental Protection Agency
U.S. Geological Survey

August 1996

Glossary, Abbreviations, And Acronyms

Abbreviation	Definition	Units of Measure
Ag	Silver	milligrams per liter
Alk	Alkalinity	milligrams per liter
As	Arsenic	milligrams per liter
B	Boron	milligrams per liter
Ba	Barium	milligrams per liter
Bicarb	Bicarbonate	milligrams per liter
Ca	Calcium	milligrams per liter
Carb	Carbonate	milligrams per liter
Cd	Cadmium	milligrams per liter
Cl	Chloride	milligrams per liter
Cr	Chromium	milligrams per liter
Cu	Copper	milligrams per liter
*	Color	standard units
County	Washoe County Utility Division	NA
EC	Electric Conductivity	standard units or micro-siemens per centimeter
EPA	U.S. Environmental Protection Agency	NA
FWS	U.S. Fish and Wildlife Service	NA
*	Gross Alpha, Gross Beta	picocuries per liter
GPS	Global Positioning System	milligrams per liter
*	Hardness	milligrams per liter
F	Fluoride	milligrams per liter
Fe	Iron	milligrams per liter
Hg	Mercury	milligrams per liter
I.D.	Inside diameter	NA
K	Potassium	milligrams per liter
MBAS	Methylene Blue Active Substances	milligrams per liter
MCL	Maximum Contaminant Level	NA
Mg	Magnesium	milligrams per liter
mg/L	milligrams per liter	NA
Mn	Manganese	milligrams per liter
msl	mean sea level	NA
Na	Sodium	milligrams per liter
NA	Not Applicable	NA
NRCS	Natural Resources Conservation Service	NA
NDEP	Nevada Division of Environmental Protection	NA
NDWR	Nevada Division of Water Resources	NA
NEPA	National Environmental Policy Act	NA
O&M	Operation & Maintenance	NA
Pb	Lead	milligrams per liter

Abbreviation	Definition	Units of Measure
pCi/L	picocuries per liter	NA
pH	Measure of acidity	standard units
PVC	Poly Vinyl Chloride	NA
QA/QC	Quality Assurance/Quality Control	NA
Reclamation	U.S. Bureau of Reclamation	NA
Se	Selenium	milligrams per liter
Si	Silica	milligrams per liter
SPPCo	Sierra Pacific Power Company	NA
S.S.	Stainless Steel	NA
S.U.	Standard Units	NA
TDS	Total Dissolved Solids	milligrams per liter
TTHMs	Total Trihalomethanes	micrograms per liter
Tribe	Pyramid Lake Paiute Indian Tribe	NA
TSS	Total Suspended Solids	milligrams per liter
Turb	Turbidity	standard units
ug/L	micrograms per liter	NA
USGS	U.S. Geological Survey	NA
VOC	Volatile Organic Compound	NA
Zn	Zinc	milligrams per liter

*** No Abbreviation in Report**

Summary Report

Washoe County Recharge Demonstration Study

Introduction

Cost Share Participants

Local Sponsor (20% of funding):	**Washoe County, Nevada, Utility Div.**
Federal Agency (80% of funding):	**U.S. Bureau of Reclamation**

Key Dates

Grant Application Submitted:	**May 29, 1986**
Cooperative Agreement:	**September 27,1990**
Period of Agreement:	**To September 30, 1995**
Agreement Extension:	**To September 30, 1997**
Begin Site Investigations:	**August 23, 1991**
Begin Monitoring:	**May 8, 1991**
Begin Construction:	**November 15,1991**
End Construction:	**October 9,1992**
Begin Operation:	**December 22, 1992**
Final Report Completion Date:	**December 31, 1996**

Bureau of Reclamation contacts for the project:

Project Manager:	**Mona Jefferies Soniea**
Assistant Project Manager:	**Federico Barajas**

These individuals can be contacted at:

Address:	**United States Bureau of Reclamation** **Mid-Pacific Region** **2800 Cottage Way** **Sacramento, California 95825-1898**
Telephone:	**(916)979-2339**

This report summarizes the project and findings of the Washoe County Recharge Demonstration Study (Project). Detailed information can be found in the main report, *Washoe County Recharge Demonstration Study-Final Report.* A copy of this report may be obtained by contacting the project or assistant project manager.

The Project is one of 13 projects implemented by the Bureau of Reclamation (Reclamation) and local sponsors in cooperation with the Environmental Protection Agency (EPA) and the U. S. Geological Survey (USGS) under the "High Plains States Groundwater Demonstration Program Act of 1983" (Public Law 98-434). The primary purpose of Public Law 98-434 is to advance the state of the art in groundwater recharge techniques. The Project was sponsored by Washoe County, Nevada. Washoe County executed a cooperative agreement with Reclamation in 1990 to conduct an artificial groundwater recharge demonstration project in Lemmon and Golden Valleys, located a few miles north of Reno, Nevada (see Figure A, Project Location Map).

Other Participants

Public Law 98-434 authorized Reclamation in cooperation with EPA and USGS to provide assistance in the Groundwater Demonstration Program. EPA has a specific responsibility under Public Law 98-434 to evaluate the impacts on surface water and groundwater quality resulting from each of the demonstration projects. USGS provided technical review and support. While not specifically required in Public Law-98-434, Reclamation also coordinated with the U.S. Fish and Wildlife Service (FWS) to assure the project would not adversely impact the habitat of an endangered species, the Cui-ui Sucker, of Pyramid Lake, Nevada. An agreement between Reclamation and FWS outlined when source water for injection could be withdrawn from the Truckee River without endangering the Cui-ui habitat. The agreement was based on projected streamflows as determined by the Natural Resources Conservation Service (NRCS) formerly the U.S. Soil Conservation Service.

The local sponsor, Washoe County Department of Public Works, Utility Division (County), is a regional water supplier for areas outside the Reno-Sparks metropolitan area. The Utility Division is governed by the Board of County Commissioners. County government has taken an active role in managing water resources and views artificial recharge as a drought storage alternative to surface reservoirs and a way to mitigate overdraft of groundwater basins.

Local County contacts for the Project are:

Project Manager:	**Dan C. Dragan, Senior Hydrologist**
Assistant Project Manager:	**Randall G. Van Hoozer, Hydrologist**
Project Engineer:	**Paul C. Orphan, P.E., Senior Utility Engineer**

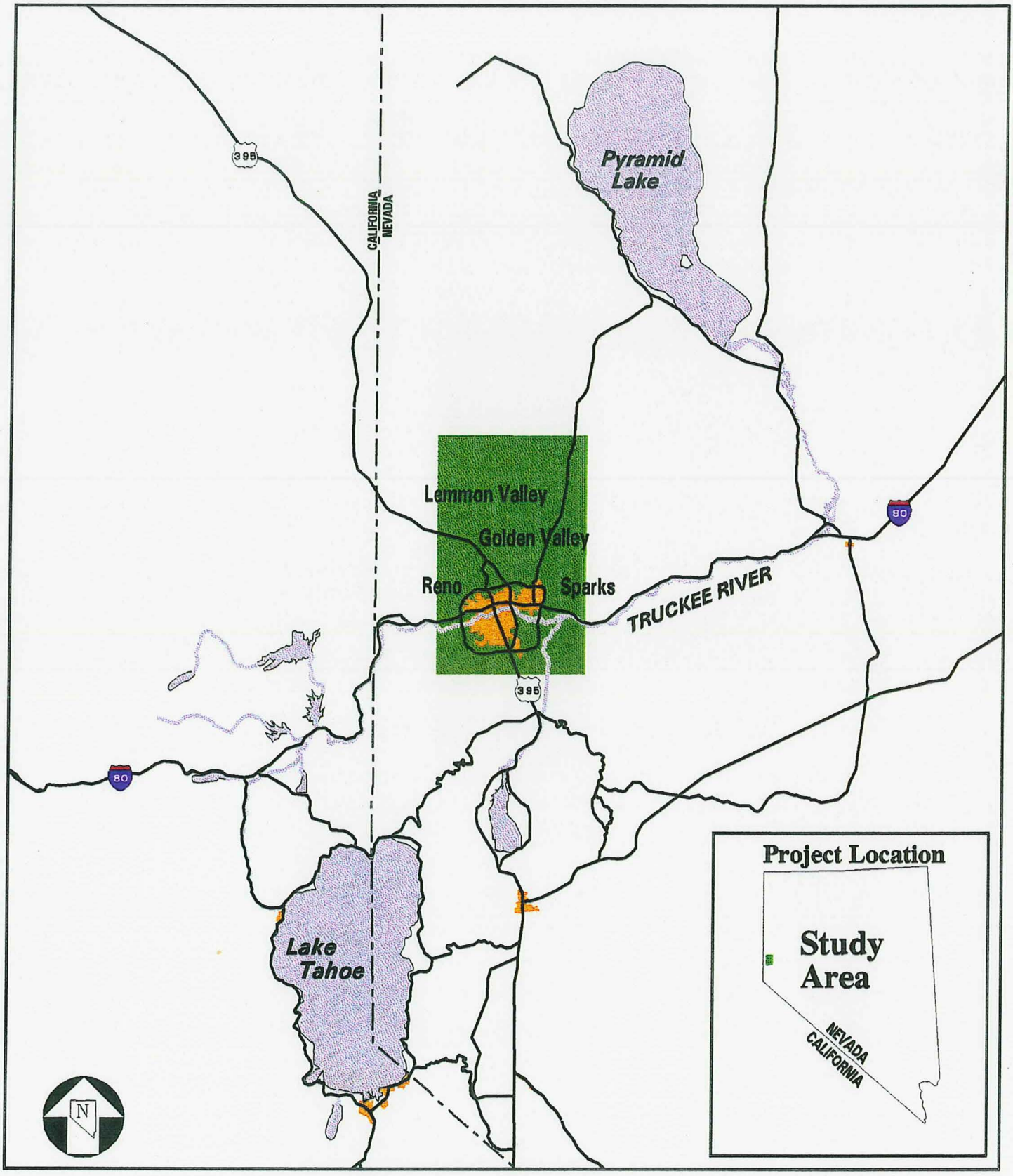

Pyramid Lake
CALIFORNIA
NEVADA
395
Lemmon Valley
Golden Valley
Reno
Sparks
TRUCKEE RIVER
80
Lake Tahoe
Project Location
Study Area
NEVADA
CALIFORNIA
N
Project Location
Lakes & Reservoirs
Truckee River & Tributaries
Cities
Major Roads
MILES
0
5
10
20
SEAL OF WASHOE COUNTY
STATE OF NEVADA

Figure A

These individuals can be contacted at:

Address:	**P.O. Box 11130** **1195-B Corporate Boulevard** **Reno, Nevada 89520-0027**
Telephone:	**(702) 856-7300**

Project Attributes

The Project diverts Truckee River Water, delivers it to Lemmon and Golden Valleys and injects it directly into aquifers through injection wells. From diversion to injection the water is treated to municipal water quality standards, pumped through miles of pipeline and "polished" by filtering through activated carbon (see Figure B, Study Area Map).

The technical and operational aspects of the project were modest, the institutional aspects required more coordination and expenses. Permitting, monitoring, acquiring water rights, and gaining public acceptance required extensive effort. For example, EPA, the Nevada Division of Environmental Protection (NDEP), and the Nevada Division of Water Resources (NDWR) each had independent water quality monitoring and reporting requirements. Obtaining a water right for injection required extensive effort to obtain a right that would be acceptable to everyone with an interest in the management of Truckee River water. Because of the ecological sensitivity of Pyramid Lake (terminus of the Truckee River) and the endangered Cui-ui Sucker, the Project successfully negotiated the timing of diversions with the FWS that were not legally required under the water right permit granted.

