WATERESOURCE
consulting engineers, inc.

HYDROGEOLOGICAL STUDY
of
WINDY HILL AREA
(SOUTHWEST TRUCKEE MEADOWS)

for
WESTPAC UTILITIES

SEPTEMBER 1991

Reviewed by:
Bob Squires
1/2/92

WATERESOURCE CONSULTING ENGINEERS, INC.

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RENO, NEVADA 89509

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WESTPAC UTILITIES

REGISTERED PROFESSIONAL ENGINEER
GEORGE W. BALL, JR.
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STATE OF NEVADA

9-30-91

SEPTEMBER 1991

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September 30, 1991
Job No. 9101.10

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P.O. Box 30028
Reno, Nevada 89520-3028

ATTN: Bob Squires, P.E.

SUBJECT: Hydrogeological Study of the Windy Hill Area

Gentlemen:

Transmitted herewith is the referenced report, pursuant with your request. An extensive field reconnaissance effort (as summarized in Appendix A) was conducted as a significant part of this effort. A comprehensive data summary (in tabluar form) of this reconnaissance is presented in Appendix A of this report.

WATERESOURCE believes this report effort presents a comprehensive, current evaluation of this portion of the South Truckee Meadows Hydrogeologic Groundwater Basin. Nonetheless, further monitoring, testing and investigation is needed to provide continual refinement to this analysis.

One significant output of this effort was that the effect of the individual wells on each other demonstrates a significant impact on the entire groundwater system.

William Harrigan of WATERESOURCE was the Principal Geologist for this Study effort and a significant contributor to this report.

We will be happy to review any questions with you. Thank you for your confidence in WATERESOURCE.

Sincerely,

WATERESOURCE CONSULTING ENGINEERS, INC.

George W. Ball

George W. Ball, Jr., P.E.

GWB/aad

Enclosures

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APPENDIX A - Contained in a separate three ring binder are all of the field interview sheets, field information sheets and field notes from the Well Owner Interview Survey by Ronald Borgognone. This Report (Appendix A) contains a copy of the detailed Well Owner Interview Summary, prepared by Ronald Borgognone.

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EXECUTIVE SUMMARY

Water level declines and well efficiencies are the primary concerns in the study area. Data were gathered on one hundred and ten (110) domestic wells. Static water level measurements available prior to the study period are relatively few. Those static water levels obtained during the study indicate a general decline in static levels as compared with measurements taken in wells a few to several years ago. The data are confined to those wells inventoried but possibly 50 to 60 more wells, not included in the study, are operating within the study area. Collectively the wells in the study area can be pumped at a relatively high pumping rate and coupled with the present drought cycle tends to emphasize this condition of water level declines.

In the study area, two distinct aquifer types exist and should be considered individually for hydrologic effect. The greater number of wells are located in the alluvial zone to the south and east of Windy Hill. The balance are in the confines of the consolidated rocks forming the Windy Hill zone. A small number of wells are located in another rock aquifer zone to the south and west of Windy Hill but distance, structural movements and dense rock components strongly suggest this area is separated from the Windy Hill rock aquifer system.

The unconsolidated alluvial aquifer wells are primarily in a relatively shallow, semi-confined to confined aquifer system. Four sources of alluvial material make up the area, but geologic re-working has to some extent molded the units into a single entity insofar as a groundwater source is concerned. In the study area, this fill mantle varies in thickness from 0 to in excess of 300 feet with more distinctive sorting and interbedding of clay, sand and gravel occurring in the sections further distant from the foothills. The Bonde Test Hole encountered consolidated rock at 323 feet and has been abandoned and sealed with concrete. Wells in the study area have been drilled from about 50 to 250 feet with screened sections at various depths.

The Windy Hill rock aquifer zone rocks have been subject to alteration, faulting and fracturing to the extent that permeable facies have been created within the rock mass. Wells in this aquifer are generally deeper and static levels are at lower depths than in the alluvial wells. Screen sections are mostly confined to the deeper or bottom levels penetrated.

The static water level has declined in a majority of the wells in the study area since the time the wells were drilled. The rock aquifer wells have indicated the greater changes. Evaluation of both rock and alluvial wells must include the increased number of wells in the last 10-20 years and subsequent higher withdrawal of groundwater as well as the lengthy drought. The greater static level declines in the rock aquifers under the prevailing conditions may be partially attributed to a more difficult recharging process than in the confined alluvial aquifer zone.

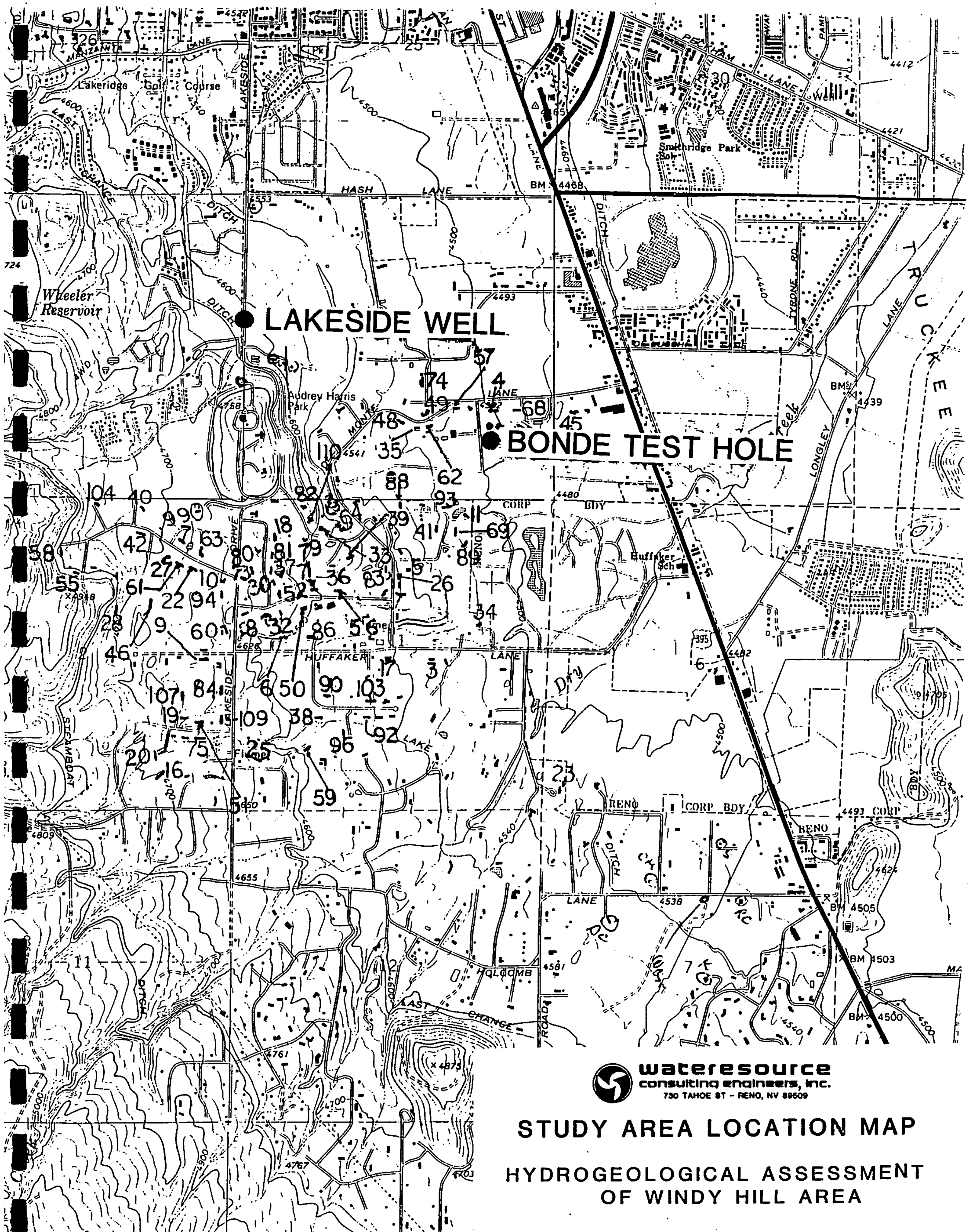
A number of rock aquifer wells in the proximity of the Lakeside Well and located in the Windy Hill rock zone have been monitored by Westpac. These observations have displayed a drop in static level in some of these wells during pumping periods of the Lakeside Well. These data indicate that some effect is produced on the wells monitored within the confines of the Windy Hill zone.

Observations to date strongly indicate limited transmittal of groundwater from the shallow, confined alluvial aquifer to the Windy Hill rock aquifer system. Static level decline could be expected from groundwater withdrawal by the large number of wells and certainly be compounded by the present drought. The estimated maximum pumping capacity of the domestic wells in the study area is approximately 4,250 gpm.

SECTION 1.0 - GENERAL

The study area (See Figure 1.1, Page 1-2) encompasses a zone approximately one and one half miles square in portions of Section 35 and 36, T19N, R19E, and Section 1 and 2, T18N, R19E, MDB&M. The study area focal point is Windy Hill extending outward a mile or so to the east and southeast and a similar distance south and southwest. In separating this relatively small area from the South Truckee Meadows Hydrographic Area, local complexities are emphasized suggesting, that within its bounds, they become quite intricate. As noted, the geological sequence displays consolidated rocks and four classifications of alluvial fill as well as several distinct faults. Conclusions and/or hypotheses proposed will attempt to interpret these conditions in relation to their cause and effect on the local ground water system.

Some 110 wells in the study area were considered for data gathering. Sixty-five owners were interviewed for available statistics on their wells. Forty-five were not contacted for various reasons or deleted during the survey. However, some information such as Driller's Logs, Owner and location was acquired. It is estimated that 50 to 60 additional wells may be in operation in the study area which were not evaluated during this



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STUDY AREA LOCATION MAP

HYDROGEOLOGICAL ASSESSMENT OF WINDY HILL AREA

FIGURE 1.1

survey. There are an estimated 160 to 170 domestic wells in the study area. The information gathered is incomplete on some wells where interviews were conducted. However, the sum of the material as well as the good distribution attained provide data for interpolation and subsequent means of concluding some issues regarding area groundwater (See Appendix A for Well Owner Interview Summary).

