Wellhead Protection Program, Lemmon Valley Water System, Washoe County, Nevada

By Michael C. Widmer and Randall G. Van Hoozer

Washoe County Department of Water Resources

October 31, 2000

Department of

Water Resources

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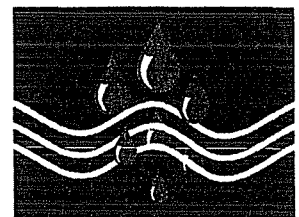
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Department of

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Submitted to:
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Bureau of Water Quality Planning
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INTRODUCTION

The Lemmon Valley water supply system, as shown in Figure 1, is operated by the Washoe County Department of Water Resources, Utility Services Division. It is comprised of six production wells that provide water to 1142 customers. The Utility Services Division undertook a Wellhead Protection Program (WHPP) for the Lemmon Valley wells. The WHPP has been developed to protect the quality of groundwater supplies through the delineation of zones of groundwater movement to municipal supply wells, and through the subsequent management of potential contaminant sources in those areas. The Lemmon Valley WHPP is supported by the Nevada Division of Environmental Protection under the Safe Drinking Water State Revolving Fund (CFDA# 66.468) grant program.

The procedure of this report follows the format suggested by the Nevada Department of Environmental Protection document entitled "STATE OF NEVADA WELLHEAD PROTECTION PROGRAM " dated February 24, 1994 (Bureau, 1994). This format asks for:
1. roles and responsibilities of the agencies involved,
2. a discussion of the hydrogeology and modeling of groundwater capture zone delineation,
3. siting of future wells and their relation to potential contamination sources,
4. an inventory of sources of potential contamination,
5. management options towards the prevention of contamination of the groundwater,
6. contingency planning in case of contamination of the aquifer and,
7. public education and participation.

Acknowledgments
The authors wish to thank the contributors to this report; Terri Svetich for her overall participation, John Hulett for his contributions to the sanitary survey, and Brent Thomas for his drafting expertise.

ROLES AND RESPONSIBILITIES

The goal of the Washoe County is to initiate a program whereby groundwater quality receives a high level of protection from contamination, both existing and future potential. This can be accomplished through the concerted efforts of Lemmon Valley policy and procedure, by monitoring development activities, through coordination of local agencies and by educating the general public. The following lists the roles and responsibilities to meet this goal.

The Washoe County Department of Water Resources is a major water purveyor of public water supply in Lemmon Valley. It is their role to set policy, make recommendations to the Washoe County Board of County Commissioners, and to operate, through the Washoe County Utility Services Division the Lemmon Valley water system. The Washoe County Utility Division is responsible for the proper maintenance of the water system, including wellhead protection. They

are also responsible for hydrogeologic investigations that pertain to wellhead protection. The reporting of unlawful activities to the proper agency for enforcement is also a responsibility of the Utility Services Division, particularly field personnel. This report will serve as the basis for those responsibilities. The Washoe County Utility Services Division at can be reached (775) 954-4600.

The Bureau of Water Quality Protection within the Nevada Division of Environmental Protection is responsible for the State's water quality. This office is charged with regulating discharges to both surface and groundwaters and any activities that may influence water quality degradation. This office can be reached at (775) 687-4670.

The Washoe County District Health Department is the local responsible agency for enforcement of policy, ordinance and statute with respect to water quality protection within Washoe County. Some operations require permitting through this office. This office can be reached at (775) 328-2434. The Truckee Meadows Fire Protection Agency is responsible for responding to emergencies with respect to toxic spills and fire. This office can be reached at (775) 328-3650. The Washoe County Sheriff's Department is responsible for responding to violations of statutory and criminal law. This office can be reached at (775) 328-3000. The general public is responsible for the proper disposal of potential contaminants or pollutants and for the reporting of such unlawful or immoral acts.

Wellhead Protection Team
This project incorporated the use of a wellhead protection team made up of local government officials, the development community, and the general public. The project team serves to notify land use planning, health, the development community and fire protection representatives of the program and associated concerns. The efforts of the team will have bearing on groundwater protection for present and future development. This team met twice to discuss the overall objectives of the program. The team participants helped to identify potential sources of contamination. This team will be continuing to meet to develop strategies for public education and protection. The Team Leader is Terri Svetich of the Washoe County Department of Water Resources. Other representatives are:

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FUTURE SITING OF WELLS

The Lemmon Valley water system is fully constructed with six wells such that all of the Lemmon Valley water rights can physically be pumped in an operational mode. The system cannot be expanded unless water rights are dedicated for new development. Because of Lemmon Valley's "Closed Basin" status under Nevada Water Law, no expansion of groundwater development is expected in the future and therefore, future well sites are not being considered. Growth may occur due to surface water supply currently being developed by the Sierra Pacific Power Company.

GROUNDWATER MODELING

INTRODUCTION

The local study area encompasses approximately 14 square miles in T. 20 and 21 N., R. 19 E., as illustrated on Figure 1, and is the approximate location of the study area specific to the Lemmon Valley water supply wells. Van Hoozer (1994) developed a numerical groundwater flow model of Lemmon Valley for Washoe County. The conceptual and numerical models were based on the compilation and review of published and unpublished hydrogeologic data, and on well-specific data collected by the Washoe County Utility Division from pumping wells throughout the groundwater basin. This data was processed in an effort to determine the following: general hydrogeologic setting; stratigraphy, location, and number of aquifer horizons; placement and length of well screens; actual or apparent aquifer thickness; degree of aquifer confinement; aquifer porosity, transmissivity, and hydraulic conductivity; hydraulic gradient and direction of groundwater flow; influence of boundary conditions; and water well discharge rates.

Hydrogeologic characteristics and well-specific data defined by this modeling effort were subsequently used in the wellhead capture zone modeling. The wellhead protection areas were defined using time-of-travel (TOT) criteria, which are expressed in terms of distance traveled per unit time. Travel times of five, ten, and fifteen years were selected as appropriate for satisfying both short and long-term planning goals. Delineation of wellhead protection areas were performed by staff of the Washoe County Utility Division using the **FLOWPATH: A Steady-State Two-Dimensional Horizontal Aquifer Simulation Model, Version 5.1** (Waterloo Hydrogeologic Software, 1989) computer modeling program. The final configuration of the wellhead protection areas were determined by combining the results of all appropriate model simulations performed during the study. The Van Hoozer (1994) MODFLOW model was also used to compare wellhead capture zone areas with the FLOWPATH model.

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PHYSIOGRAPHIC SETTING OF LEMMON VALLEY
Geologic Setting

The study area is situated in the eastern portion of Lemmon Valley, north of the Reno-Sparks Metropolitan area in Washoe County. The area is part of the transitional zone between the Basin and Range physiographic province to the east, and the Sierra Nevada province to the west. Lemmon Valley occupies a north-south trending valley that has been down-faulted relative to adjacent mountains. The Granite Hills bound this valley on the west, unnamed hills to the east, and Peavine Mountain to the south. The complex structural geology of the area resulted from widespread deformation during the Mesozoic and Cenozoic Eras; however, the present topography is a result of Cenozoic tectonic events (Bonham, 1969). The geology of East Lemmon Valley is described in reports by Harrill (1973), Cordy (1985), and Cochran et al. (1986). The following section summarizes geologic discussions from these reports.

Lemmon Valley is a topographically closed basin typical of those in the Basin and Range region (Harrill, 1973). The valley is a structural depression filled with unconsolidated valley-fill material and is surrounded by mountains comprised of igneous, volcanic, and metavolcanic rocks. Igneous rocks are Cretaceous in age and classified as granodiorite and quartz monzonite. The granodiorite is light to dark gray, fine- to coarse-grained, consisting of equigranular to porphyritic hornblende and biotite. Granodiorite is highly resistant to weathering (Cordy, 1985), and can be highly fractured (Cochran et. al., 1986).

The quartz monzonite is pink to pale-gray, medium- to coarse-grained, and equigranular to porphyritic. Generally, the quartz monzonite is deeply weathered (Cordy, 1985) and more friable than the granodiorite (Cochran et. al., 1986). Volcanic rocks are Tertiary in age and classified as Kate Peak andesites and tuffs. Kate Peak andesites are gray to reddish-gray, porphyritic to glomeroporphyritic hornblende and biotite, and are highly resistant to weathering (Cordy, 1985). Three formations of tuffs are located in Lemmon Valley. The first tuff is the Nine Hills Tuff, which is reddish-purple to pale orangish-red, pumiceous, rhyolite vitric tuff, and forms distinct ridges (Cordy, 1985). The second tuff formation is Pumice tuff which is pale- to dark gray, with very pumiceous vitric-crystal. Pumice tuff contains phenocrysts of sanidine and quartz, and is easily weathered (Cordy, 1985). The third tuff formation is Vitric tuff. Vitric tuff is cream to yellowish-tan to pale-purple rhyolite to rhyodacite and vitric to vitric-crystal. Phenocrysts include sanidine, sanidine-smokey quartz, plagioclase-biotite, and biotite. Weathering of Vitric tuff forms knobby outcrops (Cordy, 1985). The Peavine sequence outcrops at the south end of Lemmon Valley. The Peavine sequence is Jurassic to Triassic in age and is comprised of gray- to gray-green meta-andesites with lesser amounts of metamorphosed epi-clastic volcanic sedimentary rocks (Cochran et. al., 1986). The Peavine sequence is fine-grained and resists weathering.

Features other than mountain ridges in Lemmon Valley include valley-fill deposits and playa lakes. Valley fill is comprised of weathered material from the surrounding igneous, volcanic, and metavolcanic rocks. Mineral constituents of the valley fill include quartz, feldspar, and mafic

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minerals (Cochran et. al., 1986). Valley fill consists of clay, silt, fine- to coarse-grained sand, and gravel. Generally, valley fill is coarser near the mountain ridges and becomes fine-grained in the center of the valley near playa lakes. Playa lake deposits are mostly clay, silt, and fine-grained sand. The mountains surrounding and underlying the valley are complexly faulted. Regional faulting gave the mountains their large-scale size, shape, and relief (Harrill, 1973). The present topography of the basin is the result of erosion and smaller scale fault structures. Figure 2 shows the locations of faults in the Central Area of Lemmon Valley.

Elevations of the valley range from approximately 4910 feet above mean sea level (amsl) at the East Lemmon Valley playa to more than 8200 feet amsl at Peavine Mountain. Topographic slopes of valley fill range from several feet per mile at the playa lakes to 800 feet per mile on the north flank of Peavine Mountain. The playa in the Central Area covers approximately 800 acres while the playa in the Silver Lake sub-area is approximately 430 acres in size.

Hydrologic Setting

Lemmon Valley is bound on the leeward side by the Sierra Nevada, which provides an orographic "rain shadow" effect, and precipitation varies widely as an effect of elevation. The climate in this area has been classified as a cool semi-arid, continental climate with warm summers and cold winters (Gates and Watters, 1992). Precipitation at upper elevations is the primary source of groundwater recharge for East Lemmon Valley. A lesser amount of precipitation falls at lower elevations and probably has little contribution to recharge. Precipitation can enter the groundwater system by direct infiltration where precipitation falls or travel as surface runoff until permeable areas are reached. Surface runoff is infrequent in East Lemmon Valley because heavy, prolonged precipitation events seldom occur. Several factors determine the amount of precipitation that reaches the water table. These factors include type and thickness of soil, topography, vegetative cover, soil moisture content, intensity and duration of precipitation, and meteorogical factors such as temperature and humidity (Walton, 1988). The quantity and distribution of precipitation in Lemmon Valley are described in a precipitation study of the Truckee River Basin (Klieforth, et.al. 1983). The range of average annual precipitation falling in Lemmon Valley ranges from approximately 8 to 16 inches. Precipitation recharge to groundwater in the area is reported at 1,400 acre-feet per year (Harrill, 1973). The valley comprising Lemmon Valley is hydrologically closed such that surface waters, all ephemeral, drain to the Silver Lake playa in the western portion of the basin or the Lemmon Lake playa located in the eastern portion of the basin. These waters then eventually evaporate.

Hydrogeologic Setting

The hydrogeology of Lemmon Valley is documented in both Harrill (1974) and Van Hoozer (1994) reports. Groundwater recharge occurs mainly from snowmelt processes on Peavine Mountain. Recharge from snowmelt and rainfall in the Hungry Hills, Granite Hills and on the alluvial fans also contributes, but to a lesser extent. Groundwater movement is from the mountain ranges to the valley floor axis where discharge occurs. This discharge is in the form of evapotranspiration (Van

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Hoozer, 1994).