Institutional and permitting delays caused several years to pass before Reclamation and the County could sign and implement a cooperative agreement in September 1990. However, delays proved to be beneficial as a drought in the region began in 1987 and influenced project activities through 1993. If the Project had been operational in 1988, virtually no injection could have occurred until 1994 under the conditions agreed upon with various entities.

Need for the Project

The County was interested in the Project since water levels are declining and water quality is deteriorating in valleys throughout Washoe County. Declining water levels and water quality deterioration has forced homeowners to redrill existing or drill new domestic wells, which is expensive. In addition, building of new homes and businesses and property resale has been hindered because of the water quantity and quality issues. Results of the Project will help County personnel determine the feasibility of artificial recharge projects, both technically and economically. Economic development may resume in the near future if artificial recharge projects are deemed feasible for these valleys.

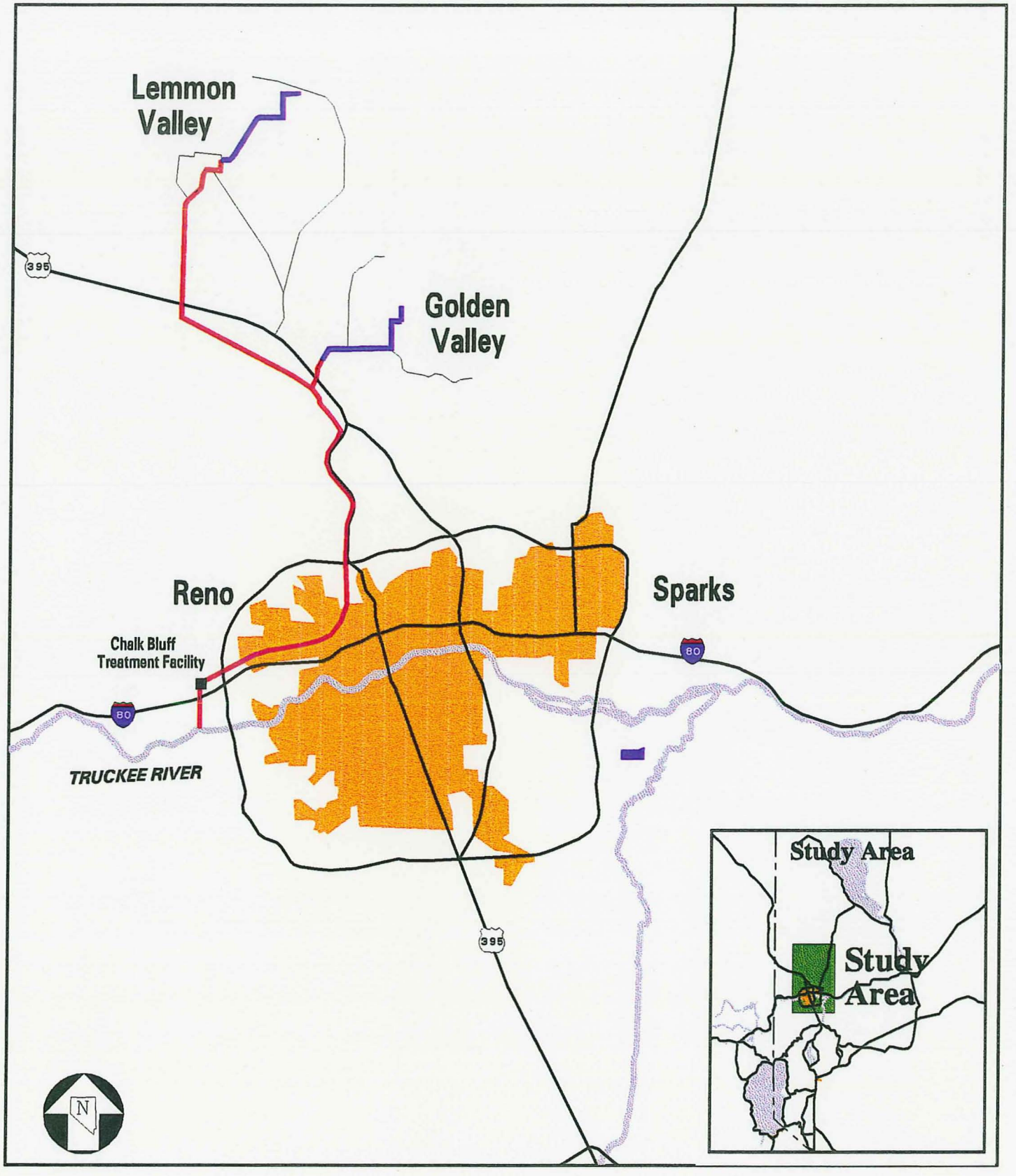

Lemmon Valley
Golden Valley
395
Reno
Sparks
Chalk Bluff Treatment Facility
80
TRUCKEE RIVER
Study Area
Study Area
N
Study Area
Sierra Pacific Water Line
Minor Roads
MILES
0
1
2
5
Washoe County Water Line
Retired Farmland
SEAL OF WASHOE COUNTY STATE OF NEVADA

Figure B

General Conclusions

The Project has shown that artificial recharge can help mitigate declining water tables and improve management of water resources in Washoe County. Artificial recharge may be an effective tool in offsetting water level declines in overpumped aquifers, storing water for drought use, and enhancing water quality of ground water supplies.

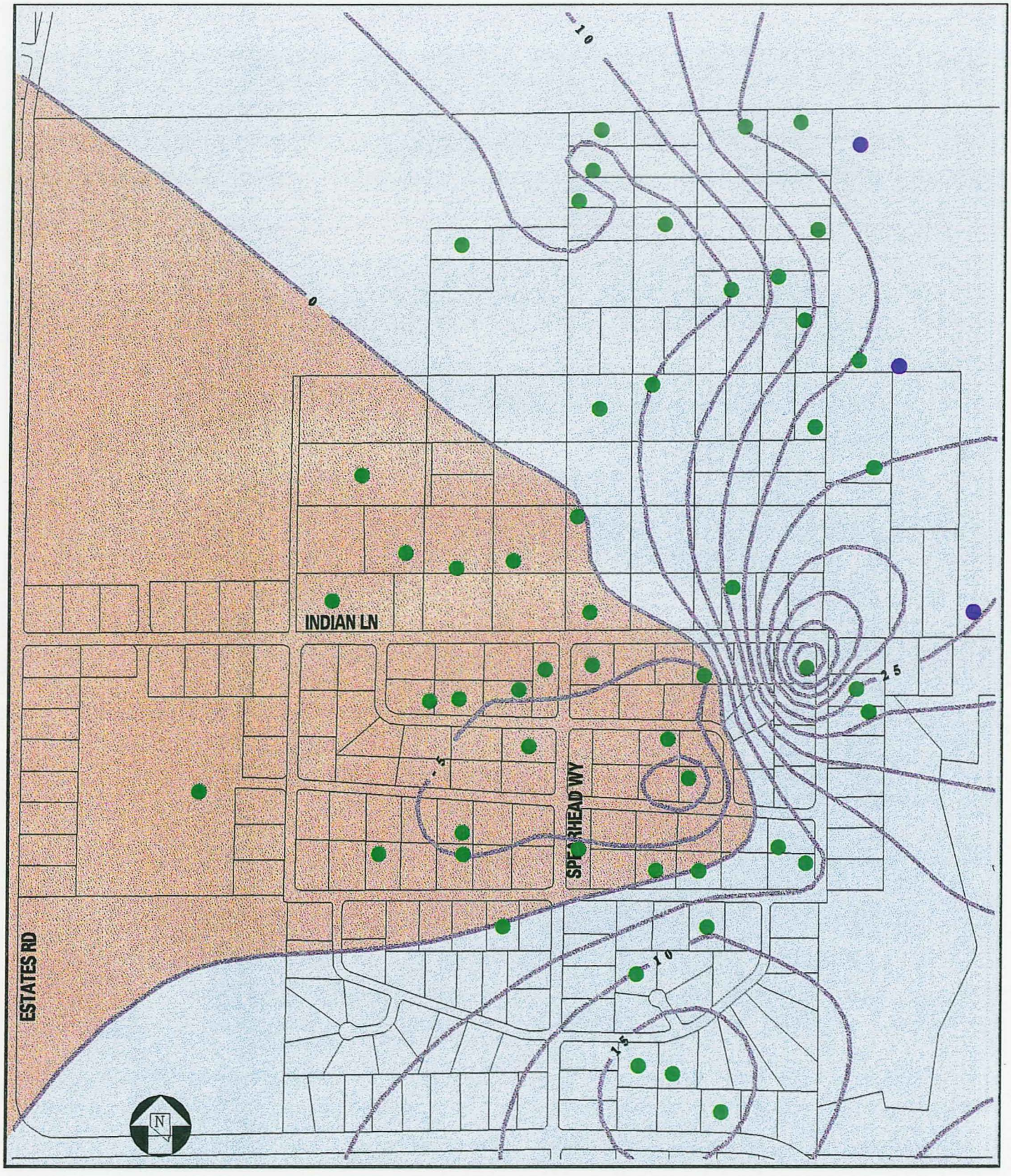
Project areas have a need to balance water supply with demand or property owners will continue to have economic problems. In Golden Valley, deterioration of the aquifer has caused economic hardships related to well deepening or redrilling and has hindered the ability to buy or sell homes in the area. Artificial recharge appears to be the most economic and best solution available to most residents of Golden Valley since construction of a municipal system would be considerably more expense than artificial recharge (see Figure 1, 1993-1996 Golden Valley Difference in Water Levels). Washoe County intends to continue artificial recharge in Golden Valley. Continuation will require financial commitment from residents in the Valley.

The County will continue "passive" artificial recharge in Lemmon Valley. Passive recharge occurs when water diverted from the Truckee River is directly served to municipal customers, allowing aquifers to recover naturally through deep percolation of precipitation. Directly serving customers with surface water results in less ground water pumping and the subsequent mitigation of declining water levels. Additionally, the County may continue injection and underground storage of Truckee River water if supply exceeds demand. Supply can exceed demand when winter precipitation is above normal. Figure 2 is the Conceptual Recharge Diagram showing the concept of underground storage.

Project Description

Background

Washoe County, Nevada, which encompasses the Cities of Reno and Sparks as its major population centers, is located in the arid rain shadow of the northern Sierra Nevada Mountains. Meeting water supply demands has become one of the major socio-economic issues in the County. Surface water from the Truckee River is the primary drinking water source for Reno and Sparks. Flows in the river vary greatly and mostly depend on the amount of precipitation falling in the Sierra Nevada mountains. When flows are high, a surplus of surface water exists. When flows are low, ground water is used to supplement drinking water needs. Prolonged use of ground water results in declining ground water tables. Western Nevada and Washoe County have had periods of drought conditions over the past 10 years. Water levels have dropped more than 20 feet in some areas of the County during the drought years. Artificial recharge was viewed as a way to meet demands with resources by storing surface water in aquifers during non-drought and low demand periods. Water stored in the aquifers can then be used to offset water table declines and provide drought and peak period water supplies.



