BEFORE THE STATE OF NEVADA,

STATE ENVIORNMENTAL COMMISSION

In Re:	)
	)
Appeal of Solid Waste Disposal Site Permit	)
Permit No. SW495REV00	)
Operator: Recology	)

OPENING BRIEF ON APPEAL

COMES NOW, the Appellant, Clean Desert Foundation, Inc., pursuant to NAC 445B.8925, and in connection with the above stated matter, respectfully submits this opening brief.

Dated this 17th day of April, 2012.

Dolan Law LLC
By: Robert E. Dolan, Esq.
311 S. Bridge St.
Suite E
Winnemucca, NV 89445
Ph: 775 625-3200
Fax: 775 625-4286
Counsel for Clean Desert Foundation, Inc.

SUMMARY

The honorable members of the Nevada State Environmental Commission (SEC) are simply being asked by and through the instant appeal to protect the beauty of the high desert, the health and safety of citizens and wildlife, and the dignity of the State of Nevada. Under the relevant facts and laws the SEC has authority to deliver those protections to the citizens of Nevada.

The Nevada Department of Environmental Protection (NDEP) staff wrongfully exercised its discretion to find grounds to issue the operating permit to permittee (or "Jungo") for a 95 year, 4,000 ton/day landfill by effectively disregarding the risk to the large aquifer that sits directly below the landfill site. The public record is peppered with instances when staff had discretion to find otherwise and not issue the permit, but failed to do so.

STATEMENT OF FACTS

As reflected in the attached affidavits of James F. Reed (Exh 30) and Massey K. Mayo (Exh 31), respective members of the Clean Desert Foundation, Inc. (CDF) the CDF's members will suffer direct and/or imminent harm from the issuance of the permit herein. CDF has standing to appeal and contest the permit herein.

///

///

///

///

///

///

STATEMENT OF ISSUES

Did NDEP staff abuse and/or wrongfully exercise its discretion to find grounds to issue the operating permit to Jungo?

ARGUMENT

I. THE AQUIFER IS AT RISK. NDEP ABUSED IT'S DISCRETION IN APPROVING A VARIANCE UNDER NAC 444.678(9).

Staff's approval of the variance under NAC 444.678 (9) from the 100 foot distance requirement from the "uppermost aquifer" to the base of the landfill site is, among other things, an abuse of discretion, arbitrary and capricious, and otherwise inconsistent with the stated goals and policies of the State of Nevada. Here, the uppermost aquifer is 59 feet below ground surface (bgs) at the site. (Vol. I Report of Design (ROD), April 2011, p. 10). Meanwhile, the bottom/base of the landfill extends to about 34 feet bgs. So, instead of the required 100 foot distance between the "uppermost aquifer" and the base of the landfill, there is not more than 25 feet distance! (Golder; GroundWater Protection Evaluation Plan (GWPEP) dated July 27, 2011, p. 1)(See, Exhibit 1, Cross-Section C-C' and Exhibit 2, Cross-Section C-C', with red line corrections, depicting 29 ft' from base of landfill to uppermost part of aquifer).

The 25 foot distance may well be reduced during the landfill's 95 years by another nine (9) to ten (10) feet because in the near past the uppermost aquifer was only 50 feet bgs (circa 1975). "The highest anticipated groundwater levels at the site are estimated to be approximately 50 feet bgs". (Vol. I ROD, April 2011, p. 10). This results in a distance of only 15 feet from the base of the landfill to the uppermost aquifer. The situation can easily be predicted that water, and the migration of same, will be effectively **simultaneously** attacking the integrity of the waste cell from below, above and the sides, and the submitted plan does not come close to addressing that situation. When is too close, too close? When does safety concerns control and mandate denial of an operating permit at an unsafe location? **The answer is now**.

The effect of this predictable situation is compounded by the fact that the aquifer below the proposed landfill site is not a closed-basin system, as purported by the permittee and contains a large volume of water. (See, Exhibit 3, Types of Groundwater Basin, Golder Figure 25). In David L.Berger's 1995, "Ground- Water Conditions and Effects of Mine Dewatering in Desert Valley, Humboldt and Pershing Counties, Northwestern Nevada, 1962-91" study, also cited by the permittee in the ROD, said basin was found to have an inflow of 2,700 acre-ft/yr and a subsurface outflow of 2,100 acre-ft/yr. (Exhibit 4, Summary and Conclusions, p.82-83, "Ground-Water Conditions and Effects of Mine Dewatering in Desert Valley, Humboldt and Pershing Counties, Northwestern Nevada, 1962-91", David L. Berger, 1995 (hereinafter "Berger Study")). NDEP staff has failed to address the potential impact of the landfill in conjunction with the reported inflow and outflow of the water basin in total. Such an oversight, or unwillingness to see, is arbitrary and an abuse of discretion in determining if the policies and goals of the State of Nevada are met in granting this operating permit.

Moreover, the volume of the aquifer is substantial. The Berger Study calculated the principal ground water reservoir may be as much as 7,000 ft thick, and consist of lenticular units of gravel, sand, silt and clay, which function as a single aquifer system. (Exh. 4, Berger Study, p. 82). In fact, Berger further concluded that the amount of ground water stored in the upper 180 ft saturated basin fill is estimated to total about 10 million acre-ft. (Exh. 4, Berger Study, p. 82). See also, (Exh. 5, Berger Study, Plate 1b, 1995; Exh. 6 Map created in GIS using data of Berger Study, Plate 1b; Exh. 7 Map of Desert Valley Area using Berger Study data in GIS, Exh. 8(a),(b) and (c), 3D images of aquifer created using Berger Study). NDEP has failed to give appropriate consideration to the volume of the aquifer, especially the probability that approximately 10 million acre-ft of water of said aquifer could be potentially contaminated by the leachate from the landfill, which will exist only within 29 ft of said precious resource. The above notwithstanding, staff still maintains that "(t)he permit complies with applicable regulations which are intended to be protective of public health and the environment". Response to Specific Comment (RSC) 42. It plainly doesn't.

In light of staff's posture, what staff could have said is that we are prepared to gamble a bit on the safety of public health and the environment by granting a waiver from Nevada rules to allow out of state waste be deposited in our high desert because, well-- permittee promises to do a good job. Facts are stubborn things, hopeful projections just fall too short of meeting the stated policy, goals, rules and law of Nevada.

Staff continues and states that "...It is highly unlikely that adverse groundwater impacts would go undetected during active landfill operations and then become apparent during post closure period". RSC 22. This is nonsense and not supported by substantial evidence. All landfills leak leachate, and (as stated below) given the deficient ground water monitoring system, coupled with the overly close proximity between the landfill base and uppermost portion of the aquifer, coupled with the poor and limited quality of the soil on site, scream that there is not substantial evidence in the public record to support staff's waiver or response(s). Indeed, said Response 22, and the successive repetitive, conclusory, non-fact based responses found to comments 25, 26, 29, 30, 31, and 53, among others, evinces bias in favor of permittee. RSC 53 contains no assurance by parroting NAC 444.6887's prohibition on the release of leachate as regards preventing same. All liners leak. All landfills release leachate. The United States Environmental Protection Agency, Solid Waste Disposal Criteria, dated 8/30/1988, stated "First, even the best liner and leachate collection system will ultimately fail due to natural deterioration…technologies suggest that releases may be delayed by many decades at some landfills." (Exh. 9(a),(b), "Deficiencies in Subtitled D Landfill Liner Failure and Groundwater Pollution Monitoring", Lee, G.F. and Lee-Jones, A., citing US EPA. July, 1988b. "Criteria for Municipal Solid Waste Landfills," US EPA Washington D.C.). As the general observer has said, this is not a matter of "if" this is a matter of "when". NDEP has abused its discretion by inadequately addressing the "when" factor.

Leachate directly threatens the safety of the aquifer which is directly under the site. In light of, among other things, the fact that the silty, clay layer between the base of the landfill and the uppermost aquifer is not suitable for the purposes of the landfill liner system, as confirmed by the USDA, Natural Resources Conservation Service paper, (attached hereto as Exhibit 10, dated October 13, 2009), and as admitted by Permittee as stated herein, the staff's finding that the landfill is "well engineered" and/or "well designed" to meet the letter and spirit of all relevant laws and rules designed to protect the health and safety of citizens, and wildlife is, inter alia, unsupportable by evidence and clear error.

Staff's reliance on the "modeling" of potential leachate being adequate to protect the aquifer is baseless and not supported by substantial evidence. Among other shortcomings, said monitoring excludes testing for other known chemical and/or pharmacological constituents typically found in the leachate from a landfill of this size and kind, and which include, without limitation, A) borate(s)-which is used in the manufacture of soap, fertilizers, anti-freeze, brake fluids, among other things; B) arsenate-which is found in treated lumber and had been linked to health risks; C) selenate(s)- (selenium +6) are water soluble and mobile because of its high solubility and inability to absorb to soil particles and is a health risk, and D) lithium- which is a class of pharmacological medications known as antimanic agents. These, like other pharmacological agents and other chemicals are not tested for under the permit pursuant to NAC

444.7487, or Appendix I & II of 40 CFR 258, or Appendix IX to 40 CFR Part 264, and nevertheless threaten the ground water.

Additionally, many individual household chemicals can cause stress cracks, or the like, in HDPE liner systems (i.e. acetic acid, aqua regia, food and food products—cider, lard, margarine, vinegar, vanilla extract, detergents, hair lotions, shoe polish, etc.). Said monitoring excludes testing for these common household chemicals which are known to cause damage to an HDPE liner system and penetrate the aquifer below. (See, Marlex Polythylene TIB 2 Packaging Properties, Plastics Division, Phillips 66 Company, Bartlesville, OK 74004.) NDEP's reliance upon the ground water monitoring system (as stated below) provides little, if any, assurance that the stated goals and policies of the State of Nevada to protect ground water resources will be met.

II. NDEP ABUSED IT'S DISCRETION IN APPROVING A VARIANCE PURSUANT TO NAC 444.678(2) AS REGARDS SURFACE WATER

Staff's approval of the variance under NAC 444.678 (2) from the 1000 foot distance requirement of any surface water from the landfill site is another abuse of discretion, and/or was arbitrary and capricious, and/or done in excess of agency authority, and otherwise inconsistent with the goals and policies of the State of Nevada.

Although, apparently the site does not technically qualify as a "floodplain", that is not controlling. There is substantial historical and anecdotal history that the landfill site is prone to regular "ponding" and/or flooding. This often results in substantial amount of surface water not only being closer than 1000 feet to the landfill site, but on top of it! (See, Exh. 11, Climate Data from US Department of Commerce, National Oceanic & Atmosphere Administration, for Jungo Meyer Ranch; Exh. 12(a), (b), (c) and (d), Maps of Jungo Area Flood for various elevations created using Meyer Ranch and Berger Study data in GIS). Indeed, permittee seemingly admits this fact by addressing the drainage control systems being needed to "minimize the presence of standing water at the landfill". Vol. III Plan of Operation (POO), July 2011 p. 17.

However, when said surface water breaches the perm (and/or trenches) and/or drainage system and makes uncontrolled contact with a cell or module of the landfill over the course of time, it is easy to see how a washout is likely resulting in an environmental catastrophe. This possibility is further made reality by the fact that very little vegetation exist at the proposed site, which further compounds the length of time standing water exists. (See, Exh. 13, Jungo Vegetation Synthesis created using USGS data in GIS). The waste from the site will be dispersed outside of the site to adjoining property. (See, Exh. 14, Jungo Area Stream Reach Overland Flow, Catchment and Ponding Area and Exh. 15, Jungo Area Slope Analysis). Remember that this is a 95 year operation accepting 4,000 tons of municipal waste every day, which means that there is a lot of garbage that may be dispersed. Meanwhile, the idea that Jungo has "proof" as required by NAC 444.6785 (1) (c) that it now must maintain which shows "that the unit or lateral expansion will not, 'result in the washout of solid waste that poses a hazard to public health and safety and the environment is fanciful.

Pictures of ponding and flooding in the southern portion of the desert valley in which the landfill is located are provided. (See, Exhibit 16 (a),(b), and (c)).. The location of a Class I site must prevent pollutants and contaminants from the landfill site from degrading water of the state. NAC 444.678 (2) and NAC 444.6785 (1) (c). This permit and plan fails in this regard, and/or there is simply conjecture that it will do so.

Meanwhile, **Fairy shrimp,** although not an endangered species, have been located near the site which provides substantial evidence that the site is prone to ponding, flooding and/or substantial intermittent precipitation. (See, Exhibit 17(a) and (b), pictures of fairy shrimp from said site). That is because Fairy shrimp inhabit large, moderately turbid cool-water vernal ponds/pools which fill with water in the rainy season, as is the case and found here. However, permittee insists on presenting (without apparent objection by staff) that "on site groundwater monitoring well development has **confirmed** that there are no saturated soils at or near the ground surface"! Vol. III POO April 2011, p. 5. Yikes! This assertion by Permittee and connivance by staff raise substantial concerns about the accuracy of all material presented to obtain permit, and again, bias by staff.

The design elements directed at diverting ponding and groundwater flows through "4 foot high berms" (ROD July, 2011 p. 21) and trenches/shallow ditches, is inadequate. The soil on site is inadequate for this task and there is no requirement for the importation of clay or use of bentonite clay for the construction or maintenance of said berms or trenches (unlike as ostensibly required to bolster the liner system). Anecdotal evidence suggest that due to the nature of the poor soil found in said site, such catastrophes as depicted in Exhibit 18 may occur and the overall impact of which NDEP has failed to address.

The post closure surface water controls rely on the soil at site and are inadequate. There is a brief discussion of monitoring "samples" of the water for unnamed "constituents" and then used for dust control. This is not safe. The entire plan is devoid of any reasonable manner to address pollution of surface water.

The "ponding" that occurs on the playa, and the poor quality of the soil at the location will inevitably cause movement of water into the trash cells above the liners. The permit fails to adequately address, if at all, what the permittee can do if and when the ponding interferes with normal operation and/or delivery of waste from train to site. Will the waste be piled on the side of the railroad during the ponding episode? Will the required daily activities of burial be impossible or unduly dangerous? These questions, and similar thoughts, remain unanswered by NDEP.

III. NDEP HAS ABUSED IT'S DISCRETION IN REGARDING THE LANDFILL GAS AND MONITORING SYSTEM

Staff's RSC 58 reflects a faith based belief that closed portions of the landfill, with a purported final cover, do not pose a risk of emitting landfill gas because "it is not necessary that they (i.e., gas collection pipes) function for the life of the landfill, but only during the time which that portion of the landfill is generating gas". (It's unclear if staff is making a distinction between the 95 year lifetime of the entire landfill or say, the ten year period for cell #1 or successive ten year periods of development for future cells.) In any case the risks to the integrity of the site and surrounding area continue past the "final cover", and the deterioration of said cover over time can and does allow for the release of landfill gas even if the cell in question is "closed". It should be expected that for the landfill of this size proposed that different parts of it will be simultaneously undergoing different phases. Therefore the rate of decomposition and release of leachate and landfill gas will vary from cell to cell.

Meanwhile, while landfill waste generally undergoes four general phases of decomposition: 1) initial aerobic phase; 2) anaerobic acid phase; 3) initial methanogenic phase; and 4) stable methanogenic phase. The proposed "dry tomb" kind of landfill proposed here once breached, and if breached again and again by virtue of future unknown causes (like animal digging, water accumulation, poor workmanship, etc.) will spread noxious odors. And, detecting the location of said breach is difficult, at best, and with there not being any continuing requirement that gas collection pipes remain on "closed" cells (as stated in RSC 58) the risks are increased, not minimized.

The idea that the gas monitoring system will effectively target those subsurface areas of the 29-15 feet distance between the aquifer and base is unreasonable, rendering RSC 48 highly doubtful.

IV. THE SOIL IS NOT ADEQUATE FOR THIS PROPOSED LANDFILL

The soil at said site is not homogenous but heterogeneous and as Berger described, an unconsolidated to partly consolidated area consisting of wind deposits and hardpan, older and younger alluvium and lake deposits. (Exh. 4, p. 13-16; Exh. 19, Map of Jungo Geology created using USGS data on GIS).