In the process of this data collection, it was noted that most well owners knew their well depth and static levels were measured wherever possible. In some cases, pumping rate or pump size was known. Pumping rates for the wells from information obtained from Owners appear to be in the range of 10 to 25 gpm, though several are 35-40 gpm, one at 55 gpm and one reported to be 100 gpm. Pumping drawdowns vary, with several reporting 8 to 12 feet while others indicated 40 to 60 feet.

Well depths ranged from 70 to 456 feet. However, a distinction must be made in that two different aquifers must be considered. Of the wells studied, drillers logs and location indicate that 14 wells on or near Windy Hill are in consolidated rocks entered at the surface or penetrated at fairly shallow depths. Two more wells about 1 1/2 mile southwesterly entered bedrock at 16 and 82 feet, respectively. Two more about 1 mile west of Lakeside are also in rock but not in the Windy Hill System. The balance of wells in the study area are constructed in alluvial fill. The rock aquifer wells on Windy Hill are from 190 to 456 feet in depth and display static water levels ranging from near 100 feet to more than 200 feet.

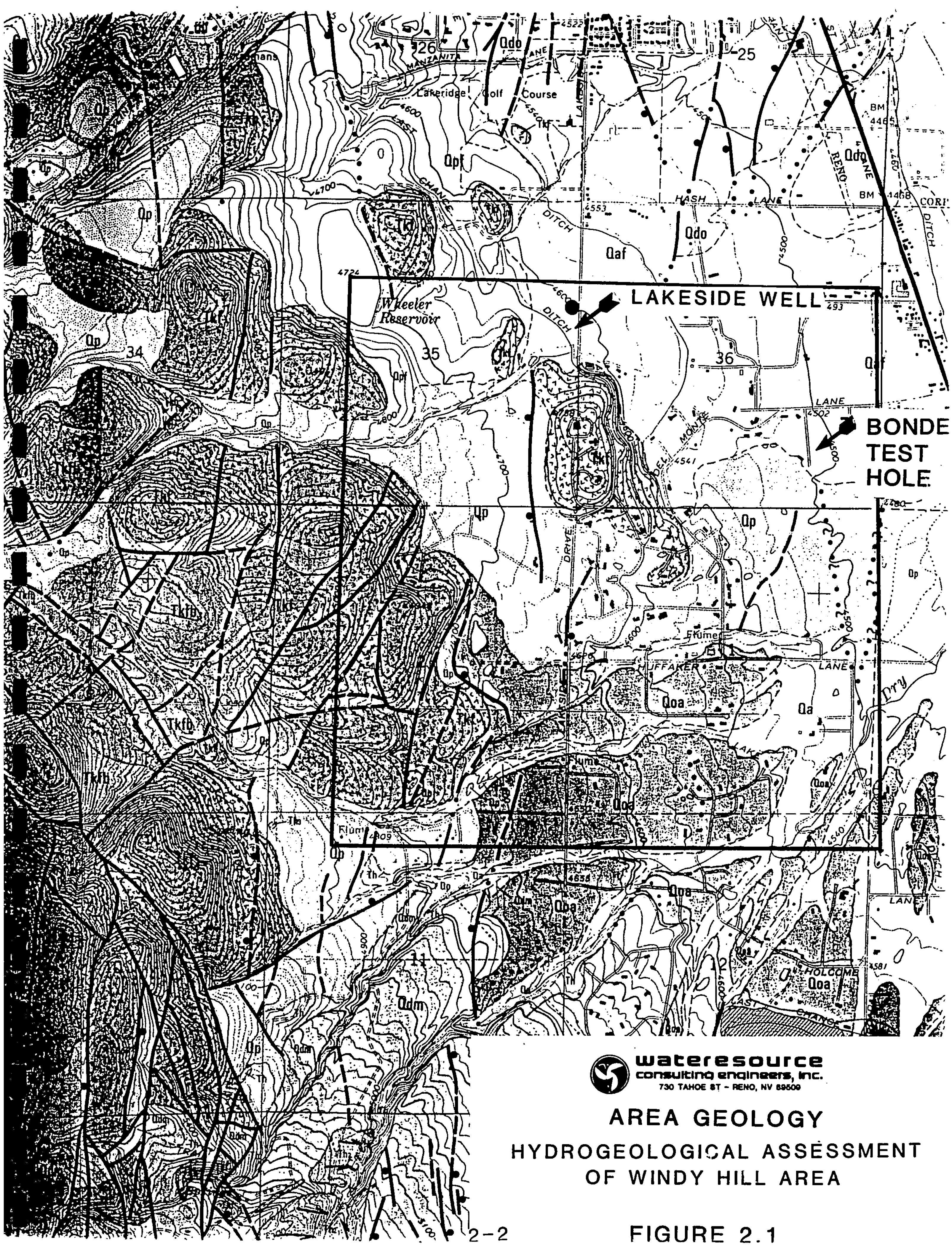
SECTION 2.0 - GEOLOGY

Rocks in the study area can be grouped into two general classifications, consolidated and unconsolidated rocks (See Figure 2.1, Page 2-2).

The consolidated rocks consist of members of the Kate Peak Formation (Tkf) of Miocene-Pliocene age. This series consists of flows, flow breccia, tuff breccia, mud flow breccia, agglomerate, volcanic conglomerate and associated intrusives ranging in composition from pyroxene andesite to rhyodacite. The formation includes intercalated sedimentary lenses of diatomite, shale, sandstone, conglomerate and waterlain tuff. Also present are locally differentiated plugs of hornblende-biotite andesite, dacite or rhyodacite porphyry characterized by conspicuous plagioclase phenocrysts.

The unconsolidated rock assemblage present consists of four members (See Figure 2.1, Page 2-2).

1. Alluvial bajada deposits (Qa). Thin sheet like aprons of fine to medium grained clayey sand and intercalated muddy, medium pebble gravel. Deposits of low gradient streams that have reworked older gravelly outwash and



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AREA GEOLOGY

HYDROGEOLOGICAL ASSESSMENT OF WINDY HILL AREA

FIGURE 2.1

alluvial fan deposits; weakly weathered and largely undissected. Little or no soil development (entisols).

2. Wisconsinan/Holocene upper Quaternary (Qaf). Windy Hill alluvial fan of locally derived silty to muddy, medium pebble gravel transported from the large Evans Creek drainage remnants of the Donner Lake Outwash. These deposits intertongue and become part of the alluvial bajada (Qa). Generally undissected but contains scattered remnants of older alluvium.

3. Wisconsinan middle to upper Quaternary (Qoa). Older alluvium, composed of highly dissected remnants of muddy, sandy, small pebble gravel in alluvial deposits transported from Thomas Creek.

4. Early Quaternary (Qp). Pediment gravel veneers of moderate to poorly sorted pebble to cobble gravel less than ten feet thick. Commonly occurs as gravelly sheet less than three feet thick over bedrock and older pediment and alluvial fan gravels; clast content dominantly volcanic.

These deposits are to varying degrees intertongued, reworked and resorted in localized areas. Sharply defined boundaries and/or limits of deposition are subject to lenient interpretation in both horizontal and vertical depositional parameters.

Structural control in the study area tends mainly to north-south trending normal faulting. These movements will be attended by localized subordinate parallel and cross faulting, cracking and inducement to weathering, bleaching and alteration by solution. The impact on the rocks, hosting a tectonic movement, by one or all these physical and/or chemical changes is a function of the displacement and width of the fault zone.

A detailed discussion of soil types are presented in Appendix B.

2.1 - Rock Aquifers

Igneous rocks such as granite, monzonite, diorite, gabbro, etc. as originally formed, generally do not have favorable characteristics for groundwater storage and transmission because they normally have low primary porosities and permeabilities. Jointing, fracturing, weathering and solution are factors that can enhance the primary permeability. Faulting and vertical displacement can take place producing significant widening of cracks. Rubble zones may develop in wide fractured areas and where vertical movement is extensive. Weathering can destroy the rock structure by alteration and remove less resistant minerals such as feldspars. Resistant minerals (Quartz, etc.) remain as a crumbly disaggregate mass which may increase porosity from 0 to as much as 10 to 30 percent.

Extrusive rocks such as andesite, rhyolite, latite, dacite, basalt and loosely consolidated volcanics such as ash, tuffs, aggregates, etc. can provide small to reasonably large volumes of water to wells. These rocks are more subject to jointing and parting planes due primarily to a more rapid cooling. Faulting, weathering and solution will also affect the rock structure. Basalt in particular may show high porosity by virtue of cracking during cooling, and may contain vesicles, empty lava tubes and alluvial sediments between flows. Other vesicular deposits such as scoria and siliceous sinter can also display a reasonable degree of porosity by virtue of their rock structure.

Metamorphic rocks are generally highly silicified, fairly hard and friable. External forces such as faulting and folding can cause extensive fracturing thus enhancing the capacity to transmit varying amounts of ground water. The rocks include slate, schist, gneiss and a considerable number of unidentified metamorphised volcanic rocks.

Rock aquifers can vary widely in their capacity to provide water. In most cases transmission is a function of the fracturing alteration, and in some cases, the dissolution of the rock. Where the fractures are narrow and interconnection is erratic, low yield and very slow recovery of water levels in wells after pumping can be expected. By the same token, recharge is restricted by the same condition that transmission suffers. This is probably the case in most rock aquifers unless they occur where faulting, weathering or solution has greatly enhanced the secondary porosity and permeability and thus, their ability to store and transmit water.

Porous rocks such as vesicular basalt, scoria, and sinter may produce large quantities of water. This production is a function of the volume of the rock members and its positioning to receive recharge. If confined, even though extensive, these rocks can, when pumped for an extended period of time, demonstrate low yields and slow recovery.

2.2 - Unconsolidated Aquifers

Unconsolidated aquifers begin with the initial weathering of the rocks into small particles. These particles can be transported by water first as sheetwash. The sheetwash will become channelized into small rills, rivulets, gullies and eventually into streams and rivers. The eroding capacity of overland flow will depend on the rate of precipitation and the length and steepness of the weathered slopes. Less sediment will be removed if the water can infiltrate the ground or flow over highly resistant bedrock or extensive vegetation cover.