Golden Valley Differences in Water Levels 1993 -1996

- Monitoring Well
- Injection Well
- Parcel Outline
- Contour Line (feet)
- Water Level Increase
- Water Level Decrease

MILES
0 .125 .25
500 1000
FEET

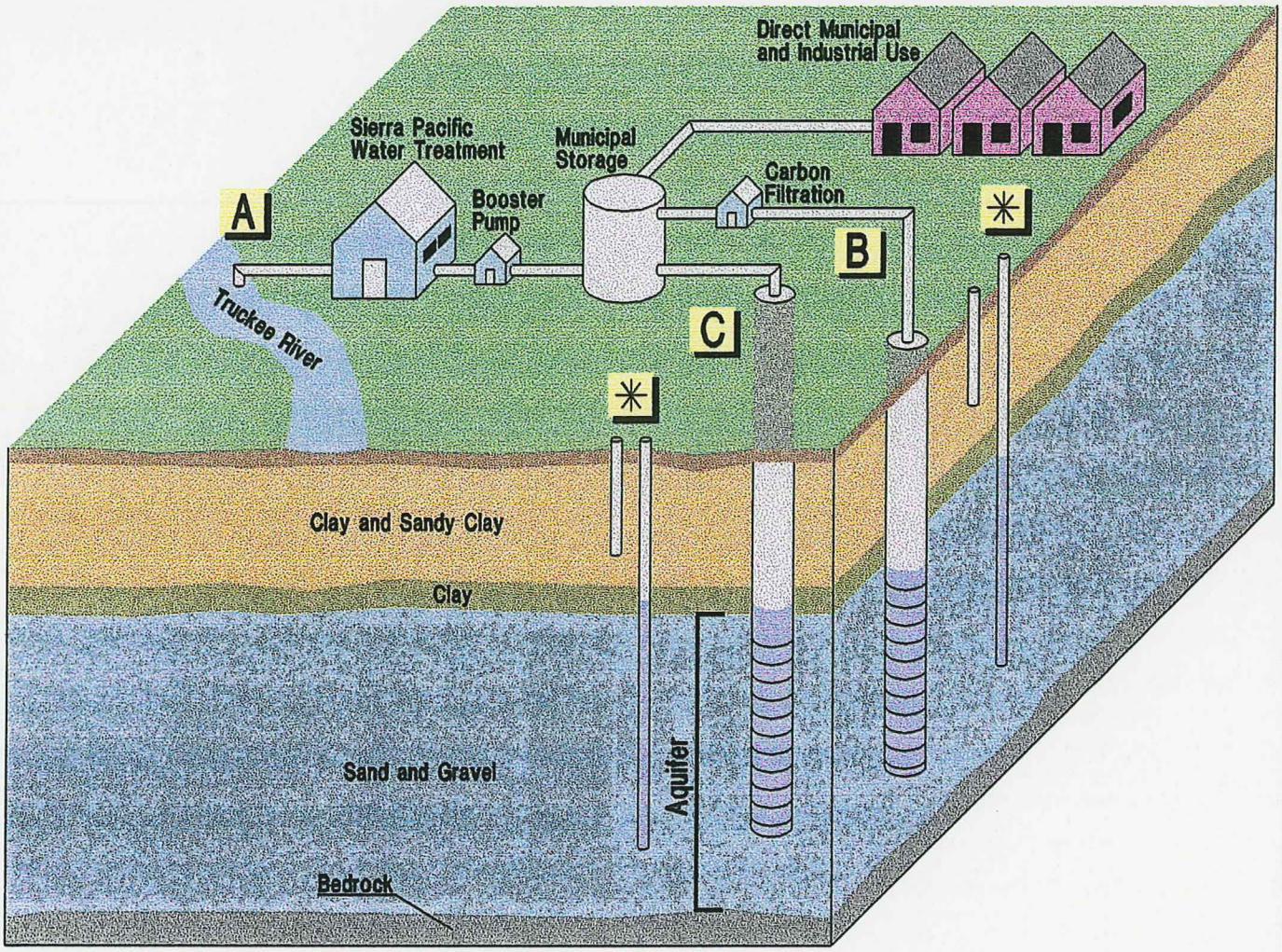
Figure 1

A — Water pumped from Truckee River to Municipal Storage

B — RECHARGE - During low demand, pump excess water into aquifer for future use

C — PUMPING - During high demand, pump water from aquifer for Municipal use

✳ — Monitoring wells used to check ground water levels



DEPARTMENT OF PUBLIC WORKS

UTILITY DIVISION
P.O. BOX 11130
RENO, NEVADA 89520
(702) 856-7300

CONCEPTUAL RECHARGE PLAN LEMMON VALLEY

FIGURE 2

LMH 1996 H:\UTIL\USERS\LHAMILTO\CONCEPT

The Washoe Recharge Project was constructed with the following specific goals:

- **Demonstrate the feasibility of recharging an aquifer tapped by hundreds of individual domestic wells (Golden Valley). Water table elevations in the aquifer have declined by as much a 100 feet since 1970.**

- **Demonstrate the feasibility of restoring water levels in a declining aquifer and provide drought storage for municipal water supplies by storing water underground through artificial recharge (Lemmon Valley). Water table elevations in the aquifer have declined more than 35 feet since 1970.**

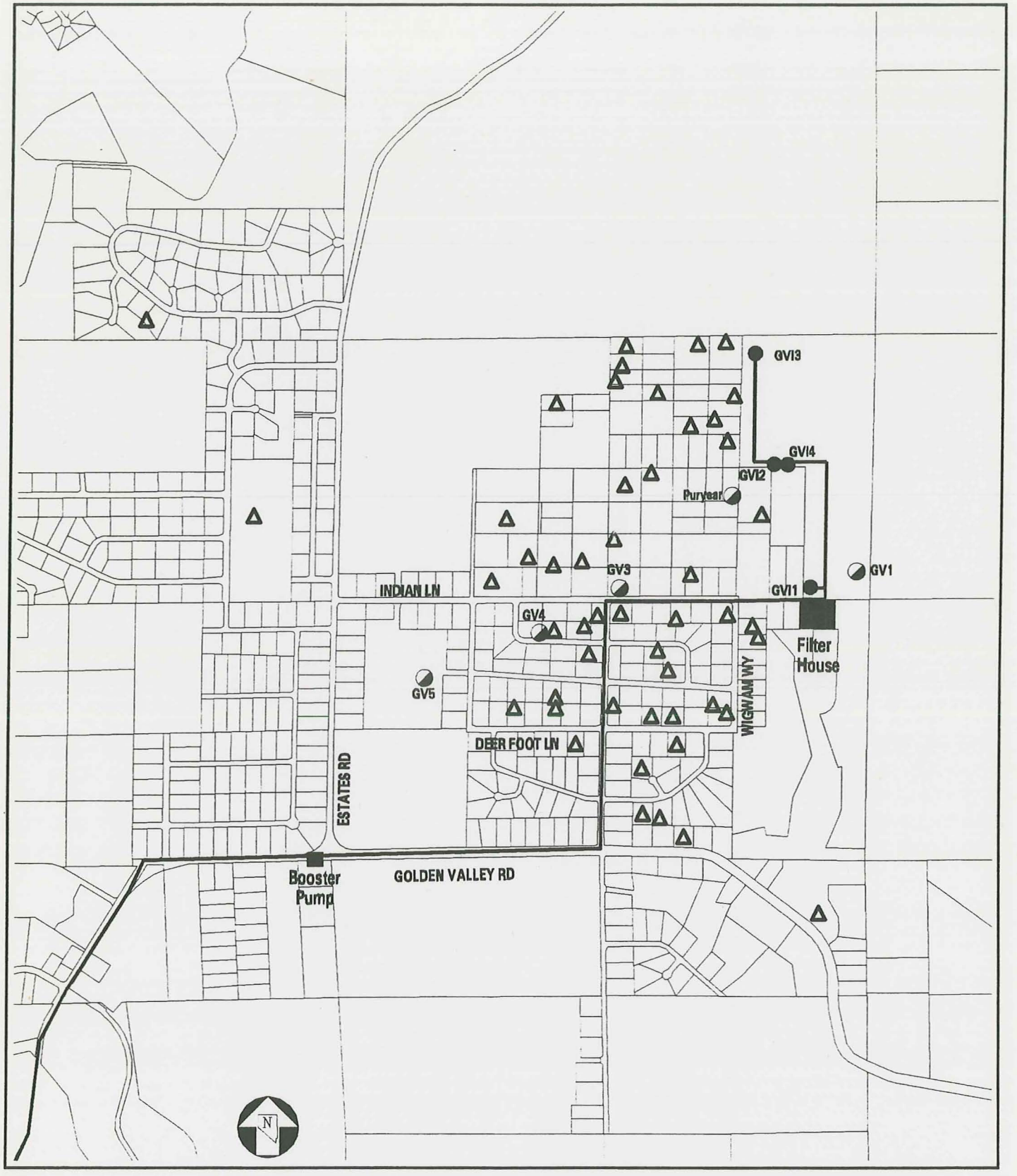
Washoe County has been evaluating recharge alternatives for Golden Valley since 1985. The County concurrently acquired a municipal water company in Lemmon Valley and recognized a need to evaluate the long term performance of the aquifer. Based on aquifer pumping tests and historical water level data, the County determined that more water was being extracted from the aquifer supplying the municipal system than was being naturally recharged. Artificial recharge appeared to be an alternative to offset the problems associated with aquifer declines. Consequently, the County submitted a proposal to participate in the High Plains States Groundwater Demonstration Program authorized by Congress in 1986. The Proposal identified the two separate recharge goals and ultimately was recommended by the State of Nevada and selected as a demonstration project. Reclamation was directed to administer the project, with cooperation from other Federal agencies (EPA, USGS, and FWS).

Construction and implementation of the project was delayed due to institutional constraints and a coincidental drought period between 1986 and 1993. Construction of the facilities necessary to deliver treated drinking water to the recharge sites was completed in October of 1992 (see Figures 3 and 4, Golden Valley and Lemmon Valley Detail maps). Because of the drought, injection did not begin until January of 1993. In response to project start up delays, Washoe County was granted a two year extension by Reclamation (as a result of drought conditions), extending the project into 1997 to allow for additional monitoring.

Facilities necessary to deliver treated drinking water from the Truckee River into the aquifers of Lemmon and Golden Valley included a booster pump, pipelines, carbon filters and injection wells. The method of recharge was to place water directly into aquifers through the wells.

Injection Water

Injection water originates in the Truckee River at a diversion point approximately 10 miles from the Golden Valley injection site and 15 miles from the Lemmon Valley injection site. Water quality from the Truckee is excellent, with a total dissolved solids content usually below 90 parts per million (see Figure 5, Typical Truckee River Water Quality). The water is filtered and chlorinated at a municipal water treatment plant and then pumped through a pipeline to the recharge sites. To minimize formation of chlorination byproducts (total