A. Soil is Inadequate for Daily Ground Cover (DGC)

The silty soil at site is not adequate for the task of covering the cell with six inches of daily ground cover as required by NAC 444.678 (4). Said soil is not "workable and compactible" for DGC as required by NAC 444.678 (4). This is also directly supported by the research and report of the USDA, in soil report of 2009, which reveals that the soil at the landfill site is either poor or limited for said purpose. (Exh. 10).

Said inadequacies are due to elemental deficiencies in composition and physical characteristics. Although staff gives lip service to the recognition of the limitations of the soil on site, the humble conditions imposed still renders the soil inadequate for all the important tasks which include, without limitation, building berms and trenches to protected against water damage to the waste cells, and for use in the liner system.

The permit inadequately considers the substantial wind gusts and/or the powerful regular prevailing winds as regards causing adverse consequences, relative to DGC.

Furthermore, at the base of the landfill, said soil is ill suited to support the weight of millions of tons of waste above the aquifer, even with the height reduction of the landfill. (See, Exh. 20, landfill cross section depiction and Exh. 21, Geological Section A-A, Figure 5). While

Permittee acknowledges that "the compressive characteristics of the underlying soils pose significant constraint to the height and weight of refuse that can be placed on the liner", possibly resulting in "(e)xessive settlement of the foundation (that) could result in adverse drainage grades on the landfill". Vol. I ROD, April, 2011, p. 8. Yet permittee simply plays lip service to this uncomfortable fact by effectively saying that at some future time "prior to the construction of the base containment system" some other relatively meaningless steps will occur, but none of which have the capacity of actually addressing the risk to the aquifer, and/or the risk of migrating water transporting waste off site! In fact, a simple demonstration with water, sand, and dye can easily depict the potential outcome of this point, and Appellant intends to demonstrate same at the hearing hereon.

B. Soil is Inadequate and Should not be used in Connection with the Liner to Guarantee Protection to the Aquifer

The soil on site is to be used in connection with the liner. Yet the site is underlain by interbedded sands, silts and clays. The "upper silty sands" from the landfill site, which exists to the depth of 40 feet, (GWPEP, p. 6) and the lower silty sand found at a depth of 145 feet, are apparently to be used as part of the groundwater protection plan, as well as to be an integral part of the proposed landfill liner system. Permittee proposes the following: "(o)n the side-slopes (of the landfill site), the base liner system is comprised of the following components from top to bottom": "2-foot thick operations soil layer" (GWPEP) p. 3). Said soil in not appropriate to meet the permeability requirements for this task, and this is recognized by Permittee. Vol. I ROD, April 2011. P. 15. Staff has adopted the wait and see approach under the guise of Construction Quality Assurance (CQA) which includes apparent reliance on the highly unlikely "importation of a massive amount of "clay soil" on a regular basis to the site or the addition of bentonite clay.

Also, this silty soil at the site will be part of the "final cover" and it too will be used and relied on as another part of the "containment system". GWPEP p. 4. And this containment system is theoretically part of preventing leachate from developing and/or landfill gas from escaping and thus ensuring that a "dry tomb" will continue forever into the future. Nonsense!

V. THE LINER SYSTEM IS INADEQUATE

The proposed double liner system relies on the silty soil at the site and is inadequate. Again, "1-foot thick operations soil layer" is used as part of the "base liner system", and "2-foot-thick operations soil layer" is used on the side-slopes of the base liner system. Vol. I ROD, April 2100, p. 14.

The liner system uses a layer of plastic sheeting (high density polyethylene-HDPE) and a clay layer. Over time this plastic layer will deteriorate and fail to prevent leachate from entering the groundwater. It is naïve to not plan for and understand that said plastic will rip, tear or be misapplied allowing for undetectable amounts of leachate to escape and poison the aquifer.

A. Liner Degradation Evaluation Program

The permit does not include an effective program. Among other practical problems not sufficiently taken into account (some which were previously mentioned in the argument related to the aquifer) is the fact that millions of tons of waste will be on top of the leak location of leachate and/or landfill gas, and the very process of locating, reaching and repairing said damaged liner (which will be accomplished with the use of heavy machinery) will result more damage to the liner. Additionally, leachate will leak at other locations that the sump and monitoring for same is inadequate.

VI. NDEP HAS FAILED TO ADEQUATELY TAKE INTO CONSIDERATION THE IMPACT OF SEISMIC ACTIVITY IN THE AREA

The permit fails to adequately take into account the instability caused and/or increase in intensity, strength and frequency of seismic activity and/or earthquakes at the landfill site and threat to the liner due to the substantial well drilling activity of Nevada Geothermal Power company at its Blue Mountain Power plant. See Exhibits "22", and "23". Said power site was placed in service on October 12, 2009 and is only four or so miles away from the landfill site.

Staff apparently relied on a Golder (vol. 1 appendix K) for the permit, and Golder relied upon inadequate and date material. Its data was from a 2002 United States Geological Survey (USGS) report that was updated in 2008, (Exh. 24) before the aforesaid nearby power plant's operation. The Golder study is completely silent on the power plant and its operation, and is not even considered as a "variable" to their formula. This results in improper and inaccurate modeling, and has resulted in arbitrary and capricious decision making and the clearly erroneous act of issuing of the permit. Said Golder data pre-date the substantial activities of Nevada Geothermal Power Company in the area. A review of relevant portions of the "Status of Resource Development at the Blue Mountain Geothermal Project", (Exhibit 25) herein, reveals that many wells have been drilled to between 2,370 to 5,426 feet deep, and that at least three of said wells are successful, and producing power. This fact raises new questions which NDEP have ignored. There is anecdotal evidence that earthquakes can be caused by the drilling of waste water wells. (Exh. 26). Indeed, the Geothermal Energy Association, as late as 2007, in its report, "A Guide to Geothermal Energy and the Environment" reveal that," … geothermal production and injection operations have at time resulted in low-magnitude events known as "microearthquakes." (Exh. 27) Yet the permit is fatally flawed in this regard.

Moreover, the likelihood that soil liquification will result in the event of a large earthquake is more than unlikely as addressed in Exhibit 28, Letter to Mr. Taylor from Chuck Schlarb.

VII. THE PROPOSED GROUND WATER MONITORING PLAN IS INADEQUATE

The four ground water monitoring wells are insufficient in number and design to adequately measure leachate throughout the lifetime of the site. The "two reports ... submitted at approximately 10 and 25 years to assess the performance of the landfill as compared to submitted values" (Response 52 to SC) is not adequate to effectively respond to health and safety risks. There is not substantial evidence in the record that the site specific monitoring plan regarding the number, spacing and depths of monitoring systems is adequate because of, inter alia, the ground water monitoring plan does not provide a "thorough characterization of the "aquifer thickness" as required by 40 CFR 258.51 (d) (1) (i); NAC 444.7483 (5) (a). The apparently adequate characterization made by Jungo is that "the thickness of the first-encountered water-bearing zone ranged from approximately 10-30 feet. Groundwater was found to occur most frequently in sand and silty/sandy silt units." (Appendix D, March 2011 p.1). This description is not more than a passing reference to the aquifer thickness, and not a "thorough description". As a result there is not substantial evidence in the public record to support the staff conclusion that the plan is appropriate or "well designed" to protect the aquifer. Such a conclusion is not supported by evidence because important factual data has not been provided, including, without limitation, what the "transmissivity" of the groundwater is (which is the amount of water moving through an entire aquifer and is calculated by multiplying the thickness of the aquifer by hydraulic conductivity) at the site. Hydraulic conductivity is a basic aquifer parameter used to calculate the amount of ground water flow using Darcy's Law.

Nor is it possible to determine the "ground water flux" at the site (which is the flow of ground water flow through a specified area.) How can staff reasonably determine that sufficient monitoring procedures exists without this information? They can't and didn't.

The public record is devoid of the required "thorough characterization of aquifer thickness", resulting is a fatal defect to the permit.

The ten and 25 year period(s) for the interim groundwater monitoring system is inadequate. The life of the landfill is 95 years.

The approval of the cost estimate to monitor and address any future damage to the environment and financial responsibility was error. (Specific Comment (SC) 3. The staff describes the ground water monitoring system as "comprehensive", (SC 4), yet the premise upon which this assertion is based is flawed. Among other things, the alleged sufficient "proximity" of the four angled borings (which is from the four corners of the 562 acre site, GWPEP p. 6) to the leachate collection sumps is too far. And it unreasonably presumes, inter alia, lack of disturbance to cell sites from, among other things, poor workmanship, poor quality of the soil at the site for landfill purposes, ponding, seismic activity, animal digging, rainfall and the like. Meanwhile, the planed four groundwater monitoring wells is insufficient to provide "sufficient detection".

Meanwhile, the chemical parameters analyzed by and through the monitoring program is apparently limited to detecting the Maximum Contaminant Levels (MCL) found in limited list of constituents in NAC 444.7487, but does not include a vast number of hazardous constituents or chemicals that are reasonably expected to be present in the leachate going forward, as allowed by said rule. This unduly threatens CDF's safety.

The 30 year post closure monitoring period is insufficient and fails to comply with the goals and policy of the state as stated in NRS 445A.305 (2) (a) and (b), which is to "maintain the quality of the water of the State". Leachate at the landfill site can be expected to be generated as long as there are leachable components buried at the landfill which reasonably can be expected to last multiple hundreds of years into the future.

Groundwater monitoring program: As found in Vol. III Appendix D (of the Jungo submission to NDEP), it does not fulfill the obligation of NAC 444.7484 (2) or (3), and the post closure monitoring period of only 25-30 years is too short. And, the financial guarantee required of the permittee under the permit is insufficient.

Among other weakness is that leachate can easily pass between the proposed widely spaced groundwater monitoring devices, and otherwise fails to meet the goals of NAC 444.7484. In short, the methods for sampling and analysis are not appropriate under the permit. Among other problems, the permit does not require sufficient time for detection and mitigation capabilities over the true life and post-closure life of the landfill, as regards the future danger to the aquifer. How then can the financial guarantees required under the permit be anything other than a mere guess? Indeed, in California the requirement is that landfill developer must bear the burden of post-closure monitoring and responsibility "until such time as the waste in the unit not longer constitutes a threat to water quality". See, applicable California Rule and Regulation, 27 CCR 20950. The instant permit completely fails in this regard.

The time period of risk to the aquifer greatly exceeds the 25-30 year period herein for post closure monitoring. Indeed, Dr. Lee opined that the risk to the aquifer exceeds multiple hundreds of years, if not thousand(s). Exhibit 29. Ultimately, future generations of Humboldt County, and Nevada generally, will be left with a massive liability in dealing with the new "superfund" site, and the damaged/polluted ground water. However, as in California, said risk and financial obligation should remain on the permittee until the risk to the aquifer is over.

VIII. NDEP HAS ABUSED IT'S DISCREATION IN PROTECTING THE HEALTH AND SAFETY OF NEVADA

Staff has blinded itself to the plans of permittee to use poison to control rodent population, and "noise cannons" to scare away birds. Vol. III, POO July 2011 p. 17. The permit has failed to adequately protect, and certainly does not meet the expectations under the law to "enhance the beauty and quality of the environment", or the beauty of the Nevada desert, in violation of NRS 444.440 (5).

PROPOSED LIST OF WITNESSES

1) Frank Gabica- he can testify as to the ponding and/or flooding in and around the landfill site.

2) Phil Jacka- he can testify as to the ponding and/or flooding in and around the landfill site.

3) Chuck Schlarb- he can testify as to the ponding and/or flooding in and around the landfill site; matters related to the fairy shrimp; matters related to the power point demonstration; matters related to aquifer; matters related to wind on site; and matters related to soil.

4) Paul Bendell—he can testify as to the ponding and/or flooding in and around the landfill site.

5) Michael Zielinski—he can testify as to the soil in and around the landfill site.

6) Dr. Fred Lee- Expert witness on Landfill issues.

7) Dr. Elizabeth Austin- Expert witness on climate.

8) Lewis Trout—He can testify as to wildlife in and around the landfill site, matters related to aquifer, and matters related to soil.

LIST OF EXHIBITS

1)	Exh. 1	Cross Section C-C'
2)	Exh. 2	Cross Section C-C', with red line corrections, depicting 29ft' from base of landfill to uppermost part of aquifer
3)	Exh. 3	Types of Groundwater Basin, Golder Figure 25
4)	Exh. 4	Berger, David, "Ground Water Conditions and Effects of Mine Dewatering in Desert Valley, Humboldt and Pershing Counties, Northwestern Nevada, 1962-91", 1995.

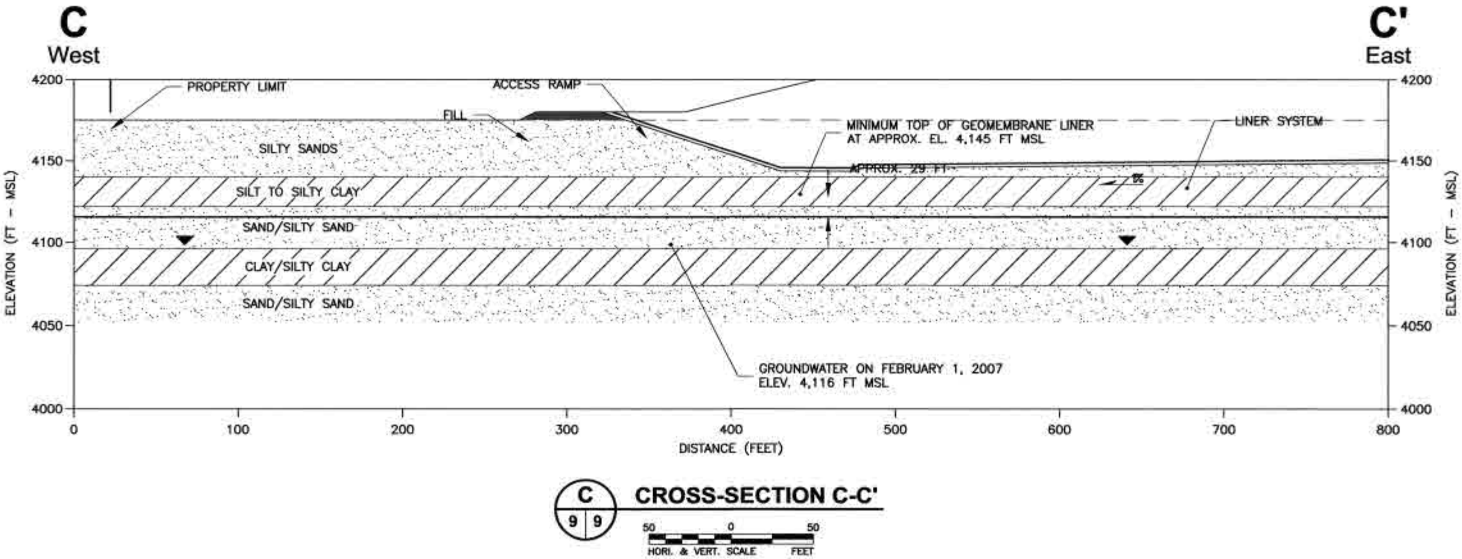
5) Exh. 5	Plate 1b, Berger Study, 1995
6) Exh. 6	Map of Desert Valley, #1, using Berger Plate 1b in GIS
7) Exh. 7	Map of Desert Valley, #2, using Berger data in GIS
8) Exh. 8(a-c)	3d Images of Aquifer in Desert Valley designed with Berger data
9) Exh. 9(a)(b)	Lee, G.F. and Lee-Jones, A., "Deficiencies in Substitled D Landfill Liner Failure and Groundwater Pollution Monitoring", citing U.S. EPA July, 1988b. "Critieria for Municipal Solid Waste Landfills," US EPA Washington D.C.
10) Exh. 10	USDA, Natural Resources Conservation Servicepaper, 10/13/2009
11) Exh. 11	Climate Data from US Department of Commerce, National Oceanic & Atmospheric Administration, for Jungo Meyer Ranch
12) Exh. 12(a-d)	Maps of Jungo Area Flood for various elevations
13) Exh. 13	Jungo Vegetation Synthesis
14) Exh. 14	Jungo Area Stream Reach Overland Flow, Catchment and Ponding
15) Exh. 15	Jungo Area Slope Analysis
16) Exh. 16(a-c)	Pictures of ponding and/or flooding on proposed site
17) Exh. 17(a)(b)	Pictures of Fairy Schrimp
18) Exh. 18	Picture of Excavator
19) Exh. 19	Map of Jungo Geology
20) Exh. 20	Landfill Cross Section