The alluvial sediments in the valley floor provide the greatest groundwater yield to water wells. These sediments are largely well sorted and fine-grained. Intermediate groundwater yields are found in alluvial fan deposits (200-600 feet thick) along the borders of the valley. Low groundwater yields are generally produced from the Tertiary volcanics and older intrusives, except where the rocks exhibit a high secondary permeability induced by fractures. Depth to groundwater varies from less than 2 feet in the central part of the basin to more than 200 feet beneath the alluvial fans near the base of the mountain blocks (Van Hoozer, 1994).

According to Van Hoozer (1994), the general direction of groundwater flow in the basin-fill deposits is from the southwest to the northeast. Figure 3 illustrates the potentiometric surface that defines the recharge area as snowmelt from Peavine Mountain and the discharge area at or near the playa at the bottom of the basin. From this Figure it is seen that a steep gradient exists in the mid-fan area. This gradient is thought to occur due to a fault structure that trends north south across the alluvial fan. It is estimated that the total natural groundwater recharge to this basin is 670 AF/yr (Van Hoozer, 1994).

Drilling logs from production wells provide information on hydrogeology and the hydrostratigraphic units comprising the Lemmon Valley water system. Each lithologic material and its associated hydrologic parameters for groundwater flow were evaluated to select specific hydrostratigraphic units that are screened and provide water to each production well. Generally, two hydrostratigraphic units are present in the area occupied by production wells: 1) valley-fill material; and 2) fractured bedrock.

The most productive zones of groundwater in Lemmon Valley are found in valley-fill material which is consists of younger and older alluvium (Harrill, 1973). Lithology of valley-fill material includes clay, silt, sand, and gravel. Lemmon Valley production wells 5,6,7,8 and 9 are screened within the valley-fill material. Based on interpretation of geophysical survey and drilling logs, valley fill is estimated to be thickest underneath the playa lake. The valley fill is estimated to have a maximum thickness of approximately 1,000 feet and thins toward the bedrock outcrops around the perimeter of the valley. Lemmon Valley production well 3 is located in the southeast portion of East Lemmon Valley where valley-fill material is thin and is screened in bedrock. Groundwater is present in fractures and the fractures can have a wide range of hydrologic properties depending on the degree of fracturing. Highly fractured zones will have high porosity and specific yield, and low specific retention.

Each type of hydrologic material has different hydrologic properties and abilities to transmit water. Hydrologic properties of the hydrostratigraphic units found in East Lemmon Valley were derived from aquifer pumping test data for each production well. Hydraulic conductivity (K) is a property describing the ability a material has to transmit water in the horizontal (K_h) and vertical (K_v)

direction, expressed as length per time (L/t). Typical values of K_h are summarized in Table 1 (from Harrill, 1986).

Table 1.
Typical values of horizontal hydraulic conductivity for lithologic materials found in Lemmon Valley.

Lithologic description	Typical material	Range of horizontal K (feet per day)
Playa deposits	clay, silt	0.001 - 0.3
	very fine sand	0.1 - 1.6
Lacustrine- fine-grained deposits	silt, clay,	0.1 - 0.5
	fine sand	1 - 4
Fanglomerate and coarse gravel	silt, sand, gravel	0.1 - 4
	sand	4 - 30+
	gravel	20 - 150

Information in Table 1 indicates that coarse-grained material transmits water more easily than fine-grained material. K_v values are typically much smaller than K_h values. Fine-grained material may have K_v values one-hundredth to one-thousandth times smaller than K_h (Harrill, 1986).

Specific yield (S_y) represents the storage term for unconfined aquifers. S_y is defined as the volume of water a unit will release due to gravity drainage per unit surface area of aquifer per unit decline of the water table. S_y ranges from 0.01 for fine-grained material to 0.3 for coarse material (Freeze and Cherry, 1979). Storage coefficient (S), defined as specific storage times aquifer thickness, is the storage term for confined aquifers. S is defined as the volume of water released from storage by compressibility of the aquifer and expansion of water per unit surface area per unit decline in the potentiometric surface. S typically ranges from 0.00005 to 0.005 (Freeze and Cherry, 1979).

Groundwater production has remained relatively constant due to the closed basin status imposed in 1977 by the Nevada State Engineer. It is estimated that over 1,200 domestic wells are in use and fourteen municipal wells. In 1993 the estimated total groundwater pumpage was approximately 2,840 AF (Widmer and McKay, 1993). Water quality is generally good in groundwaters pumped on the basin floor. In specific areas of Golden Valley and the North Heppner Subdivision (north of Lemmon Lake playa), septic tank effluent has elevated nitrate and sulfate levels in the groundwater. There are also iron concerns in several areas on the slopes of Peavine Mountain.

Lemmon Valley Water Supply Wells
The Lemmon Valley water supply system is comprised of six wells numbered Lemmon Valley 3 and 5 through 9 where wells 1,2 and 4 have been abandoned. The generalized location of these wells is illustrated on Figure 1. Well construction and aquifer properties associated with these

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wells are included in Appendix A. Five of the wells are completed in alluvial deposits. The construction dates for the wells in use today range from 1963 for well #3 and 1997 for well #9.

Wells 5 through 9 are constructed in undifferentiated and unconsolidated alluvium. Concise stratigraphic correlation of these sediments, or aquifer materials, cannot be made between wells on the basis of available lithologic data. Well 3 is screened in fractured rock. Well depth ranges from 300 to 700 feet and production rates vary from 44 (well #3) to 800 gpm (well #8). See Appendix A for details of the specific wells. The Lemmon Valley wells pumped 348.6 million gallons in 1999.

CONCEPTUAL AQUIFER MODEL

A conceptual model of the WHP area is needed before data can be put into a numerical model. Data needed to conceptualize a groundwater system and develop a numerical model include:

1)   Aquifer parameters such as horizontal and vertical hydraulic conductivity;
2)   Model layer designation or top and bottom elevations;
4)   Boundary Conditions; and
5)   Water budget, groundwater flow direction and gradient.

Generally, the East Lemmon Valley area is comprised of valley fill in the center with bedrock outcrops around the perimeter and bedrock underlying the valley. Faults also exist at the perimeter of the model domain on the west and southwest boundaries. The following sections include detailed information of the conceptual model, the hydrologic parameter selection process, and the numerical model design for both numerical models developed for the East Lemmon Valley WHPP.

Boundary Conditions

Perimeter and bottom boundaries of the modeled area are conceptualized as specified flow. No-flow (specified flow equals zero) boundaries are associated with the contact between low permeability bedrock and higher permeability valley fill, topographic divides, or fault barriers. Specified flow representing recharge was introduced into the model at the first cell inside the no-flow boundary at locations where precipitation is presumed to infiltrate into the valley fill. Presumably, most precipitation will infiltrate into the higher permeability valley fill and not the low permeability bedrock that defines the no-flow boundary.

West, south, and northeast boundaries of East Lemmon Valley are defined with no-flow cells along faults and a topographic divide. Typically, fault zones are low permeability zones that hinder the flow of groundwater. The northeast boundary is a topographic divide also defined as a no-flow boundary. Precipitation falling at the divide either flows away from or into the model domain.

Boundary conditions as initially conceptualized were maintained throughout the calibration process. Specified flow boundaries were placed along the north, south, and east boundaries at the groundwater recharge locations for the model. Flows representing recharge were input using wells. About 40 wells were distributed around the modeled perimeter at locations where precipitation is

believed to enter the groundwater system for the MODFLOW model. A well was also placed in the southeast corner of the model to input subsurface inflow from Golden Valley.

During model calibration, a constant head boundary was placed at the west boundary where Harrill (1974) proposed a sink (Harrill, 1974) near the Airport Fault. Approximating the west boundary with constant head cells helped determine the volume of water entering or exiting at the fault since MODFLOW computes flow at constant head boundaries and includes the computed value as part of the water budget printout.

Aquifer Thickness / Model Layer Designations
Distinct and extensive layers are difficult to discern in basins containing valley fill. Evaluation of data from drilling logs, aquifer tests, geologic maps, and borehole geophysical logs resulted in the identification of two hydrostratigraphic units in East Lemmon Valley: an upper unconfined layer and a lower confined layer. Layer selection was based on differences in water levels for adjacent wells (well pairs), aquifer tests, and locations of well screens. The following summary describes how model layers were selected by interpretation of the various data sets.

Differences in depth-to-water for well pairs range from approximately 5 to 15 feet. Generally, the deeper well of well pairs has a water level at a higher elevation. Differences in water levels for well pairs means: 1) the wells are separated by confining material and their well screens are installed in different aquifers; or 2) the wells are screened in the same aquifer but there is a vertical gradient within the aquifer. Since the materials in the valley fill are intermixed and fine-grained material is abundant it is likely that the well screens are separated by confining material and are located in what may be considered different aquifers.

The 72-hour constant discharge aquifer test completed for a recharge demonstration project revealed delayed or no connection between the deeper pumping well (depth of 465 feet) and shallow monitoring wells (less than 150 feet depth) during the aquifer test period. Water levels in some shallow monitoring wells initially rose during the aquifer test then declined several feet as the pumping period approached 72 hours, indicating delayed connection. One shallow well (total depth of 65 feet) located within 200 feet of the pumping well did not show any water level decline during the 72-hour test, indicating no connection during the aquifer test.

Drilling logs were also reviewed to help select model layers and hydraulic conductivity values. Based on drilling log descriptions, clay is abundant to a depth of approximately 200 feet below ground surface, especially in the vicinity of the playa lake. Most domestic wells are screened within the upper 150 feet of the saturated zone. Municipal wells are typically screened at greater depths where potential water yield is greater. Most municipal wells are screened at depths greater than 200 feet. After review of data from well pairs, aquifer test results, and drilling logs, the bottom elevation of the upper layer was designated to be approximately 150 feet below the water table, meaning the bottom of the layer was essentially flat except at the south end of the model area where

elevation of the water table begins to rise. Based on the geophysical survey (Shaeffer and Maurer, 1981) and drilling logs, the maximum thickness of valley fill is approximately 1,000 feet below the playa lake and thins laterally. Both model layers are at least partially comprised of valley fill. Layer 2 extends to the bottom of the valley fill and includes fractured bedrock. It should be noted that drilling has not encountered bedrock in the thickest valley fill area or at the proposed sink area along the Airport Fault, the depth to bedrock along the fault is based solely on the geophysical survey.

Transmissivity (T) values represent the aquifer flow parameter for layer 2 of the MODFLOW model since the layer is confined and flow is horizontal. MODFLOW calculates T values internally from input data of K_h, the top elevation of model layer 2, and the bottom elevation of layer 2. T values generated by MODFLOW were compared to approximately 40 T values from aquifer test and specific capacity data. Most MODFLOW-generated T values were in close agreement with T values estimated from aquifer test and specific capacity data. As with the K values, T values needed minor adjustments in order to reproduce field-measured heads values. The final distribution of T values range from 0 to 6,000 ft²/d.

Lengths of screened intervals were used for modeling purposes instead of overall aquifer thickness in the FLOWPATH II model. Using screen lengths results-in capture zones that are more extensive than capture zones resulting from total aquifer thickness. Capture zones resulting from screen lengths can be considered "conservative capture zones" when compared to capture zones from total aquifer thickness. The FLOWPATH II model requires input top and bottom elevations instead of actual screen lengths or aquifer thickness.

Total aquifer thickness was used in the MODFLOW model. Results from MODFLOW and MODPATH are capture zones that are less extensive since the vertical flow component is utilized. MODFLOW also uses top and bottom elevations instead of actual layer thickness values.

Aquifer Parameters
FLOWPATH II uses porosity along with horizontal hydraulic conductivity (K_h) to simulate capture zones. Porosity was estimated using lithologic logs for each municipal well. A porosity value of 0.15 was calculated and used in the FLOWPATH II model. K_h values are derived from 1) aquifer constant flow tests, 2) specific capacity tests, and 3) lithologic descriptions of well logs. Estimates of K_h in East Lemmon Valley range from 0.0005 ft/d for fine sediments to 35 ft/d for coarse sediments and fractured bedrock. Vertical hydraulic conductivity (K_v) are estimated using the same information as K_h. Estimates of K_v range from approximately 0.000001 ft/d for fine material to 1.0 ft/d for coarse material in East Lemmon Valley. Additional information on aquifer parameters is included in the Definition of Model Parameters section of this report.