Material is transported three ways by stream or river action, i.e. bedload, suspended load and in solution. Bedload is the coarser material moved along the channel bottom comprising about 10 to 50 percent of the load depending on stream gradient. Suspended load is that weathered material which the stream transports in suspension. The suspended material will consist of clay and loam to coarse sand, depending on the stream gradient. The dissolved material in solution is mainly calcium, magnesium, iron, chloride, sulfate and sodium ions. Upon reaching a lake or ocean or, should the flow be restricted, over saturation may be reached resulting in precipitation forming sedimentary rocks or, in the latter case, causing cementation of the unconsolidated deposits.

Ancient rivers or streams constantly worked to achieve equilibrium. These flows caused significant changes in the landscape in their effort to attain the conditions of equilibrium. All stream or river systems tend to extend their drainage areas upstream and occasionally downstream, cut down or build up the channel and widen their valley walls. These changes occur because streams are extremely sensitive to changes in sediment load, discharge gradient and velocity. Subsequently, continual adjustments are being made to accommodate the changes.

This flux is most significant in the formation of aquifers. Near the mountain bases, the alluvium and slope wash is poorly sorted and contains a high percentage of coarse material. As the detritus is moved by the several transportation means to streams with constant or more voluminous flow, a more consistent washing and sorting procedure can be effected. Though temporary and of rather wide range in time in the equilibrium procedure, deposits of well sorted gravel and sand can be deposited which will contain and transmit groundwater.

SECTION 3.0 - ROCK AQUIFER WELLS

Windy Hill is composed of rocks of the Kate Peak Formation primarily hornblende andesite and rhyolitic rocks which have been moderately to extensively bleached and altered as displayed on the road cuts on Lakeside Drive. On the south flank of Windy Hill an occurrence of sooty black colored dacite is exposed. To the northwest, in a road cut on Meadow Lane, a fresh rock of phaneritic texture is exposed composed of grey blue silica, plagioclase and some pyroxene. The western foothills display rhyolite porphyry featuring distinct plagioclase phenocrysts. Surface exposures display jointing, parting and cracking. Bleaching and alteration occur to some extent in the joints in some rock members and has penetrated the entire rock structure in others.

A north-south trending fault is mapped to the southwest of the Lakeside Well west of and adjacent to Windy Hill (See Figure 2.1, Page 2-2). Another partially concealed fault is inferred in the valley floor to the northeast of the Lakeside Well but may be of little or no influence insofar as the Lakeside Well is concerned. Faults can act as barriers to the movement of ground water or may enhance groundwater flow. Rock aquifers are more responsive to limited source or cone of depression boundaries by compact rocks or faults. In many cases, wells in formations such as Lakeside do not recover as rapidly as alluvial wells even though they have a fairly good yield.

The Lakeside Well is reported to have penetrated consolidated rocks for the depth interval of 170 to 400 feet noted as bleached andesite and altered rhyolite (Meador 1981). The mill slotted casing was installed from 180 to 400 feet indicating the aquifer is located in consolidated rock. From surface observation, the physical condition of the exposed rocks imply that the well is obtaining water from the south and probably through consolidated rock elements to the east and north. The source area to the west may be restricted by the present fault and hard rock outcrop exposed on Meadow Lane. Lakeside Well initiated production in May of 1985. Pumping rates from 1985-1990 range from 750 to 900 gpm and in 1991 from 700 to 760 gpm. Based on Westpac data, the Lakeside Well static level has shown a decline from 79.3 feet (4532), as measured on May 2, 1985 to 102 feet (4509) on July 16, 1991. As this well is lower in surface elevation (4,611 feet) than most of the domestic wells located to the south, which have been designated as rock aquifer type, and has been drilled to elevation 4211 feet with screened section from 4431 feet to 4211 feet, it is obviously screening the lower part of this rock aquifer.

Water level measurements were made at other wells located in the same rock aquifer as the Lakeside Well. The original Quilici Well, No. 64 (See Figure 1.1, Page 1-2), at 1655 Davis Lane had an estimated surface elevation of 4,600 feet and was drilled in 1964 to a depth of 78′ with a reported static level of 63 feet or elevation 4537 feet. A new well was drilled to replace Well #64 in

1988 to a depth of 173 feet or elevation 4427 feet. The water level in the new well at that time was 87 feet. In May, 1991, the static level was 95 feet or elevation 4505 feet. An observation well, located on the north side of Windy Hill, referenced in Section 5.0 of this report (Observation Well #2) was drilled in 1986 and had a recorded depth to water of 200 feet. The same well in 1991 recorded a measured depth of 203 feet. Westpac's Meadowridge Observation Well (located approximately 4,000 feet southwest of the Lakeside Well) had a depth to water of 76.0 feet on 7/1/83, 75.9 feet on 7/1/85 and 77.7 feet on 7/9/91. It is probable that other wells in the Windy Hill Study Area have had water level declines over the past several years, with the magnitude of decline being site specific.

Two wells are located at the west end of Faretto Lane about 1 mile west of Lakeside with surface elevations of approximately 4810 and 4790 feet (No. 55 and No. 58, See Figure 1.1, Page 1-2). One is reported drilled to 850 feet and has a static level of 123 feet or elevation 4687±. The other drilled to 220 feet has a static level at 123 feet or elevation 4667±. Well No. 58 reports de-watering in 30 to 40 minutes by running a 3/4 inch hose. Both of these wells are some distance west of the Windy Hill fault and, are suspect to being influenced by extensions of mapped faults in the immediate vicinity. The static levels as reported are considerably greater than the Lakeside and Windy Hill wells. On this basis, it would suggest that these two wells are in an entirely different aquifer system than the Lakeside-Windy Hill group and are subject to a separate set of conditions.

Aquifers in consolidated but fractured rock masses bounded to some extent by faulting and peripheral compact rocks may respond as one unified aquifer below the surface. Others may feature less permeable to non-permeable rock layers at varying depths isolating and creating distinctive aquifers. The latter condition is comparable to interbedded clay-sand-gravel deposits, creating a given number of aquifers which can normally be tapped individually at specified depths.

Recharge is also more difficult in rock aquifers as there is no evidence of an extensive rubble zone caused by major fault activity at or near the surface or in contact at depth with the alluvial deposits through which recharge may occur. Some recharge is no doubt entering the rock mass on its perimeter surfaces from the alluvium, but is probably restricted by the size of the cracks, possibly by clayey layers, clays carried by the water and clays from alteration products in the cracks. Some of the rock mass such as the altered and bleached material along Lakeside Drive demonstrates a weak porosity texture and may be able to contribute to the recharge. Also, it must be considered that the ground water movement in this instance is directed through the more transmissive alluvial deposits directing itself somewhat west to east thence north-easterly at a fairly steep gradient of up to 120 feet per mile.

It is concluded that all the water wells clustered in the Windy Hill rock aquifer area can be influenced by high pumping rates in one or more wells. Present drought years have not provided as much surface water as in normal years for recharge and may have contributed to the present situation. However, it is more the cause and effect inherent in rock aquifers of this type and the proliferation of closely spaced domestic wells that has accentuated the existing situation.

SECTION 4.0 - ALLUVIAL AQUIFER WELLS

The majority of the domestic wells in the study area are completed in the unconsolidated alluvial fill. These wells range in depth from 70 to 260 feet and display static levels from artesian flowing conditions to 40-50± feet below land surface.

The unconsolidated mantle in the study area displays thicknesses of 0 feet at the rock outcrops to 323 feet at the Bonde Test Hole near the east limit of the investigation. This shallow zone extends across the narrow east-west dimension of the valley to the Huffaker Hills.

The alluvial deposition process was limited to, and resulted in the shallow thickness of valley fill. The various stages of the deposits were somewhat intertongued and moderately re-worked during this process. This re-working process would tend to increase with the distance the outwash was moved from its origin to flatter areas where accumulation and channeling of water would become more effective. It would then be inferred that the different alluvial deposits would maintain more original integrity nearer the hills and become dispersed as extended into the valley floor. This would also suggest that better conditions for larger capacity wells may be expected at increased distance from the rock outcrops. This is apparent in what logs are available in this area. Wells drilled nearer the hills penetrate more coarse material mixed with clays and minimal sand and gravels. These aquifers are often erratic in both vertical positions, thickness and lateral extent. The Bonde Test Hole and wells at the east limit of the study area, display lithology of clay, sand and gravels in more selective interbedded deposition with coarser material mostly absent.

For the most part, these wells have tapped the shallow groundwater encountered in drilling from slightly under 100 feet to as much as 260 feet with the majority of wells in the 100 to 150 foot range. Surface elevations in the area of alluvial wells range from 4500 to 4700 feet. With this difference as well as wide variation and inconsistency in the well depths over the area, it is reflective of a system of weak unconfined and dispersed aquifers, displaying low transmissive characteristics and difficulty in determining and positioning the lithology. The surface slope south of Windy Hill in the study area and in the alluvial province drops about 200 feet easterly in one mile. The movement of groundwater is generally in the same direction. A mapped fault beginning near the southeast flank of Windy Hill trending southwesterly crosses Lakeside Drive near View Crest Drive and thence extends along Lakeside beyond Huffaker may exert influence on both groundwater movement and static levels in this area. Another fault, trending north-south from MillDrae Lane southerly to Huffaker may also affect the groundwater conditions in this area (See Figure 2.1, Page 2-2, for reference).

A review of the data collected in Appendix A indicates the erratic behavior in the alluvial wells in the study area. The static levels exhibit a lower elevation, overall in a west-east to northeast trend. It is interesting to note the artesian feature in Wells No. 9, No. 25, No. 75 and No. 84 (See Figure 1.1, Page 1-2). This may be caused by the fault occurring through the area north-south along Lakeside Drive.