21) Exh. 21	Geological Section A-A, Figure 5
22) Exh. 22	"Blue Mountain: The Power is On at Faulkner 1!" article from Nevada Geothermal Power website, July 2011.
23) Exh. 23	Blue Mountain, Nevada, information from Nevada Geothermal Power website, March 4, 2012
24) Exh. 24	Updated Design Seismic Ground Motions and Seismic Impact Evaluation for the Proposed Jungo Disposal Site, Humboldt County, NV, April 1, 2011
25) Exh. 25	Status of Resource Development at the Blue Mountain Geothermal Project
26) Exh. 26	Sheeran, Thomas, "Ohio Earthquakes Caused By Drilling Wastewater Wells, Expert Says", dated 1/2/2012
27) Exh. 27	A Guide to Geothermal Energy and The Environment, April 2007
28) Exh. 28	Undated Letter to Mr. Taylor from Chuck Schlarb
29) Exh. 29	Lee, G.F., "Review of Potential Public Health & Groundwater Quality Impacts of the Proposed Jungo Landfill." December 9, 2011
30) Exh. 30	Affidavit of James Reed
31) Exh. 31	Affidavit of Massey K. Mayo

Robert E. Dolan

EXHIBIT 1

EXHIBIT 1

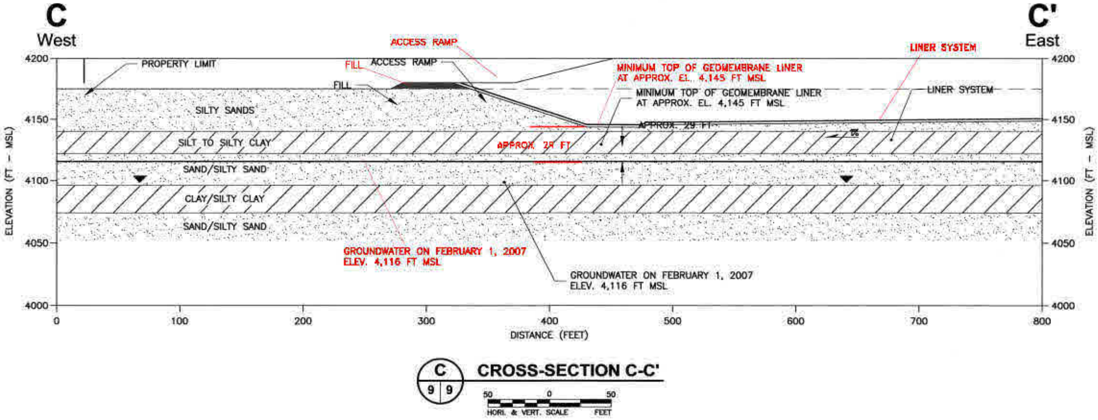


C
9 9

CROSS-SECTION C-C'

EXHIBIT 2

EXHIBIT 2



CROSS-SECTION C-C'

EXHIBIT 3

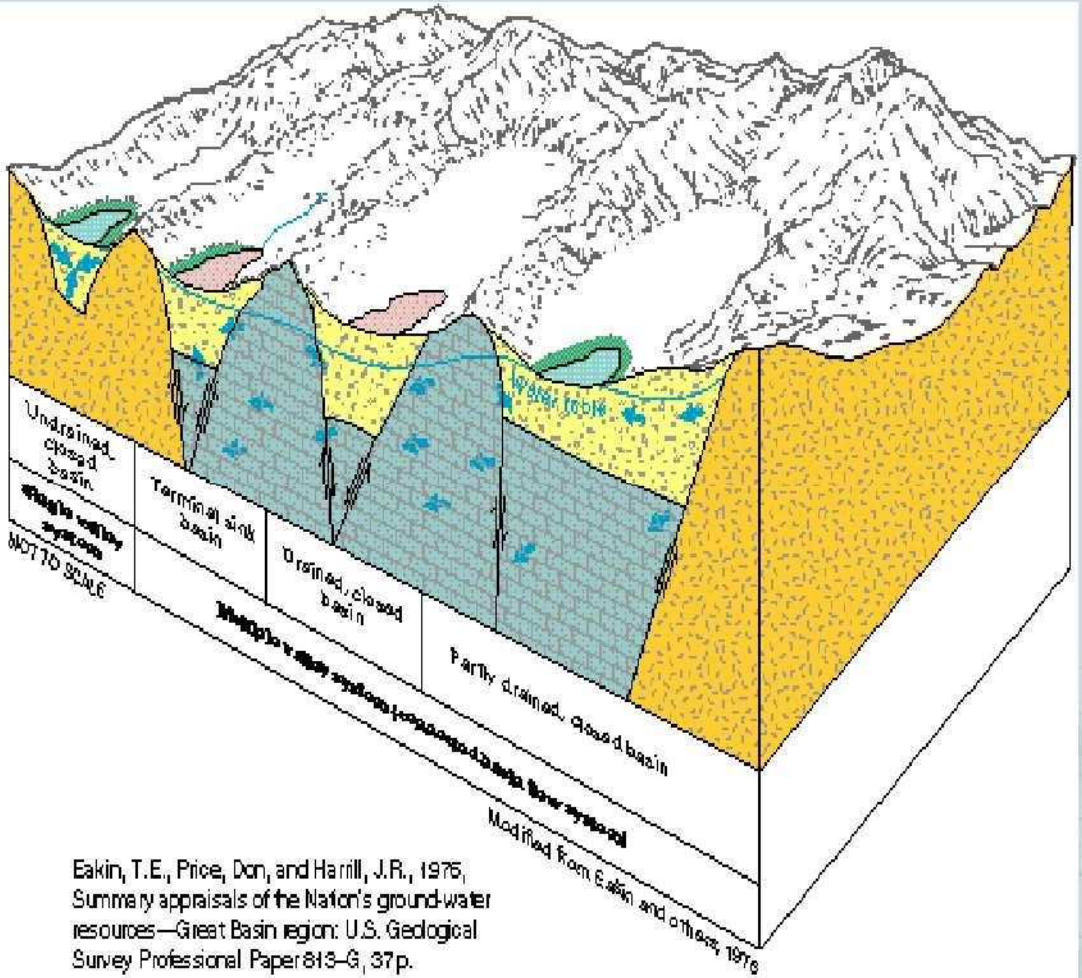
EXHIBIT 3

Types of Groundwater Basins

Figure 25. Four types of basins have been identified in the Basin and Range area and are classified on the basis of differences in ground-water flow.

EXPLANATION

- **Basin-fill deposits**
- **Playa that receives ground-water discharge**
- **Dry playa**
- **Phreatophytes**—Plants with roots that extend to water table
- **Low-permeability bedrock**
- **Permeable bedrock**
- **Direction of ground-water movement**
- **Fault**—Arrows show relative vertical movement



Eakin, T.E., Price, Don, and Harrill, J.R., 1976, Summary appraisals of the Nation's ground-water resources—Great Basin region: U.S. Geological Survey Professional Paper 813-G, 37p.

Golder Associates

EXHIBIT 4

EXHIBIT 4

Ground-Water Conditions and Effects of Mine Dewatering in Desert Valley, Humboldt and Pershing Counties, Northwestern Nevada, 1962-91

By DAVID L. BERGER

U.S. GEOLOGICAL SURVEY

Water-Resources Investigations Report 95-4119

Prepared in cooperation with the
NEVADA DIVISION OF WATER RESOURCES

Carson City, Nevada
1995

U.S. DEPARTMENT OF THE INTERIOR
BRUCE BABBITT, Secretary

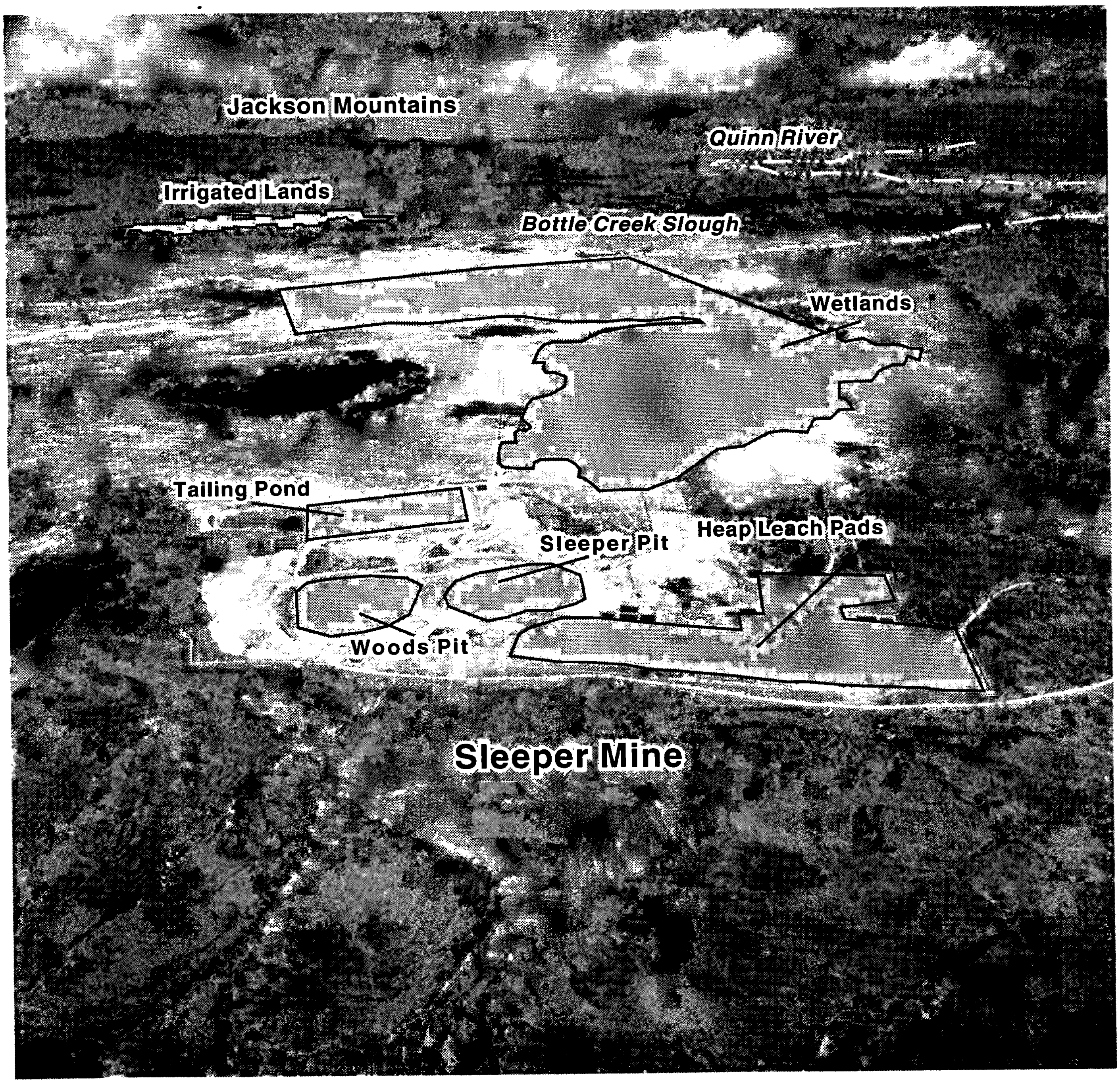
U.S. GEOLOGICAL SURVEY
GORDON P. EATON, Director

For additional information write to:

U.S. Geological Survey
333 West Nye Lane, Room 203
Carson City, NV 89706-0866

Copies of this report can be purchased from:

U.S. Geological Survey
Information Services
Box 25286, MS 517
Denver Federal Center
Denver, CO 80225-0046


Jackson Mountains
Quinn River
Irrigated Lands
Bottle Creek Slough
Wetlands
Tailing Pond
Heap Leach Pads
Sleeper Pit
Woods Pit
Sleeper Mine

CONTENTS

PLATE [In pocket]

FIGURES

TABLES

CONVERSION FACTORS, VERTICAL DATUM, AND ABBREVIATED WATER-QUALITY UNITS

Multiply	By	To obtain
acre	0.4047	square hectometer
acre-foot (acre-ft)	0.001233	cubic hectometer
acre-foot per year (acre-ft/yr)	0.001233	cubic hectometer per year
cubic foot per second (ft^3/s)	0.02832	cubic meter per second
foot (ft)	0.3048	meter
foot per mile (ft/mi)	0.1894	meter per kilometer
foot per year (ft/yr)	0.3048	meter per year
gallon per minute (gal/min)	0.06308	liter per second
inch (in.)	25.4	millimeter
mile (mi)	1.609	kilometer
square foot per day (ft^2/d)	0.09290	square meter per day
square mile (mi^2)	2.590	square kilometer

Temperature: Degrees Celsius (°C) can be converted to degrees Fahrenheit (°F) by using the formula °F = [1.8(°C)]+32. Degrees Fahrenheit can be converted to degrees Celsius by using the formula °C = 0.556(°F-32).

Sea level: In this report, "sea level" refers to the National Geodetic Vertical Datum of 1929 (NGVD of 1929, formerly called "Sea-Level Datum of 1929"), which is derived from a general adjustment of the first-order leveling networks of the United States and Canada.

Abbreviated water-quality units used in this report:

mg/L (milligram per liter)
µm (micrometer)
pCi/L (picocurie per liter)
µS/cm (microsiemens per centimeter at 25°C)
µg/L (microgram per liter)

Ground-Water Conditions and Effects of Mine Dewatering in Desert Valley, Humboldt and Pershing Counties, Northwestern Nevada, 1962-91

By David L. Berger

Abstract

In the Spring of 1985, dewatering began at an open-pit mine along a slope of the Slumbering Hills in the northeastern part of Desert Valley. Ground-water withdrawal for mine dewatering in 1991 was about 23,000 acre-feet, more than three times the estimated average annual recharge from precipitation in Desert Valley. The mine discharge has been allowed to flow to areas west of the mine, where it ponds on the valley floor and either is consumed by evapotranspiration or infiltrates to the basin-fill aquifer. An artificial wetlands, which has attracted various waterfowl, has subsequently formed in the discharge area. The mining operation is expected to last at least through 1998, with steadily increasing pumping rates. As a result of the apparent potential for ground-water overdraft due to mine dewatering, the U.S. Geological Survey, in cooperation with the Nevada Division of Water Resources, began a 4-year study in 1989 to evaluate probable long-term effects of ground-water withdrawal on a basin-wide scale. This report documents the change in hydrologic conditions since predevelopment (pre-1962) and describes the effects of mine dewatering.

The Desert Valley study area, which includes both the Desert Valley hydrographic area and the Sod House hydrographic subarea, encompasses about 1,200 square miles in northwestern Nevada. The basin-fill deposits make up the principal ground-water reservoir and may be as thick as 7,000 feet in the south-central part of the basin. Most ground-water recharge is generated in the northern Jackson Mountains, which bound the west side of Desert Valley. Since 1980, an average of about 5,300 acres of farmland, mostly along the west side of the valley floor, have been irrigated annually with ground water, supplemented by local runoff from the Jackson Mountains.