DELINEATION OF WELLHEAD PRPTECTION AREAS

Washoe County chose time-of-travel (TOT) criterion to delineate wellhead protection areas for the East Lemmon Valley water supply system. Although the capture zone of a well is determined by the entire recharge area which contributes water to a well, a time-related capture zone defines the recharge area which will contribute water to a well within a specified period of time. The county decided that TOT limits of five, ten, and twenty years were appropriate for achieving the desired protection and planning goals of the East Lemmon Valley system. The basis for defining TOT distances, which FLOWPATH II and MODPATH approximate by a particle tracking method, is the average linear velocity of groundwater. Results of TOT calculations simulated by FLOWPATH II for this study only refer to horizontal movement of water within the aquifer. MODPATH TOT results do account for vertical transport through the aquifer. TOT calculations performed for this study do not address processes that may cause contaminants to move non-linearly such as dispersion, diffusion, sorption, and biodegradation. These processes can cause some contaminants to move faster or slower than groundwater. Whether or not a contaminant moves linearly depends upon the contaminant characteristics. Therefore, the time-related capture zones defined for the East Lemmon Valley wells should be viewed as approximations of what may occur under actual field conditions since the capture zones are based on the average linear velocity of groundwater and the assumption of advective flow. If the contaminant is known, the flow system should be modeled with a contaminant transport model that utilizes characteristics specific to the contaminant.

The FLOWPATH II Model

Wellhead protection areas (WHPA) were delineated using the computer programs FLOWPATH II and MODFLOW combined with MODPATH as described earlier in this report. FLOWPATH II uses numerical modeling techniques to perform two-dimensional aquifer analyses. Model users can simulate anisotropic, heterogeneous hydrogeologic properties, spatially varying aquifer thicknesses and/or bottom elevations, areal recharge, and evapotranspiration. In addition, the modeling program will simulate multiple injections and pumping wells, well interference effects, and aquifer interaction with surface water bodies. Confined, unconfined, or leaky-confined aquifers can also be simulated. FLOWPATH II calculates steady-state hydraulic head, drawdown, velocity distributions, water balances, time-related pathlines, and capture zones (Waterloo Hydrogeologic Software, 1989, 1997).

The numerical code for FLOWPATH II is based on the assumption that ground-water movement is at steady-state and horizontal in the aquifer. The steady-state assumption precludes modeling of temporal variations of sources and sinks and will not account for intermittent use of wells. Even though the wells included in this study are not in continuous service and steady-state flow may not apply consistently, use of a steady-state model is appropriate for wellhead protection modeling since the assumption of continuous pumping defines a more conservative or larger capture zone. Calculating only horizontal movement in the aquifer is another conservative approach used by FLOWPATH II. If vertical movement of a contaminant through the unsaturated zone is required

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prior to entry into the well's zone of contribution, total travel time of a particle to the well will be longer than the time-of-travel calculated using horizontal flow. This means that deeper aquifers receive extra protection not reflected in FLOWPATH II modeling results.

The MODFLOW and MODPATH Model
In addition to using FLOWPATH II, wellhead protection areas (WHPA) also were delineated using the computer programs MODFLOW combined with the particle tracking post-processing program MODPATH as described earlier in this report. MODFLOW uses numerical modeling techniques to perform three-dimensional aquifer analyses. Model users can simulate anisotropic, heterogeneous hydrogeologic properties, spatially varying aquifer thicknesses and/or bottom elevations, areal recharge, and evapotranspiration. In addition, the modeling program will simulate multiple injections and pumping wells, well interference effects, and aquifer interaction with surface water bodies. Confined, unconfined, or leaky-confined aquifers can also be simulated. MODFLOW will calculate either steady-state or transient hydraulic head, drawdown, velocity distributions, water balances. MODPATH must be used in conjunction with MODFLOW to produce time-related pathlines and capture zones.

MODFLOW was run under steady-state conditions with vertical flow between model layers. The steady-state assumption precludes modeling of temporal variations of sources and sinks and will not account for intermittent use of wells. Even though the municipal wells in this study are not in continuous service and steady-state flow may not apply consistently, use of a steady-state model is appropriate for wellhead protection modeling since the assumption of continuous pumping defines a more conservative or larger capture zone.

Calculating horizontal and vertical movement in the aquifer with MODPATH is less conservative than FLOWPATH II but more realistic. Vertical movement of groundwater does occur in East Lemmon Valley according to field data collected during aquifer stress tests. Vertical flow results in larger travel times for particles traveling a specified distance when compared to travel times calculated using horizontal flow only.

Definition of Model Parameters
A number of model parameters were defined to complete delineation of wellhead protection areas for East Lemmon Valley. Specifically, the groundwater models require the establishment of a model grid, well locations, well pumping rates, model domain boundary placement and type, aquifer porosity and hydraulic conductivity values, and aquifer thicknesses. Establishment of these parameters and model development are discussed below.

Model Grid Configuration and Well Locations
East Lemmon Valley was divided into distinct cells or blocks with a model grid. Each grid cell is 1,000 feet by 1,000 feet in both models. The FLOWPATH II model has 36 rows and 30 columns

and the MODFLOW model has 16 rows and 32 columns. The MODFLOW model is smaller because it was originally developed to simulate artificial recharge in a smaller section of East Lemmon Valley not the entire East Lemmon Valley area. Both models are oriented with more cells positioned in the north-south direction. Grids for both models are oriented parallel to the west boundary along the Airport Fault which trends nearly north-south. Figures 4 and 5 show final grid designs. Cells for each model layer were designated as being active or inactive. Inactive (no-flow) cells represent the low permeability characteristics of bedrock outcrops. Wells were incorporated into the models by using a global positioning system (GPS) to locate the wells then placing the wells at the grid intersection that comes closest to duplicating the GPS position.

Domain Boundaries
FLOWPATH II was used to model the entire East Lemmon Valley sub-basin. The groundwater gradient is a primary component that influences the size and shape of capture zones. Constant head nodes were selected to reproduce the groundwater gradient revealed by measuring water levels. Several constant head nodes were placed along the north, south, and west boundaries. For FLOWPATH II, using constant heads eliminates the need to include specific fluxes in or out of the model such as areal recharge, and evapotranspiration (ET). The assumption made is that the water levels remain nearly constant over time at the constant heads. Components of groundwater gradient, steepness and direction, have changed over time in East Lemmon Valley. However, the gradient has not changed significantly over the past 10 years and probably will not change greatly over the next 10 to 20 years. Replicating fluxes with many parameters is more appropriate for transient and not steady state models.

MODFLOW was used to model a local regime of the East Lemmon Valley sub-basin. The model was developed as part of an artificial recharge pilot study in 1993. As with FLOWPATH II, the groundwater gradient is a primary component that influences the size and shape of capture zones in the MODFLOW model. Water budget components of precipitation, ET, and constant heads were selected to reproduce the groundwater gradient revealed by measuring water levels. The additional water budget components were included in the model since they were part of the original model developed for the artificial recharge pilot study. The MODFLOW model was run as steady state and the assumption that the water levels remain nearly constant over time was used. The steepness and direction of the groundwater gradient have changed over time in East Lemmon Valley. However, the gradient has not changed significantly over the past 10 years and probably will not change greatly over the next 10 to 20 years. Replicating fluxes with many parameters is more appropriate for transient and not steady state models.

Well Discharge Rates
Both groundwater models require simulated wells to have daily discharge or pumping rates to generate capture zones. Pumping data were obtained from in-house County files and the summarized well discharges are expressed as cumulative gallons per month. These values were reduced to gallons per day and incorporated into the model. Pumping by domestic wells was

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included directly into the FLOWPATH II model and indirectly into the MODFLOW model. Daily pumping values for each County municipal well are summarized in Table 2.

Table 2.
Municipal Well Discharge Rates for East Lemmon Valley Wellhead Protection Models.

WELL I.D.	AVERAGE DAILY DISCHARGE RATE (gallons)
LV3	45,475
LV5	353,463
LV6	108,004
LV7	144,807
LV8	280,412
LV9	123,247

Domestic wells were incorporated into the FLOWPATH II model by adding up the number of well in each model grid and assuming that each well pumps 1 acre foot of water each year. Domestic wells were included in the MODFLOW model indirectly by adjusting perimeter recharge and ET until the groundwater gradient was replicated by the model.

Porosity

FLOWPATH II requires porosity values as part of the input database. Porosity values were selected using published values corresponding to sediment types described in the drilling logs for each municipal well. Data from Freeze and Cherry (1979), Driscoll (1986), and Fetter (1988) were compiled and average porosity values calculated. Table 3 summarizes the porosity values used in the FLOWPATH II model.

Table 3.
Average porosity values for the FLOWPATH II model.

Well sorted sand and gravel	0.35
Mixed sand and gravel	0.25
Silt	0.40
Clay	0.50
Mixed sand or gravel with clay	0.20
Clay with minor sand or gravel	0.45

The following procedure was used to estimate the average porosity of each municipal well.
1. Cumulative thicknesses of each lithologic type intersected by the screen interval were calculated.
2. Average porosity of the each lithologic type found in the screen interval was assigned.
3. An average porosity for the cumulative screen length was determined.

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Calculations revealed that porosity values are similar for all munilcipal wells in East Lemmon Valley. Consequently, the porosity values from each municipal well were averaged and the average value was used for modeling. A porosity value of 0.15 was used.

Hydraulic Conductivity

Horizontal hydraulic conductivity (K_h) values are derived from 1) aquifer constant flow tests, 2) specific capacity tests, and 3) lithologic descriptions of well logs. Aquifer constant flow tests provide estimates of transmissivity (T) that can be converted to K_h using the equation $K_h = T/b$, where b is the length of the screened interval of the well. Time-drawdown data from approximately 10 constant discharge aquifer tests were evaluated to obtain K_h values using this method. The drawdown data was collected from pumping wells and monitoring wells during aquifer tests.

Driscoll (1986) states that if typical values are used in the Modified Theis Non-equilibrium equation, then specific capacity or T can be calculated using the equation $T = 300(Q/s)$, where 300 converts gallons per minute per foot of drawdown to square feet per day. K_h can then be found from the equation $K_h = T/b$ as previously described. Specific capacity tests are typically completed on domestic wells. Over 200 drilling logs for wells located in East Lemmon Valley were reviewed to obtain specific capacity results. Review of the specific capacity data revealed that the duration of specific capacity tests ranged from 1 hour to 48 hours. K values were estimated from more than 30 24-hour specific capacity tests.

Lithologic descriptions summarized in drilling logs also can be interpreted to estimate K_h values if aquifer or specific capacity tests are not available. The following equations give approximations of K_h values from drilling log interpretation (Maurer, 1986):

$$K_h = (K_c)(\% \text{ coarse}) + (K_f)(\% \text{ fine}),$$

where K_c is a typical value of hydraulic conductivity for coarse-grained material; K_f is a typical value of hydraulic conductivity for fine-grained material; % coarse is the percentage of coarse-grained material in the screened interval; % fine is the percentage of fine-grained material in the screened interval.

The percentage of fine- and coarse-grained material described in each drilling well log must be estimated in order to approximate K_h. K_h values were computed from approximately 40 drilling logs using this method. Some of the computations helped verify K values estimated from aquifer and specific capacity test data.

Based on the procedures described above, estimates of K_h in East Lemmon Valley range from 0.0005 ft/d for fine sediments to 35 ft/d for coarse sediments and fractured bedrock. The estimated K_h values were input into the model in the vicinity of the production well location for the FLOWPATH II model. K_h values for MODFLOW were derived with a contouring program that

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uses kriging to interpolate between irregularly spaced input data and create regularly spaced data points. Kriging is based on the regional variable theory and the algorithm assumes an underlying linear variogram (Golden Software, Inc., 1990). All estimated K_h values were used initially and adjusted during model calibration. Most adjustment was needed for K_h values in the playa lake area during calibration of the MODFLOW model. K_h values were only adjusted minimally for the FLOWPATH II model and are shown in Figure 6.

MODFLOW models require vertical hydraulic conductivity (K_v) values to estimate flow between model layers while Flow Path II does not require K_v values. Lithologic descriptions summarized in well logs can be interpreted to estimate K_v values. The following equation can be used to compute approximations for K_v values from interpretation of drilling logs (Maurer, 1986):

$$K_v = 1/(\% \text{ coarse}/K_c + \% \text{ fine}/K_f),$$

where K_c is a typical value of hydraulic conductivity for coarse-grained material; K_f is a typical value of hydraulic conductivity for fine-grained material; % coarse is the percentage of coarse-grained material in the screened interval; % fine is the percentage of fine-grained material in the screened interval.