Golden Valley Detail

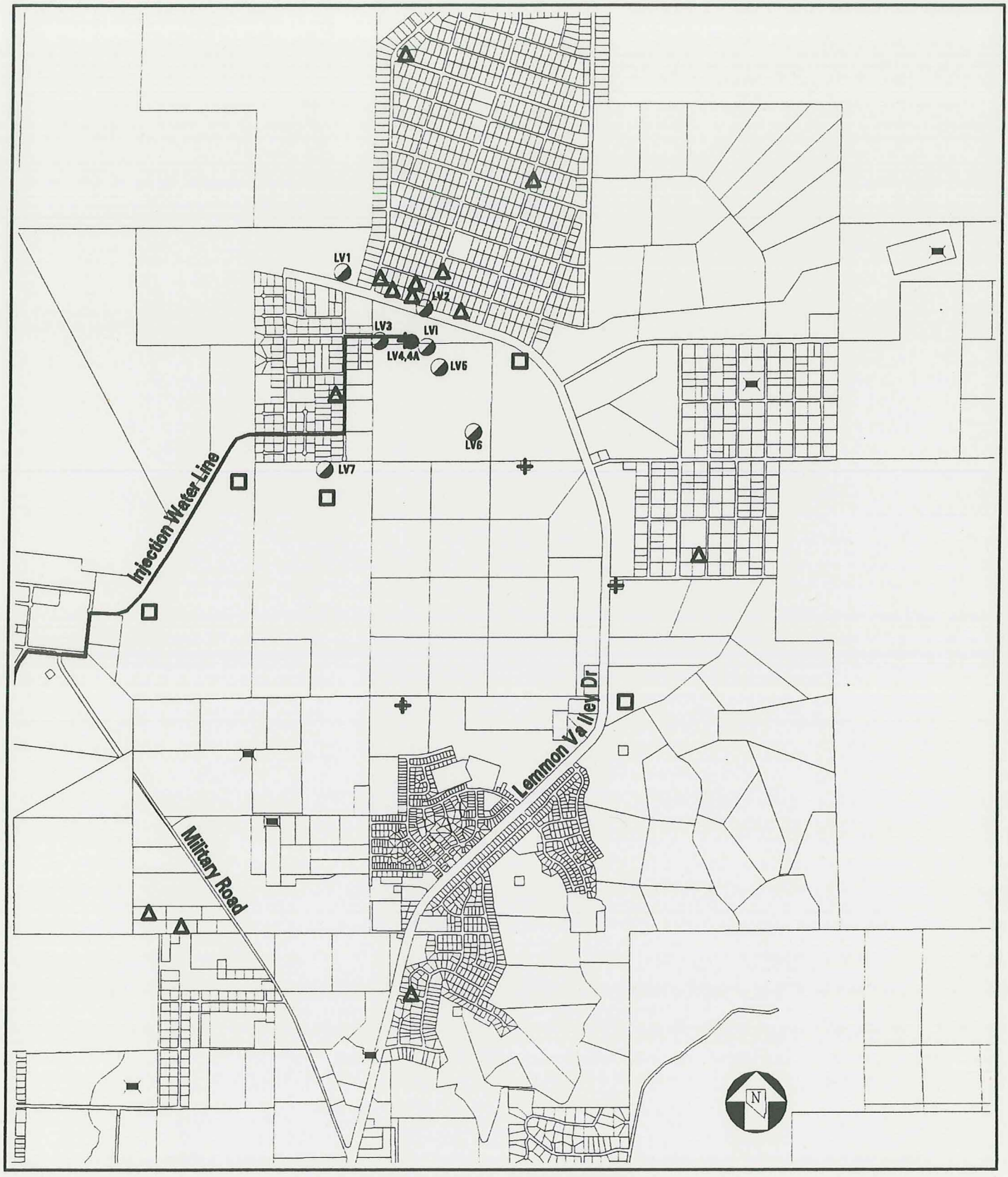
- Injection Well
- Monitored Domestic Well
- Dedicated Monitoring Well
- Injection Water Line

Miles: 0, .125, .25, .5

Feet: 500, 1000, 2000

SEAL OF WASHOE COUNTY * STATE OF NEVADA *

Figure 3



Lemmon Valley Detail

- Injection Well
- Dedicated Monitoring Well
- Monitored Domestic Well
- U.S.G.S. Monitoring Well
- Municipal Production Well
- Monitored Permitted Well

Miles: 0, .25, .50, 1

Feet: 1000, 2000, 4000

SEAL OF WASHOE COUNTY * STATE OF NEVADA *

Figure 4

trihalomethanes), the water is filtered again through activated carbon. The result is the injection of high quality water with a very low suspended solids content.

Figure 5 – Typical Quality of Truckee River Water

Constituent	mg/L	Constituent	mg/L	Constituent	mg/L	Constituent	S.U.	Const -ituent	mg/L
TDS @ 103 degrees C.	65	Chloride	5	Iron	0.02	Color	3	Cd	<0.001
Hardness	37	Nitrate	0.1	Manganese	0.01	Turbidity	0.3	Cr	<0.005
Calcium	10	Alkalinity	30	Copper	0.01	pH	7.34	Ag	<0.005
Magnesium	3	Bicarbonate	37	Zinc	0.00	EC	115	Pb	<0.005
Sodium	6	Carbonate	0	Barium	0.02			Se	<0.001
Potassium	2	Fluoride	0.06	Boron	0.0	Gross Alpha (pCi/L)	<3	Hg	<0.0005
Sulfate	10	Arsenic	<0.003	Silica	13	Gross Beta (pCi/L)	<3	MBAS	<0.1

Water Quality Summary

All water quality data were compared to drinking water primary and secondary MCLs. Detected concentrations of organic compounds did not exceed any MCLs for baseline and injection cycle samples. One inorganic compound, gross alpha, was detected in a single baseline ground water sample at a concentration exceeding the primary MCL. The ground water sample was collected in Golden Valley, where radionuclides are naturally occurring, in a domestic well located approximately 1/3 mile downgradient from the nearest injection well. The homeowner using the well has been informed about the naturally occurring compound exceeding the primary MCL.

Several inorganic compounds were detected above secondary MCLs. Secondary MCLs are based on the aesthetic quality of water and are non-enforceable guidelines. Inorganic compounds exceeding secondary MCLs were sulfate, iron, manganese, zinc, copper, color, and total dissolved solids. These compounds were detected in ground water samples collected from a shallow monitoring well located near a playa in Lemmon Valley. Shallow ground water in the vicinity of playas typically contains inorganic compounds at levels exceeding secondary MCLs. No response is needed since the compounds exceeding secondary MCLs were detected in a monitoring well.

Construction

Mitigation of agency concerns, acquisition and transfer of water rights, collection of background water quality information required by the EPA, and a coincidental drought in the region delayed project construction until August of 1991. Construction was completed October 9, 1992.

Constructed facilities include:

Golden Valley
(Figure 3)

1) Approximately 10,000 feet of 4-inch diameter water line.
2) One carbon filter, including filter house.
3) Three, 250-feet deep, 8-inch diameter injection well.
4) Four, 2-inch diameter dedicated monitoring wells.
5) All necessary valves, meters and electrical equipment to operate the facility.

Lemmon Valley
(Figure 4)

1) Approximately 10,500 feet of 6-inch diameter water line.
2) Two carbon filters, including filter house.
3) One 10-inch diameter, 400 feet deep injection well.
4) Eight, 2-inch diameter dedicated monitoring wells.
5) All necessary valves, meters and electrical equipment to operate the facility.

Institutional Constraints

Proposing to deliver Truckee River water outside the Truckee River Basin for use as artificial recharge required the support and approval of many competing interests and regulatory agencies in Nevada.

Each of the interests or agencies had ample opportunity to prevent the Recharge Project from occurring. The Project required changes in the point of diversion, place, and manner of use of water under Nevada Water Law. Applications for these changes are subject to protest by anyone believing they may be harmed by the change. Protests may be filed with the Nevada State Engineer. Reclamation's policy as stated in the beginning of the program was that projects generating significant controversy would not be funded. The goal then became for Washoe County to contact all concerned interests prior to making applications for changes to discuss and mitigate any concerns that might generate a protest. The following is a summary of each Agency and competing interest, their concerns about use of Truckee River water for the recharge project, and the efforts undertaken to mitigate those concerns.

Pyramid Lake Paiute Tribe (Tribe)

The Truckee River terminus is at Pyramid Lake, Nevada, a remnant of one of the great Pleistocene lakes that once covered much of the Great Basin. Pyramid Lake is part of the Pyramid Lake Paiute Tribe Indian Reservation. Lake levels in Pyramid Lake began dropping dramatically around the turn of the century as Truckee River water was diverted for irrigation and municipal use. The Tribe believes that lower lake levels caused by the diversions has resulted in a deterioration of the natural spawning conditions for fish native to Pyramid lake, specifically the Cui-ui Sucker. The Cui-ui is considered to be an integral part of Tribal heritage and culture and has been placed on the endangered species list. Consequently, the Tribe was sensitive to the impacts of a project that would divert water out of the Truckee River Basin.

Mitigation of the Tribal Concerns

Washoe County committed to seek water rights that were being used for irrigation in the Truckee Meadows. The water right was transferred to the Project and the existing irrigated land was retired. Also, to alleviate the loss of any return flow to the Truckee from the irrigation, the amount exported to the Project was limited to 70 percent of the total right. The end result, which was satisfactory to the Tribe, was that the project would not change current diversion amounts and would allow the remaining 30 percent of the water right to pass directly into the Truckee River for return flow credit.

U. S. Fish and Wildlife Service (FWS)

Citing the endangered Cui-ui fish, the FWS was concerned about the diversion of water from the Truckee River for the Recharge Project. The historic decline in Pyramid Lake level has created a delta where the Truckee enters into the lake. The formation of the delta has made it more difficult for the Cui-ui fish to migrate upstream to spawn even when flows are average. Thus, the FWS would not permit the Project to impact flows in the river during fish spawning season.

Mitigation of FWS Concerns

While the project did not divert more water from the Truckee than had been historically diverted under the water right used, the timing of the diversion was changed to meet FWS's concerns. The County agreed to use a criteria established by the FWS based on the predicted flows in the Truckee. Each month, the NRCS publishes a streamflow forecast for the Truckee River. The criteria agreed upon by the County and FWS were:

1) Injection will not occur from September through March when the Truckee River discharge is less than 80 percent of normal at the Farad streamflow gauge;

2) Injection can occur from September through March when discharge in the Truckee River is 80 to 120 percent of normal discharge at the Farad gauge;

3) Injection can occur from September through June when discharge in the Truckee River is greater than 120 percent of normal discharge at the Farad gauge.

Truckee Carson Irrigation District (TCID)

TCID diverts water below Reno for irrigation in the Fallon, Nevada area. TCID was formed as a result of Reclamation's Newlands Project completed in the early part of this century. Because the Truckee provides a major source of water to TCID, they were very sensitive to any diversion changes.

Mitigation of TCID Concerns

Washoe County met with the attorney representing TCID and discussed the Recharge Project. The attorney relayed the information to the District Board and recommended TCID support the Recharge Project. The Board agreed and supported the project as presented.

Sierra Pacific Power Company (SPPCo)

SPPCo is the major municipal water supplier in Washoe County. Over 80 percent of the water used by SPPCo to serve the metropolitan areas of Reno and Sparks, Nevada comes from the Truckee River. As with TCID, FWS, and the Tribe, SPPCo was very sensitive to any diversion changes in the Truckee River system.

SPPCo became an important participant in the Recharge Project because they deliver the water through their system to a connecting pipeline with the County Recharge facilities. SPPCo's major concern was that their involvement in the project might upset other major users of Truckee River water.

Mitigation of SPPCo Concerns

Before agreeing not to protest the water right transfers and providing the water delivery service to the Project, SPPCo requested that the County obtain approval letters from FWS, TCID, and the Pyramid Lake Paiute Tribe.

Annual Injection Summary

1992

With the exception of a near average water year (July 1 through June 30) in 1990-1991, the 1991-1992 water year was the fifth consecutive year of below average precipitation in the Truckee River drainage basin. Diversions in the Truckee for municipal, industrial and agricultural use resulted in the river ceasing to flow in a section through east Reno and Sparks

during the late summer of 1992. In compliance with the conditions agreed upon and described under "Institutional Constraints", no significant injection occurred in 1992.

1993

An above average precipitation year beginning in December 1992 allowed injection to begin in earnest in 1993. The injection plan was to inject through gravity only, not building any significant pressure at the well heads. After several months of injection using gravity it became apparent that injection under pressure at the well head would generate the following benefits:

1) Stop negative pressure at the above ground connections and fittings. Negative pressure caused leaks to develop in rubber seals. The leaks allowed air to enter injection piping and cause entrainment problems.

2) Increase injection rates. Gravity feed injection rates were less than anticipated in all injection wells. Tests showed injection could be increased under pressure. Beginning in July and August of 1993, injection rates were increased by injecting under pressures ranging from 5.5 pounds per square inch (psi) to 30 psi . Total injection for golden Valley was 26.6 acre feet (see Figure 6, 1993 Injection Volumes-Golden Valley) representing about 53 percent of the 50 acre feet goal. Total injection in Lemmon Valley was 79.5 acre feet (see Figure 7, 1993 Injection Volumes-Lemmon Valley), about 40 percent of the 200 acre feet goal.