From the information gathered (Appendix A), Table 4.1 was compiled (Page 4-4). From Table 4.1 it appears that pumping rates vary from about 10 to 40 gpm with exceptions at 55 and 100 gpm. Twenty to twenty-five gpm is a possible average rate. On the basis of 160 to 170 domestic and small irrigation wells, the total pumping rate capability of the domestic wells appears to be on the order of 4,250 gpm. In essence, what has been created in the area is a well field of rather closely spaced, shallow wells. Summer pumping is high with the rate of pumping varying with the time of use by individuals. A large number of the wells pumping simultaneously would be expected to affect the aquifer and cause a decline in static levels and increase interference drawdown between wells. During pumping, each well will create its own cone of depression around the well. The individual cones of depression will expand

TABLE 4.1

ALLUVIAL WELL CHARACTERISTICS

WELL NO.	PUMP/ PUMPING RATE	PUMP SETTING(FT)	PUMPING DRAW DOWN(FT)	SPECIFIC CAPACITY (gpm/ft) DRAWDOWN
7	18 GPM	90	?	?
10	10 GPM	45	8	1.25
16	27 GPM	175	?	?
18	10 GPM	163	144	0.07
27	10/12 GPM(PUMP)	?	?	?
36	18 GPM (2 HRS)	135	42	0.43
37(LOWER)	8/10 GPM	75	0	?
41	100 GPM (PUMP)	?	?	?
42	22 GPM	?	?	?
46	20 GPM (PUMP)	130	?	?
48	10 1/2 GPM	63	63	0.17
50	55 GPM (PUMP)	100	?	?
52	20 GPM	163	60	0.33
57	30 GPM (4 HRS)	80	60	0.50
64	37.5 GPM (1 HR)	163	8''	?
68	40 GPM	?	80	0.50
71	10/15 GPM (1 HR)	169/189?	71	0.21
79	20 GPM (PUMP)	152	?	?
83	25 GPM (2 HRS)	105	47	0.53
88	38 GPM (PUMP)	105	49	0.78
94	35 GPM	100	55	0.64
99	40 GPM (1987)			
	5 GPM (2 MIN) 1991	210	210	?
107	22 GPM (PUMP)	135	?	?
109	40 GPM (40 MIN)	115	11	3.64

and overlap to create a regional cone of depression. In the study area, where there are many closely placed wells, this condition can readily occur on a local scale. See Figure 4.1 and 4.2 (Pages 4-6 and 4-7 for domestic well locations and estimated growth between 1979 and 1987.

Table 4.1 suggests that the transmission capability of the alluvial formation, as indicated by the specific capacity, is low. This condition will cause increased drawdowns in the alluvial aquifer. As pumping is increased (resulting from the growth of domestic wells in the Study Area) this condition will be exacerbated.

The Bonde Test Hole was drilled to obtain information on the thickness and position of the various geologic formations and to obtain water samples at selected depth intervals. As a result, the pumping time was limited and the pumping rate restricted. No monitoring of nearby wells was done as any data gathered would be short term and inconclusive. This test hole has been abandoned and plugged with cement grout.

Recharge in the area is primarily from leakage in the Lake, Last Chance, Steamboat and smaller ditches, precipitation in the alluvial contact zone and irrigation of pasture and some crops. Direct recharge from weather induced moisture has declined during the recent drought years contributing to well water level declines.