The components of the ground-water budget for the aquifer system beneath the study area were estimated using empirical techniques and refined using a ground-water flow model. Under predevelopment conditions (pre-1962), the total flow through the aquifer system beneath the study area was about 11,000 acre-feet per year (acre-ft/yr). The flow components are (1) total inflow that includes about 7,300 acre-ft/yr of recharge from precipitation, about 2,700 acre-ft/yr of infiltration beneath ephemeral rivers that traverse the northern part of the study area, and about 1,100 acre-ft/yr of subsurface inflow from the Quinn River and Kings River Valleys, and (2) total outflow that includes about 9,100 acre-ft/yr discharge by evapotranspiration and about 2,100 acre-ft/yr subsurface outflow.

During 1991, net ground-water withdrawals for irrigation were about 8,600 acre-feet, resulting in 10-20 feet of water-level declines near the irrigated areas since predevelopment time. The mine-dewatering operation pumped 23,000 acre-feet in 1991. As of Spring 1991, maximum water-level

declines beneath the open pits at the mine ranged from 295 to 315 feet. Changes in the ground-water flow regime between predevelopment and current conditions are predominantly near the dewatering operations and associated discharge areas. The previously undisturbed natural flow directions are interrupted by the dewatering operations, which cause capture of ground water as it enters from the Quinn River Valley and as it moves toward the exit point to Pine Valley.

A ground-water flow model was developed and then used to simulate continued mine dewatering for periods of 7 and 25 years, each followed by a 100-year recovery period during which dewatering is discontinued and irrigation pumpage is held constant. For one scenario of the model, mine-discharge water was removed from the system and not allowed to infiltrate beneath the artificial wetlands. Results from the hypothetical dewatering scenarios suggest that a new equilibrium would not be reached after 100 years of recovery following the end of simulated dewatering. Water-level declines would be significantly reduced west of the mine by infiltration beneath the wetlands and north of the mine by the capture of ground water from Quinn River Valley. Water-level declines would expand farther south as ground water is captured from storage.

INTRODUCTION

Background

This study, made in cooperation with the Nevada Division of Water Resources (NDWR), evaluates the ground-water conditions in Desert Valley with emphasis on long-term effects of open-pit mine dewatering. The study, in part, updates an earlier reconnaissance report by Sinclair (1962b), which documented the general hydrogeology of Desert Valley, including an estimate of the water budget and occurrence, movement, and chemical quality of the ground water. At the time of the reconnaissance study, ground-water development had been minimal, with an estimated pumpage of about 700 acre-ft/yr, mainly for irrigation purposes but also for stock and domestic use (Sinclair, 1962b, p. 10). Net ground-water withdrawals for irrigation steadily increased through the 1970's and 1980's to about 8,600 acre-ft/yr and have remained at that level through 1991. The average annual recharge from precipitation to the ground-water reservoir in Desert Valley was estimated as about 5,000 acre-ft by Sinclair (1962b, p. 8).

Early in 1982, a gold-silver deposit, herein designated the Sleeper Mine, was discovered at the base of the Slumbering Hills in northeastern Desert Valley (Nash and others, 1989; fig. 1). Removal of the overburden and subsequent pit dewatering began in the Spring of 1985; actual mining and milling began early in 1986 (Nash and others, 1989, p. 2). The volume of ground water pumped from the dewatering operations has increased from 2,100 acre-ft in 1985 to more than 23,000 acre-ft in 1991. The pumped water has been allowed to flow northwest of the mine, where a marsh and wildlife habitat have developed. The planned duration of the pit dewatering was at least 7 years, but may be more than twice that. Because of concerns that a ground-water overdraft may have developed, the NDWR began this 4-year study to assess the potential effects of the dewatering.

Purpose and Scope

This report documents 1991 hydrologic conditions in Desert Valley and discusses the extent of change in those conditions since 1962. It describes the basin-fill aquifer system and quantifies the components of the ground-water budget for both time periods. Changes in the ground-water flow regime and in water quality are also documented. The report includes the results of a three-dimensional, finite-difference, mathematical model used to evaluate long-term effects of ground-water withdrawals on a basin-wide scale. Simulated responses of the aquifer system to three hypothetical dewatering scenarios are also presented. (The report does not discuss possible changes in ground-water quality associated with the hypothetical scenarios.)

This report is based in part on an initial inventory and compilation of available data in the study area that began in the Spring of 1989, followed by a field canvass of wells and other hydrologic sites. These work elements were part of the basic-data program of the U.S. Geological Survey in Nevada. Actual project work began in October 1989 and continued through the spring of 1992. The report present the results of field work that consisted of (1) measuring water levels in about 55 wells, (2) installing 6 shallow observation wells, (3) obtaining water-chemistry samples from 16 ground-water and 3 surface-water sites, (4) measuring streamflow, (5) installing two crest-stage gages, (6) making additional gravity measurements, (7) collecting evapotranspiration data, and (8) mapping phreatophyte distribution.

Location and General Features of the Study Area

The study area encompasses about 1,200 mi^2 in Humboldt and northern Pershing Counties in northwest Nevada (fig. 1, pl. 1*A*). The study area, herein called Desert Valley, includes both Desert Valley (hydrographic-area number 31; Rush, 1968) and the southern part of Kings River Valley that was named the Sod House subarea by Malmberg and Worts (1966, p. 4) and assigned hydrographic-subarea number 30B by Rush (1968). Desert Valley is a tributary to the Black Rock Desert and, hence, is part of the Black Rock Desert hydrographic region. In May 1975, the office of the Nevada State Engineer, declared Desert Valley a "Designated Basin," which authorizes the State Engineer to declare preferred uses of water and limit the exercise of committed ground-water rights to not exceed a basin's estimated long-term recharge (Nevada Revised Statutes, Chapters 534 and 535, 1975).

Desert Valley is a north-trending structural basin with a valley floor about 55 mi long and 12 mi wide. The valley floor is at an altitude of about 4,200 ft above sea level and has an area of about 680 mi^2. Topographic relief of the valley does not exceed 100 ft. A minor drainage divide trends northeastward from the Jungo Hills to the Slumbering Hills. The valley floor is principally composed of alkali lake sediments and eolian deposits. Large areas, particularly in the southern part of the valley, are covered by hardpan (pl. 1*A*, fig. 1). Vegetation is generally sparse; greasewood, which grows locally in scattered, dense patches, is, for the most part, of low density. Agricultural lands are generally along the bajada east of the Jackson Mountains. An average of about 5,300 acres of mostly alfalfa and meadow grass were irrigated during the period 1985 through 1991 (U.S. Department of Agriculture, written commun., 1992). An active dune field, in the southeastern part of the study area (pl. 1*A*), covers about 12,000 acres of the valley floor. (An active dune field is one in which the dune ridges slowly migrate in the direction of the prevailing wind.) This section of the dune field in Desert Valley is the trailing edge of a much larger dune field that totals about 31,000 acres, extends about 28 mi to the east, and terminates in Paradise Valley (fig. 1). The prominent surface-water feature is the ephemeral Quinn River, which traverses the northern part of the study area. During late Pleistocene time, Desert Valley was inundated by ancient Lake Lahontan, the largest pluvial lake in the Great Basin (Mifflin and Wheat, 1979, pl. 1; Morrison, 1964, fig. 1). Terraces produced by shoreline erosion and the complex assemblages of the basin fill record the fluctuations of the lake. Ancient Lake Lahontan reached a depth of nearly 200 ft in Desert Valley (Sinclair, 1962b, p. 6).

The study area is bounded on the west by the southern Bilk Creek Mountains and the Jackson Mountains (pl. 1*A*), the northern summits of which approach altitudes of 9,000 ft. The southern end of the Jackson Mountains, characterized by low relief, terminates at the pass on the Jungo-Sulphur road, where the northern Antelope Range completes the western boundary. The eastern boundary is comprised of the southern Double H Mountains, the Slumbering Hills, Blue Mountain, and the northern Eugene Mountains. Low alluvial divides occupy the areas between each mountain range that make up the eastern boundary. The Coyote Hills and a low alluvial divide between the Coyote Hills and the Double H Mountains make up the northern boundary. The northern boundary also coincides with the hydrographic boundary that divides the Kings River Valley into the Rio King and Sod House subareas (Rush, 1968). The southern boundary is made up of two alluvial divides separated by Alpha Mountain. Donna Schee Peak of the Jungo Hills, and several other bedrock outcrops along the west side, rise from the valley floor and are considered to be outliers of the Jackson Mountains (Sinclair, 1962b, p. 4).

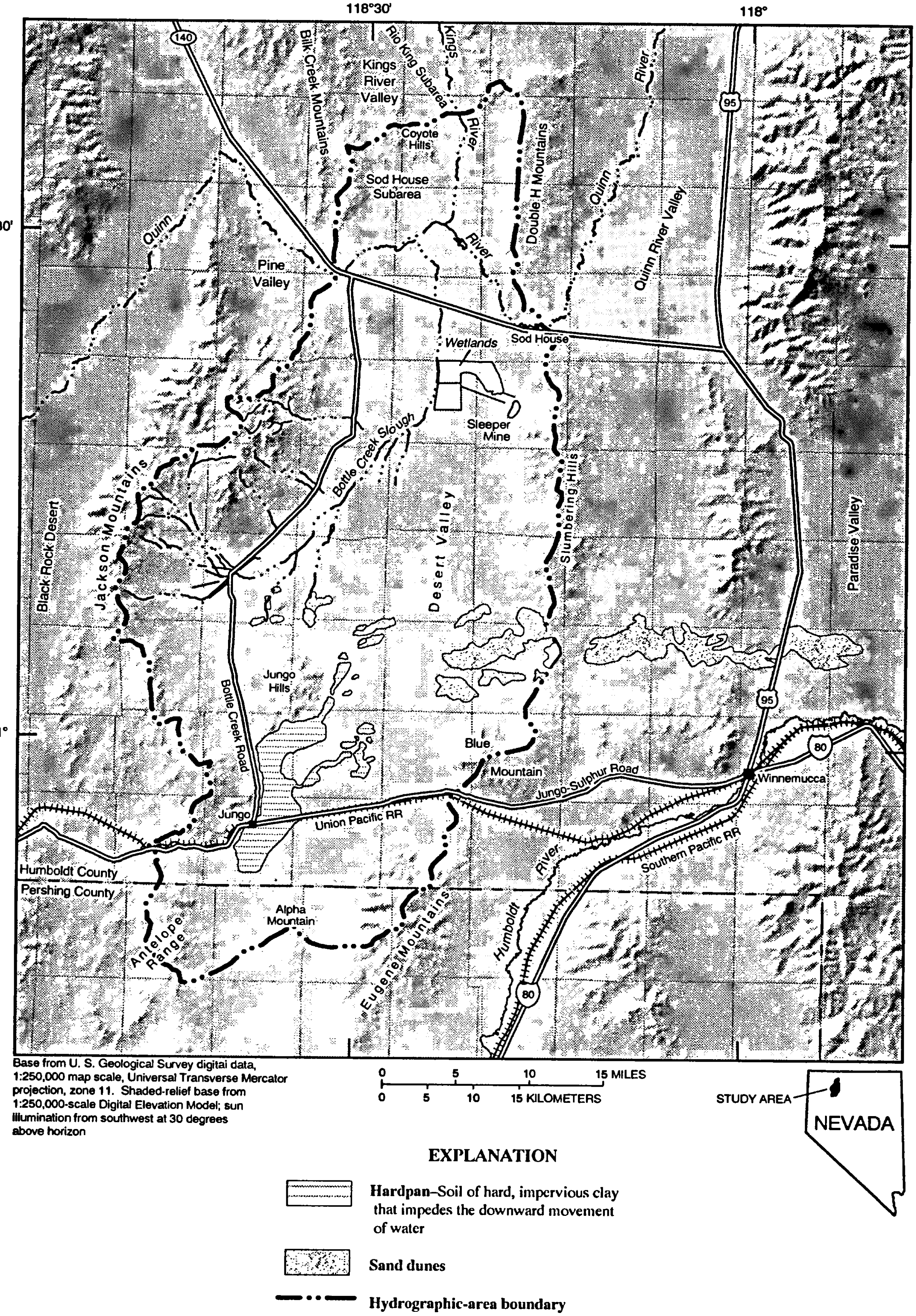


Figure 1. Location and general features of Desert Valley area.

State Route 140 crosses the northern part of the study area and provides access from Winnemucca to northwestern Nevada and southern Oregon. The tracks of the Union Pacific Railroad and the graded Jungo-Sulphur road cross the southern part of the study area. In addition, numerous graded and dirt roads, which are generally passable except under extremely wet conditions, crisscross the study area. Two sites of historical significance within the study area include now-deserted Sod House and Jungo. Sod House, also known as Sod House Station, in the northeastern part of the area, was probably a stagecoach stop (Malmberg and Worts, 1966). During the early 1960's, the small town of Jungo, adjacent to the railroad, had a population of less than 100 (Sinclair, 1962b, p. 3). Jungo historically functioned as the location of a railroad siding for the loading of iron ore mined in the Jackson Mountains and had a post office from 1911 to 1952 (Carlson, 1974, p. 147).

The Sleeper Mine (fig. 1, pl. 1*A*) is about 5 mi south of Sod House at the base of the Slumbering Hills in what was known as the Awakening Mining District (Calkins, 1938). The present-day mining operation consists of two separate open pits—the Sleeper Pit to the north and the Woods Pit to the south. Mining of the bedrock beneath the pits began in January 1986 at the Sleeper Pit and in October 1987 at the Woods Pit, and work is currently (1991) underway to combine the two into a single pit (Hydrotechnica, 1989, p. 1). As the pits were deepened below the local water table, arrays of wells were installed to dewater the bedrock ore body. Ground water from the dewatering operation originally formed a shallow lake, or wetlands, about 6,000 ft northwest of the Sleeper Mine (fig. 1, pl. 1*A*). A 4,500-ft unlined canal conveyed the water to the lake, where it was allowed to flow unconstrained onto the valley floor. On the basis of satellite data collected August 19, 1988, the lake covered an area of about 1,400 acres. As aquatic vegetation colonized the lake, it became an attractive wetlands habitat for wildlife. By 1991, water infiltrating beneath the wetlands was being captured and recirculated by the mine-dewatering well field. As a result of the recirculation, a new discharge area was created about 4 mi west of the Sleeper Mine (Geoffrey Beale, Water Management Consultants Inc., oral commun., 1990; fig. 1; pl. 1*A*). A 4-mi unlined canal is used to convey discharge water from the mine to the new discharge area, which also functions as an artificial wetlands. The new wetlands area covers about 4,700 acres. The initial wetlands area remains in place to collect overflow of mine-discharge water from the second wetlands.

Previous Investigations

Published reports on the general hydrogeology of Desert Valley include a reconnaissance report by Sinclair (1962b) and studies by the State of Nevada in response to a request by the Department of Energy for proposed sites for the Superconducting Super Collider (Nevada Commission on Economic Development, 1987). The Sod House subarea was included in investigations by Zones (1963) and later updated by Malmberg and Worts (1966), who documented the hydrology of the Kings River Valley. Arteaga (1978), in making a water-resources appraisal in parts of the Fort McDermitt Indian Reservation, studied the Hog John Ranch area along the Quinn River in the Sod House subarea. Numerous reports document plans and designs for the dewatering operations of the Sleeper Mine. They provide hydrogeologic data on monitoring and production-well specifications in the vicinity of the mine.

Two reports of significant geologic detail and interest were published documenting the general geology of the Jackson Mountains (Willden, 1963) and the gold deposits of the Slumbering Hills (Calkins, 1938). Willden (1964) also documented the geology and mineral deposits of Humboldt County, which provides a source of regional geology of the entire study area. A report on the geology of the southern part of the study area, in northern Pershing County, was published by Johnson (1977). In addition, and as a result of the Sleeper gold-silver discovery in the Slumbering Hills, numerous reports have been published documenting the geochemistry and geology of the Sleeper Mine area.

U.S. Geological Survey Site Designations

Each data-collection site is assigned a unique identification on the basis of geographic location. Wells and miscellaneous stream sites are identified by both a local (Nevada) system and a standard "latitude-longitude" system. For convenience, short numbers, which range from 1 to 134, also are used for all sites in this report.