Water levels in Lemmon Valley were not influenced by injection because a municipal well near the injection well was in use during the injection period. Water levels in Golden Valley were influenced by injection, with monitoring wells near the injection site showing a water table rise of several feet.

Field measurements of water quality did not show any apparent correlation between injection water and ground water at either the Lemmon Valley or Golden Valley injection sites. This indicates that injected water may have influenced water tables but the actual water injected had not reached any domestic or production wells.

1994

Drought conditions returned for the winter of 1993-1994. In fact, precipitation for the winter was the lowest since the drought began in 1987. In late summer, the Truckee River once again ceased to flow in a section of East Reno and Sparks. Because of the drought, recharge was limited to the month of March, 1994. Only 5 acre feet were injected in Golden Valley and 15 acre feet in Lemmon Valley (see Figures 8 and 9, 1994 Injection Volumes for Golden and Lemmon Valleys).

Goals of 1994 were to obtain permission to extend injection periods and reduce sampling and analyses requirements. Extending the injection period primarily required obtaining permission

from FWS. Reducing the sampling and analyses requirements required permission from the EPA, NDEP, and NDWR.

In a 1989 memo referred to as the Cook, Mlay memo dated January 26,1989, EPA outlined the sampling and analyses requirements for recharge projects under the High Plains States Aquifer Recharge Demonstration Program. Requirements were stringent to ensure protection of aquifers proposed for injection. Incorporated in the 1989 memo was the option to reduce the sampling frequency and schedule based on sampling results prior to 1994. Washoe County provided justification. requesting changes in the frequency and number of samples collected.

After review, EPA approved the suggested modification of sampling requirements. Local approval from NDEP and NDWR was also granted. The proposed changes reduced projected sampling and analyses costs from approximately $123,000 per year to $21,000 per year. Direct savings were projected at over $100,000 per year with additional personnel cost savings by reducing the number of sampling events.

Because of the lower than expected injection capacities, Washoe County sought to extend the original injection period from September through January of each year to September through June of each year. FWS was primarily concerned with the timing of diversion for injection. Washoe County, through Reclamation, requested permission from the FWS to extend the injection period. Responding in a memo dated August 10, 1994 , FWS granted extensions to injection periods based on predictions of flow in the Truckee River. Predictions of flow are prepared monthly by the NRCS, based on water content of snow pack in the Truckee drainage basin.

1995

The winter of 1994/95 was one of the wettest on record. Snow pack in the Sierra Nevada Mountains approached 200 percent of average. The NRCS issued the first streamflow predictions for 1995 in February of that same year. Based on the higher than average streamflow predictions, recharge began in early February and continued throughout the year except for the months of July and August, as agreed upon with the FWS.

Injection pressures were gradually increased to improve injection rates. In Lemmon Valley, injection pressures were at about 43 psi at the well head with flow into the well exceeding 150 gallons per minute. However, at 43 psi, water began percolating at the ground surface along a distinct radial fracture around the nearby production well and the injection well. The nature of the fracture suggested that a subsidence crack may have formed as a result of the long term pumping of the municipal well and the de-watering or depressurizing of the aquifer. The subsidence crack provided a pathway for injection water to migrate upward to the ground surface. Injection pressures were reduced to a few psi, reducing injection to less than 50 gallons per minute.

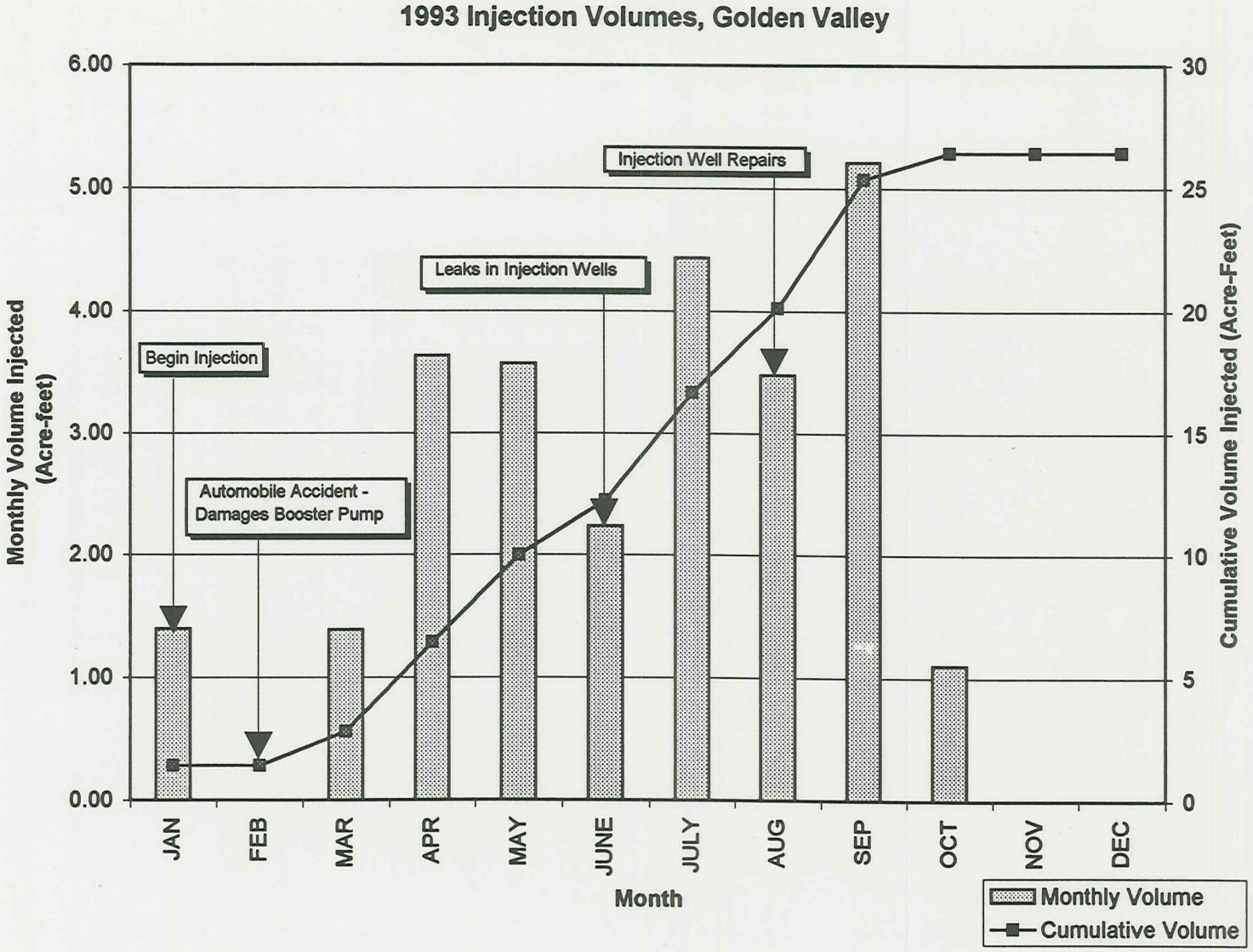

1993 Injection Volumes, Golden Valley
Monthly Volume Injected (Acre-feet)
Cumulative Volume Injected (Acre-Feet)
6.00
5.00
4.00
3.00
2.00
1.00
0.00
30
25
20
15
10
5
0
Begin Injection
Automobile Accident - Damages Booster Pump
Leaks in Injection Wells
Injection Well Repairs
JAN
FEB
MAR
APR
MAY
JUNE
JULY
AUG
SEP
OCT
NOV
DEC
Month
Monthly Volume
Cumulative Volume

Figure 6

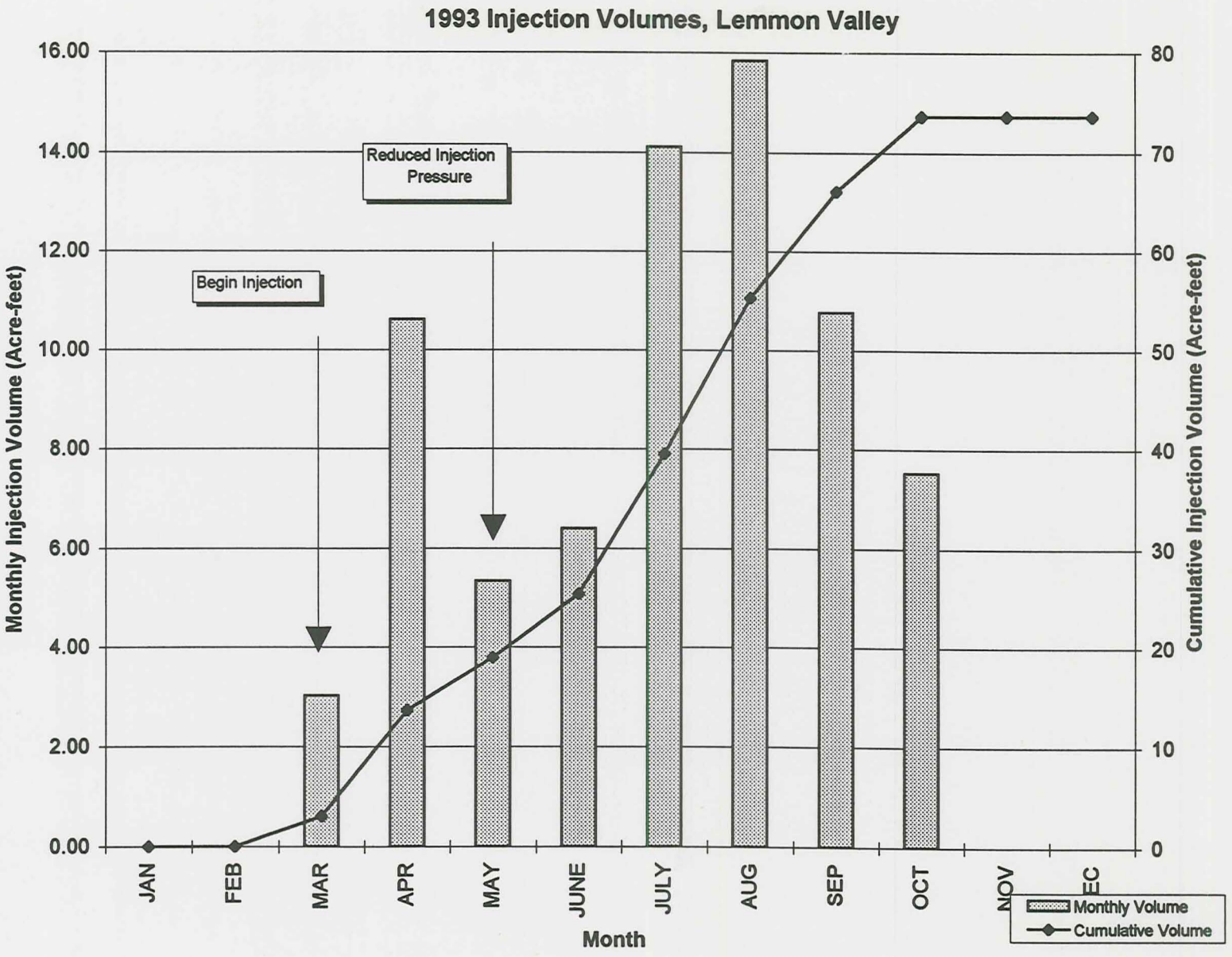

1993 Injection Volumes, Lemmon Valley
Monthly Injection Volume (Acre-feet)
Cumulative Injection Volume (Acre-feet)
16.00
14.00
12.00
10.00
8.00
6.00
4.00
2.00
0.00
80
70
60
50
40
30
20
10
0
Reduced Injection Pressure
Begin Injection
JAN
FEB
MAR
APR
MAY
JUNE
JULY
AUG
SEP
OCT
NOV
EC
Month
Monthly Volume
Cumulative Volume

Figure 7

Water quality testing and, specifically, the presence of low concentrations of total trihalomethanes (TTHMs), indicated that injected water in Lemmon Valley had reached the adjacent production well and one nearby monitoring well. TTHMs are byproducts of the chlorination of water containing organic material. TTHM levels reached about 60 micrograms per liter in the injection water, 28 micrograms per liter in water pumped from the nearby production well and about 4.5 micrograms per liter in water sampled from a nearby monitoring well. The fact that TTHMs were not present in the production well and monitoring well prior to injection showed that injection water had reached the nearby wells. Water quality analyses from Golden Valley wells showed that the injection water had not reached the sampled wells. TTHMs were detected in one monitoring well at a level below the established MCL in 1995.