The percentage of fine- and coarse-grained material described in each drilling log must be estimated in order to approximate K_v. K_v values were computed from approximately 40 drilling logs using this method. Based on the equation described above, estimates of K_v in Central Area range from approximately 0.000001 ft/d for fine material to 1.0 ft/d for coarse material.

K_v values are not input directly into the MODFLOW program. The modeler must compute a vertical leakance term (V_{cont}) that represents the vertical flow between model layers. V_{cont} incorporates vertical hydraulic conductivity and thickness of each aquifer layer. V_{cont} values are estimated by summing the following two values: 1) the multiple of K_v for layer 1 times one-half the thickness of layer 1, and 2) the multiple of K_v for layer 2 times one-half the thickness of layer 2. The MODFLOW program then multiplies V_{cont} by cell area to derive the conductance term representing vertical flow between two model cells. Adjustments were made to the initial V_{cont} values in the playa lake area. V_{cont} values were decreased from initial estimates in order to reproduce the field-measured head values. Smaller values of V_{cont} are indicative of an abundance of fine-grained material, which is present in the playa lake area. Decreasing V_{cont} values reduces the amount of flow between model layers 1 and 2. Final V_{cont} values range from approximately 0.004 to 0.0000001.

Aquifer Thickness
Aquifer thickness is a required input parameter for confined aquifer analyses. As describe previously, the cumulative screen intervals were used to represent aquifer thicknesses in the

FLOWPATH II model. Cumulative screen lengths are summarized in Table 4 for each municipal well.

Table 4.
Aquifer thicknesses for East Lemmon Valley municipal wells - FLOWPATH II Model.

Well I.D.	Aquifer thickness (feet)
LV3	40
LV5	212
LV6	160
LV7	200
LV8	267
LV9	212

Thickness data were input as top and bottom elevations for FLOWPATH II and for model layer 1in the MODFLOW model. Entire aquifer or model layer thicknesses were estimated instead of screen intervals for MODFLOW. Estimates of actual thickness were derived from well logs and existing geophysical data. Using estimates of actual thickness should produce capture zones closer to reality but less conservative than FLOWPATH II. Thicknesses range from approximately 0 to 200 feet in layer 1.

Thicknesses in layer 2 of the MODFLOW model were derived from transmissivity data since the layer is confined. MODFLOW estimated aquifer thickness and K_h values that reproduced T values that were part of the input database.

Procedures and Results
As previously described, the FLOWPATH II model was developed as a confined aquifer. The MODFLOW model had layer 1 unconfined and layer 2 confined. Confined conditions were revealed when storage coefficients were computed from aquifer test data.

Model Calibration
A steady-state calibration process was performed on both models. Water-level measurements collected from production wells show relatively little annual fluctuation since the early 1970s. Some wells show seasonal fluctuations but return (rebound) to non-stress elevations during late winter and spring months when water consumption decreases. Model calibration is a subjective process resulting in a non-unique solution based on Darcy's equation:

$$Q = KAI$$

where Q is volumetric flow (L^3/t); K is hydraulic conductivity (L/t); A is the area where flow is occurring (L^2); and I is the groundwater gradient (L/L).

For example, an increase in K with Q held constant produces the same effects on the computed gradient and heads as a decrease in Q with K held constant. Thus, it is possible to calibrate the model by adjusting only K, only Q, or by increasing K and decreasing Q simultaneously (Anderson and Woessner, 1992). Variables of ET can also be adjusted during model calibration.

The FLOWPATH II model was calibrated by adjusting constant head values and maintaining aquifer parameters. Aquifer parameters are more definite values since they are derived from field tests and drilling logs. Aquifer parameter values were incorporated into the model in zones around the wellheads where capture zone results are more crucial. Aquifer values between zones do not affect capture zone simulations as much in 2-D models.

Adjustments were made to aquifer parameters in the MODFLOW model. Adjustments to aquifer parameters are justified since there are more model layers, and entire aquifer thicknesses were represented by the model not just screen intervals of the production wells. For example, there are not many well logs providing actual data for model layer 2 in the MODFLOW model and a kriging program was used to interpret values between the widely spaced known data points.

Capture Zone Simulations by FLOWPATH II

East Lemmon Valley was modeled as a confined aquifer using FLOWPATH II as previously described. Aquifer thickness values were estimated as the cumulative screen length for each well, respectively. Aquifer porosity and hydraulic conductivity values were estimated using well logs and aquifer stress test data. Constant head boundary values were also obtained by interpretation of groundwater level and elevation. Constant head nodes and hydraulic conductivity values were adjusted during the model calibration process. The FLOWPATH II model was calibrated until steady-state water levels contours nearly matched current water elevation contours. The well discharge rates were approximated from County pumping records.

Delineation results of the 5-, 10-, and 20-year capture zones are depicted in Figure 7. Capture zones generally extend to the southwest from each wellhead. Particle line of travel is perpendicular to groundwater elevation contour lines. The groundwater gradient in the area ranges from nearly flat or 0.0 ft/ft near LV6, LV7, and LV8 to 0.08 ft/ft near LV3 and LV9. Capture zones are generally elliptical in shape. Maximum widths of 20-year capture zones ranges from approximately 2,000 feet at LV9 to 3,000 feet at all other production wells. Maximum lengths of 20-year capture zones range from approximately 1,500 feet at LV7 to 4,700 feet at LV3.

Capture Zone Simulations by MODFLOW / MODPATH

East Lemmon Valley was modeled as an unconfined upper layer and a confined lower layer using MODFLOW and MODFLOW as previously described. Aquifer thickness values were estimated as the cumulative screen length for each well, respectively. Aquifer porosity and hydraulic conductivity values were estimated using well logs and aquifer stress test data. Constant head boundary values were also obtained by interpretation of groundwater level and elevation. Constant

head nodes and hydraulic conductivity values were adjusted during the model calibration process. The FLOWPATH II model was calibrated until steady-state water levels contours nearly matched current water elevation contours. The well discharge rates were approximated from County pumping records.

Delineation results of the 5-, 10-, and 20-year capture zones are depicted in Figure 8. Capture zones generally extend to the southwest from each wellhead. Particle line of travel is perpendicular to groundwater elevation contour lines. The groundwater gradient in the area ranges from nearly flat or 0.0 ft/ft near LV6, LV7, and LV8 to approximately 0.02 ft/ft near LV3 and LV9. The MODFLOW model domain does not include the steeper gradient area included in the FLOWPATH II model so the gradients between the two models differ slightly. Capture zones are generally elliptical in shape but smaller for the MODFLOW model when compared with the FLOWPATH II model. The smaller capture zones are attributed to vertical water flow in the MODFLOW model: water can flow upward or downward and not only horizontal. The smaller capture zones are also related to wells located in thicker saturated zones, higher hydraulic conductivity values, or the wells pump less water. Maximum widths of 20-year capture zones are approximately 1,000 feet at all production wells. Maximum lengths of 20-year capture zones range from approximately 1,000 feet at LV5 and LV8 to 4,000 feet at LV3 and LV7. It should be noted that boundary locations probably limit the length of capture zones by preventing particles from passing beyond the boundary.

LIMITATIONS
This report was prepared in accordance with generally accepted hydrogeologic practices applicable at the time the study was undertaken. Information presented in this report is based on data and computer models generated by staff of the Washoe County Utility Services Division. Additional field data is always helpful. Conclusions presented in this report are specific to the delineation of wellhead protection areas for the Lemmon Valley water supply wells. Incorporating additional wells or trying to model areas outside the domain boundary of this model most likely would necessitate refinement of the groundwater model presented in this study.

INVENTORY OF SOURCES OF CONTAMINATION

PROCEDURE
A database of chemical storage permits in Washoe County were obtained from the Nevada State Emergency Response Commission (Elizabeth Ashley). This 102-page database was searched for any permits issued in the Lemmon Valley area. The Washoe County District Health Department was contacted (Paul Donaldson, Dave McNinch) to locate current or future hazardous waste generators, underground storage tanks and landfills.

In 1995, Utility Services Division staff conducted a field investigation jointly with the Bureau of Health Protection Services contractor for the Vulnerability Assessment Program. The wells and

potential contaminant sources were located using the Global Positioning System (GPS). These sites were reviewed for current validity and included in the current program.

Washoe County's Land Use Plan was reviewed in order to locate future construction types and drainage. Domestic wells and septic tanks were located within the larger area of interest as well as community water and sewer lines. All this information was found in or incorporated into Washoe County's Geographic Information System (GIS). A field inspection of the predicted capture zones was conducted to determine if other potential sources of contamination could be found. Of particular importance were improperly abandoned wells, underground storage tanks and industrial/commercial properties.

RESULTS

Wellhead capture zones were incorporated into the GIS in order to allow all available information described above to be plotted atop the capture zones. A useful map generated contained the Assessor's Parcel Numbers (APN), water and sewer service types for each parcel, and any known potential source of contamination. From the results of this mapping and field surveys (some were conducted with NDEP and District Health staff), Figure 10 locates potential sources of contamination within the capture zones as calculated from FLOWPATH.

From this survey a significant potential contaminant threat the groundwater in this study area are septic tanks shown in Figure 9. Proper maintenance of septic tanks can help to alleviate the amount of nitrate contamination to the water table. Washoe County will mail brochures to all septic tank owners within the capture zones and adjacent areas. Washoe County has been working diligently to make community sewer available to the existing areas on septic systems. In particular, the County has extended sewer lines throughout the Valley Village subdivision. This area had been identified as having a high incidence of septic system failure and there was evidence of surface water contamination. Consequently, there are 242 homes abandoning their septic systems and connecting to County sewer. To date, 217 homes have made the switch. It is anticipated the remaining 25 will connect by the end of this year.

An uncapped, improperly abandoned well has been identified, located east of well #5 and north of well #9, but outside of any delineated zone. Five wells identified on the Figure as abandoned were done so properly by the Washoe County Department of Water Resources as reported to the State of Nevada Division of Water Resources. No improperly abandoned wells have been identified within our wellhead protection areas.

A goat ranch was identified in the vicinity of Well #3. This well is being monitored quarterly for nitrates. The presence of the ranch does not appear to be of great concern.

Six underground storage tanks exist in the study area, three located at the 7-11 store and three at the General Store. All six tanks were constructed as per 1998 Federal construction guidelines

and are monitored for discharge every thirty days. A third tank, that leaked, was located between these two sites. This tank was removed as well as the contaminated soil and monitored for one year. The groundwater met SDWA standards for volatile organic compounds (McNinch, 2000). A second tank was removed from Smith's Feed (60 Surge St.) where no contamination was reported. A future underground storage tank is proposed near US 395 (Texaco station) and will be equipped with automatic leak detection devices. Systematic monitoring of these three underground storage tanks (gasoline) on Lemmon Drive will alert the proper authorities to any leakage of petroleum products.

FLOOD PLANNING

Figure 10 delineates the 100-year flood zones with respect to the capture zones. Two of the wellheads, Lemmon Valley #8 and #9, are out of the delineated flood zones. Lemmon Valley wellheads #5 and #7 are secured above flood elevations. These wellhouse buildings were rebuilt after the 1996 flood to prevent future flooding problems. Lemmon Valley well #3 is secured from flood related problems because of existing drainage structures. Lemmon Valley #6 is estimated to be at or slightly above the flood plain. However, a dirt berm has been built around the well enclosure to divert flood waters. During a significant flood, our emergency plan calls for this well to be shut off if flooding of the wellhead is eminent. Contamination to the aquifer from a large-scale flooding event would largely come from pollutants located at residential sites and from erosion, exposure and rupture of natural gas and sewer pipelines.

MANAGEMENT OPTIONS

This section describes the appropriate measures to be taken, as a management tool, to ensure the protection of groundwater quality. The State of Nevada's Wellhead Protection Program gives several options towards managing groundwater quality and wellhead protection (Bureau of Water Quality Planning, 1994). The management tools that are appropriate for this program are:

1. initiating zoning ordinances,
2. requiring site plan reviews,
3. implementing operating standards,
4. implementing source prohibitions,
5. implementing groundwater monitoring programs, and
6. conducting periodic public education programs.