A local site designation is used in Nevada to identify a site by hydrographic area (Rush, 1968) and by the official rectangular subdivision of the public lands referenced to the Mount Diablo base line and meridian. Each site designation consists of four units: The first unit is the hydrographic area number. The second unit is the township, preceded by N to indicate location north of the base line. The third unit is the range, preceded by E to indicate location east of the meridian. The fourth unit consists of the section number and letters designating the quarter section, quarter-quarter section and so on (A, B, C, and D indicate the northeast, northwest, southwest, and southeast quarters, respectively), followed by a number indicating the sequence in which the site was recorded. For example, site 31 N42 E34 15CACC1 is in Desert Valley (hydrographic-area 31). It is the first site recorded in the southwest quarter (C) of the southwest quarter (C) of the northeast quarter (A) of the southwest quarter (C) of section 15, Township 42 North, Range 34 East, Mount Diablo base line and meridian.

The standard site identification is based on the grid system of latitude and longitude. The number consists of 15 digits. The first six digits denote the degrees, minutes, and seconds of latitude; the next seven digits denote the degrees, minutes, and seconds of longitude; and the last two digits (assigned sequentially) identify the sites within a 1-second grid. For example, site 413035118090901 is at 41°30′35″ latitude and 118°09′09″ longitude, and it is the first site recorded in that 1-second grid. The assigned number is retained as a permanent identifier even if a more precise latitude and longitude are later determined.

Acknowledgments

The author sincerely thanks the local residents of Desert Valley for allowing access to their private property for data collection during the course of this study. Mr. Mel Hummel of the Willow Creek Ranch and Mr. Herb Clarno of the Bottle Creek Ranch provided considerable information about the agricultural history of the study area. Gratitude is also due to the personnel at the Sleeper Mine and to Mr. Geoffrey Beale, of Water Management Consultants, for providing valuable technical assistance. The study documented in this report was made in cooperation with the Nevada Division of Water Resources.

HYDROGEOLOGIC SETTING

Geology

The rocks and basin-fill deposits within the study area record complex geological events that include deposition of large volumes of volcanic rocks and marine sediments, intense mountain-building activity, basin-and-range extensional faulting, and cyclic fluctuations of a large, closed-basin lake. The following section briefly describes the lithology and basin structure that characterize and control ground-water movement in the Desert Valley study area. A more detailed geologic history of the study area can be obtained from the work of Willden (1958 and 1963), Stewart (1980), and Nash and others (1989).

Lithology

The several geologic units identified in the study area can be subdivided into two broad lithologic types primarily on the basis of their ability to transmit and store water. The first type, consolidated rocks, makes up the surrounding mountains and underlies the valley. The second type, basin-fill deposits, is unconsolidated to partly consolidated and consists of wind deposits and hardpan, older and younger alluvium, and lake deposits. Descriptions of age, lithology, and general hydrologic properties of the principal geologic units are given in table 1. The generalized geology of the study area is shown on plate 1*B*.

The consolidated rocks consist predominately of Tertiary-age volcanic flows, clastic sediments of Jurassic(?) and Triassic age, and Permian or older volcanic rocks. In general, the consolidated rocks have low porosity and permeability and do not store or transmit large amounts of water. However, the volcanic rocks adjacent to the low alluvial divide north of the Slumbering Hills are highly fractured and may transmit some water to the basin-fill aquifer from the Quinn River Valley to the east (Huxel and others, 1966, p. 29). Fractured volcanic rock was reported at depths of less than 500 ft in several irrigation wells of moderate yield in the Bottle Creek Ranch area (pl. 1*A*). Because the wells are perforated in both basin-fill deposits and volcanic rock, the amount of water contributed by the volcanic rock is uncertain, but may be large.

Table 1. Age, lithology, and general hydrologic properties of principal geologic units, Desert Valley, northwestern Nevada

[Descriptions based on those of Ferguson and others (1951), Nash and others (1989), and Russell (1885), Russell (1984), Stewart (1980), and Willden (1958, 1963, and 1964); geologic units shown on plate 1*B*]

Age	Geologic unit	Lithology	General hydrologic properties
		Basin-fill deposits	
Holocene and Pleistocene	Eolian deposits	Fine, well sorted sand. Predominantly barchan dunes and extensive sand sheets.	Deposits have high porosity and permeability. Continuous dune field covers about 12,000 acres, trending northeast from Donna Schee Peak to south of the Slumbering Hills.
Do.	Hardpan	Unconsolidated clay, silt, and fine sand.	Deposits have generally high porosity and low permeability that impedes the downward movement of water. Located on and near Jungo Flat in south part of study area and in other places as small deflation basins.
Do.	Younger alluvium	Unconsolidated sand, gravel, silt, and clay. Includes lacustrine deposits of Pleistocene Lake Lahontan.	Deposits have generally high porosity and permeability. Where saturated, are the principal ground-water reservoir. Located on valley floor, beneath stream channels, and in alluvial fans at margins of valley. Lacustrine deposits associated with Lake Lahontan are below ancient high lake stand (about 4,380 feet) and include gravel embarkment at south end of Double H Mountains mapped by Russell (1885).
Pleistocene and Pliocene	Older alluvium	Unconsolidated and partly consolidated, poorly sorted sand to cobbly gravel.	Deposits may transmit moderate to large amounts of water; hydraulic conductivity decreases with depth. Positioned high on alluvial fans above 4,380 feet, along east side of Jackson Mountains and west side of Slumbering Hills. Include gravel deposits of Willden (1963). Underlie younger alluvium in valley. Upper part makes up principal ground-water reservoir. Partly consolidated at depth.
Tertiary	Extrusive rocks	Basaltic and andesitic flows and related dikes, andesite-dacite welded tuffs, rhyolite ash-flow tuffs, and porphyry dikes.	Virtually no interstitial permeability; may have zones of moderate to high hydraulic conductivity related to fractures and joint-set cooling. Compose valley margin of Sod House hydrographic subarea, including Coyote Hills. In part, related to McDermitt caldera.
Do.	Sedimentary rocks	Shale, water-laid tuff, shaly sandstone, diatomaceous shale, conglomerate, and bedded opaline chert.	Generally low permeability. Crop out in Jackson Mountains. Maximum thickness, about 400 feet.
Do.	Intrusive rocks	Dacitic porphyry dikes.	Virtually no interstitial permeability; locally may transmit water where highly fractured. Represent two minor bodies in Jackson Mountains.
Tertiary and Cretaceous	Intrusive rocks	Granodiorite, quartz diorite, quartz monzonite, and related stocks.	Virtually no interstitial permeability; locally may transmit water if highly fractured. Crop out in Jackson Mountains, on north side of Donna Schee Peak, and in minor exposures in northern Antelope Range and Eugene Mountains, including Haystack Butte. Large quartz-monzonite stock in Slumbering Hills.
Do.	Sedimentary rocks	Pebble to boulder conglomerate, coarse-grained sandstone, siltstone, and fine crystalline limestone.	Water-bearing character generally unknown. Minor exposures in Jackson Mountains. Include Pansy Lee Conglomerate (about 400-500 feet thick) and King Lear Formation of Willden (1958). Make up major part of Blue Mountain.
Jurassic(?) and Triassic	Intrusive rocks	Quartz-free dioritic stocks and gabbro dikes.	No interstitial permeability; water-bearing character unknown. Stocks exposed in Jackson Mountains; gabbro dikes exposed in Blue Mountain.

Table 1. Age, lithology, and general hydrologic properties of principal geologic units, Desert Valley, northwestern Nevada—Continued

Age	Geologic unit	Lithology	General hydrologic properties
		Consolidated Rocks	
Jurassic(?) and Triassic	Sedimentary rocks	Limestone, phyllite, slate, and quartzite.	Water-bearing character generally unknown; may transmit water through fractures and along bedding-plane features. Comprise most of Eugene Mountains, Antelope Range, Alpha Mountain, and large part of Slumbering Hills and Blue Mountain. Include the Quinn River Formation of Willden (1963; about 500-600 feet thick) and may include Raspberry Formation of Ferguson and others (1951).
Triassic and Permian, or older	Metasedimentary rocks	Interbedded mafic volcanic rocks, shale, pebble conglomerate, thin-bedded chert, and carbonate rocks.	Low to no permeability; water-bearing character unknown. Major exposures in Jackson Mountains. Include Boulder Creek beds of Russell (1984).
Do.	Volcanic rocks	Massive andesitic to basaltic flows and flow breccia, agglomerates, and tuffs.	Virtually no interstitial permeability; may have fractured zones of moderate hydraulic conductivity. Comprise almost entire northern half of Jackson Mountains and most all of Jungo Hills. Include Happy Creek Group of Willden (1963), also known as the Happy Creek Igneous Complex of Russell (1984).

The basin-fill deposits compose the principal ground-water reservoir in the study area and are as much as 7,000 ft thick in the south-central part of the basin. For the most part, these deposits store and transmit much larger quantities of water than the consolidated rock because of their higher porosities and permeabilities. The lithology of the basin-fill deposits is the result of weathering and erosional processes of the rock that make up the surrounding mountains. These deposits consist of interlayered, noncontinuous beds of coarse-and fine-grained sediments. This textural variability within the deposits causes much heterogeneity in the distribution of the hydrologic properties. For example, a driller's log of a well near the abandoned town site of Jungo recorded nearly 500 ft of clay with thin lens of fine sand; however, less than 10 mi to the east, well logs showed as much as 300 ft of interbedded coarse sand and gravel with little or no clay. The water yield of wells that penetrate the basin-fill aquifer ranges from less than 5 gal/min for a well in the south-central part of the valley floor to as much as 4,000 gal/min for a well in the Bottle Creek Ranch area.

Structural Features

Basin-and-range extensional faulting appears to be the major cause of the present geometry of the basin-fill aquifer beneath Desert Valley. These range-bounding faults are high-angle faults that trend generally north and south. The estimated total vertical displacement along the prominent fault in the northeastern part of the Jackson Mountains is about 1,000 ft (Willden, 1964, p. 103-111). Geophysical data suggest that the eastern range-bounding faults of the Jackson Mountains are 1 to 2 mi east of the mountain front and are buried under alluvial deposits (Willden, 1963, p. 18). A depth-to-bedrock map, presented on plate 1*B*, indicates that the main part of Desert Valley is underlain by a north-trending, elongated structural trough. The bedrock surface of this trough appears to be made up of two depressions, one centered beneath the southern part of the valley east of Jungo and the other centered northeast of the Jungo Hills. The northern part of the bedrock surface is composed of another structural trough that trends northwest and may continue beneath Pine Valley. An isolated bedrock depression is also indicated beneath the alluvium northwest of the Jungo Hills.

Geologic History

During Permian or earlier time, thick sequences of andesitic to basaltic volcanic rocks accumulated in the area now occupied by the Jackson Mountains and are considered to be part of an extensive island-arc terrain (Stewart, 1980, p. 51). Marine deposition of clastic and carbonate sediments took place in Permian time and possibly continued into Jurassic time (Willden, 1963, p. 15). During the late Jurassic, the Permian- and Triassic-age rocks were subjected to regional metamorphism and intruded by diorite stocks. Following the low-grade regional metamorphism, a period of uplifting allowed extensive erosion of the Permian- and Triassic-age sedimentary rocks and produced geologic units such as the King Lear Formation (table 1; Willden, 1958, p. 2382). The area was then subjected to multiple phases of deformation, during Cretaceous and early Tertiary time, which included the Deer Creek thrust sheet and many high-angle faults and overturned folds. Extensive volcanic and intrusive activity occurred during much of the early Tertiary period. The large quartz monzonite stock in the Slumbering Hills and diorites in the Jackson Mountains were emplaced during this period. Regional extension commenced during the middle Tertiary period and produced the present-day basin-and-range topography that is characteristic of most of Nevada. Displacement along normal faults that bound the mountain blocks and define the lateral extent of the basin-fill deposits are a result of this regional extension (Stewart, 1980, p. 105).

Climate

The climate of the Desert Valley study area ranges from subhumid in higher altitudes of the Jackson Mountains to arid on the valley floor; precipitation is controlled primarily by the rain-shadow effects imposed by the Sierra Nevada range 150 mi to the west. The Jackson Mountains, because they border the western side of Desert Valley, cause a similar orographic effect but of a lesser magnitude and, as a result, receive most of the precipitation that falls in the study area. Precipitation is generally greater on the west-facing slopes than the east-facing slopes and increases with altitude (Huxel and others, 1966, p. 15); however, variations can be caused by local topography throughout the area. Thunderstorms are the main source of precipitation in the summer months. Snow and occasional freezing rain fall in the winter months. The growing season generally lasts from 120 to 150 days during May-September. Hay, in the form of alfalfa, is the principal crop grown in the study area, with lesser amounts of grain. About 4,000 head of range cattle winter on the valley floor (Mel Hummel, Willow Creek Ranch, oral commun., 1990; Herb Clarno, Bottle Creek Ranch, oral commun., 1990).

Precipitation data for sites in and adjacent to the study area include 23 precipitation gages with variable record lengths and 9 weather stations that have 30 years or more of record (table 2). A precipitation map (fig. 2), developed for this study from the altitude-precipitation relation shown in figure 3, is in fairly good agreement with Hardman's (1965) precipitation map that was used in the reconnaissance estimate of precipitation. The altitude-precipitation relation, developed from long-term precipitation data, has a coefficient of determination equal to 0.69. This indicates that nearly 70 percent of variation in mean annual precipitation with altitude is explained by the linear regression relation shown in figure 3. Figure 2 is based on altitude and long-term data from 25 stations and, thus, is slightly different from Hardman's map.

Weather information collected at Winnemucca (altitude, about 4,300 ft), approximately 15 mi southeast of Desert Valley (fig. 1), provides more than 70 years of continuous precipitation and temperature data. For the period 1920-91, the mean annual precipitation at Winnemucca was 8.33 in. (fig. 4*A*). The minimum precipitation during this period was 3.13 in. in 1954, and the maximum was 14.54 in. in 1945. The least amount of precipitation generally falls during the months from July through October (fig. 5*A*). Successive years with above- or below-mean annual precipitation for the period 1920-91 are shown by cumulative departure from the mean in figure 4*B*. An upward slope to the right indicates above-mean precipitation, and a downward slope indicates below mean. The duration of areas above and below zero show the length of potential effects of excessive or deficient precipitation. For example, potential effects of above-average precipitation in 1983 and 1984 (fig. 4*A*) may have persisted until 1991, even though the trend during the 1984-91 study period was one of below-average precipitation.