Measured water levels were influenced by recharge in both Lemmon and Golden Valleys. Influence of injection water is more apparent in Golden Valley because ground water is only extracted by small volume domestic wells. In Lemmon Valley, water level impacts were not as apparent because of the pumping of the nearby municipal well.

Total amounts injected were 81.6 acre feet in Lemmon Valley and 40.6 acre feet in Golden Valley (see Figures 10 and 11, 1995 Injection Volumes-Golden and Lemmon Valleys). Golden Valley injection well No. 2 developed a leak around the sanitary seal and had to be abandoned as an injection well. Washoe County requested and was granted additional funds to drill a replacement injection well next to injection well No. 2. The replacement well (Golden Valley injection well No. 4) was drilled in 1995 and is currently in use.

1996

The winter of 1995/1996 ended with above average snow pack and high runoff predictions. Recharge began with the release of the first NRCS streamflow prediction in February of 1996. As of July 1, 1996, 31.36 acre feet had been injected in Golden Valley and 17.48 acre feet had been injected in Lemmon Valley (see Figures 12 and 13, 1996 Injection Volumes in Golden and Lemmon Valleys). Injection was running smoothly with recharge projected to reach the goal of 50 acre feet in Golden Valley and about 30 acre feet in Lemmon Valley (reduced because of the surface leak that developed around the well).

Conclusions

Artificial recharge using injection wells is a viable alternative to offset aquifer declines. Barriers to recharge projects in Northern Nevada are likely to be more institutional, economical or political than technical. Competing demands for water exclude the concept of available "excess" water for recharge. Even during high flow events, water that might be considered as excess has a demand. Any amount of flow in the Truckee River reaching ecologically sensitive Pyramid Lake is viewed by some to be critical to the survival of the lake and its species. Competition for high flows for municipal, agricultural, and industrial drought

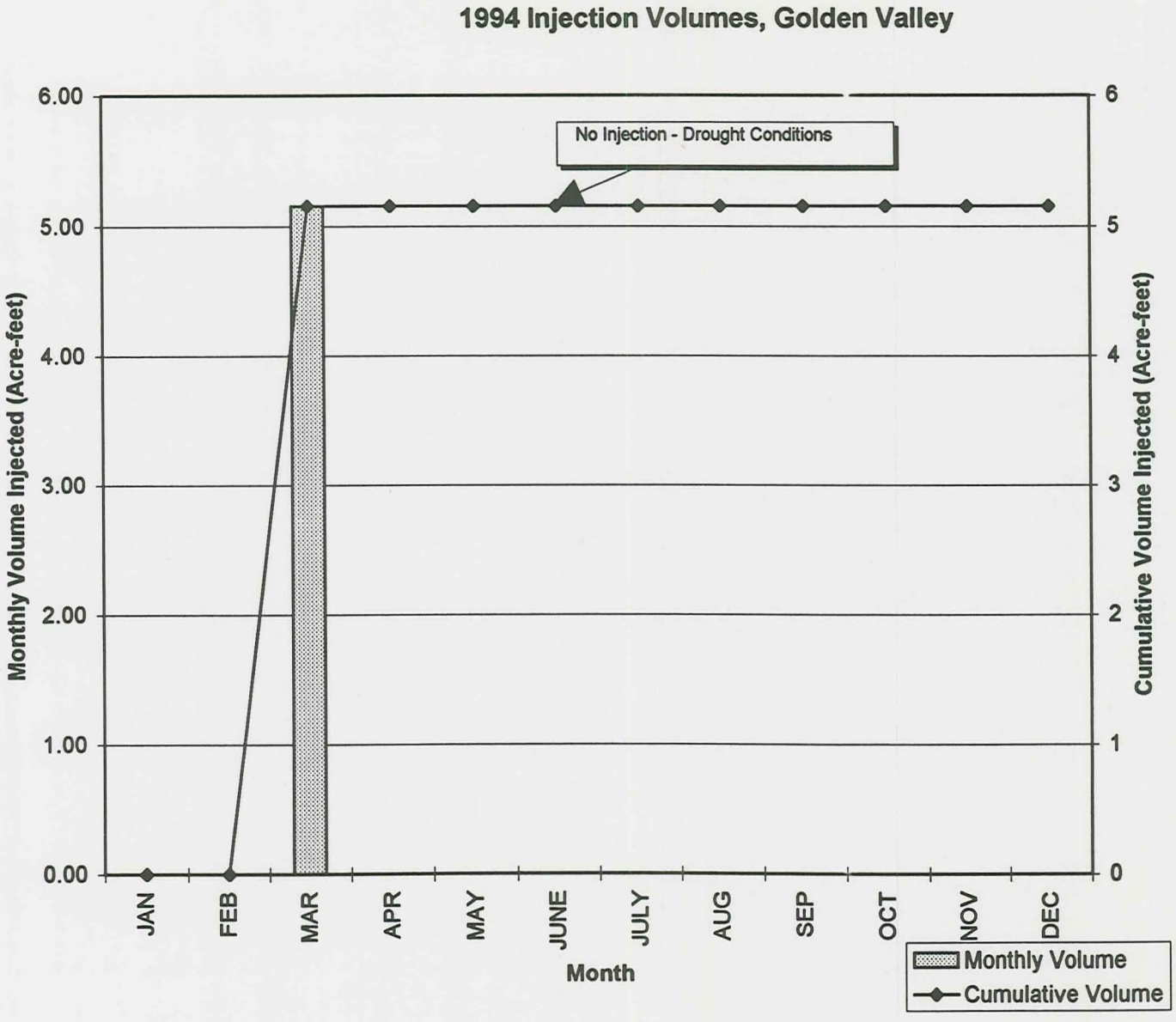

1994 Injection Volumes, Golden Valley
No Injection - Drought Conditions
Monthly Volume Injected (Acre-feet)
Cumulative Volume Injected (Acre-feet)
6.00
5.00
4.00
3.00
2.00
1.00
0.00
6
5
4
3
2
1
0
JAN
FEB
MAR
APR
MAY
JUNE
JULY
AUG
SEP
OCT
NOV
DEC
Month
Monthly Volume
Cumulative Volume

Figure 8

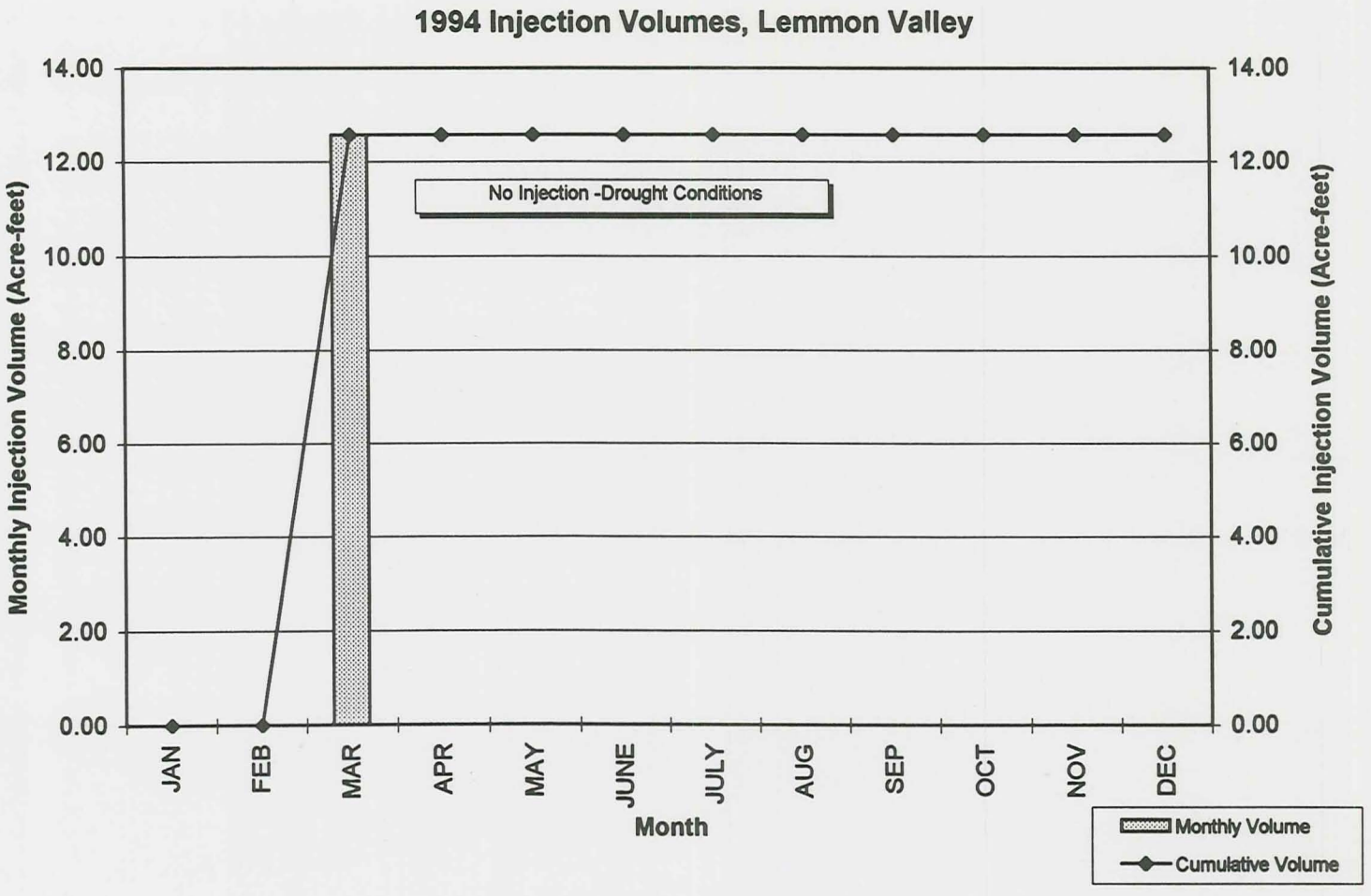

1994 Injection Volumes, Lemmon Valley
14.00
12.00
10.00
8.00
6.00
4.00
2.00
0.00
Monthly Injection Volume (Acre-feet)
Cumulative Injection Volume (Acre-feet)
No Injection -Drought Conditions
JAN
FEB
MAR
APR
MAY
JUNE
JULY
AUG
SEP
OCT
NOV
DEC
Month
Monthly Volume
Cumulative Volume

Figure 9

storage, and artificial recharge exist. Competition between entities for the unappropriated water in the Truckee River is high. Entities that have filed applications to appropriate water rights and their intended uses include:

1) **Pyramid Lake Paiute Tribe**-maintain Pyramid Lake ecosystem;

2) **Washoe County**-municipal and industrial drought storage, agricultural and artificial recharge (drought storage, aquifer restoration);
3) **Truckee-Carson Irrigation District**-agricultural;

4) **Sierra Pacific Resources**-municipal and industrial, artificial recharge, drought storage.