The existing land use zoning (Figure 11) for the Lemmon Valley area is almost entirely residential. Small areas of land are designated for commercial activities, but these are limited to service oriented and therefore are not expected to impose a significant threat towards groundwater. Development applications, such as special use permits and site plan reviews for proposed development, are routinely reviewed by staff within the Department of Water Resources. These

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reviews and conditions of approval are incorporated into overall project approvals. There is a portion of Lemmon Valley, along Military Road, which is within the purview of the City of Reno. Administrative permits within this area are not reviewed by the Washoe County Department of Water Resources. For this reason, City of Reno staff, from their Community Development and Fire Departments, have been included in the Wellhead Protection Team. Education of their staff will be key to insuring that development activities are monitored. There is cooperative effort in this regard between the City of Reno and Washoe County. Objections to specific development that would place hazardous material within specified wellhead capture zones will be made. Additionally, representatives of the Lemmon Valley Wellhead Protection Team will notify existing, commercially zoned landowners, if located within or near a capture zone, of this Wellhead Protection Program and that certain activities may create potential problems for groundwater protection.

Groundwater monitoring is already in place for the Lemmon Valley area. The Lemmon Valley Water System participated in the State of Nevada Bureau of Health Protection Services' Water Quality Vulnerability Assessment Program in 1995. Consequently, monitoring waivers have been issued. As a result, the monitoring frequency of certain contaminants has been reduced. Annual nitrate sampling is required. In any case where the nitrate concentrations exceed one half of the maximum contaminant level, quarterly monitoring is initiated. Lemmon Valley Well #3 is the only well where this has been implemented. It is suspected that the elevated nitrates are due to the high concentration of goats adjacent to the well.

Public education is a proper tool for water quality protection. This amounts to exposing the public to the importance of proper disposal of household hazardous wastes, septic tank maintenance and the reporting to proper authorities of illegal acts of groundwater or land pollution. This program will periodically give presentations to Citizen Advisory groups on the Wellhead Protection Program.

CONTINGENCY PLANNING

This section discusses what steps are to be taken should a toxic spill or non-point source pollution to the aquifer occur when water supply response is required. This response is two-fold. The first is to protect the groundwater from an increase in pollution spreading. The second is to prepare for the use of alternate water sources until remediation is complete.

In the event that a toxic spill should occur within a capture zone that threatens the water supply, the water well potentially affected will be shut down. Lemmon Valley well #3 appears to be the most vulnerable to this type of scenario due its proximity to commercial activities and arterial traffic. The Washoe County District Health Department will promptly notify the Washoe County Utility Services Division. Within the Utilities Services Division, the Engineering and the Operations and Maintenance sections will issue an order to turn off the well. The appropriate investigation will be

initiated to determine the extent of the problem and the clean-up duration of the toxic spill. If a toxic spill does occur, the list of agencies and personnel to contact are:

Washoe County Emergency Management: Press Clewe, 328-2095
Washoe County District Health: Bob Sack or Doug Colter, 328-2434
Reno Fire Protection District: Marty Scheuermann, 328-3650
Washoe County Utility Services Division: Jesse Coffman or Paul Orphan, 954-4600

There exists the possibility of nitrate contamination of the aquifer because of the number of septic tanks in the area. An area of very high septic tank density, the Valley View Subdivision, has been converted to sewer service to prevent contamination due to the high water table. Septic tank density in other areas is one acre or greater. In the area north of Lemmon Valley well #7, nitrate levels are approaching 10 mg/l (Widmer and McKay, 1993). At this time there does not appear to be a large threat to Lemmon Valley well #7 as this well pumps groundwater from a much deeper aquifer. Monitoring of nitrate in the groundwater will give ample time to identify if this source of contamination becomes a serious problem.

In the event that a toxic spill requires that a well is taken out of service, alternative water sources will be accessed. Initially, other Lemmon Valley wells would be used to back-up the affected services. If required, conservation measures would be requested of the customers as a short-term solution. Another short term means of alleviating the inconvenience to customers is either through providing bottled water or the hauling of potable water in approved trucks. The long-term may require buying wholesale water from Sierra Pacific Power Company. Currently, one intertie exists between the two water systems. There are plans to intertie the two systems to accommodate future development and more fully utilize water resources regionally.

If the contamination to the well cannot be contained within the immediate spill area, the production well may need to be equipped with a "pump and treat system". The costs of these remediation processes could vary from hundreds of dollars to in excess of one million dollars as witnessed by Sierra Pacific Power Company. Five of their wells are contaminated from industrial wastes. These wells are currently equipped or will be equipped with "pump and treat" systems at a cost of greater than one million dollars each. Regardless, the persons responsible for the spill will be legally held responsible for the cost of the spill mitigation. In the event that the responsible party cannot pay for the costs, other sources will have to be pursued.

PUBLIC EDUCATION

Public awareness of water quality can make a significant impact on the future of our groundwater. While public participation in keeping our waterways clean has improved over the last two decades, there has probably been little improvement towards groundwater. This can be attributed to lack of education.

Two major areas of education should target proper septic tank maintenance and the proper disposal of household hazardous waste. Keeping septic tanks cleaned on a regular basis improves the functioning of the tank both in terms of the life of the infrastructure and the quality of the effluent. Regular cleaning can reduce the concentration of contaminants, mainly nitrate, that the effluent contains. The disposal of paints, solvents and antifreeze onto the ground is most likely a common practice. This practice, over time and multiplied by hundreds of households, will eventually pollute the groundwater. This contamination cannot realistically be cleaned up and it cannot be policed. Therefore, the only feasible process is to continually educate the public of proper disposal practices.

Our public education process will target Citizen Advisory Boards (CABs) and residents. Water service customers receive a quarterly new letter from the Department of Water which is used as a mechanism for education. A video of wellhead protection will be shown on the local County broadcasting channel, SNCAT. Brochures mailed or will be made available on septic tank maintenance and the proper disposal of household hazardous wastes. Presentations to the CABs will be given every two years. The presentation will consist of presenting the Lemmon Valley Wellhead Protection program, viewing the wellhead protection video, and distributing brochures on household hazardous waste and septic tank maintenance.

The effectiveness of this program cannot be easily measured. Public response may be accounted for by an increase in the amount of business that commercial septic tank cleaners may have. This may also be accounted for at commercial hazardous waste collection sites. Public phone calls with questions about this topic may also increase at the Washoe County District Health Department and the Department of Water Resources.

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APPENDIX A

Well construction and aquifer properties

Well Name	PWSI[1] Number	Screen Interval (feet)	Transmis-sivity (gpd/day)	Specific Capacity (gpm/ft)	Pump Capacity (gpm)	Depth (feet)
LV well 3	0202-01	250-590	7,000	5.9	44	296
LV well 5	0202-02	410-760	26,000	16.7	800	457
LV well 6	0202-04	260-650	46,000	23	200	440
LV well 7	0202-05	175-236	1,500	1.5	500	600
LV well 8	0202-06	160-440	1,500	0.9	700	701
LV well 9	N/A	230-455	1,250	4.0	400	460

[1] State of Nevada Public Water Source Identification Number Listing

APPENDIX B

Current water quality for existing wells in operation (reported in parts per million)

Well	TDS	Ca	Mg	Na	K	SO4	Cl	NO3[1]	HCO3	Fl	As
MCL[2]	1000[3]	N/A	150[3]	N/A	N/A	500[3]	400[3]	10	N/A	4	0.050
LV well 3	237	31	17	20	4	56	14	3.2	117	0.13	0.000
LV well 5	231	18	5	49	3	43	5	1.0	127	0.14	0.005
LV well 6	202	26	9	30	3	57	8	1.8	127	0.16	0.006
LV well 7	171	13	3	40	2	27	15	0.7	90	0.20	0.006
LV well 8	222	23	4	40	4	37	5	1.2	124	0.17	0.008
LV well 9	260	32	8	35	3	51	9	1.7	N/A	<0.1	0.004

Well	Fe	Mn	Cu	Zn	Ba	B	Si	pH
MCL[2]	1.0[4]	0.1[3]	1.3	N/A	2	N/A	N/A	N/A
LV well 3	0.01	0.00	0.00	0.00	0.04	0.0	42	7.70
LV well 5	0.01	0.00	0.00	0.00	0.06	0.0	52	8.00
LV well 6	0.01	0.00	0.00	0.00	0.07	0.0	44	7.80
LV well 7	0.08	0.00	0.01	0.00	0.03	0.0	40	8.13
LV well 8	0.00	0.00	0.00	0.00	0.06	0.0	57	7.98
LV well 9	<.05	0.02	0.00	0.01	0.11	N/A	N/A	8.05

[1] reported as nitrogen

[2] "Must not exceed Concentration Level" as per Clean Water Drinking Act

[3] Secondary MCLs

[4] Secondary MCL is 0.6

Map labels (as they appear on the map):

- LEMMON VALLEY
- Lemmon Valley Well #7
- Lemmon Valley Well #8
- Lemmon Valley Well #6
- Swan Lake
- Lemmon Valley Well #5
- Lemmon Valley Well #4
- Silver Lake
- STEAD
- US 395
- Lemmon Valley Well #3
- PEAVINE MTN
- RENO
- AREA OF DETAIL COLD SPRINGS and LEMMON VALLEYS, WASHOE COUNTY, NEVADA
- RENO
- CARSON CITY
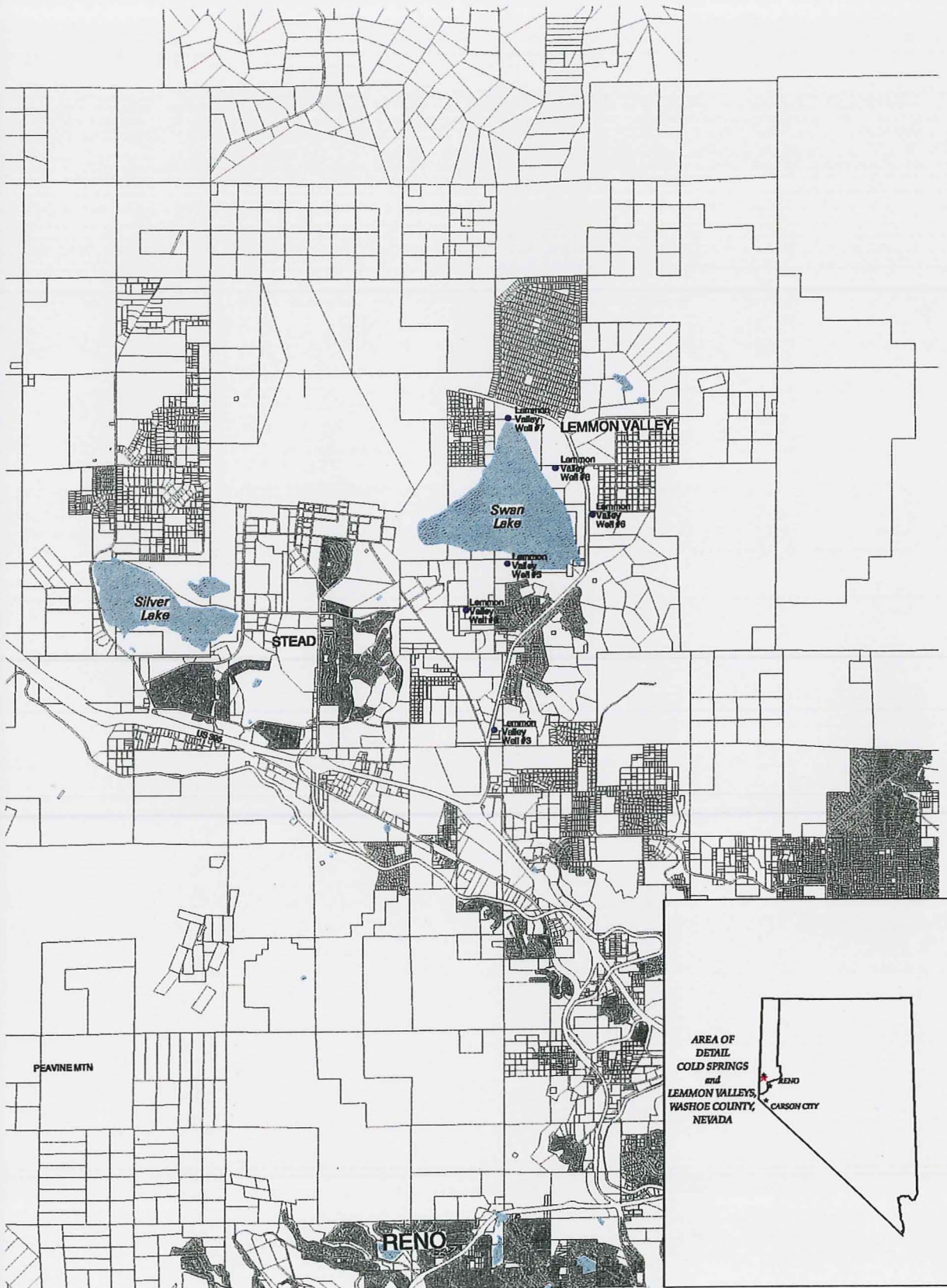
FIGURE 1
LOCATION MAP