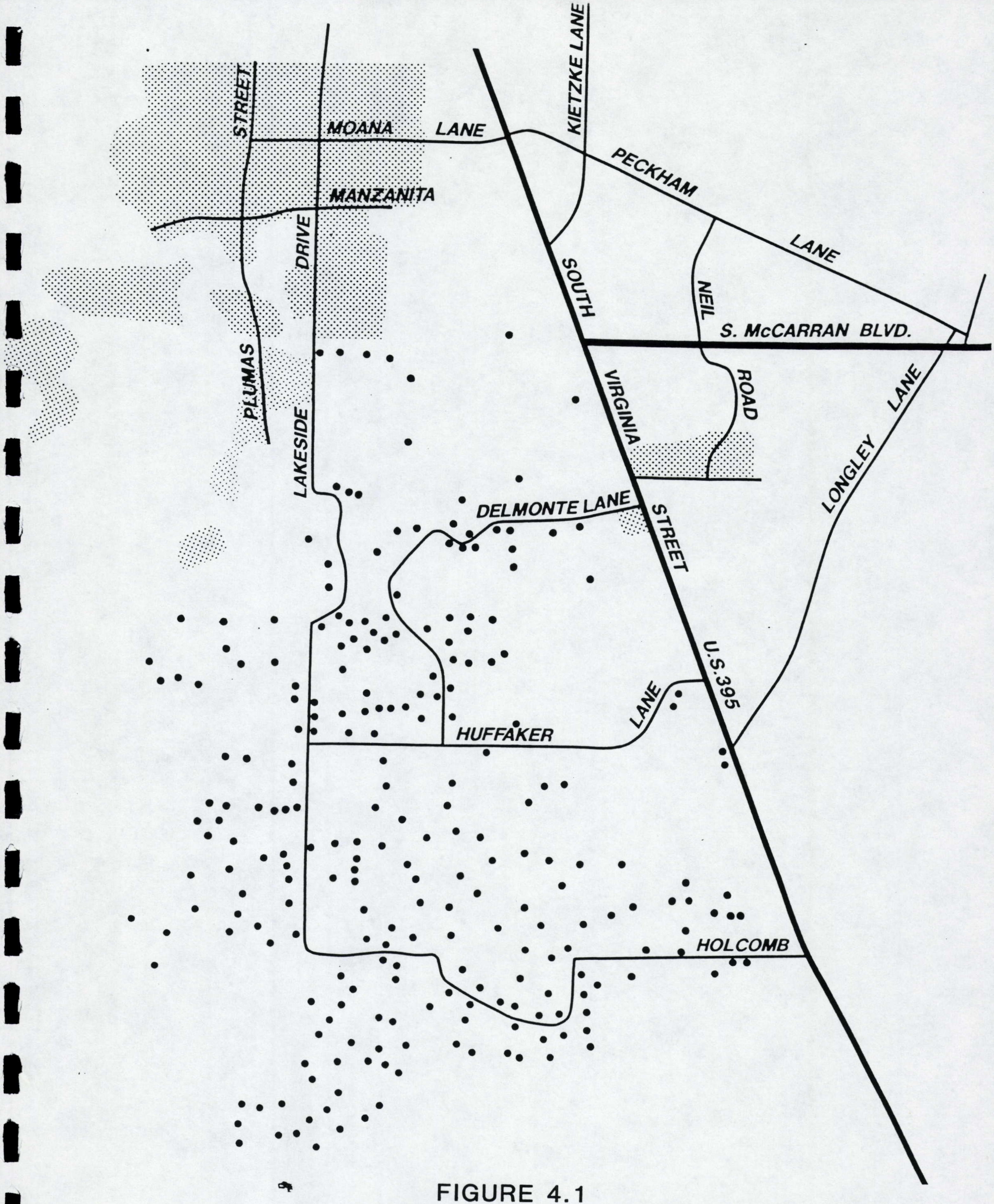


FIGURE 4.1

PRIVATE DOMESTIC WELLS, AUG. 1979
(estimated via air photography) by: WESTPAC

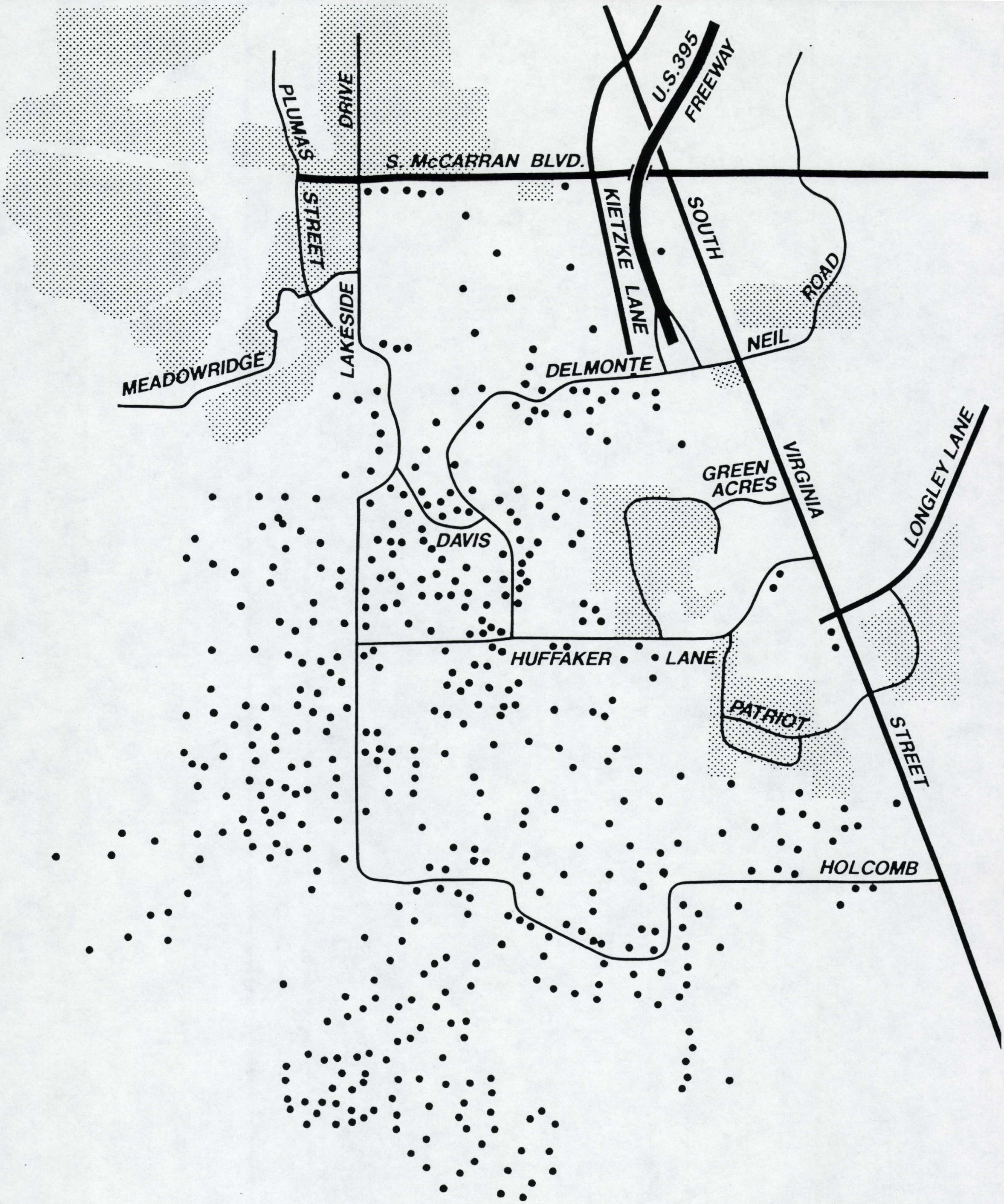


FIGURE 4.2

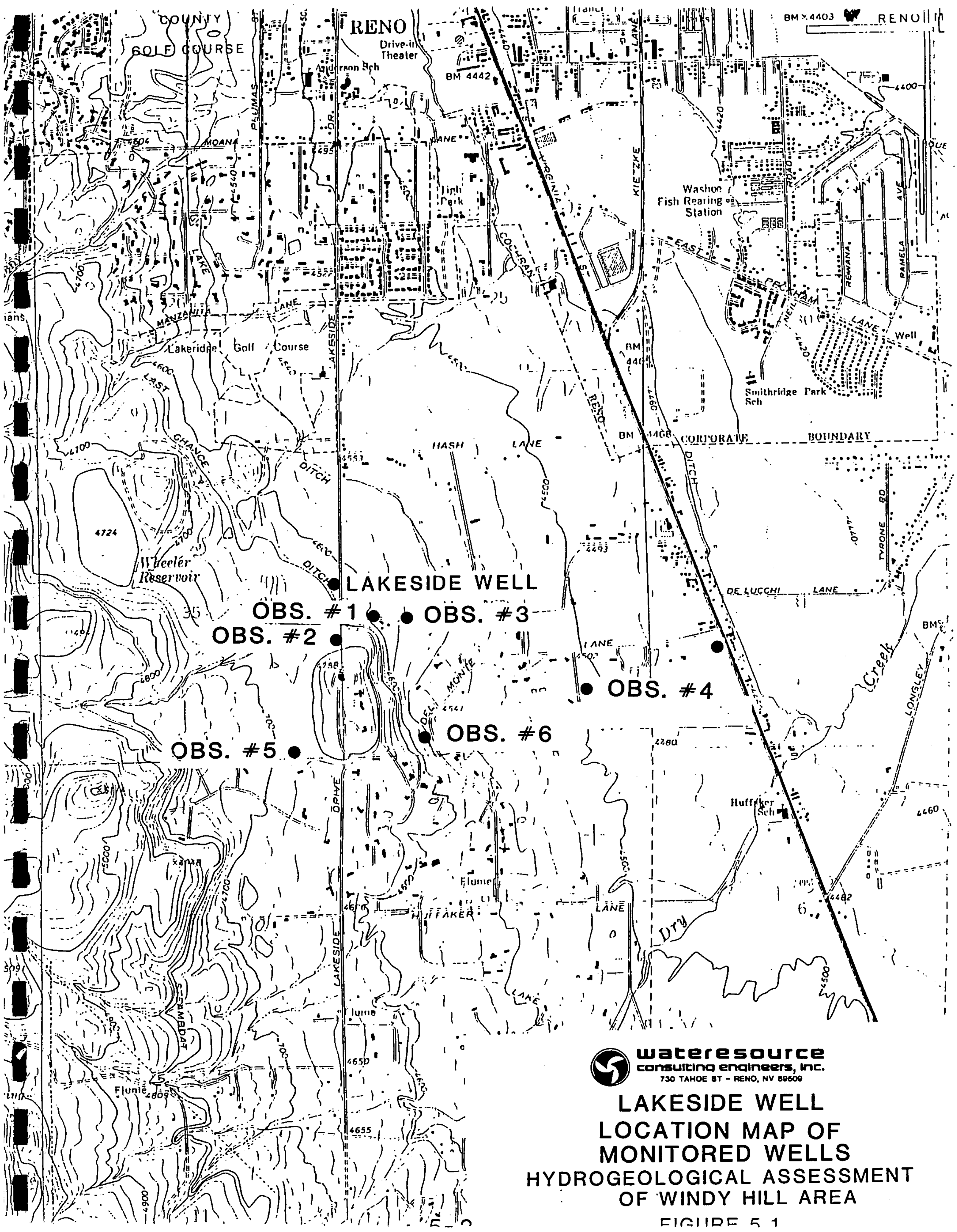
PRIVATE DOMESTIC WELLS, SEPT. 1987
(estimated via air photography) by:WESTPAC

SECTION 5.0 - LAKESIDE WELL MONITORING (by WESTPAC)

In addition to the efforts of Wateresource Consulting Engineers, Inc., described in Sections 1.0, 2.0, 3.0, 4.0 and 6.0 of this report, Westpac Utilities conducted water level monitoring for the collection of data beginning April 15, 1991. The first phase monitored wells adjacent to the Lakeside Production Well from April 15 to June 15, 1991. Figure 5.1, Page 5-2 identifies the location of Westpac's Lakeside Well and the observation wells which were monitored.

Observation Well No. 1 (OBS-1), located approximately 900 feet southeast of the Lakeside Well, was not pumped during the monitoring. Observation Well No. 2 (OBS-2), located 1,200 feet south of the Lakeside Well, was not pumped during monitoring. Observation Well No. 3 (OBS-3), located approximately 1,500 feet southeast of the Lakeside Well, experienced minor domestic use during monitoring.

Data collected during the first phase of monitoring are presented in Table 5.1, Page 5-3. Groundwater data indicate some similarities between the Lakeside, OBS-1 and OBS-2 wells. The OBS-3 Well appears to be in a different aquifer since groundwater levels in it were consistently 50-60 feet higher in elevation than



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LAKESIDE WELL
LOCATION MAP OF
MONITORED WELLS
HYDROGEOLOGICAL ASSESSMENT
OF WINDY HILL AREA
FIGURE 5.1

TABLE 5.1

WESTPAC'S PHASE 1 GROUNDWATER DATA

WELL	DATE	GROUNDWATER ELEVATION
LAKESIDE	4/17/91	4483.32*
2	4/19/91	4466.80
1	4/23/91	4494.30
2	4/23/91	4466.10
3	4/23/91	4545.30
LAKESIDE	4/24/91	4482.32*
2	4/29/91	4466.30
LAKESIDE	4/29/91	4481.22
1	4/29/91	4492.70
3	4/29/91	4544.50
LAKESIDE	5/04/91	4481.22*
LAKESIDE	5/09/91	4482.02*
2	5/09/91	4465.20
LAKESIDE	5/13/91	4495.92
2	5/13/91	4468.10
LAKESIDE	5/20/91	4498.67
2	5/20/91	4470.95
LAKESIDE	5/28/91	4500.72
2	5/28/91	4472.95
1	5/28/91	4501.60
3	5/28/91	4561.10
LAKESIDE	6/06/91	4503.99
2	6/06/91	4476.50
1	6/06/91	4505.10
LAKESIDE	6/11/91	4505.22
2	6/11/91	4477.50
1	6/11/91	4505.95
LAKESIDE	6/13/91	4492.82*
2	6/13/91	4477.45
1	6/13/91	4505.50
3	6/13/91	4564.50
LAKESIDE	6/14/91	4505.77
2	6/14/91	4478.23
1	6/14/91	4506.95

* Well was pumping

in neighboring wells. During the period of pumping of the Lakeside Well from mid April to early May only a small amount of water level decline occurred in OBS-2 Well. Following termination of pumpage from the Lakeside Well, all the nearby monitored wells showed a rise in static groundwater levels of 10-20 feet. Because pumping ceased shortly after the start of irrigation season, some of this recovery may be due to recharge from ditch flows and irrigation. Additional ongoing study by Westpac will investigate these effects. Figure 5.2, Page 5-5, shows these collected groundwater data and their relationships.

A second phase of monitoring was conducted to respond to concerns expressed by homeowners located near Bonde Lane and in an area enclosed by a one-mile diameter circle centered at Lakeside Drive and Huffaker Lane intersection. This phase of monitoring began on June 19 and continued to July 12, 1991. Wells monitored included the Lakeside Well, OBS-1 Well, OBS-2 Well, the New Hope Church Well (OBS-4), located on Bonde Lane approximately 4,800 feet southeast of the Lakeside Well, Mr. David Pugh's Residential Well (OBS-5), located approximately 3,300 feet south of the Lakeside Well, and Dr. Gregory's Residential Well (OBS-6), located approximately 3,500 feet southeast of the Lakeside Well (See Figure 5.1, Page 5-2 for locations). Water level measurements obtained during this period are listed on Table 5.2, Page 5-6 graphically presented in Figure 5.3, Page 5.7.