Applications for unappropriated Truckee River Rights are on file at the Nevada State Engineer office and each application has generated protests from competing entities. Resolution will require hearings before a decision is reached by the Nevada State Engineer.

Competition over unappropriated water has necessitated recharge projects to seek the use of already appropriated water for recharge. Because the amount of appropriated water is limited, acquiring a water right for artificial recharge is expensive.

For example, to acquire a permanent water right and operate the Washoe Recharge Project at the maximum injection of 250 acre feet per year would require an initial purchase of 350 acre feet * of Truckee River water. The cost of Truckee River water is approximately $2,500 per acre foot. Based on this cost, an initial investment of about $875,000 would be incurred. Using injection wells for recharge requires water with a low suspended solids content to minimize well screen plugging. Delivery of clean, treated water with low suspended solids currently costs about $0.84 per 1000 gallons (1000 gallons equals 0.003067 acre feet). The resulting delivery cost for the 250 acre feet of recharge water per year is about $68,400. Based on County investigations about 85 percent of recharged water can be recovered. Based on these water costs and about $10,000 per year operations and maintenance cost, the cost to recharge the aquifer is about $1.13 per 1000 gallons.

* * Truckee River water rights are considered to have a "return flow component," meaning that water diverted from the river has an amount that eventually returns flow back to the river. Return flow usually occurs as treatment plant effluent discharge, irrigation runoff or groundwater discharge back into the river. In the case of the Washoe Recharge project, water is diverted outside the Truckee River Drainage Basin, eliminating the normal pathways for return flow. To compensate, a portion of the water right used for recharge outside the Truckee Basin must be allowed to "pass through" the river system. In the Washoe Project, 100 acre feet of the total 350 acre feet was allowed to pass through as the return flow component, leaving 250 acre feet for recharge.

Recommendations

Golden Valley

Artificial recharge may be the best alternative for maintaining a water resource for residents of Golden Valley. The limited recharge that occurred during this demonstration project clearly showed that artificial recharge can reverse the historical trend of water table declines. Review of Figure 1 shows ground water surface elevation differences between 1993 and 1996. The figure shows recharge had an impact, causing water tables to rise by as much as 40 feet near the recharge wells. Water levels continued to decline outside the area influenced by injection.

Residents of Golden Valley are heavily committed to using the limited local aquifer to supply their domestic wells. Even though the aquifer is showing significant deterioration due to over pumping, the cost to purchase water rights and build the infrastructure for a municipal water system would likely exceed $15,000 per household ($6,000 for Truckee River water rights, $7,000 for infrastructure, and $2,000 to abandon each existing domestic well). Local support for a municipal system would be hindered by the "leap frog" pattern of deepening or re-drilling domestic wells. The leap frog pattern may be described as that, for any given time, only a few residents need to deepen or re-drill wells in Golden Valley. Once the homeowner has paid to deepen or re-drill, that resident feels their problem is solved and would be opposed to further expenditures to build and connect to a municipal water system.

Artificial recharge is viable in Golden Valley since residents are dependent upon the limited aquifer and are most likely against the building of a municipal system. With the recharge facilities constructed under the High Plains States Artificial Recharge Demonstration Project, and the availability of surface water during average or above average precipitation years, it is recommended that recharge operations continue in Golden Valley.

Golden Valley has approximately 500 homes with domestic wells. Annual cost to maintain the current injection capacity of about 50 acre feet per year is about $35,000 which includes an $0.84 per 1000 gallons delivery of water by the local water utility, Sierra Pacific Power Company. Monthly cost distributed among the residents would be approximately $6. Unless a consensus among competing agencies could be reached allowing delivery of non-drought year unexercised water rights, a one time cost of about $175,000 would be required to purchase a water right to continue recharge. This would cost each homeowner approximately $350. Continuing recharge would require approval from the majority of the residents in Golden Valley. If approval were granted, Washoe County would operate and maintain the injection facilities. County personnel will make public presentations to Golden Valley residents summarizing the impact of the recharge project and present proposals to continue recharging the aquifer.

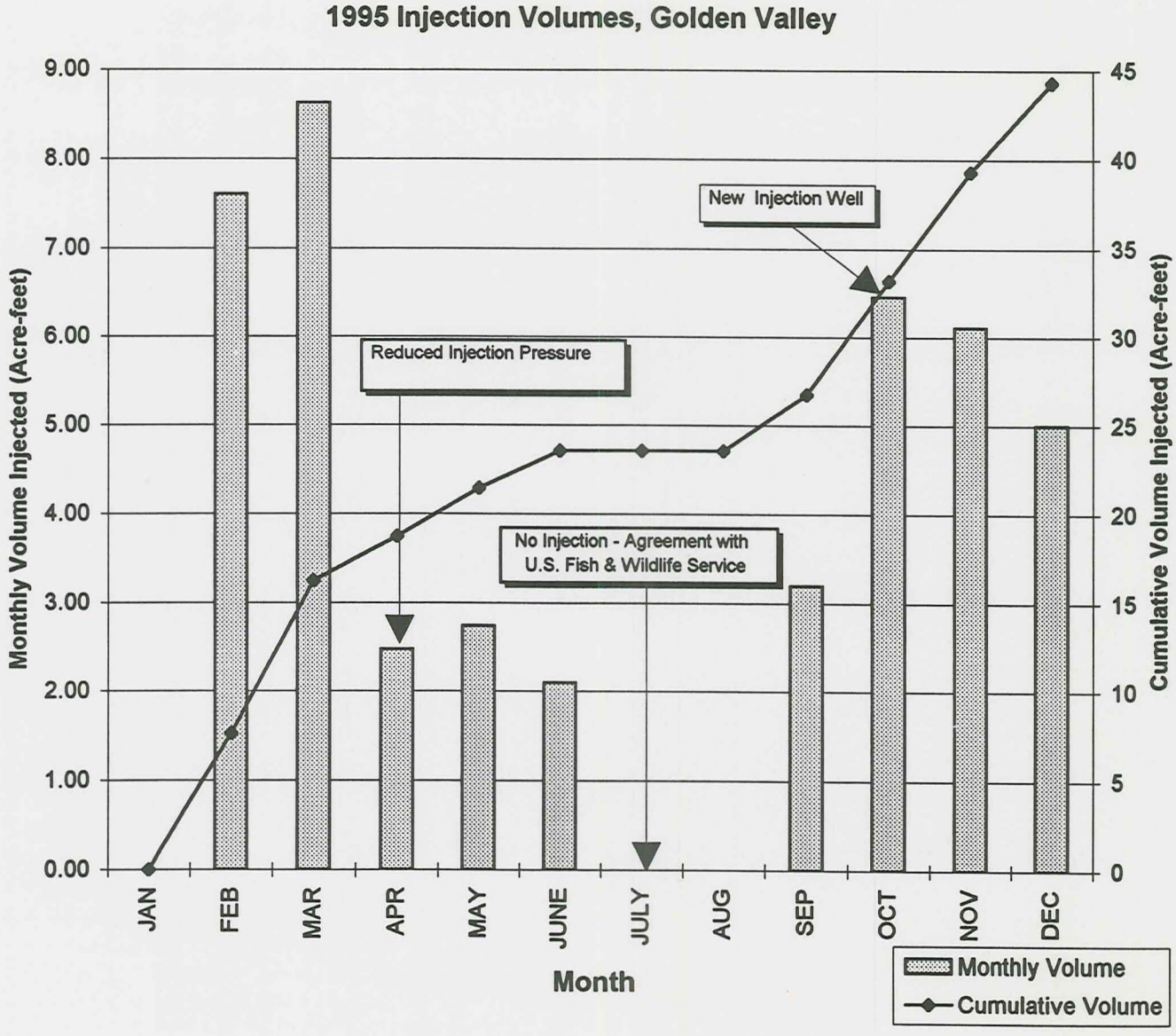

1995 Injection Volumes, Golden Valley
Monthly Volume Injected (Acre-feet)
Cumulative Volume Injected (Acre-feet)
9.00
8.00
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.00
45
40
35
30
25
20
15
10
5
0
New Injection Well
Reduced Injection Pressure
No Injection - Agreement with
U.S. Fish & Wildlife Service
JAN
FEB
MAR
APR
MAY
JUNE
JULY
AUG
SEP
OCT
NOV
DEC
Month
Monthly Volume
Cumulative Volume

Figure 10

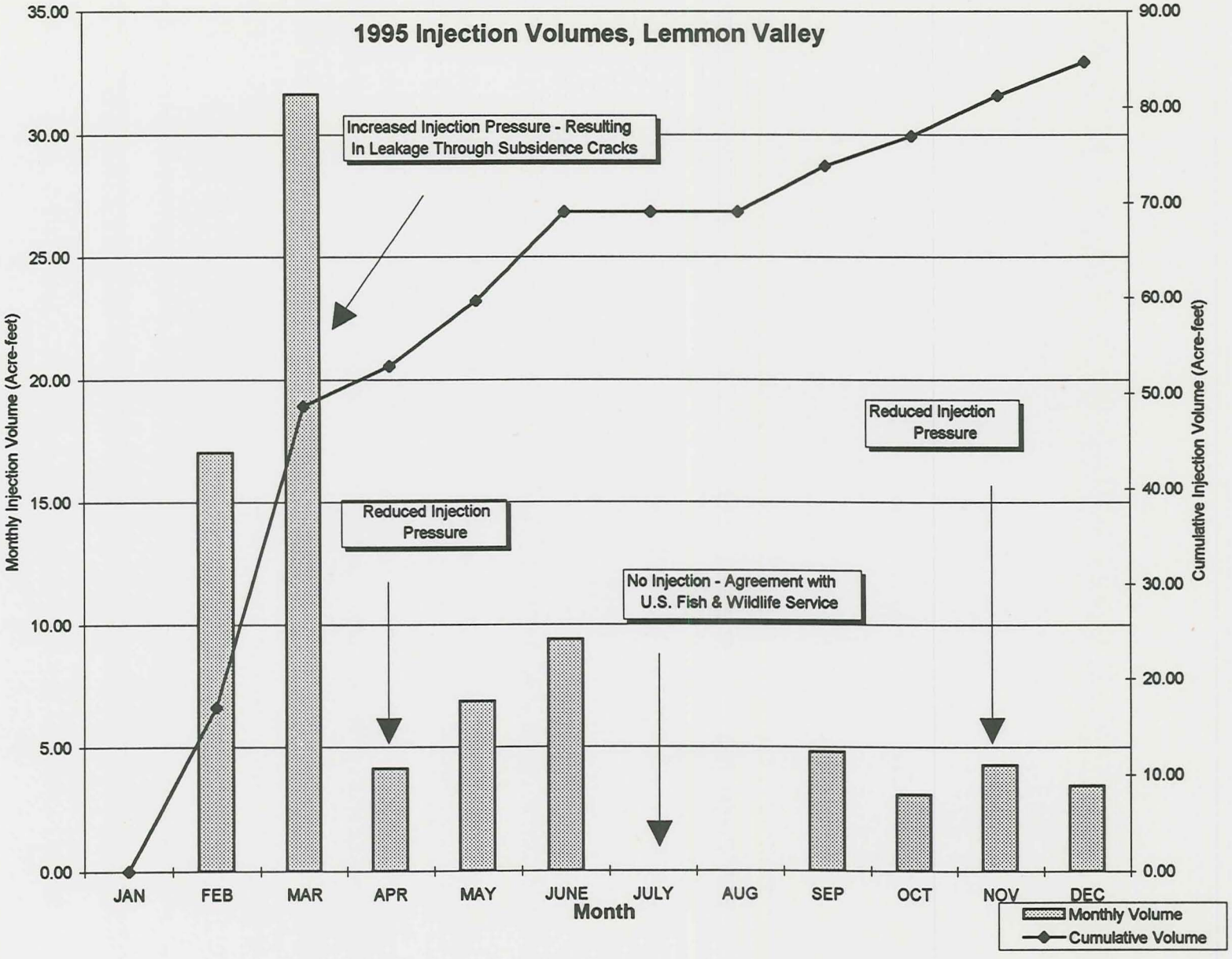

1995 Injection Volumes, Lemmon Valley
Increased Injection Pressure - Resulting In Leakage Through Subsidence Cracks
Reduced Injection Pressure
Reduced Injection Pressure
No Injection - Agreement with U.S. Fish & Wildlife Service
Monthly Injection Volume (Acre-feet)
Cumulative Injection Volume (Acre-feet)
35.00
30.00
25.00
20.00
15.00
10.00
5.00
0.00
90.00
80.00
70.00
60.00
50.00
40.00
30.00
20.00
10.00
0.00
JAN
FEB
MAR
APR
MAY
JUNE
JULY
AUG
SEP
OCT
NOV
DEC
Month
Monthly Volume
Cumulative Volume