Table 2. Site locations and mean annual precipitation for weather stations, Desert Valley area, Nevada

[From published records of National Climatic Center, National Oceanic and Atmospheric Administration, National Weather Service, and Bureau of Land Management. Stations at sites 3 and 19 are maintained by personnel of Nevada Gold Mining, Inc.; and station at site 6 is maintained by foreman at Willow Creek Ranch; sites are listed in order of ascending altitude within each group]

Site number (figure 2)	Station name	Latitude	Longitude	Altitude (feet above sea level)	Period of record	Length of record (years)	Mean annual precipitation (inches)
		Degrees, minutes, seconds					
1	Sulphur	40 52 25	118 44 10	4,044	1915-52	38	4.82
2	Quinn River Ranch	41 34 44	118 26 01	4,087	1901-26 1947-55	35	5.75
3	Sleeper Mine [1]	41 20 08	118 03 46	4,138	1990-91	2	5.69
4	Jungo	40 55 01	118 22 55	4,165	1914-26	13	3.77
5	Denio	41 59 25	118 38 00	4,189	1952-90	39	8.85
6	Willow Creek Ranch[1]	41 12 26	118 21 08	4,190	1989-91	3	5.22
7	Jungo-Meyer Ranch	40 53 12	118 25 47	4,200	1969-86	18	8.22
8	Leonard Creek	41 31 05	118 43 00	4,224	1955-90	36	7.86
9	Kings River Valley	41 46 10	118 12 11	4,234	1957-90	34	8.78
10	Imlay	40 39 37	118 09 02	4,260	1896-1990	95	7.20
11	Orovada	41 34 09	117 47 07	4,300	1911-90	80	10.92
12	Winnemucca	40 57 50	117 42 45	4,300	1920-91	72	8.33
13	Pahute Meadows	41 18 10	118 56 02	4,375	1964-75	12	7.88
14	Paradise Hill	41 17 04	117 41 44	4,500	1961-63 1966-67	5	7.79
15	Paradise Valley	41 30 37	117 32 04	4,675	1894-1952 1955-90	95	9.20
16	Thacker Pass[1]	41 42 18	118 05 19	5,000	1962-64	3	11.53
17	Kings River Canyon[1]	41 56 03	118 18 49	5,500	1960-64	3	12.84
18	Nine-Mile Pass[1]	41 42 04	118 17 17	5,500	1960-64	3	10.14
19	Jumbo Mine[1]	41 17 57	117 59 58	5,723	1990	1	10.98
20	Jackson Mountain	41 17 24	118 27 40	6,200	1966-71	6	15.32
21	Disaster Peak	41 57 06	118 11 22	6,800	1960-64	5	17.40
	Crowley Creek Watershed						
22	Can No. 2	41 46 40	117 55 39	4,840	1962-80	19	10.27
23	Can No. 3	41 47 29	117 56 20	5,100	1962-77	16	10.59
24	Can No. 5	41 48 24	117 57 27	5,400	1962-77	16	11.44
25	Can No. 7	41 47 23	118 00 28	6,000	1962-80	19	12.04
26	Can No. 10	41 48 27	118 03 58	6,900	1962-80	19	14.50
	Cow Creek Watershed						
27	Can No. 1	40 44 03	118 44 01	4,500	1964-80	17	8.16
28	Can No. 2	40 40 56	118 42 42	4,600	1964-80	17	7.32
29	Can No. 4	40 44 06	118 35 55	5,200	1964-80	17	8.10
30	Can No. 7	40 38 32	118 43 35	5,000	1964-80	17	7.63
31	Can No. 16	40 35 58	118 45 03	5,900	1964-80	17	10.07
32	Can No. 17	40 35 54	118 45 43	6,200	1964-80	17	10.08

[1] Excluded in linear-regression analysis shown in figure 3 because of short period of record.

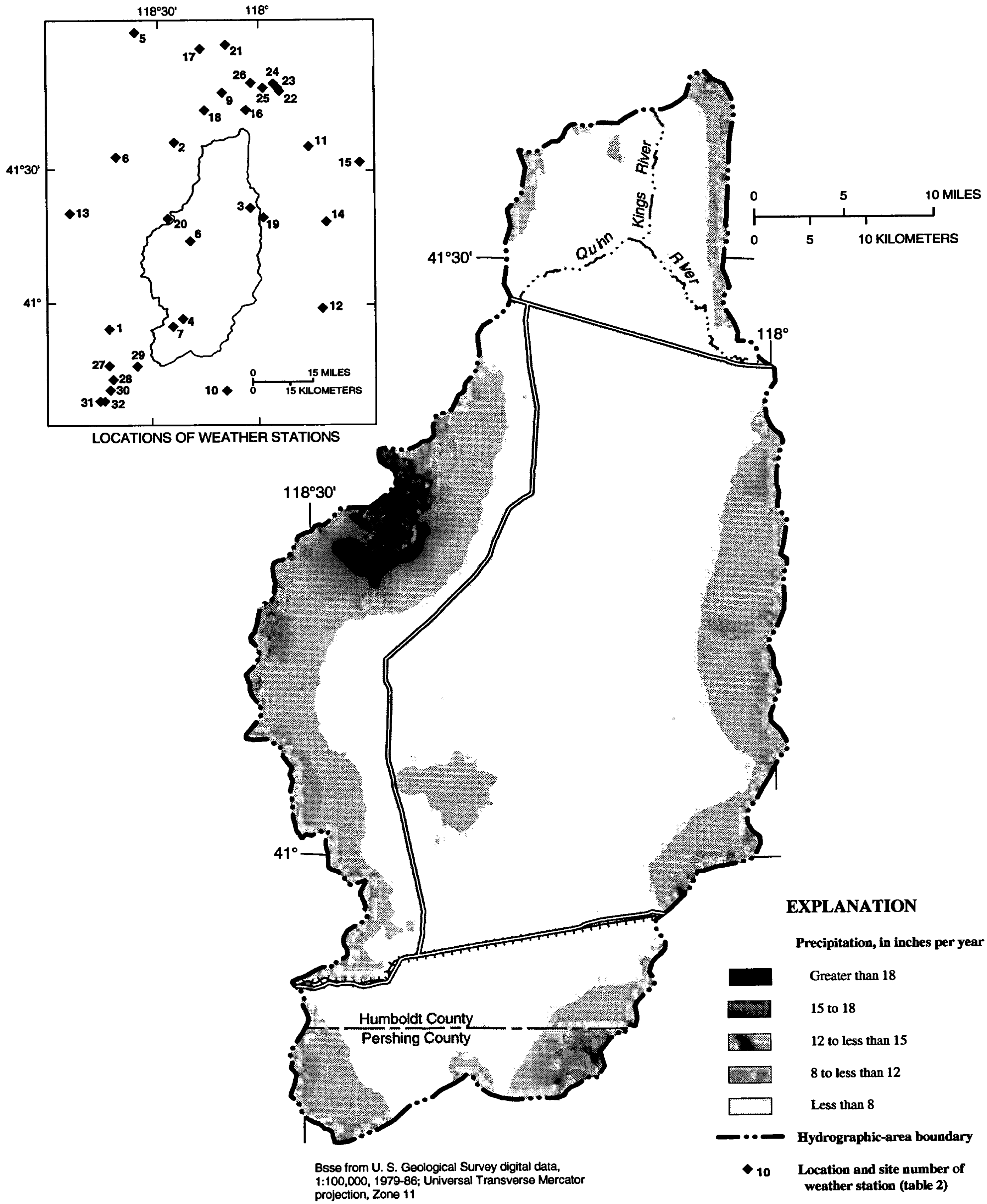


Figure 2. Areas of equal mean annual precipitation and locations of weather stations, Desert Valley area, Nevada. Site numbers listed in table 2.

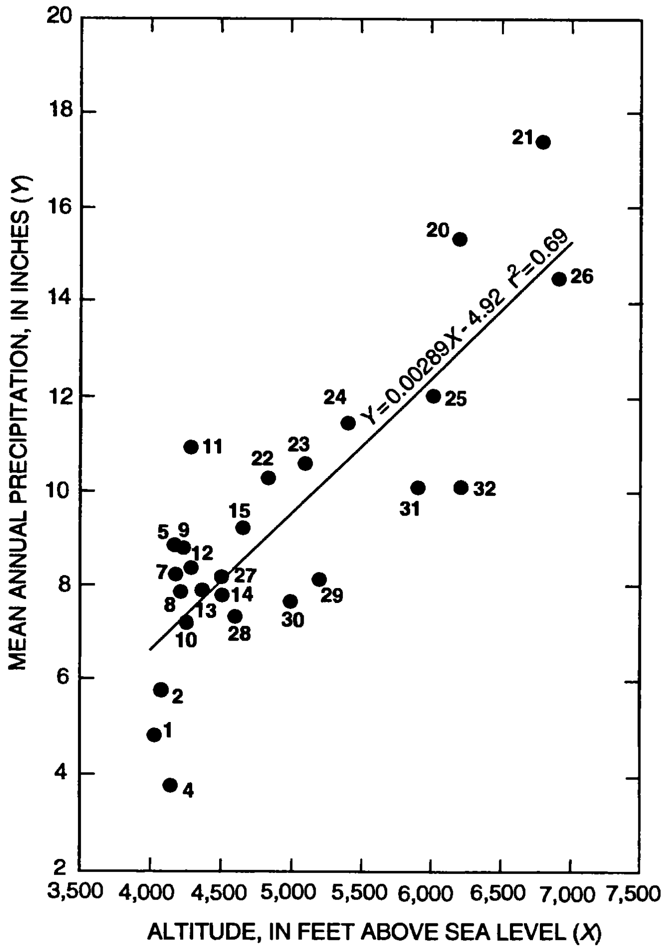


Figure 3. Relation between mean annual precipitation and altitude used in determining distribution of precipitation, Desert Valley area, Nevada. Site numbers listed in table 2. Abbreviation: r^2, statistical coefficient of determination.

Summer temperatures occasionally exceed 100°F and may fluctuate as much as 40°F in a 24-hour period. Winters are cool, with temperatures often below 0°F; the mean annual temperature at Winnemucca is 49°F (fig. 5*B*). Data collected at Rye Patch Reservoir, about 25 mi south of the study area, suggest that evaporation from free-water surfaces is on the order of 4 ft/yr (Cohen and others, 1965, p. 12). The prominent wind direction in Desert Valley is from west-southwest, which is evident from the pattern of the dune field in the south-central part of the valley (fig. 1).

Surface Water

Most streams in Desert Valley are ephemeral. The upper reaches of some streams that drain the Jackson Mountains are perennial but those streams typically cease to flow where they reach the coarse deposits of the upper alluvial fan. Streamflows from the remaining drainage basins within the study area are ephemeral and rarely debouch from the canyon mouths. During periods of Spring runoff, generally from March to early May, significant amounts of streamflow from the Jackson Mountains generated by snowmelt may reach the valley floor. However, most of the runoff probably infiltrates to the basin-fill aquifer or evaporates before reaching the valley floor. In the southwest part of the valley near Jungo, runoff from the Jackson Mountains and rainfall occasionally accumulate on hardpan surfaces and subsequently evaporate. On May 11, 1989, a large area of hardpan near Jungo had as much as 2 to 3 in. of standing water as a result of intense rain storms. During the same time, an estimated 10 to 15 ft^3/s was flowing near Bottle Creek road from both the Willow Creek and Big Creek watersheds (pl. 1*A*). The ranches are strategically placed near the terminus of each major stream channel and ranchers take advantage of the Spring streamflow and flood-irrigate for as long as possible. Streamflow that infrequently reaches the valley floor beyond the irrigated lands drains to the Quinn River by way of the Bottle Creek Slough (fig. 1).

Major streams on the valley floor include the Quinn River, the Kings River, and the Bottle Creek Slough, all of which are ephemeral. The Quinn River enters the study area from the Quinn River Valley through a low alluvial divide near Sod House, traverses west along the northern part of the study area, and exits west to Pine Valley. The drainage area of the Quinn River extends into Oregon, north of Quinn River Valley, and includes over 3,500 mi^2. The Kings River, which drains Kings River Valley, enters from the north between the Coyote Hills and the Double H Mountains and joins the Quinn River about midway through the valley (fig. 1). The poorly channelized Bottle Creek Slough drains northward to the Quinn River and collects Spring runoff and irrigation return flow from the agricultural lands east of the Jackson Mountains. Table 3 lists available discharge data for miscellaneous surface-water sites used in this study.

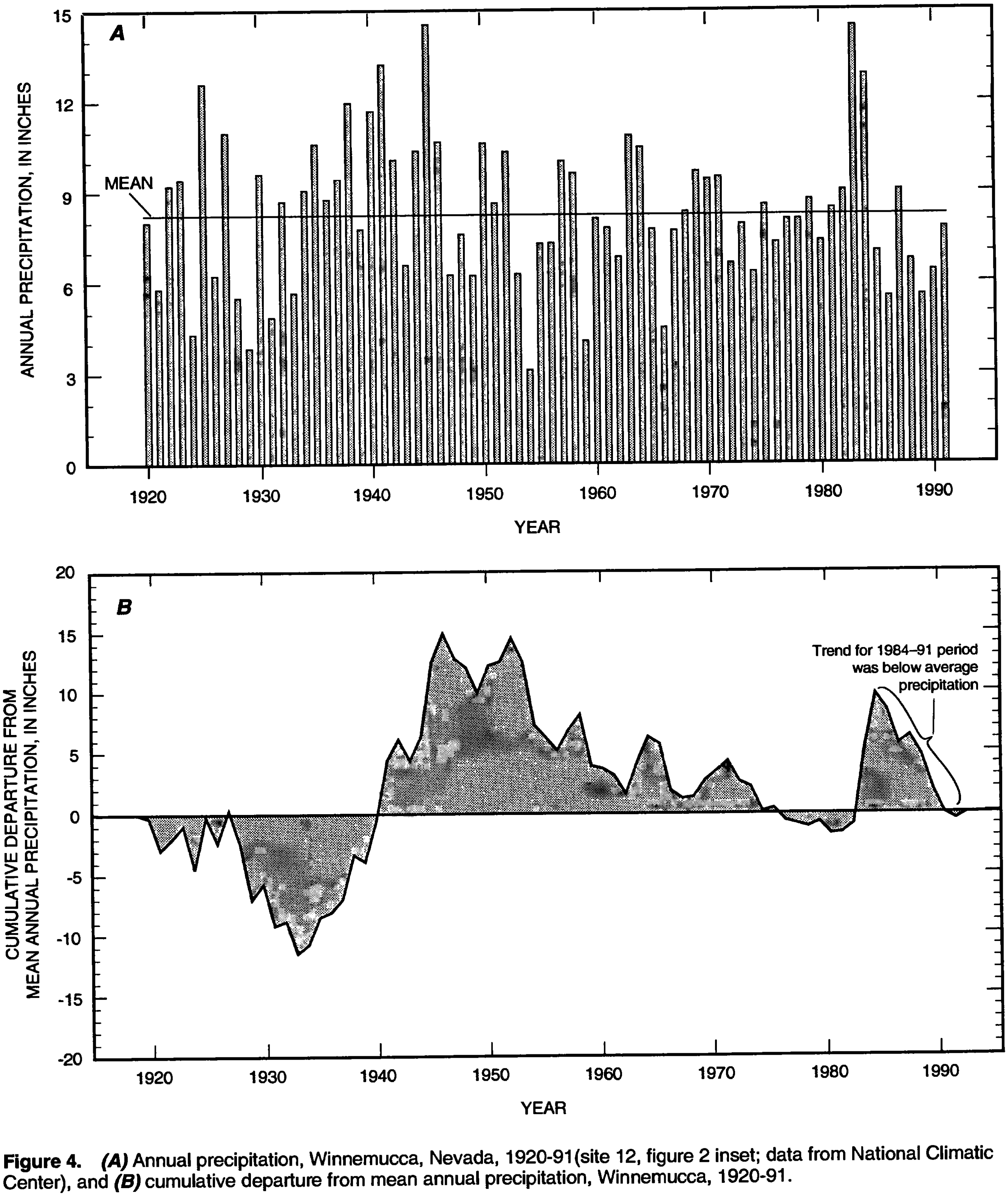


Figure 4. ***(A)*** Annual precipitation, Winnemucca, Nevada, 1920-91(site 12, figure 2 inset; data from National Climatic Center), and ***(B)*** cumulative departure from mean annual precipitation, Winnemucca, 1920-91.