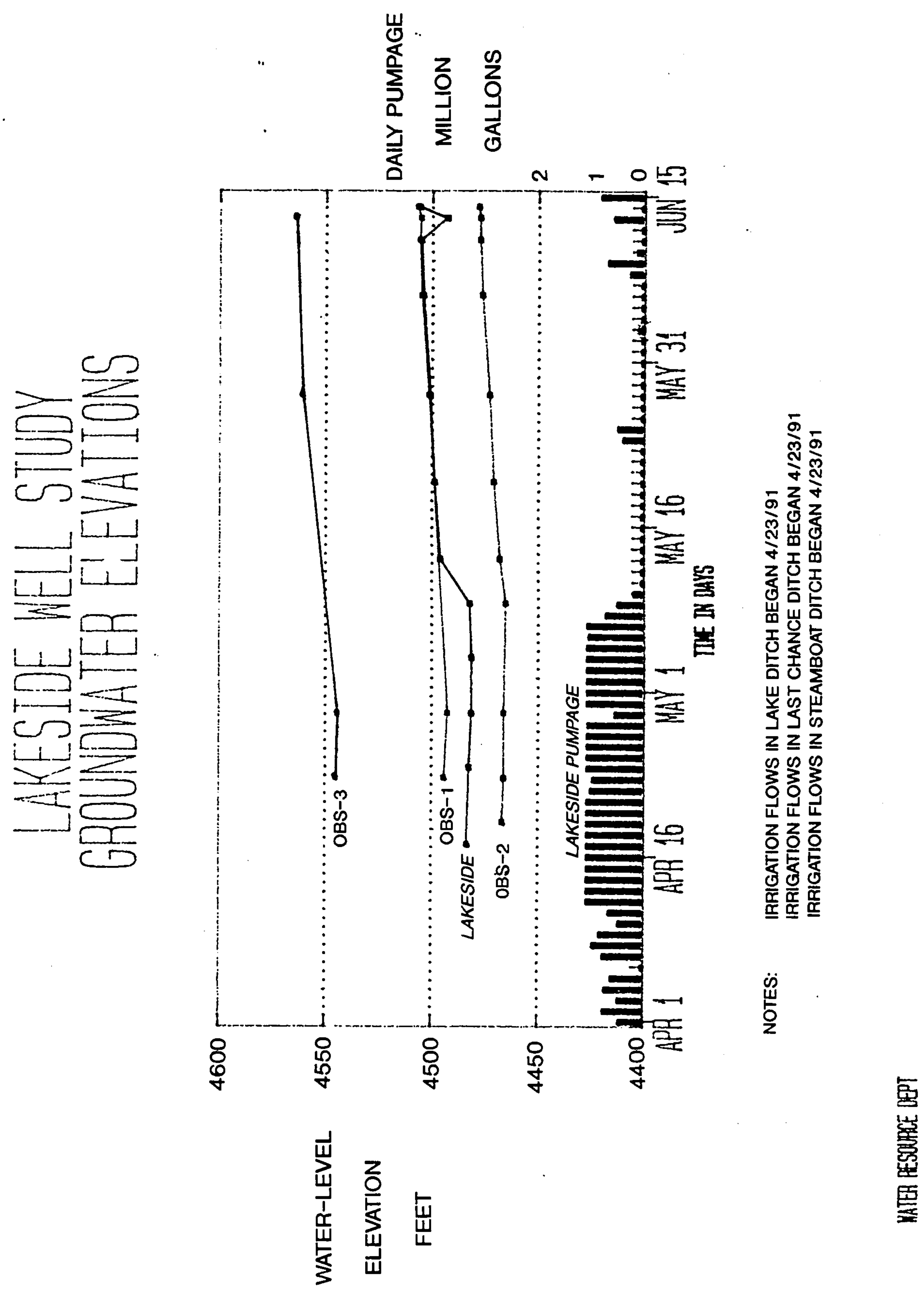

FIGURE 5.2 — Westpac's Phase 1 Groundwater Data

TABLE 5.2
WESTPAC'S PHASE 2 GROUNDWATER DATA

WELL	DATE	GROUNDWATER ELEVATION
LAKESIDE	6/19/91	4507.04
2	6/19/91	4479.40
1	6/19/91	4507.93
4	6/19/91	4490.90
5	6/19/91	4506.25
6	6/19/91	4522.43
LAKESIDE	6/21/91	4494.16*
2	6/21/91	4478.42
1	6/21/91	4506.75
4	6/21/91	4491.08
5	6/21/91	4504.20**
6	6/21/91	4522.60
LAKESIDE	6/24/91	4492.70*
2	6/24/91	4477.34
1	6/24/91	4505.77
4	6/24/91	4491.13
5	6/24/91	4506.15
6	6/24/91	4522.96
LAKESIDE	6/27/91	4492.90*
2	6/29/91	4476.96
1	6/29/91	4505.40
4	6/29/91	4491.57
5	6/29/91	4506.43
6	6/29/91	4523.27
LAKESIDE	7/01/91	4505.11
2	7/01/91	4477.22
1	7/01/91	4506.07
4	7/01/91	4492.83
5	7/01/91	4505.81
6	7/01/91	4523.44
LAKESIDE	7/08/91	4507.25
2	7/08/91	4479.65
1	7/08/91	4508.35
4	7/08/91	4491.64
5	7/08/91	4507.65
6	7/08/91	4523.90
LAKESIDE	7/09/91	4508.16
LAKESIDE	7/12/91	4495.04*
2	7/12/91	4479.30
1	7/12/91	4507.70
4	7/12/91	4492.62
5	7/12/91	4508.77
6	7/12/91	4523.95

* Well was pumping
** Well was recently pumped

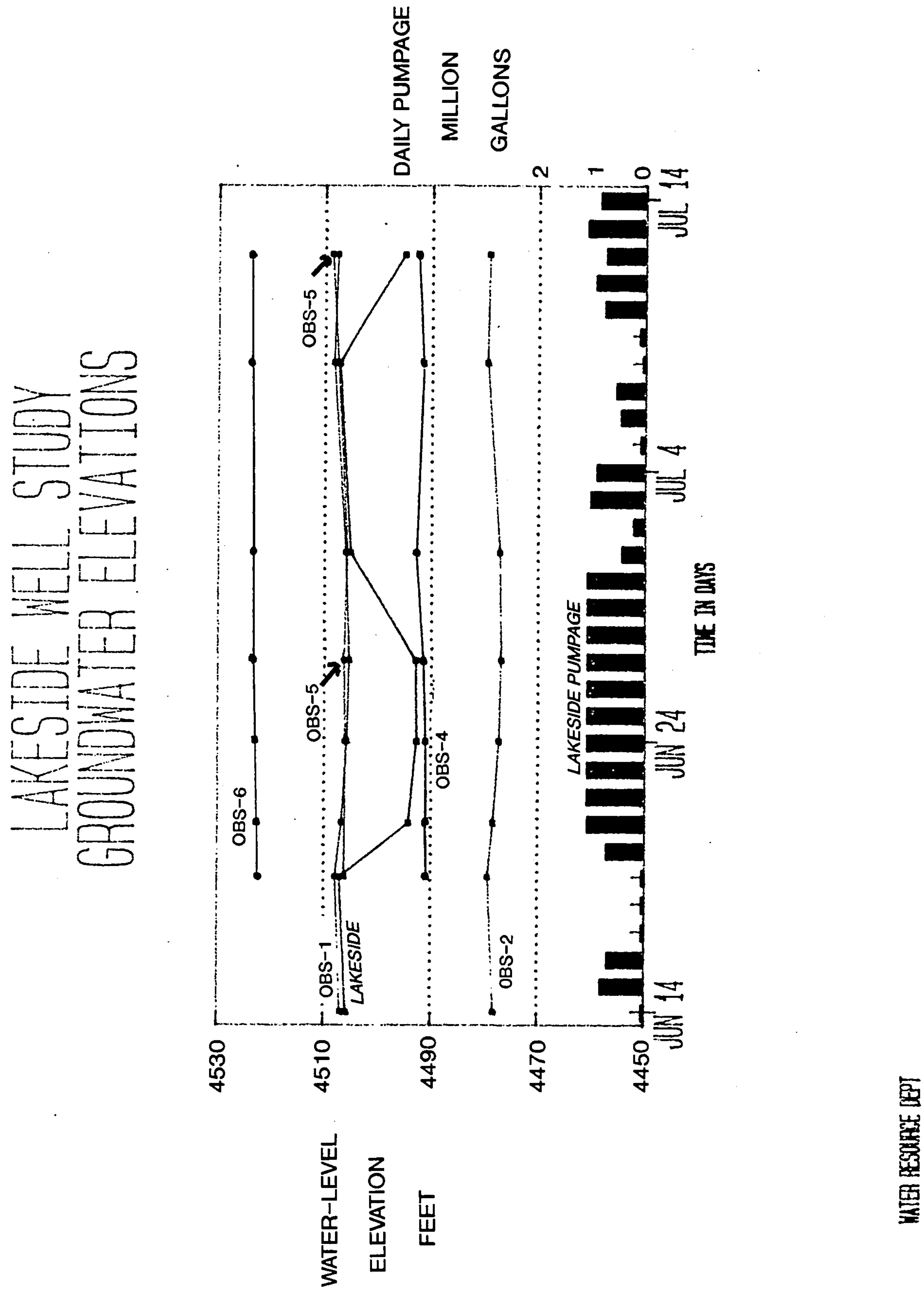

FIGURE 5.3 -- Westpac's Phase 2 Groundwater Data

The Phase 2 data indicate a groundwater decline during the Lakeside Well pumpage of about 2.5 feet at Observation Wells No. 1 and 2. No effect was observed at Mr. Pugh's Well, Dr. Gregory's Well and the New Hope Church Well. Conversation with the Owner of a well located 2,100 feet north of the Lakeside Well indicated they have not been negatively influenced over the years by the Lakeside Well.

In order to collect additional data in the area closest to the Lakeside Well, Westpac Utilities has contacted well owners located on Windy Hill for permission to access and measure water levels in their wells. Periodic monitoring will then be scheduled to further define the Lakeside Well influence.

SECTION 6.0 - CONCLUSIONS

1. In the study area there are two distinct aquifer types; rock and unconsolidated alluvium. All indications strongly suggest very limited interaction between the two systems.

2. The Lakeside Well located in the Windy Hill rock aquifer can exert an influence on other nearby wells within the confines of that aquifer.

3. Rock aquifer wells located to the west and south of the Windy Hill zone are isolated from Windy Hill by faulting and rock structure and appear to have minimal interconnection with the alluvial system or Windy Hill system.

4. The alluvial wells may be loosely defined by the surface soil development. The deposition occurred at relatively shallow depths and in a confined area, which encouraged intertongueing, dispersing and some reworking of the outwash. This process has blended these deposits into an undefined system of aquifers. Drill cutting samples, except in the eastern limits of the study area where sorting and re-working is more evident, suggest little lithologic variation. Re-working and sorting resulting in improved classification, deposition and interbedding of clays, sand and

gravel with minimal or absent coarse material is evident in the Bonde Test Hole. The fill mantle is relatively thin near the mountains and increases in depth toward the valley floor. The Bonde Test Hole at the east extent of the study area entered consolidated rock at 323 feet. The only effect of faulting in the alluvial area is in evidence where a mapped movement runs near or parallel to Lakeside Drive south of Windy Hill. This faulting is very possibly the influence creating a group of flowing wells in this area.

5. The Well Owner Interview Summary (see Appendix A) indicates that water levels in the Study Area domestic wells have generally declined over time. Considering all Study Area wells as a group, they have an estimated combined maximum pumping capacity on the order of 4,250 gpm. Pumping from these wells has influenced the groundwater supply in the Study Area, causing these general water level declines. These impacts on the Study Area have been emphasized over the past several years due to the increase in the number of domestic wells and the resulting increase in pumpage in the Study Area and probably the extended drought.

6. The information and data evaluated to this point in time suggest that the only aquifer directly influenced by the Lakeside Well is the Windy Hill Rock Aquifer.

REFERENCES

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William F. Guyton Associates, Inc. Report on Sierra Pacific Power Company Lakeridge Well, 1984.

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William F. Guyton Associates, Inc. Report on Groundwater Availability in the South Truckee Meadows Area, Washoe County Nevada, 1986.