Figure 11

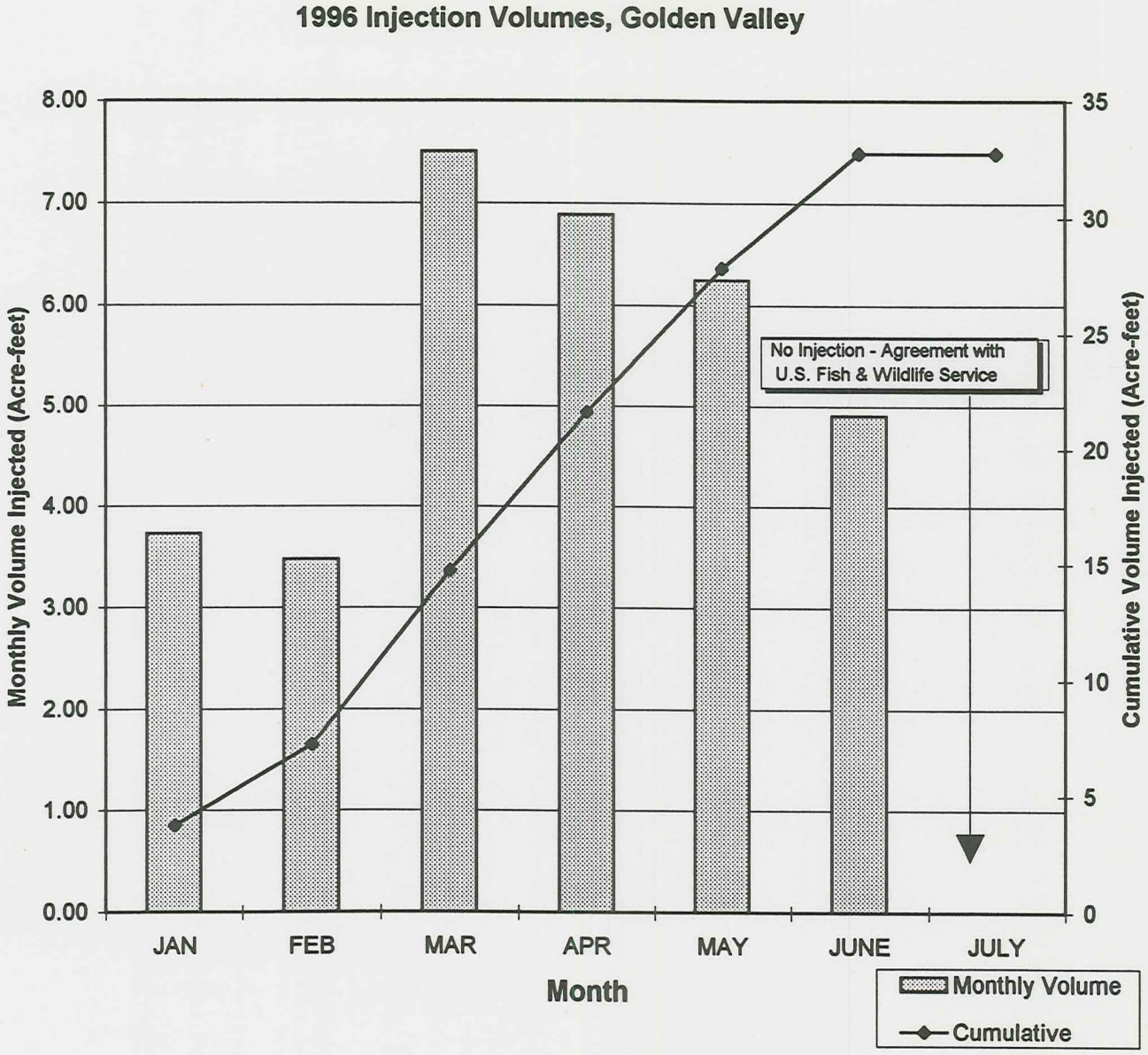

1996 Injection Volumes, Golden Valley
Monthly Volume Injected (Acre-feet)
Cumulative Volume Injected (Acre-feet)
8.00
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.00
35
30
25
20
15
10
5
0
JAN
FEB
MAR
APR
MAY
JUNE
JULY
Month
No Injection - Agreement with U.S. Fish & Wildlife Service
Monthly Volume
Cumulative

Figure 12

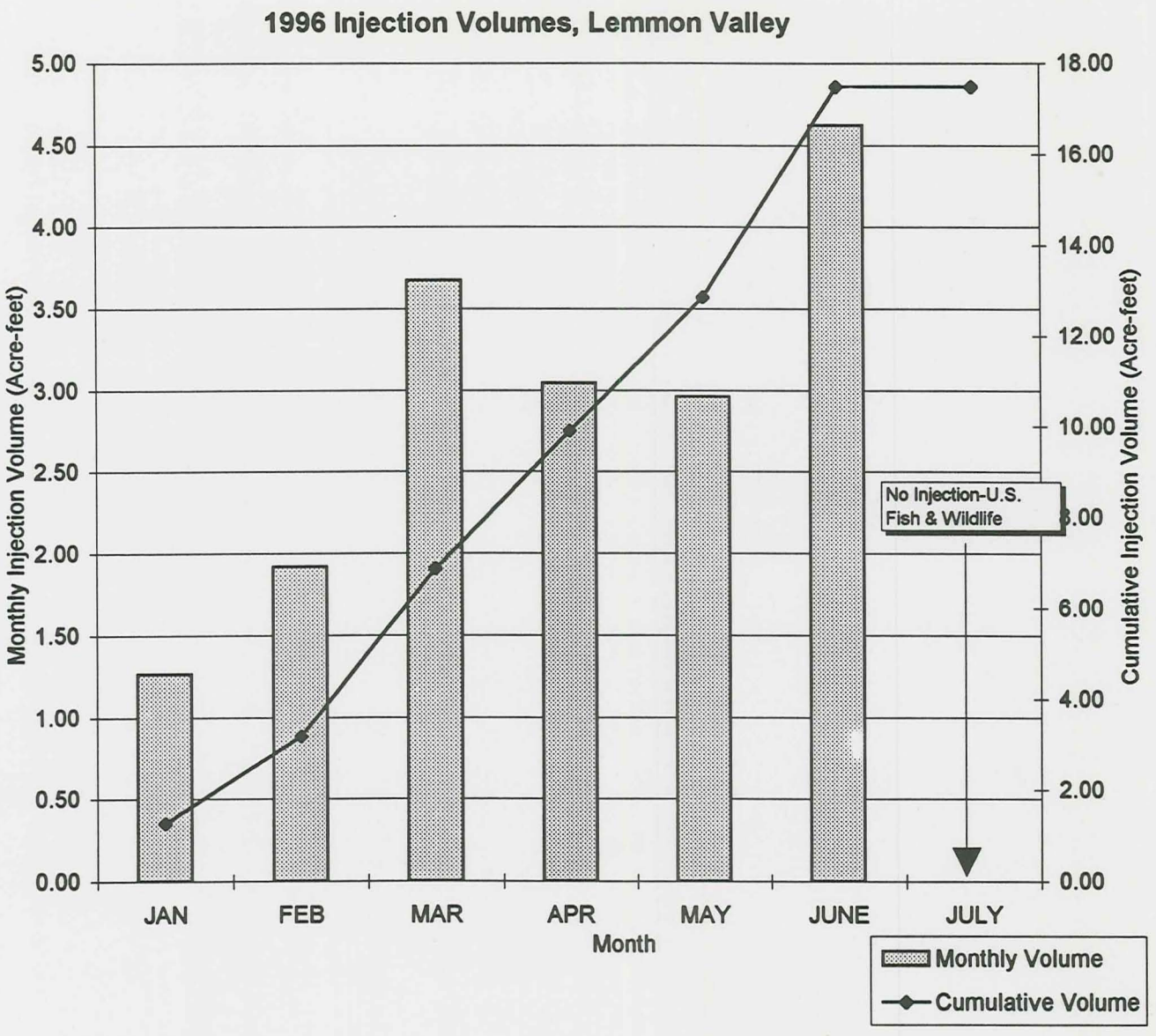

1996 Injection Volumes, Lemmon Valley
Monthly Injection Volume (Acre-feet)
Cumulative Injection Volume (Acre-feet)
5.00
4.50
4.00
3.50
3.00
2.50
2.00
1.50
1.00
0.50
0.00
18.00
16.00
14.00
12.00
10.00
8.00
6.00
4.00
2.00
0.00
JAN
FEB
MAR
APR
MAY
JUNE
JULY
Month
No Injection-U.S. Fish & Wildlife
Monthly Volume
Cumulative Volume

Figure 13

Lemmon Valley

Artificial recharge in Lemmon Valley did not show any significant changes in water levels as water level elevations continued to decline during the period of artificial recharge. The amount of recharge was not enough to offset the drawdown caused by water pumped from the nearby municipal well.

Because the infrastructure for a municipal system is in place in Lemmon Valley, artificial recharge may not be the most efficient method to recharge the aquifer. Water for recharge is treated to drinking water standards before it is recharged. Delivering treated water directly to consumers would allow aquifer recharge to occur naturally by pumping the wells less, in effect creating "passive recharge." The wells could be used when surface water cannot meet municipal demands or is unavailable due to drought. Conversely, water could be recharged when municipal demands are low and surface water is available (see Figure 2). This conjunctive use of surface and groundwater supplies would greatly enhance the reliability of the water supply for the region.

Other Discussion

The Washoe Recharge project is considered a major success. The project promoted a concept of water resource management that was mutually acceptable to many competing entities. Recharge has entered mainstream thought as a water supply management tool and therefore, projects involving recharge are incorporated in regional, long range water resource planning.

The Golden Valley recharge facilities may be incorporated as one of Washoe County's permanent facilities for ongoing use. We believe artificial recharge will stabilize the aquifer that has been declining historically. The Lemmon Valley component may be used intermittently based on the concept of direct municipal use of available surface water and recharge of excess availability.

From a technical viewpoint, recharge through injection wells works best with the cleanest water available and the system kept fully pressurized for as long as possible. Suspended solids are the primary culprit causing injection well plugging. Keeping the system pressurized prevents problems associated with air or other foreign matter entering the system and potentially plugging the wells during recharge. Pressurization also prevents corrosion associated with repeated wetting and drying created by the changing water column in the well. Assuming the hydrogeology has been determined to be favorable for recharge, design of injection systems should focus on water as free of suspended solids as possible. Physical facilities should include injection wells, valves, pressure gages, and flow meters that are designed to minimize the potential for air entrainment, plugging, or contamination.