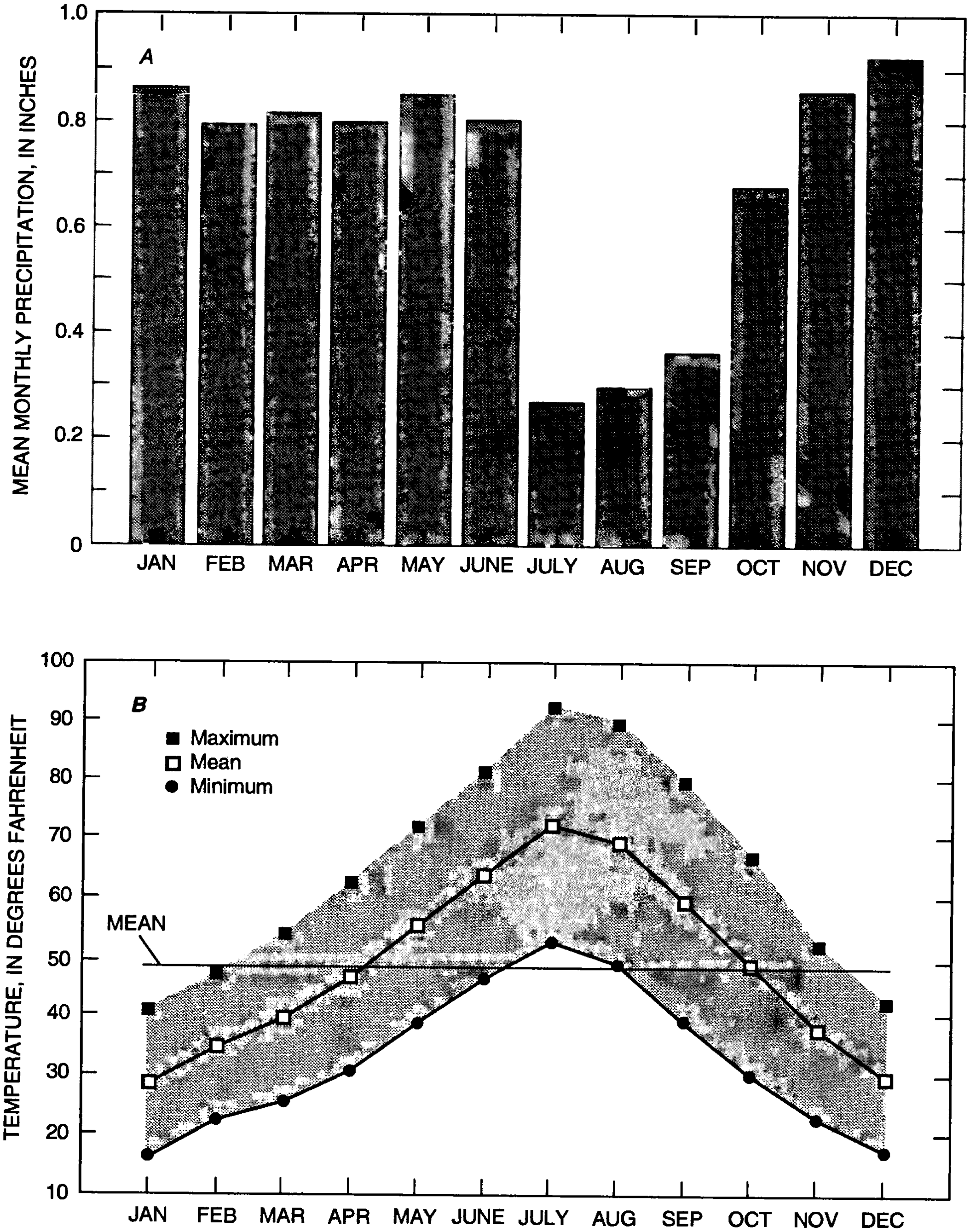


Figure 5. Precipitation and temperature data, Winnemucca, Nevada (site 12, figure 2 inset; data from National Climatic Center). ***(A)*** Mean monthly precipitation, 1920-91, and ***(B)*** maximum, minimum, and mean monthly air temperatures, 1920-90.

Table 3. Streamflow measurements for miscellaneous sites, Desert Valley, Nevada

[Data published by Garcia and others (1992)]

Site number (plate 1*C*)	Site name	Altitude (feet above sea level)	Measurement date	Measured discharge (cubic feet per second)
33	Quinn River near Denio [1]	4,120	03/27/90	1.8
			04/12/90	.19
			05/09/90	No flow
34	Quinn River [2] near Sod House	4,250	03/27/90	No flow
			04/12/90	No flow
			05/09/90	No flow
35	Bottle Creek	4,960	03/28/90	2.03
			04/12/90	2.96
			05/10/90	4.54
			09/24/90	.50
36	Big Creek	5,240	03/28/90	1.65
			04/12/90	1.94
			05/10/90	1.57
			09/25/90	.20
37	Trout Creek[2]	5,250	03/28/90	.37
			04/12/90	.43
			05/10/90	.64
38	Clover Creek	5,050	03/29/90	.64
			04/12/90	.55
			05/10/90	.19
39	Louse Creek	5,000	09/25/90	.25
40	Big Cedar Creek	4,920	03/29/90	.12
			04/13/90	.61
			05/10/90	[e] .1
41	Bull Creek	4,950	03/29/90	.04
			04/13/90	.08
			05/10/90	No flow

[1] Near exit point to Pine Valley, where continuous-record streamflow station was operated during water years 1964-67 and 1978-81; use of town name Denio is for ease of identification only.
[2] Crest-stage gage.
[e] Estimated.

A partial record from a continuously recording streamflow-gaging station, operated on the Quinn River where it exits Desert Valley (site 33 on pl. 1*C*, table 3), indicates an annual-mean discharge of about 1,300 acre-ft over an 8-year period (water years 1964-67 and 1978-81; U.S.Geological Survey, 1965-68, 1979-82, published annually). The gage was discontinued at the end of the 1981 water year. Long-term streamflow data (about 70 years) collected on Martin Creek in Paradise Valley, east of Desert Valley, were used to estimate the long-term discharge for the Quinn River at its exit point to Pine Valley. An annual average of about 1,400 acre-ft/yr was estimated and is in good agreement with the average discharge over the 8-year record for the discontinued gaging station. During the 8-year record, most of the annual flow occurred during the months of April and May and no flow was recorded for the months from July through December. In addition, during the water years 1966 and 1981 no flow was recorded at the gaging station. On April 28, 1984, during Spring flood conditions, an indirect measurement of 1,000 ft^3/s was estimated for the Quinn River near the discontinued gaging station (Rhea P. Williams, U.S. Geological Survey, written commun., 1992). If this rate of discharge were sustained for one day, it would represent more streamflow than the mean-annual estimate of 1,400 acre-ft. Table 3 includes streamflow-discharge measurements made during the months of March, April, and May for 1990 on the Quinn River. A measurement of 1.8 ft^3/s was made on the Quinn River near Denio (site 33), where the river leaves the study area and enters Pine Valley to the west. During this same time period, no flow was observed upstream in the Quinn River near Sod House (site 34), where the river enters Desert Valley from the Quinn River Valley. This no-flow observation suggests that streamflow passing the gage on the Quinn River near Denio is probably a combination of flow from ground-water discharge and the Bottle Creek Slough.

Huxel and others (1966, p. 28) estimated that the annual streamflow of the Quinn River leaving the Quinn River Valley and entering Desert Valley ranges between 1,000 and 5,000 acre-ft. Malmberg and Worts (1966, p. 29) estimated that the long-term streamflow of the Kings River, carrying outflow from the Kings River Valley to the Desert Valley study area, may average 1,000 acre-ft/yr. However, no flow was observed in the Kings River near its confluence with the Quinn River during the course of this study. This observation may be, in part, a result of sustained ground-water pumping for irrigation in the Kings River Valley.

Miscellaneous streamflow measurements were made on seven of the principal streams (sites 35-41; table 3) that drain the east side of the Jackson Mountains. Measurements were made at the contact between the bedrock and the alluvial material near the apex of the alluvial fan. Six of the streams were measured during the Spring runoff period, March through May of 1990. During this period, no streamflow reached the valley floor. Crest-stage gages were installed on the Quinn River near Sod House (site 34) and at the bedrock contact along Trout Creek (site 37). Crest-stage gages are typically installed within flood channels of active streams and are used to indicate the stage of maximum streamflow. During this period of study, 1989-91, neither gage registered high streamflow.

Ground Water

Source, Distribution, and Movement of Ground Water

Most of the ground water in the study area originates as precipitation that falls within the drainage basin. Some ground water enters the basin as subsurface inflow from the Quinn River and Kings River Valleys. Most precipitation and, consequently, most ground-water recharge, originates in the higher altitudes of the mountainous regions surrounding the basin. Recharge from precipitation and snowmelt reaches the basin-fill aquifer by infiltrating through fractured and weathered rock or during intermittent streamflow that percolates through coarse channel deposits on the alluvial fans. Following intense rain showers, some precipitation may infiltrate through areas in the south-central part of Desert Valley covered by active sand dunes. Streamflow may also infiltrate through the streambeds of the Quinn and Kings Rivers during periods of Spring runoff.

Most ground water in the study area is a component of the saturated basin-fill deposits. It is generally unconfined at shallow depths and slightly confined beneath areas containing fine-grained deposits and at greater depths. Ground water flows from areas of recharge, or high hydraulic head, downgradient toward areas of discharge, or lower head. The general depth to ground water and the configuration of the water table prior to much ground-water development in Desert Valley are shown on plate *1D*. Table 4 lists the available data for ground-water sites used in this study. Water-level measurements made during the late 1950's to middle 1960's (see table 15 at back of report) were used to construct the predevelopment water-level contours. Differences in water-level altitudes between those listed in table 15 and those reported by earlier investigators, for identical wells, are a result of more accurate estimates of land-surface altitudes. In the eastern and western parts of the valley, adjacent to the mountains, flow is generally toward the center of the basin. In the northern part of the study area, water-level contours indicate that ground water enters Desert Valley from the Quinn River Valley near Sod House and from the Kings River Valley beneath the divide between the Coyote Hills and the northern Double H Mountains. Huxel and others (1966, p. 29) estimated that subsurface inflow from the Quinn River Valley was about 300 acre-ft/yr. Malmberg and Worts (1966, p. 31) used an average transmissivity of 7,000 ft^2/d, a hydraulic gradient of 5 ft/mi, and an effective width of about 3 mi to estimate an annual flow of nearly 900 acre-ft/yr moving southward from the Kings River Valley.

Table 4. Site number, location, and type of data available for stream and well sites, Desert Valley, Nevada

[Abbreviations for available data: Q, discharge; QW, water quality, WL, water levels. Data are listed in tables 3, 6, and 15]

U.S. Geological Survey site designations[1]			Site name	Available data
Site number (plate 1C)	Local identification	Standard identification		
		Stream stations		
33	31 N42 E33 33DC 1	411634118265601	Quinn River near Denio[2]	Q
34	31 N41 E35 23CB 1	412451118005801	Quinn River near Sod House[3]	Q
35	31 N40 E32 25AA 1	411919118195701	Bottle Creek	Q,QW
36	31 N39 E32 11CC 1	411559118215201	Big Creek	Q,QW
37	31 N39 E31 12AA 1	411634118265601	Trout Creek[3]	Q
38	31 N39 E31 26CC 1	411323118290701	Clover Creek	Q
39	31 N39 E31 34AA 1	411308118293501	Louse Creek	Q,QW
40	31 N38 E31 10AB 1	411117118294401	Big Cedar Creek	Q
41	31 N38 E31 28AD 1	410828118305201	Bull Creek	Q
		Well sites		
42	30A N44 E34 35DDBC1	413835118065801	Thacker well No. 3	WL
43	30B N43 E35 31CDDC1	413320118052501	Rimrock well	WL
44	30B N43 E34 13BBCA1	413617118070301	Thacker well No. 2	WL,QW
45	30B N43 E34 28DBBB1	413412118100201	Coyote Point well	WL
46	30B N43 E33 35AAAD1	413347118140101	Pinnacle Point well	WL
47	30B N42 E35 19ACDD1	413017118050801	Cleto well	WL
48	30B N42 E34 04BABC1	413253118101401	Thacker well No. 4	WL
49	30B N42 E33 10DDBA1	413123118151901	Radar well	WL
50	31 N42 E34 15CACC1	413035118090901	Quinn River Lakes well	WL,QW
51	31 N42 E34 30ABCC1	412916118122201	Hog John Ranch windmill	WL
52	31 N42 E34 36BBBB1	412835118071001	Sod House-Quinn River well	WL
53	31 N41 E35 20AADD1	412510118024801	Sod House No. 1	WL,QW
54	31 N41 E35 23CBCD1	412441118010801	Quinn River well No. 1	WL
55	31 N41 E35 33BBCC1	412330118033101	PI-2	WL
56	31 N41 E35 33CABC1	412312118031101	PI-3	WL
57	31 N41 E34 02CDDA1	412710118073801	Sod House well No. 3	WL
58	31 N41 E34 08BCCC1	412644118112701	Bottle Creek Slough No. 1	WL
59	31 N41 E34 13DDAD1	412518119192201	Bottle Creek Slough No. 3	WL
60	31 N41 E34 27CD 1	412354118082601	OH-50S	WL
61	31 N41 E34 27CD 2	412354118082602	OH-50D	WL
62	31 N41 E33 04BAAC1	412725118170701	Quinn River holding-corral well	WL,QW
63	31 N41 E33 10BBBD1	412636118152101	Bottle Creek well no. 2	WL
64	31 N41 E33 15DCDD1	412453118151701	Bottle Creek well no. 3	WL
65	31 N40 E35 03ADCB1	412228118013801	Franklin replacement well	WL
66	31 N40 E35 04DDCC1	412158118025101	PI-1	WL
67	31 N40 E35 09ACAD1	412137118025101	OH-22	WL
68	31 N40 E35 16ABAC1	412052118030001	Franklin well	WL
69	31 N40 E35 16ACB 1	412042118030401	OH-25	WL
70	31 N40 E35 16BCBC1	412048118034101	INJ No. 1	WL,QW
71	31 N40 E35 20ABBB1	412013118040801	OH-45S	WL

Table 4. Site number, location, and type of data available for stream and well sites, Desert Valley, Nevada—Continued

U.S. Geological Survey site designations [1]				
Site number (plate 1C)	**Local identification**	**Standard identification**	**Site name**	**Available data**
72	31 N40 E35 20ABBB2	412013118040802	OH-45D	WL
73	31 N40 E35 29CCCC1	411832118050101	Austin well	WL
74	31 N40 E35 30DDBA1	411838118050001	Austin replacement well	WL
75	31 N40 E34 08AABA1	412153118103501	OH-51S	WL
76	31 N40 E34 08AABA2	412153118103502	OH-51M	WL,QW
77	31 N40 E34 08AABA3	412153118103503	OH-51D	WL
78	31 N40 E34 09DA 1	412141118095101	OH-68	WL
79	31 N40 E34 10CD 1	412128118091801	OH-67	WL
80	31 N40 E34 13AAAD1	412100118061401	OH-49S	WL
81	31 N40 E34 13AAAD2	412100118061402	OH-49D	WL
82	31 N40 E34 22CB 1	411958118093301	OH-66	WL
83	31 N40 E34 22CA 1	411950118091901	OH-65	WL
84	31 N40 E34 24AB 1	412017118063701	OH-64	WL
85	31 N40 E33 02BABD1	412240118144001	Bottle Creek Slough No. 2	WL
86	31 N40 E33 22D 1	411921118151201	Herbs well No. 2	QW
87	31 N40 E33 23DACC1	411929118141401	Herbs well No. 1	WL
88	31 N39 E35 07DCDA1	411606118050901	Jackson well	WL,QW
89	31 N39 E34 31BDAD1	411311118122801	Presnel well No. 2	WL,QW
90	31 N39 E33 13C 1	411504118134201	Delong	WL
91	31 N39 E33 20AACD1	411445118173401	Alta well No. 2	WL
92	31 N39 E33 26B 1	411356118150101		WL
93	31 N39 E33 33D 1	411231118162901		WL
94	31 N39 E32 35DDBB1	411225118210801	Willow Creek Ranch well	WL,QW
95	31 N38 E35 27DCBC1	411205118071001	Crescent well	WL
96	31 N38 E34 01BCCD1	411209118070101	Gabica well	WL
97	31 N38 E34 16CCCC1	410957118103001	Presnel well	WL
98	31 N38 E34 24ACBB1	410935118064101	Corbeal well	WL
99	31 N38 E33 16DCAA1	410943118170101	Sand dunes well No. 1	WL
100	31 N38 E32 17DDBB1	410949118245601	Trout Creek Ranch well No. 1	WL,QW
101	31 N38 E32 35DACD1	410718118221401	Five-Mile well	WL
102	31 N37 E34 04ACDD1	410644118094501	Mormon Dan well	WL,QW
103	31 N37 E34 14CCCC1	410423118075601	Banks windmill	WL
104	31 N37 E34 28BBAD01	410338118102101	Lee windmill	WL
105	31 N37 E33 14ACCA1	410458118143201	Sand dunes well No. 2	WL
106	31 N37 E33 33AAAD1	410237118162101	McNinch well	WL
107	31 N37 E33 36DBCD1	410208118132401	Hidden Playa well	WL
108	31 N36 E34 05DCDB1	410114118111101	Delong windmill	WL
109	31 N36 E34 19ADBC1	405902118123701	Gaskell well No. 7	WL
110	31 N36 E34 19DDBB1	405838118120201	Gaskell well No. 6	WL
111	31 N36 E34 21CACD1	405838118101901	Gaskell well No. 4	WL