Notes: The scale and configuration of all information shown hereon are approximate only and are not intended as a guide for design or survey work. Reproduction is not permitted without prior written permission from the Washoe County Department of Water Resources.
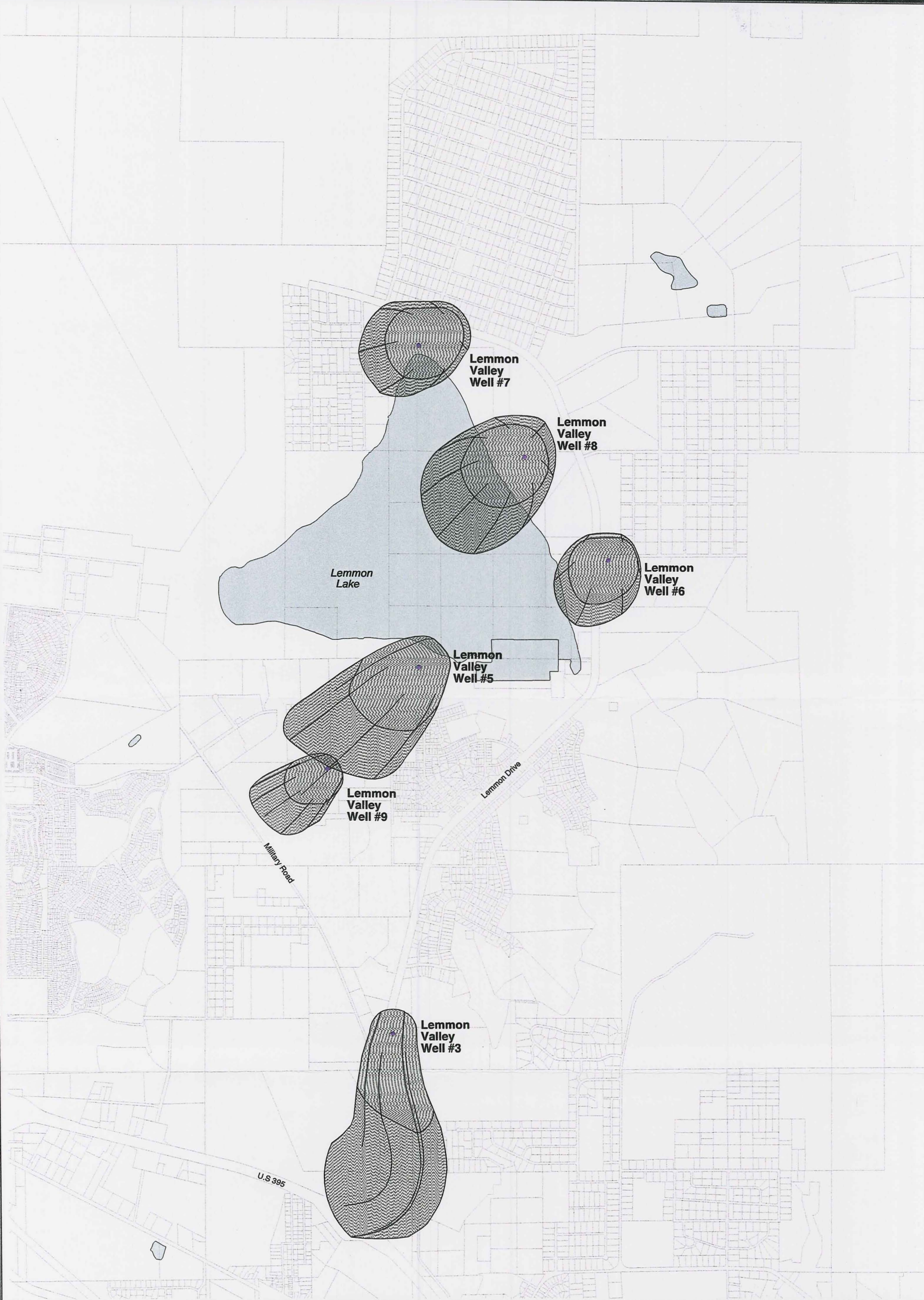
Department of Water Resources

WASHOE COUNTY NEVADA

Post Office Box 11130
Reno, Nevada 89520
(775) 954-4600

0   2500   5000

SCALE IN FEET

DATE: OCTOBER 2000
SOURCE: WASHOE COUNTY DEPARTMENT OF WATER RESOURCES
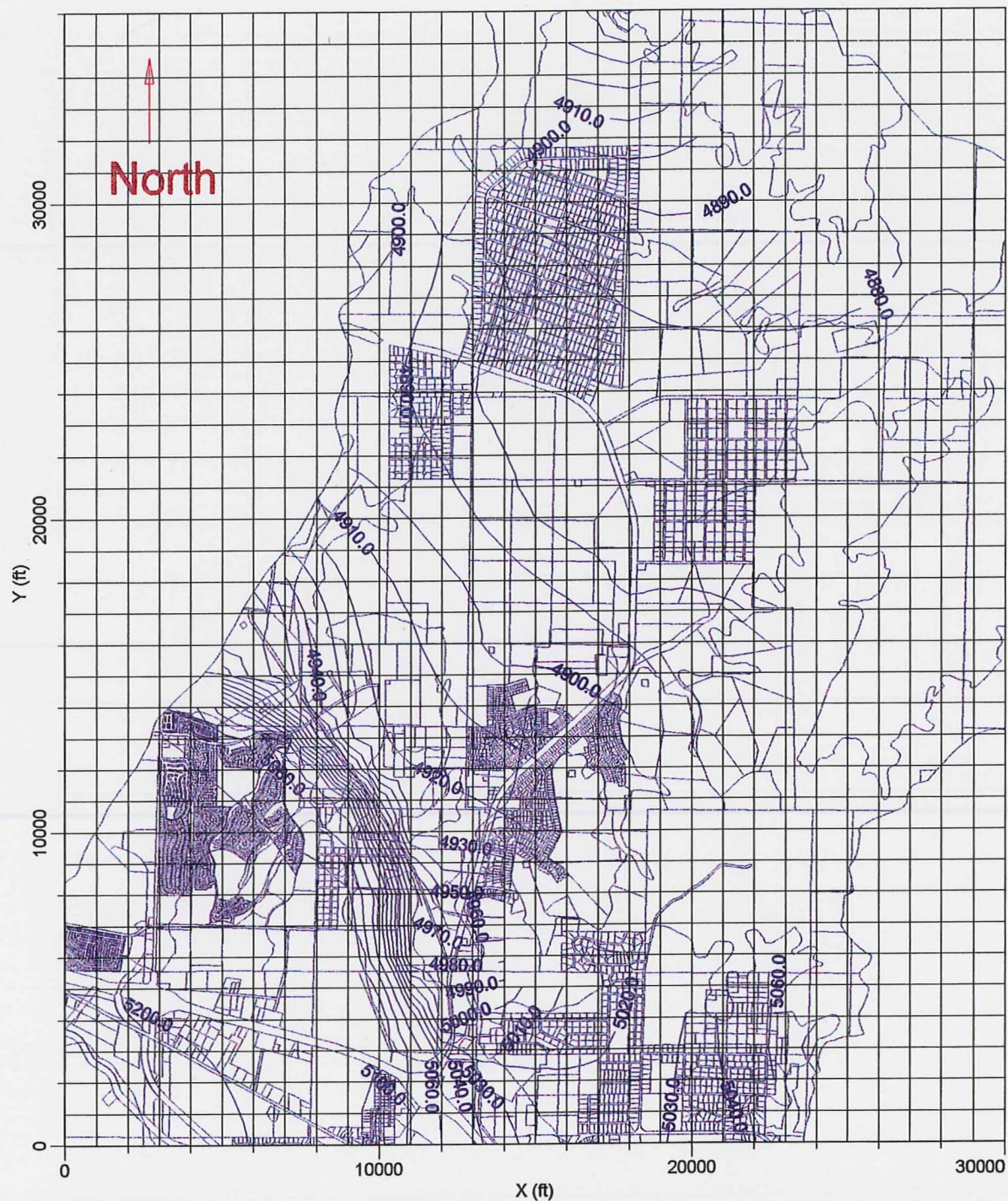
FIGURE 3. Potentiometric Map

FLOWPATH II Model for East Lemmon Valley WHP

FlowPath II Ver. 1.1
© 1989-1998 WHI

Washoe County Department of
Water Resources

North

Y (ft)