APPENDIX A

Well Owner Interview

Summary

APPENDIX B

Soils

APPENDIX B

SOILS

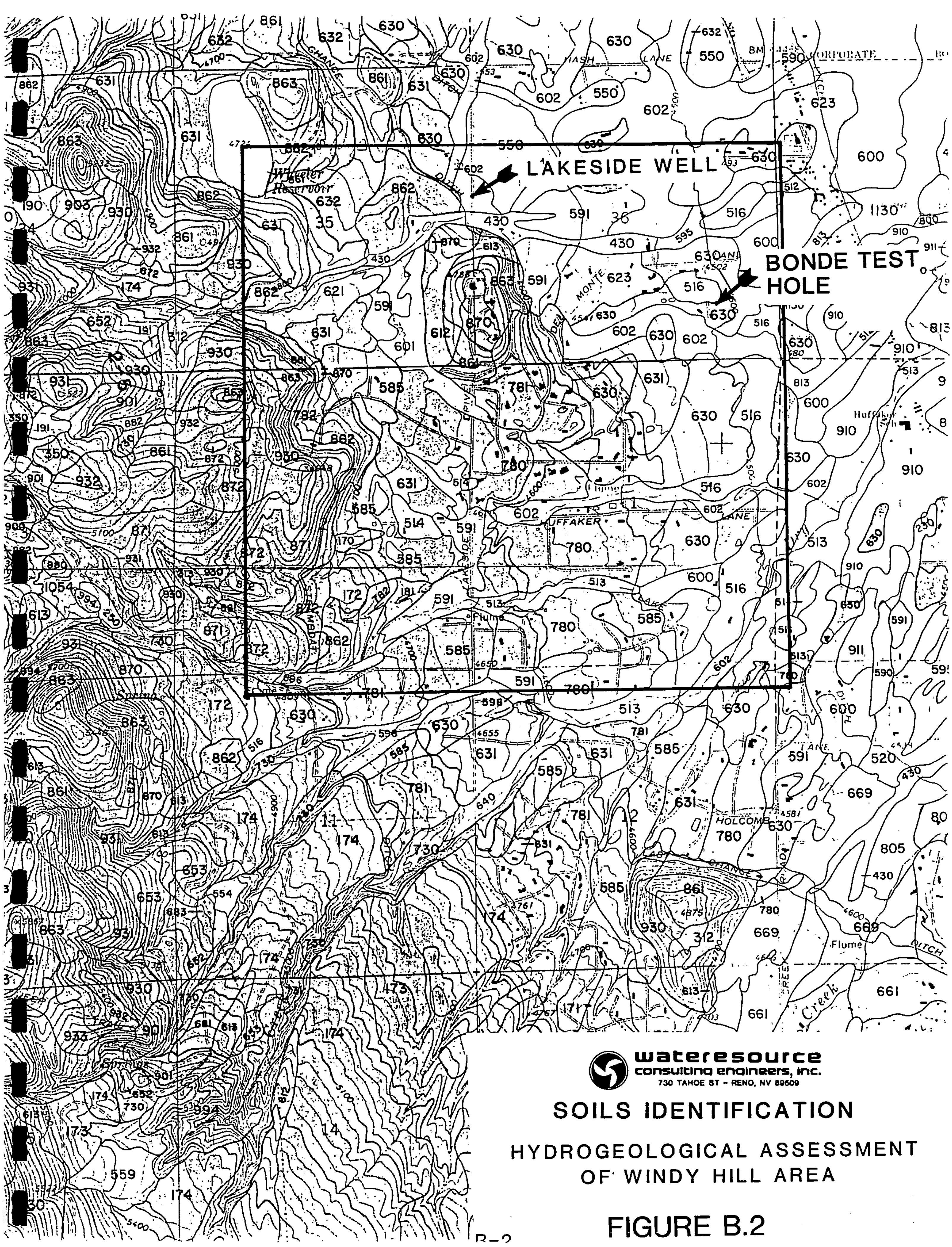
In the study area some 19 soil types are noted. Each soil delineation may contain small areas of soil(s) different from those shown. Soil names are subject to revision based on future correlations. Soils identified are as follows: (See Figure B.1, Page B-2).

A. Poor and poorly drained soils on flood plains and low terraces.

1. 430 Sagouspe Variant, loamy very fine sand.
2. 513 James Canyon notus complex.
3. 514 James Canyon sandy clay loam, 2-4% slopes.
4. 516 James Canyon very fine sandy loam, overwash 0-2% slopes.
5. 601 Idlewild sandy loam, drained.
6. 602 Idlewild gravelly sandy loam.

B. Very deep soils with coarse to medium textured subsoil on alluvial fans, terraces, scarps, land slides and glacier deposits.

1. 591 Springmeyer stony loam, 2-4% slopes.



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SOILS IDENTIFICATION

HYDROGEOLOGICAL ASSESSMENT OF WINDY HILL AREA

FIGURE B.2

2. 621 Orr stony sandy loam, 4-8% slopes.

C. Moderately deep to deep soils with moderate fine to fine textured subsoils on alluvial fans, terraces and pediments over hardpan and bedrock.

1. 585 Barnard stony sandy loam, 2-4% slopes.
2. 612 Verdico very stony sandy loam, 4-8% slopes.
3. 613 Verdico extremely stony sandy loam, 8-15% slopes.
4. 630 Fleishmann gravelly clayey loam, 2-4% slopes.
5. 631 Fleishmann gravelly clayey loam, 4-8% slopes.

D. Shallow soils on alluvial fans terraces, pediment and scarps over hardpan or bedrock.

1. 780 Bieber stony sandy loam, 0-2% slopes.
2. 781 Bieber stony sandy loam, 2-4% slopes.

E. Shallow soils with moderate coarse to fine textured subsoils over bedrock.

1. 861 Reywat extremely stony loam, 15-30% slopes.
2. 862 Reywat very cobbly sandy loam, 8-15% slopes.
3. 863 Reywat rock outcrop complex.
4. 870 Xman rock outcrop complex, 4-15% slopes.

Soils Comparison on the Unconsolidated Deposits

A moderate difference in soil development is suggested on the various unconsolidated deposits present.

The Qa classification is primarily types 516 and 602. The Qaf deposits consist mainly of types 430, 591 and 623 with small areas of 516 and 630 included. The Qoa area is principally types 585 and 780. Qp is composed of types 585,630, 631, 780 and 781 with minor areas of 591, 601 and 621. The areas where consolidated rocks outcrop or are very near the surface display types 612, 613, 781, 861, 862 and 870.

Since the general topography has not greatly changed for a considerable span of time, the sources of material and outwash deposition patterns become relatively repetitive. As the alluvial deposits intertongue during the extended depositional periods and become interspersed by either continual or periodic washing, sorting, colian, laceustrine and, to a degree, faulting the present surface may be considered a continuation of this process. The materials derived from the consolidated masses contributing to the outwash are mainly clay, silt, sand, gravel, cobbles and boulders.

APPENDIX C

Well and Pump Efficiency

APPENDIX C

Well and Pump Efficiency Excerpts from
Improving Well and Pumping Efficiency
by Otto J. Hekueg, Verne H. Scott and Joseph C. Scalmann

Increasing the efficiency of wells and pumps can substantially combat rising costs and conserve precious energy and fuel. Municipalities, urban water districts, and other water users who are dependent on wells and pumps are acutely aware of increasing operating costs. Because energy demands for pumping may account for 60 to 70 percent of their costs, improved well and pump efficiencies are essential and should be a high-priority item.

The efficiencies of the various components of groundwater supply systems are important because they directly affect the consumption of energy and the cost of pumping. Operating efficiency can be optimized and controlled via good design and operation and maintenance techniques.

The performance of a groundwater supply system is governed by four principal components; (1) an aquifer system that yields water, (2) the well that collects and conducts water, (3) the pumping equipment that lifts the water from the well and supplies the energy to deliver the water to a point of application or other use, and (4) the distribution system.

Efficiency is generally defined as a ratio of the output work done by a mechanical device to the input energy consumed and is usually expressed as a percentage. There are several areas of efficiency related to the consumption of energy for pumping groundwater. They include efficiency of the pump, and electric motor, the drive system, the hydraulic system (pipes, shafts, tubes) between the pump intake and discharge; and the electrical system.

Pump efficiency is derived from a comparison of actual water horsepower to theoretical input horsepower based on laboratory tests. It is influenced by hydraulic and mechanical losses of the pump unit that result from the manufacturer's design and manufacturing procedures. Motor efficiency is dependent on the type of driver used to rotate the pump shaft. Drive efficiency accounts for the effectiveness of the motor to transmit its power to the shaft, such as through a direct-connected drive or a right-angle gear drive. Hydraulic efficiency is determined by the reduction in energy at the pump unit caused by hydraulic losses that occur when water flows from the pump unit throughout the pump column and to the pump discharge. Hydraulic losses can be calculated or determined from tables. Electrical efficiency applies to the use of an electric motor and accounts for the relatively small losses of transmitting electrical power through the leads and starter that serve the pump. A voltage meter can be used to measure this loss, if appreciable.

Well efficiency is a measure of the effectiveness of a well in extracting water from an aquifer.

Reduced efficiency and increased energy usage can be associated with characteristics of the aquifer, well and pumping equipment. Details concerning factors for each of these follow.

Aquifer Characteristics

Aquifer characteristics set practical limits on the ability of formations to yield water to wells and affect well-design and pump-selection parameters. Aquifer characteristics also set limits on the drawdown that will be caused by pumping, the specific capacity of the well and the well spacing needed to minimize interference effects.

The principal aquifer characteristics are (1) the size, uniformity and arrangement of mineral grains, which affect the permeability and storage of groundwater; (2) thickness and permeability, which affect transmissivity (a characteristic measure of an aquifer's ability to transmit water); (3) the presence of confining beds, which affect the storage coefficient and the design of a well's intake structure and the performance of the aquifer under pumping conditions; (4) the degree of consolidation of the formation, which affects the selection of well-casing and screen materials; and (5) the chemical composition of formation materials and groundwater, which affects the potential for encrustation and corrosion in wells.

Although aquifer characteristics significantly affect both the design and performance of groundwater supply systems, they are not controllable. They reflect natural conditions and are constraints within which wells and pumping equipment must be designed and operated.