30000

20000

10000

0

0   10000   20000   30000

X (ft)
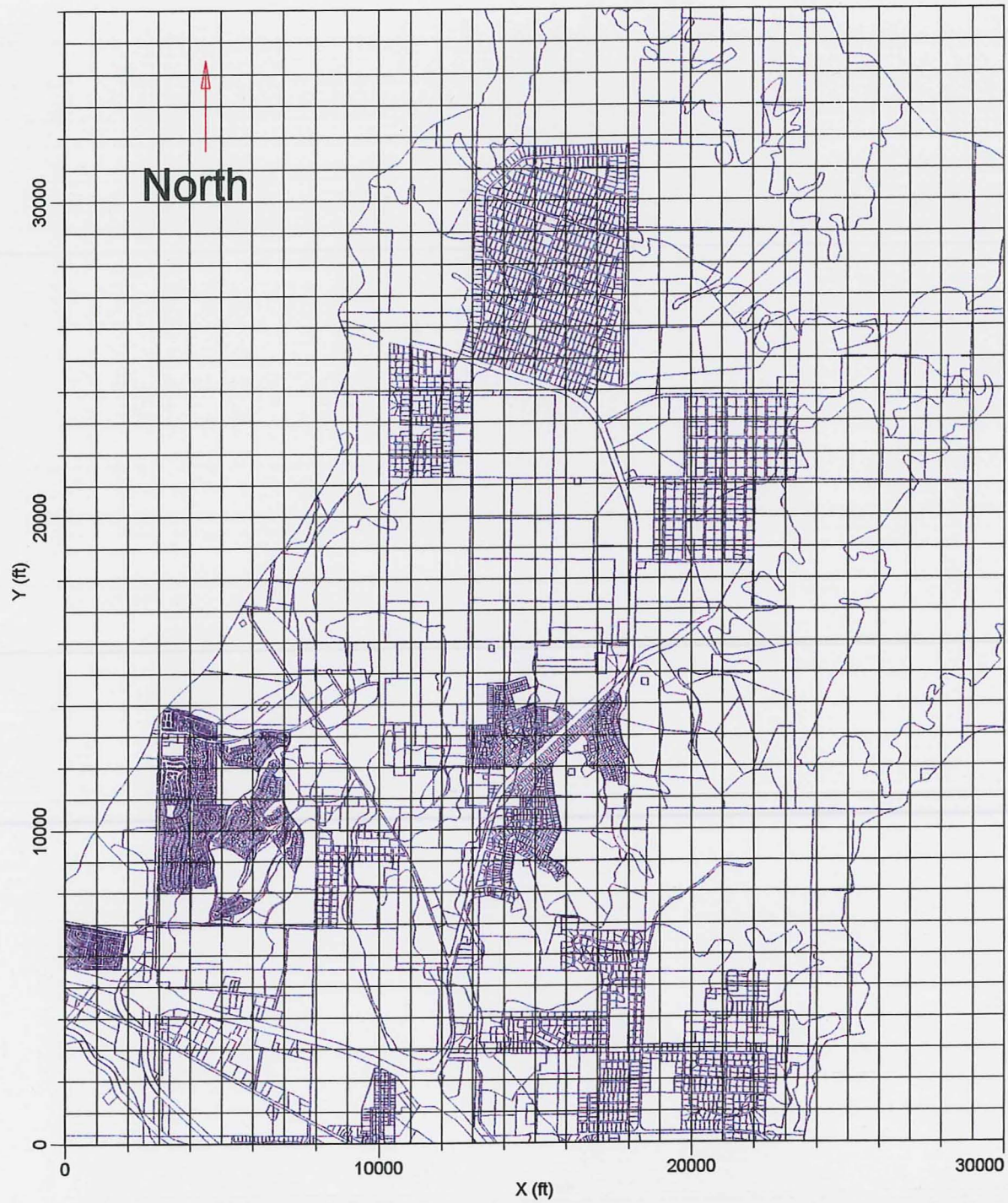
FIGURE 4. Model Grid Spacings	FLOWPATH II Model for East Lemmon Valley WHP
FlowPath II Ver. 1.1 © 1989-1998 WHI	Washoe County Department of Water Resources
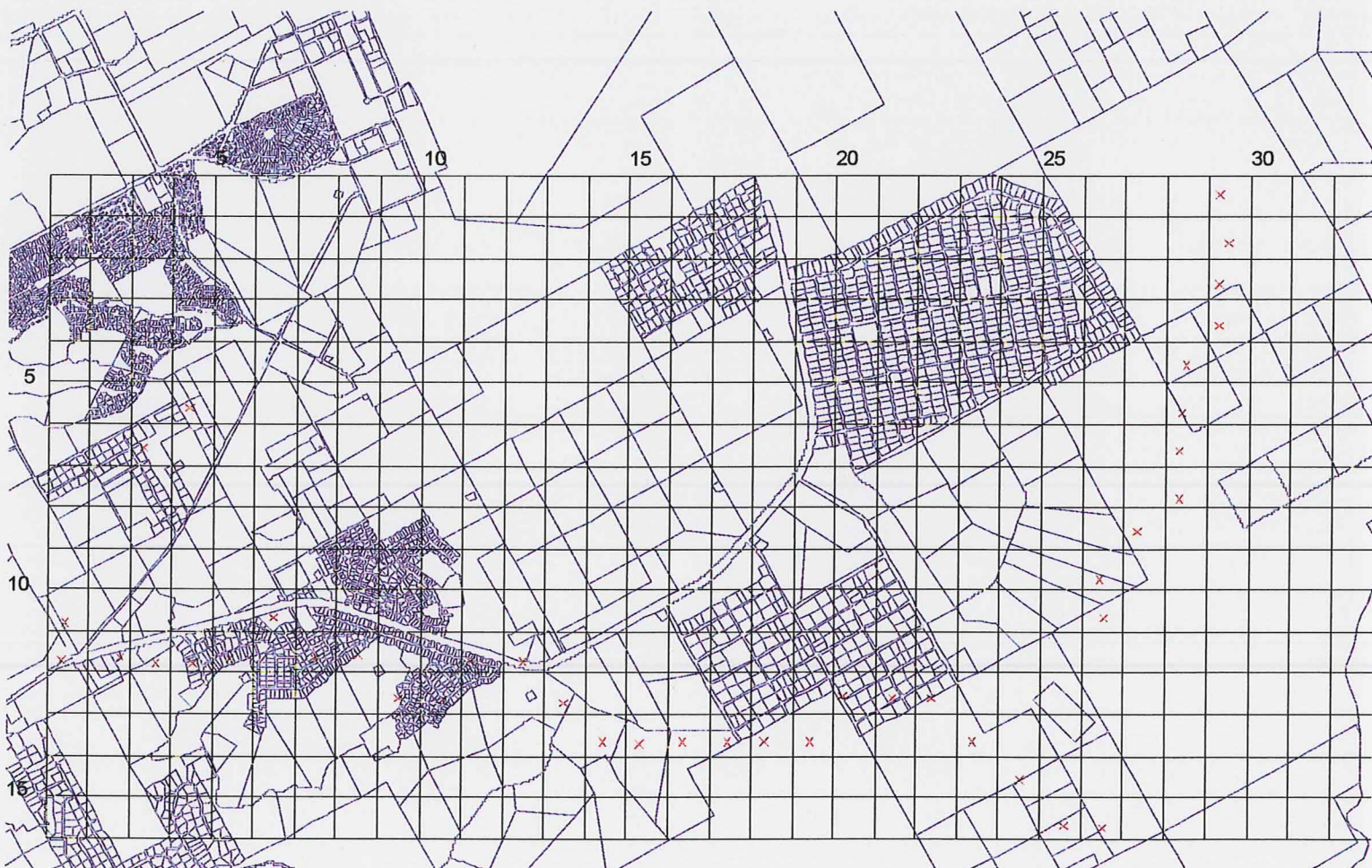
Grid Cell = 1,000 x 1,000 feet

N

DEPARTMENT OF WATER RESOURCES	Model Grid Spacings for	FIGURE
UTILITY DIVISION P.O. BOX 1130 RENO, NV 89520 (775)954-4600	**MODFLOW Model**	5
	East Lemmon Valley WHP	
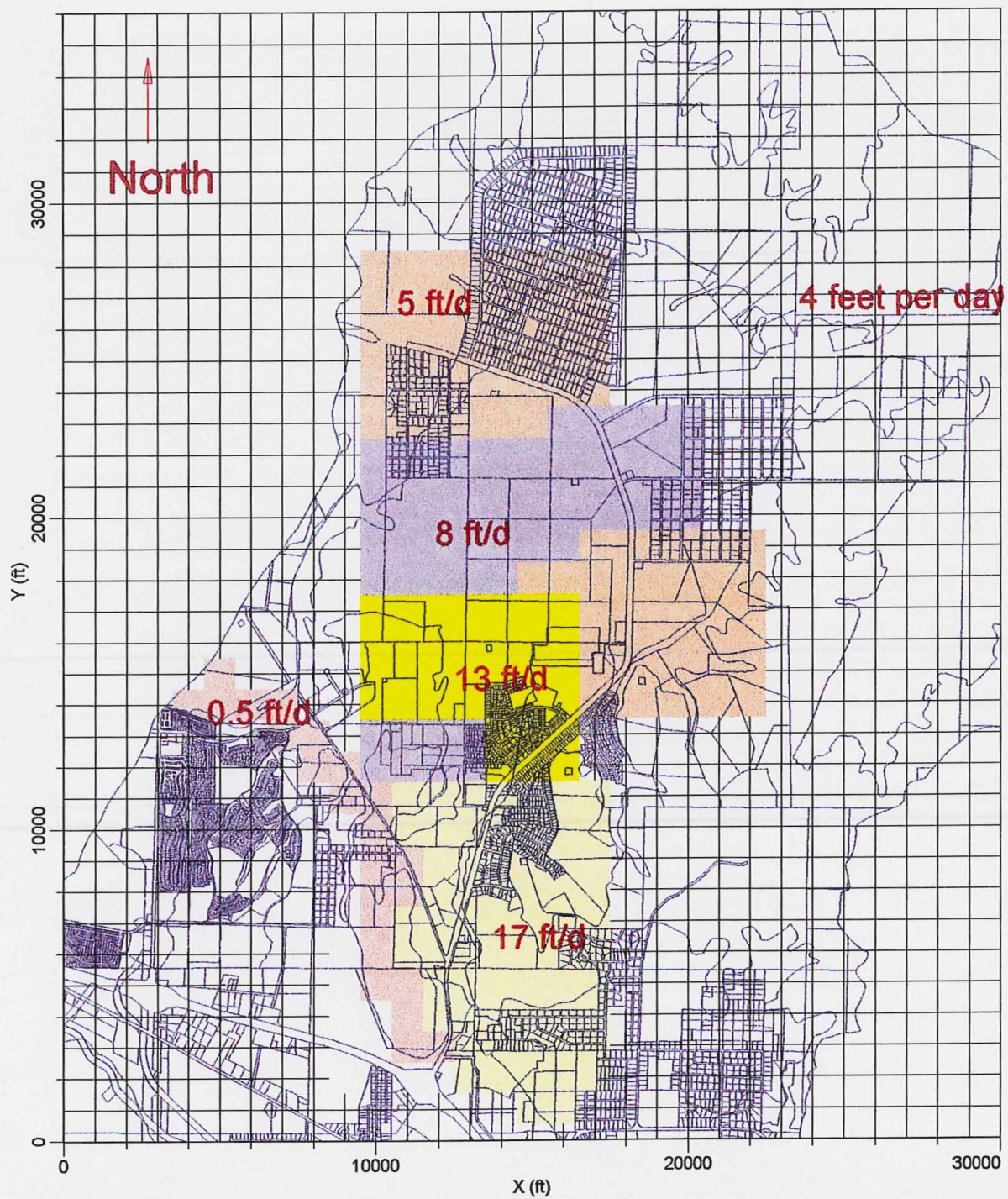
FIGURE 6. Hydraulic Conductivity Zones | FLOWPATH II Model for East Lemmon Valley WHP

FlowPath II Ver. 1.1
© 1989-1998 WHI

Washoe County Department of
Water Resources
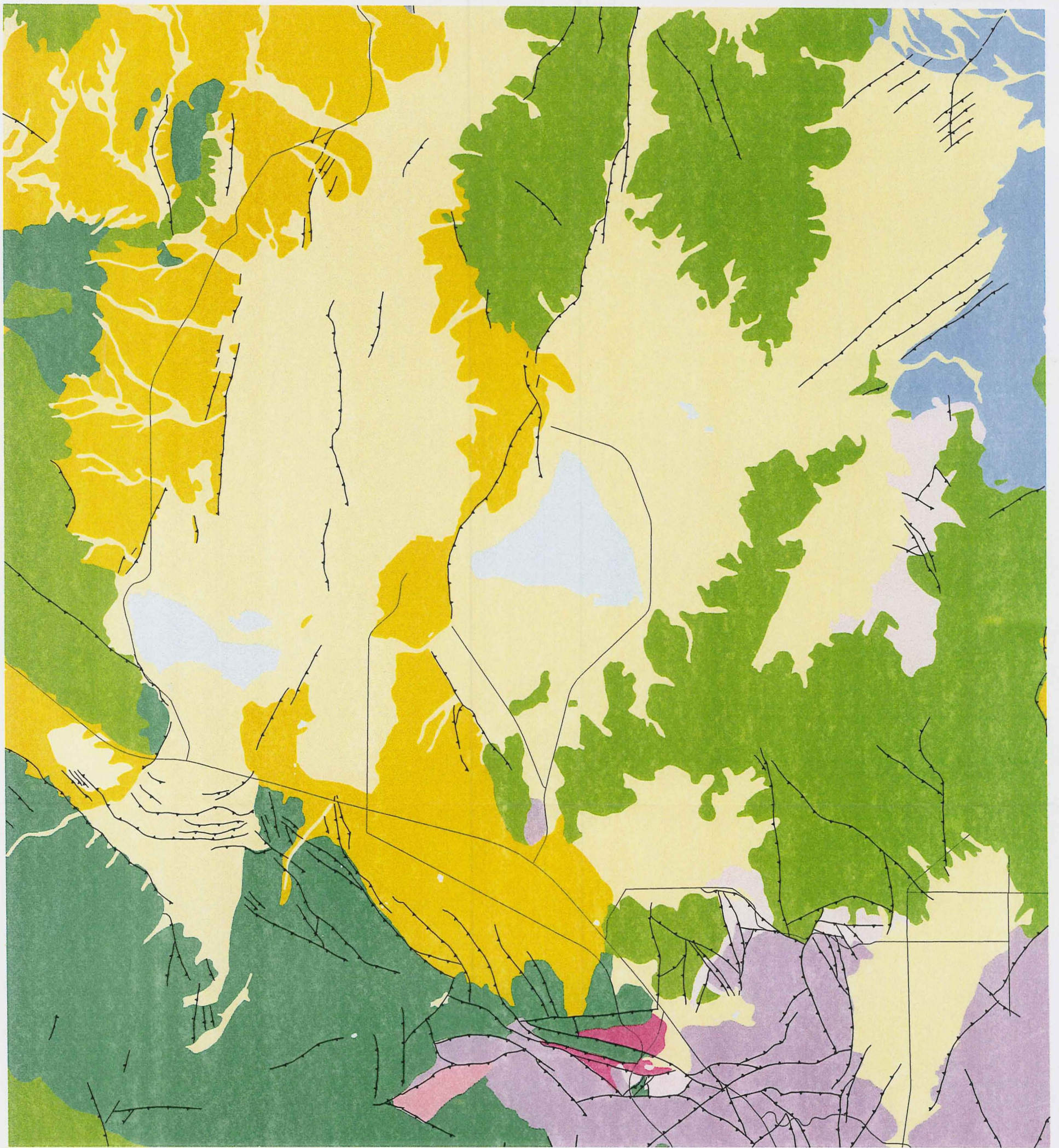
FIGURE 2.
Geology of East Lemmon Valley with Faults

Notes: The scale and configuration of all information shown hereon are approximate only and are not intended as a guide for design or survey work. Reproduction is not permitted without prior written permission from the Washoe County Department of Water Resources.