Well Characteristics

The majority characteristics of a well that affect its ultimate performance and efficiency are the drilling method, the water intake section and its design and placement, the gravel pack and its design and placement, and well development. Other factors, such as sand pumping, encrustation, and corrosion, also have an impact on the performance of a well during its operation life. For a new installation, all of these must be considered carefully in the initial design.

The efficiency and effectiveness of the well intake section is largely dependent on its design, which is in turn dependent on the accuracy of the formation samples gathered during the drilling process.

A properly designed intake section ensures efficient and sand-free well operation. The principal factors affecting the design and performance of the intake section are open area, slot size and shape, length, diameter, entrance velocity and transmitting capacity, and material.

The selection of proper slot size for effective sand control is well documents. Whether a well is to be naturally developed or gravel packed, the screen slot openings are designed to retain a certain percentage of aquifer materials.

Well inefficiency is often related to the selection of gravel-pack size. If the gravel-pack particles are too large in relation to the aquifer materials, small particles from the formation can migrate into the well and cause excessive sand pumping. conversely, a gravel envelope that is too fine in relation to the aquifer materials will be relatively impermeable to the potential flow from the aquifer and will result in an inefficient well.

Another cause of inefficiency in gravel-packed wells is excessive thickness of pack materials. Although well efficiency improvements with increased thickness of the pack, effectiveness of development decreases.

The development of a well at the end of the construction process is essential to well efficiency. Lack of development is a major cause of well inefficiency and prevents maximum utilization of many aquifers tapped by irrigation and municipal wells, which results in the owners paying extra thousands of dollars each year.

Well development serves three major purposes. First, it minimizes the formation damage incurred during drilling and reduces clogging of the aquifer. Second, it increases the porosity and permeability of the formation near the well by removing fine particles. Third, it stabilizes the aquifer or gravel-pack materials around the well by causing the natural formation or pack to settle against the screen.

Well Operation

Factors that can affect the performance of a well and its pumping equipment during their operation life include encrustation, corrosion and sand pumping.

Encrustation is caused by calcium and magnesium carbonates (scale), iron and manganese hydroxide and oxides, iron bacteria or other slimes, and the deposition of clay and silt on the openings of a well intake section. Any of these can plug screens or perforation, thereby reducing open area and well efficiency. Pore spaces in the aquifer materials or gravel pack immediately adjacent to the intake section can also be clogged, reducing permeability near the well bore.

Corrosion is an electrochemical action exerted on metals that causes their gradual destruction. In a well, corrosion can attack the metal intake section, the casing, and the pump. Corrosion of only a few thousandths of an inch of metal from the screen openings can permit the entrance of excessive sand. Flow through the slot openings continually sweeps away corrosion products, thus contributing to a continuing corrosion rate. Corrosion substantially reduces the useful lift of a well because sand pumping affects the lift and performance of the other system components.

Sand pumping is a major problem that affects the performance of the entire system. Sand particles moving through the system abrade pump bowls and impellers, distribution pipes and other components, reducing their useful life and increasing maintenance costs. If sufficient sand is deposited in the bottom of the well to begin to fill the intake section, the deposits may have to be removed, adding to maintenance costs.

APPENDIX D

Westpac Utilities'
South Truckee Meadows
Production Well Static
Groundwater Elevations

APPENDIX D

WESTPAC UTILITIES' SOUTH TRUCKEE MEADOWS
PRODUCTION WELL STATIC GROUNDWATER ELEVATIONS

(This appendix was added at the request of the South Truckee Meadows Citizens Advisory Board.)

1.0 SOUTH VIRGINIA STREET WELL

Westpac's South Virginia Street Well was permitted on November 14, 1968 (See Figure D.1 for all South Truckee Meadows Production Well locations). The certificated water right for this well is #24758. The annual duty for the well is 1,614 acre feet. Ground elevation of the well is 4460.66 feet. The static water levels listed below are calculated by subtracting a measured depth to water from the ground elevation.

DATE	GROUNDWATER ELEVATION
1973	4448
1975	4454
1977	4440
1979	4436
1981	4454
3/2/83	4444.96
3/1/84	4452.57
1/31/86	4452.66
3/2/87	4451.54
11/30/88	4452.18
2/2/89	4448.49
1/8/90	4445.69
7/9/91	4438.91

2.0 DELUCCHI LANE WELL

Westpac's Delucchi Lane Well was permitted on March 10, 1971. The certificated water right for this well is #8811. The annual duty for the well is 803.5 acre feet. Ground elevation of the well is 4454.61 feet. The static water levels listed

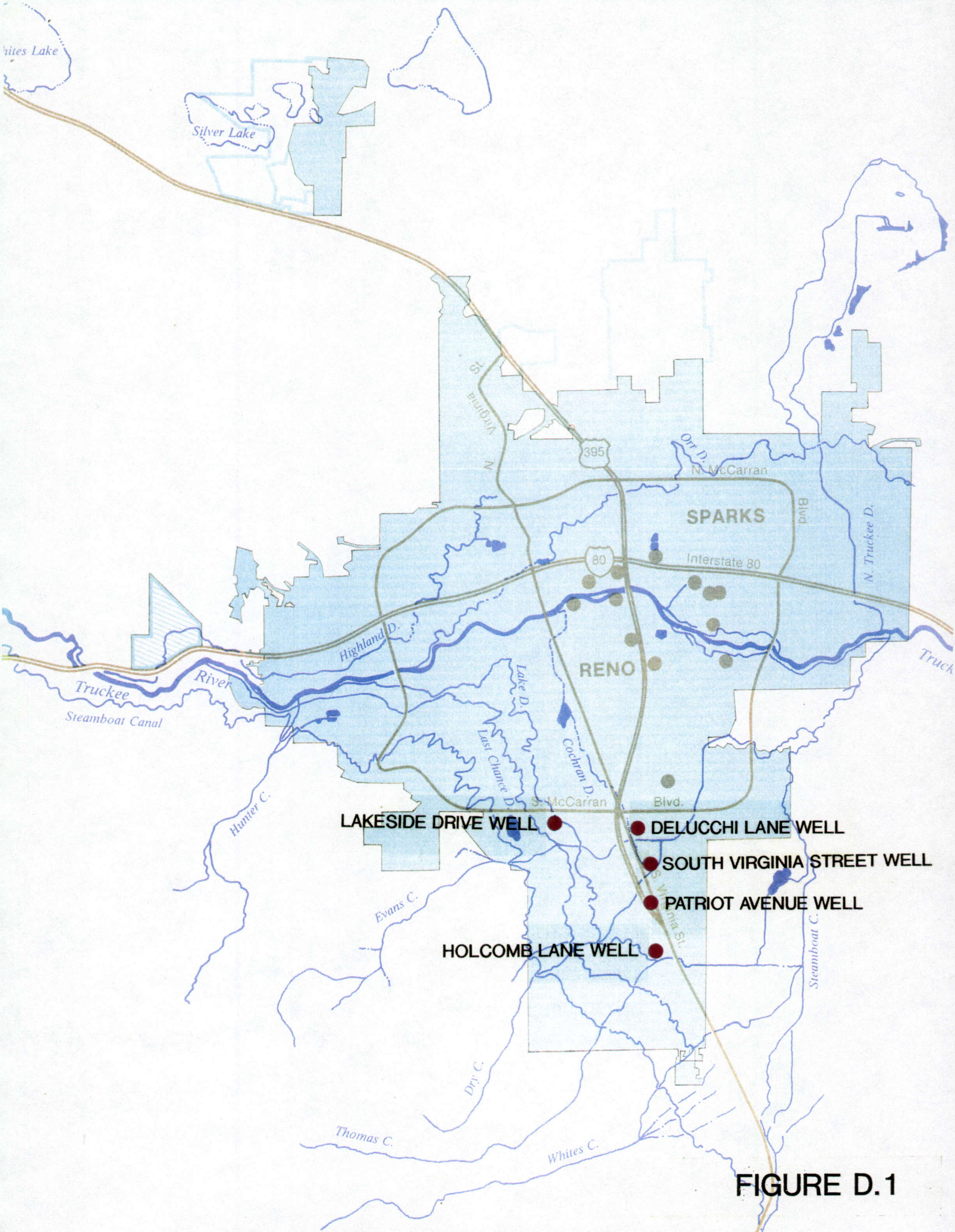

FIGURE D.1

WESTPAC'S SOUTH TRUCKEE MEADOWS PRODUCTION WELLS.

annual duty for the well is 803.5 acre feet. Ground elevation of the well is 4454.61 feet. The static water levels listed below were calculated by subtracting a measured depth to water from the ground elevation.

DATE	GROUNDWATER ELEVATION
1973	4439
1975	4444
1977	4442
1979	4436
1981	4440
4/1/83	4430.39
3/1/84	4440.26
4/1/85	4435.90
4/1/86	4430.61
3/31/87	4437.68
3/1/88	4432.11
1/18/89	4433.32
3/22/90	4426.76
7/9/91	4428.95

3.0 LAKESIDE DRIVE WELL

Westpac's Lakeside Drive Well began production in 1985. The water rights for this well are permit numbers 47977 and 47978. The annual duty for the well is 616 acre feet. Ground elevation of the well is 4611.32 feet. The static water levels listed below were calculated by subtracting a measured depth to water from the ground elevation.

DATE	GROUNDWATER ELEVATION
4/1/85	4533.68
5/1/86	4527.78
5/1/87	4522.32
3/31/88	4516.87
2/28/89	4514.03
3/22/90	4518.49
7/16/91	4508.69

4.0 HOLCOMB LANE WELL

Westpac's Holcomb Lane Well began production in 1989. The water rights for this well are permit numbers 50016 and 53354-57. The annual duty for the well is 892 acre feet. Ground elevation of the well is 4530.00 feet. Static water levels listed below were calculated by subtracting a measured depth of water from the ground elevation.

DATE	GROUNDWATER ELEVATION
5/1/89	4488.10
3/22/90	4496.16
7/9/91	4489.25

5.0 PATRIOT AVENUE WELL

Westpac's Patriot Avenue Well began production in late 1990. The water rights for this well are permit numbers 53716-20 and 54334. The annual duty for the well is 896.7 acre feet. Ground elevation of the well is 4485.00 feet. The static water levels listed below were calculated by subtracting a measured depth to water from the ground elevation.

DATE	GROUNDWATER ELEVATION
6/8/91	4451.00