QUATERNARY

- UNDIFFERENTIATED QUATERNARY SEDIMENTS
- LANDSLIDE DEPOSITS
- ALLUVIAL FANS
- PLEISTOCENE BASALTS AND ANDESITES

TERTIARY

- PLIOCENE SEDIMENTARY ROCKS
- RHYOLITE PLUGS
- KATE PEAK FORMATION
- TERTIARY GRANITIC ROCKS
- ALTA FORMATION
- HARTFORD HILLS RHYOLITE

MESOZOIC

- CRETACEAOUS INTRUSIVE - GRANODIORITE
- PEAVINE SEQUENCE
- WATER BODIES
- Fault

0   2500   5000

SCALE IN FEET

Department of Water Resources

WASHOE COUNTY NEVADA

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Reno, Nevada 89520
(775) 954-4600

SOURCE: WASHOE COUNTY DEPARTMENT OF WATER RESOURCES

DATE: JANUARY 2000

Lemmon
Valley
Well #7

Lemmon
Valley
Well #8

Lemmon
Valley
Well #6

Lemmon
Lake

Lemmon
Valley
Well #5

Lemmon Drive

Lemmon
Valley
Well #9

Military Road

Lemmon
Valley
Well #3

U.S 395

FLOWPATH II 10-, and 20-year capture zones

FIGURE 7

10 Year Capture Zone

20 Year Capture Zone

Production Well

SCALE 1:12,000
1 inch represents 0.19 miles
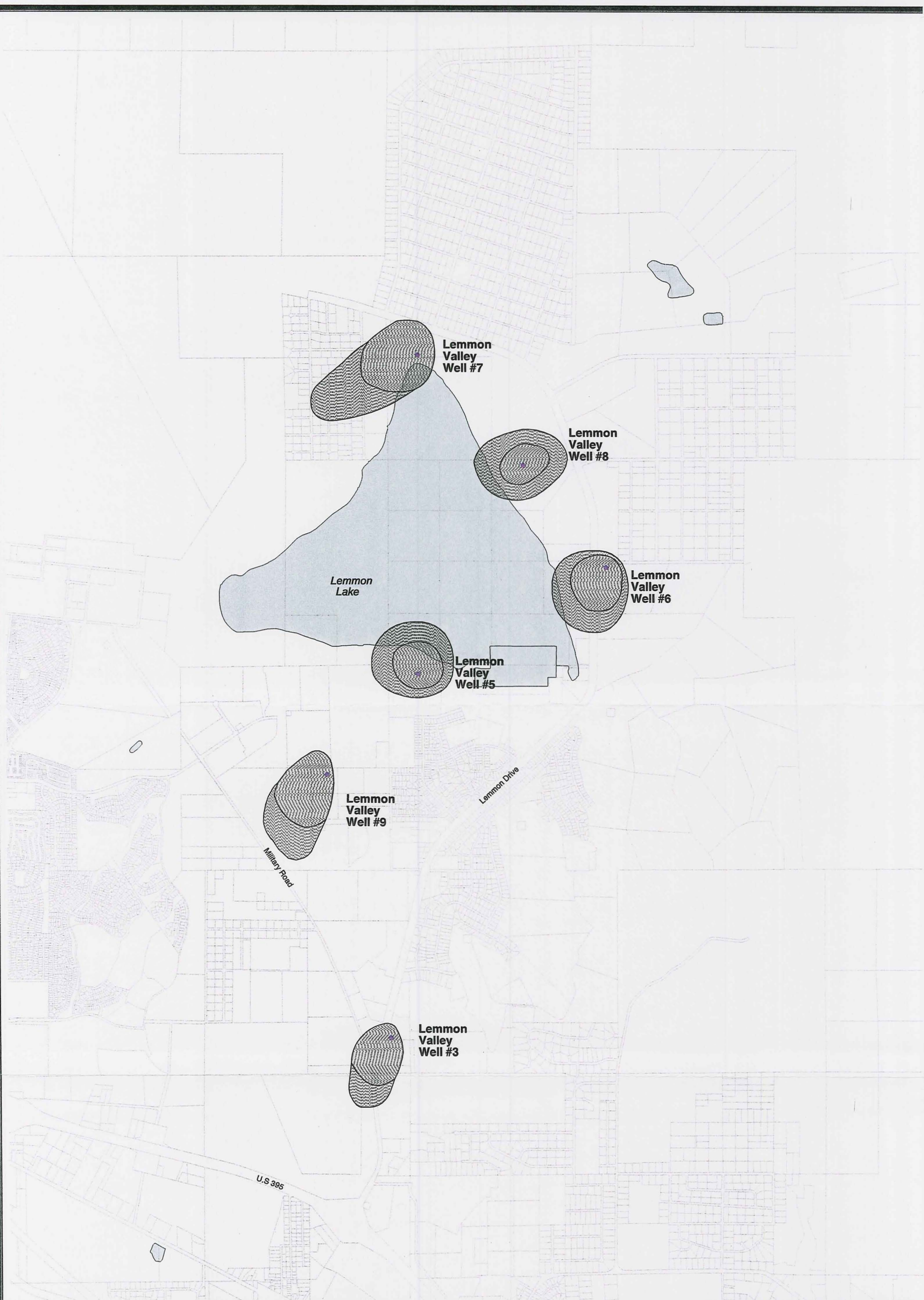
MODFLOW/MODPATH 10-, and 20-year capture zones

FIGURE 8

Legend:
- 10 Year Capture Zone
- 20 Year Capture Zone
- Production Well

Map labels:
- Lemmon Valley Well #7
- Lemmon Valley Well #8
- Lemmon Valley Well #6
- Lemmon Valley Well #5
- Lemmon Valley Well #9
- Lemmon Valley Well #3
- Lemmon Lake
- Lemmon Drive
- Military Road
- U.S 395

SCALE 1:12,000
1 inch represents 0.19 miles

Capture zone delineation map of the Lemmon Valley water system

FIGURE 9

Map labels:

NCNT Production Well

Lemmon Valley Well #7

Injection Well

Lemmon Valley Well #8

Abandoned Well

Lemmon Valley Well #6

Lemmon Lake

Lemmon Valley Well #5

Sewage Treatment Plant

Abandoned Well

Abandoned Well

Valley View Subdivision

Lemmon Drive

Lemmon Valley Well #9

UST (3)

CWS Well

UST (3)

Abandoned Well

Military Road

Improperly Abandonded Well

CWS WELLS

Lemmon Valley Well #3

Livestock

U.S 395

UST (3)

Legend:

- 10 Year Capture Zone
- 20 Year Capture Zone
- Municipal Water and Sewered
- Municipal Water and Septic
- Domestic Well and Sewered
- Domestic Well and Septic
- Monitoring Well
- Potential Source of Contamination
- Production Well
- Fault

SCALE 1:12,000
1 inch represents 0.19 miles

Capture zones and areas of flooding

FEMA 100 Year Flood Zone

Production Well

FIGURE 10

Lemmon Valley Well #7

Lemmon Valley Well #8

Lemmon Valley Well #6

Lemmon Lake

Lemmon Valley Well #5

Lemmon Drive

Lemmon Valley Well #9

Military Road

CWS WELLS

Lemmon Valley Well #3

U.S 395

SCALE 1:12,000
1 inch represents 0.19 miles

Lemmon
Valley
Well #7

Lemmon
Valley
Well #8

Lemmon
Valley
Well #6

Lemmon
Lake

Lemmon
Valley
Well #5

Lemmon
Valley
Well #9

Lemmon Drive

Military Road

CWS WELLS

Lemmon
Valley
Well #3

U.S 395
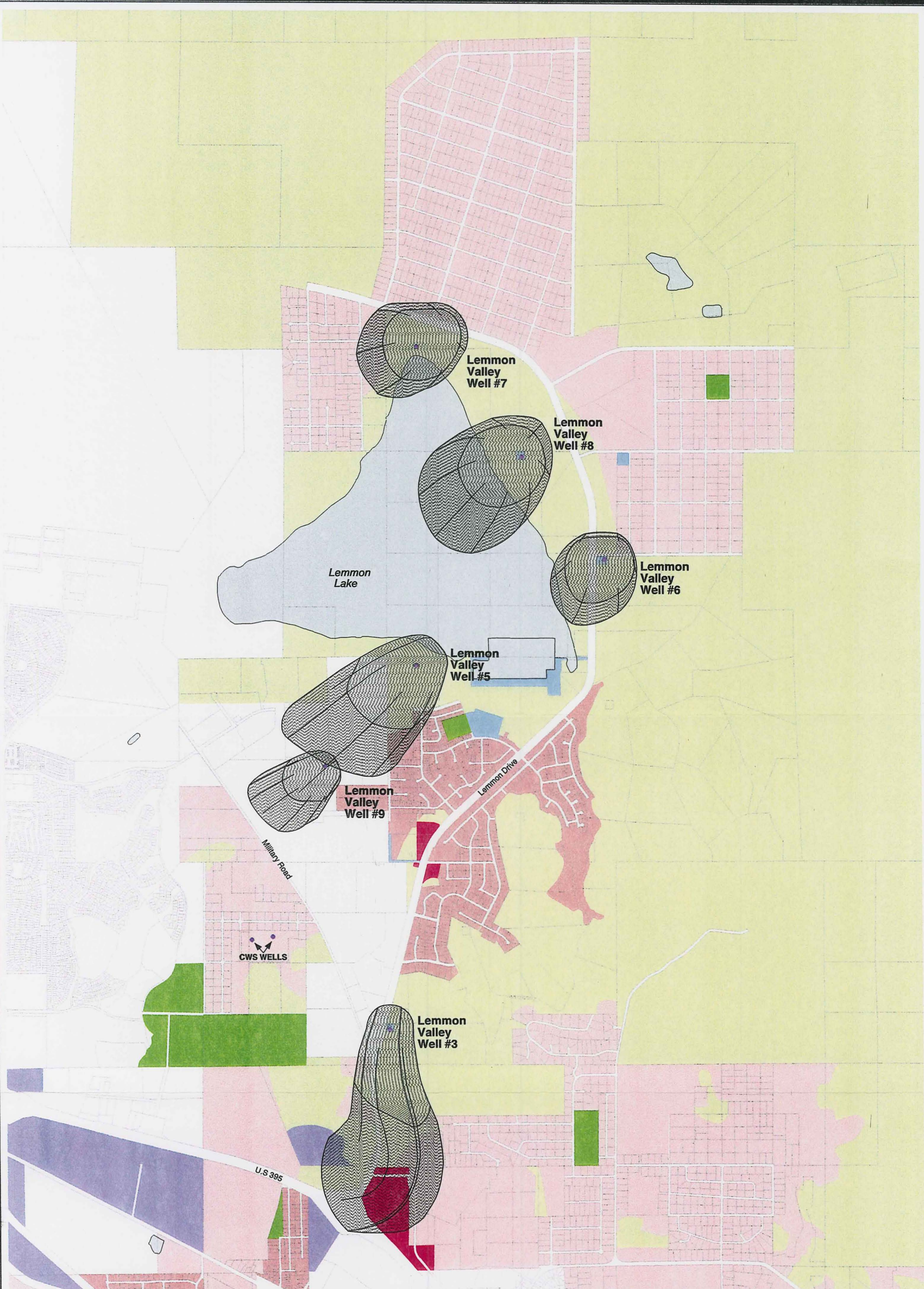
Washoe County Land Use map for East Lemmon Valley

FIGURE 11

CITY / PUBLIC ROADS	SPECIFIC PLAN	GENERAL RURAL
LOW DENSITY SUBURBAN	PUBLIC AND SEMI-PUBLIC FACILITIES	Production Well
MEDIUM DENSITY SUBURBAN		
GENERAL COMMERCIAL	PARKS AND RECREATION	

SCALE 1:12,000
1 inch represents 0.19 miles