Table 4. Site number, location, and type of data available for stream and well sites, Desert Valley, Nevada—Continued

U.S. Geological Survey site designations [1]				
Site number (plate 1*C*)	Local identification	Standard identification	Site name	Available data
112	31 N36 E34 21DACD1	405838118094401	Gaskell well No. 5	WL
113	31 N36 E34 30DACD1	405726118121901	Corral windmill	WL,QW
114	31 N36 E34 33ADBA1	405720118093901	Gaskell well No. 2	WL
115	31 N36 E34 33BACD1	405730118101501	Gaskell well No. 3	WL
116	31 N36 E34 34CBBC1	405703118092701	Gaskell well No. 1	WL
117	31 N36 E33 04CD 1	410109118165601	Jungo Hills well	WL,QW
118	31 N36 E33 26DADB1	405750118140901	Hardpan well	WL
119	31 N36 E32 22BABD1	405813118230501	Jungo Point well	WL,QW
120	31 N35 E33 20ADAA1	405346118172701	Berg well	WL
121	31 N35 E32 10CACD1	405508118224801	Jungo city well	WL
122	31 N35 E32 10CC 1	405501118224501	Jungo	WL
123	31 N35 E32 30BCBB1	405250118263401	Jungo well No. 1	WL,QW
124	31 N34 E32 11CBCC1	404934118220101	Alpha Mtn well No. 2	WL
125	31 N34 E32 16ABDC1	404901118223601	Haystack Butte well	WL
126	32 N41 E36 31ACBB1	412331117581901	Corral well	WL
127	32 N37 E36 19ACAB1	410418117581301	Barrett Springs well No. 2	WL
128	32 N37 E36 23BDBB1	410421117540701	Barrett Springs well No. 1	WL
129	33A N41 E35 03DADB1	412719118012301	Gone with the Wind well	WL
130	33A N41 E35 23DCCD1	412436118003401	Sod House well No. 2	WL
131	33A N41 E36 17DDDB1	412538117564701	Gallagher well	WL,QW
132	70 N36 E36 30AABB1	405820117580601	Abel Flat well	WL
133	70 N35 E35 09BBDC1	405538118032801	Pronto well No. 1	WL,QW
134	70 N35 E34 01ACDB1	405620118061501	Pronto well No. 2	WL

[1] USGS site designations are described in section titled "U.S. Geological Survey Site Designations" of this report.

[2] Operated as continuous record station, water years 1964-67 and 1978-81.

[3] Crest-stage gage.

Ground water exits the basin beneath the channel of the Quinn River to Pine Valley under a gradient of about 1 ft/mi. Estimates of outflow to Pine Valley made by Sinclair (1962a, p. 10; 1962b, p. 10), Zones (1963, p. 20), and this study ranged from 100 to 400 acre-ft/yr. The difference between the estimated surface-water outflow and inflow indicates that a total of 700-4,700 acre-ft/yr of streamflow from the Quinn and Kings Rivers may recharge the shallow basin-fill aquifer system. The water table beneath the central part of the basin is nearly flat, with a gradient of less than 1 ft/mi. A broad ground-water divide exists northeast of the Jungo Hills (pl. 1*D*). Water flows north from the divide toward the Quinn River and drains to Pine Valley. The water-level contours also indicate that water flows southwest from the divide and presumably exits the basin in the vicinity of the northern Antelope Range where water-level altitudes are less than 4,100 ft. An estimated 120-1,200 acre-ft/yr may exit the basin as subsurface flow to the southwest. This estimate was based on an assumed transmissivity and effective width of the basin-fill aquifer and later refined using the ground-water flow model. No prior estimates have been made of the volume of subsurface flow moving out of the valley to the southwest. Depth to the water table beneath the valley floor in the northern part of the study area is generally less than 20 ft; however, it may be less than 5 ft in areas near the Quinn River during periods of streamflow. Beneath the central part of the valley, depths to ground water are generally greater than 30 ft and increase to nearly 70 ft in the southwest (site 124). However, at the ground-water divide (site 102), water depth was about 17 ft below land surface in 1961—an altitude of about 4,116 ft (Sinclair, 1962b, pl. 1).

Basin-Fill Aquifer

The basin-fill deposits, which occupy structural depressions in the bedrock beneath Desert Valley, constitute the primary ground-water reservoir in the study area. The basin fill is composed of stream, alluvial-fan, lacustrine, hardpan, and eolian deposits derived mostly from the adjacent mountains. However, a large volume of basin fill may have been reworked and transported from outside the present-day topographic boundary of Desert Valley. According to Davis (1982, p. 59), the Humboldt River may have been a tributary to the Quinn River through Desert Valley approximately 22,000-35,000 years ago. Davis (1982, p. 59) also suggests that the extensive dune field in the south-central part of the valley may have been derived from a Humboldt River delta that formed in the Jungo area. In general, the basin-fill deposits within the study area consist of discontinuous units and heterogeneous mixtures of gravel, sand, silt, and clay and, as such, function as a single aquifer system.

Areal Extent and Thickness

The areal extent of the basin-fill aquifer is approximated by the contact between the consolidated rock and the basin fill at the periphery of the valley floor. In the northern part of the study area, the saturated basin-fill deposits are continuous with saturated deposits in adjacent basins, allowing movement of ground water between aquifer systems. The low alluvium-covered topographic divides in the southern part of the study area are underlain by consolidated rock at relatively shallow depths and generally act as barriers to ground-water flow. The basin fill covers nearly 850 mi^2 of the study area, or about 70 percent of the total drainage area.

Wells in the study area range in depth from 10 ft to nearly 1,000 ft; however, most are completed in basin-fill deposits and are typically only about 200 ft deep. Volcanic bedrock was penetrated in a number of irrigation wells adjacent to the Jackson Mountains, along the western margin of the valley floor, at depths less than 500 ft. These wells are a few miles from the range front and support the earlier interpretation that the range-boundary faults are east of the Jackson Mountains (Willden, 1963, p. 48). Numerous observation and exploratory holes drilled for the Sleeper Mine penetrate hundreds of feet of basin fill; however, most of these drill holes are adjacent to the Slumbering Hills and provide little information on the depth to bedrock within the study area. Sites 60 and 75 (pl. 1*C*), in the north-central part of the valley, are completed in the basin fill at reported total depths of 700 and 650 ft, respectively (Nevada Gold Mining, Inc., written commun., 1991). The deepest wells drilled in the southern part of the study area include sites 110 and 122, with reported basin-fill type deposits to depths of 310 ft and 500 ft, respectively.

Estimated thicknesses of the basin fill, shown on plate 1*C* as depth to bedrock, were determined by interpretation of gravity data obtained during this study and in an earlier study (Saltus, 1988). Several gravity profiles across the study area were used as input to a two-dimensional model based on a technique described by Cordell and Henderson (1968). Lines of equal depth to bedrock were constructed from the model results and drill-hole data (pl. 1*B*). The basin can be divided into at least four structural depressions, which suggests that the bedrock geometry is complex.

Hydraulic Properties

The response to development of basin-fill aquifer systems depends, in part, on the hydraulic conductivity and storage properties of the deposits that make up the basin fill. Both of these properties are dependent on the textures and depositional histories of the basin-fill deposits. Because of the inhomogeneity and lenticular nature of these deposits within the study area, hydraulic conductivity and storage estimates were determined as the average of these properties over several depositional textures. Most deposits in the study area are flat lying, resulting in much greater hydraulic conductivities in the horizontal direction than in the vertical. Coarse-grained deposits, such as sands and gravels, commonly transmit the greatest quantity of water and tend to control ground-water flow in the horizontal direction, whereas fine-grained deposits, which impede ground-water movement, control flow in the vertical direction. For purposes of this study and because hydraulic properties below the deepest well are unknown, hydraulic conductivity was assumed to decrease 50 percent for every 1,200 ft in depth, a rate similar to that reported by Durbin and others (1978, p. 76) for basin-fill deposits beneath Salinas Valley, Calif. The initial estimates of horizontal hydraulic conductivity were adjusted during the calibration procedure of the ground-water flow model, as explained in the section "Calibration and Results of Predevelopment Simulations."

Estimates of horizontal hydraulic conductivity were made using lithologic descriptions from drillers' logs and the results of 19 specific-capacity tests. A minimum depth of 180 ft was used to optimize available drillers' logs and provide the best areal coverage. The general distribution of estimated horizontal hydraulic conductivity for the upper 180 ft of saturated basin fill is shown in figure 6. The approximation of transmissivity (hydraulic conductivity multiplied by aquifer thickness) from the specific capacity of wells is based on a method developed by Theis (1963). Transmissivity estimates computed using this method were divided by the length of the screened interval in each well to arrive at the horizontal hydraulic conductivity value of the basin fill directly adjacent to the perforations. Transmissivity estimates and, hence, horizontal hydraulic conductivity, derived from specific-capacity data may be greater than an average value because the screened interval in most wells is adjacent to the more productive zones (coarser deposits), avoiding the less permeable fine-grained deposits. Conversely, well losses tend to lower the specific-capacity value and, therefore, lower the estimate of horizontal hydraulic conductivity. However, this lower value may be somewhat compensated for if the well has a larger effective radius than what was used in the calculation. On the basis of analysis of a limited number of drillers' logs, most of the upper 180 ft of saturated basin fill appears to be fairly transmissive. Estimates of horizontal hydraulic conductivity, determined from specific-capacity data, range from 5 to 320 ft/d and average about 110 ft/d (fig. 6).

Estimates of an equivalent vertical hydraulic conductivity were made for the upper 180 ft of saturated basin fill by determining the thickness of coarse- and fine-grained deposits reported on drillers' logs and using the following equation:

$$K_v = b/\left[(b_c/K_{zc}) + (b_f/K_{zf})\right] ,$$

where K_v is equivalent vertical hydraulic conductivity (in feet per day),

b is total thickness (in feet),

b_c, b_f are the sum of thicknesses of coarse- and fine-grained deposits, respectively (in feet), and

K_{zc}, K_{zf} are the vertical hydraulic conductivities of coarse- and fine-grained deposits, respectively (in feet per day).

The vertical hydraulic conductivity used for the coarse-grained deposits equaled the estimate of horizontal hydraulic conductivity shown in figure 6. The vertical hydraulic conductivity used for the fine-grained deposits was 9×10^{-3} ft/d. Figure 7 shows the general distribution of estimated vertical hydraulic conductivity for the upper 180 ft of saturated basin fill within the study area. In areas where drillers' logs report large thicknesses of clay, vertical hydraulic conductivity is less than 15×10^{-3} ft/d. In general, these areas are beneath the large hardpan near Jungo and in the northern part of the study area. Lithologic descriptions from wells (sites 109-116) drilled in the southern part of T.34 N., R.35 E indicate the presence of coarse sand and gravel with almost no clay or silt, resulting in vertical hydraulic conductivities greater than 7.5×10^{-2} ft/d.

The amount of ground water available from storage in basin-fill aquifers depends on whether the aquifer is under unconfined or confined conditions. The term "storage coefficient" is used to describe the storage capabilities of an aquifer. Storage coefficient is defined by Lohman (1992, p. 8) as the volume of water an aquifer releases or takes into storage per unit surface area of the aquifer per unit change in head. Under unconfined conditions, the storage coefficient is nearly equal to the specific yield. Specific yield is the amount of water released from storage by gravity drainage. Water released from storage under confined conditions depends on the elastic characteristics of the aquifer and the expansion of water. Storage coefficients for confined aquifers are three to five orders of magnitude smaller than the specific yields of unconfined aquifers.

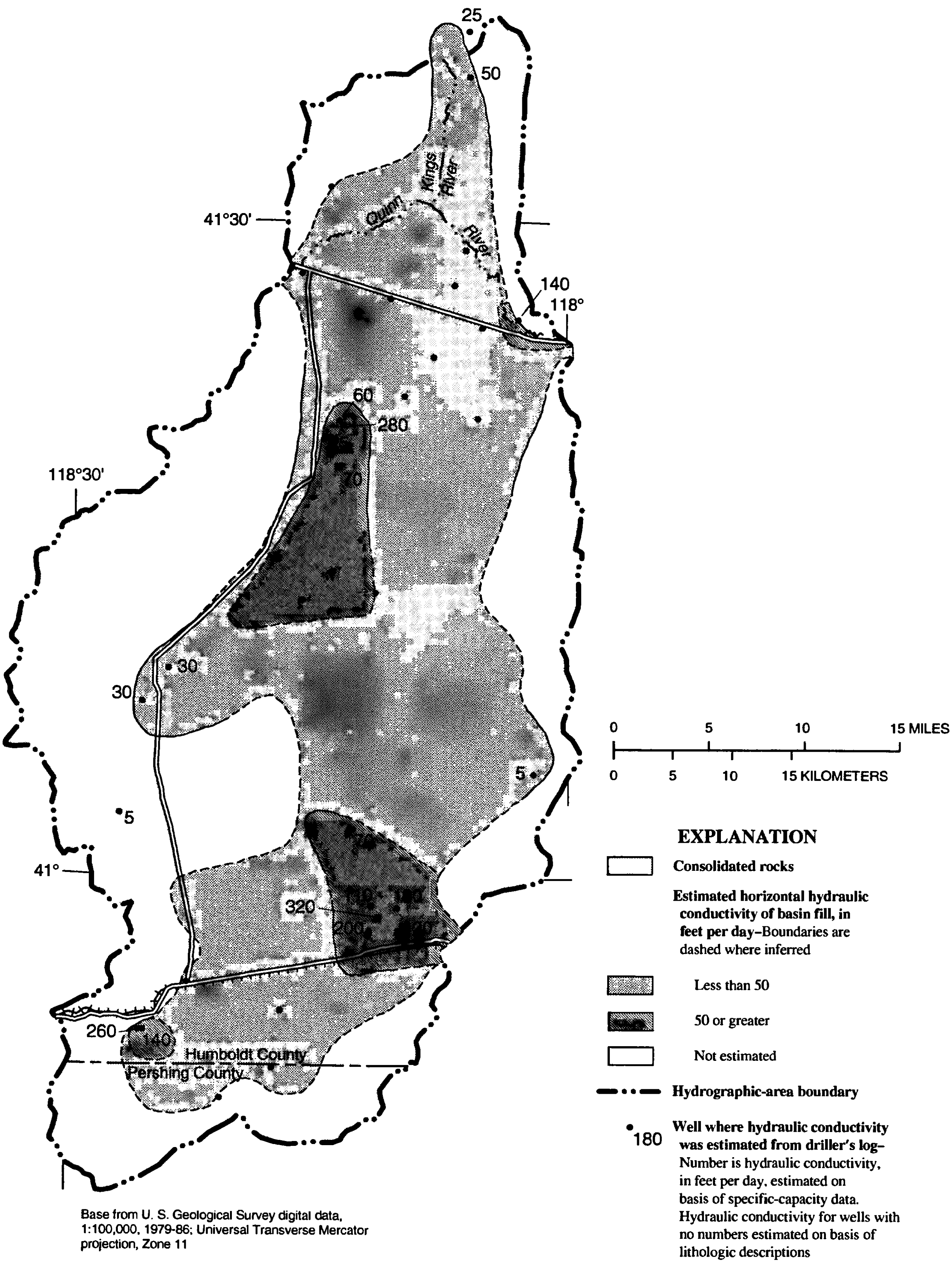


Figure 6. Distribution of estimated horizontal hydraulic conductivity in upper 180 feet of saturated basin fill, Desert Valley, Nevada.

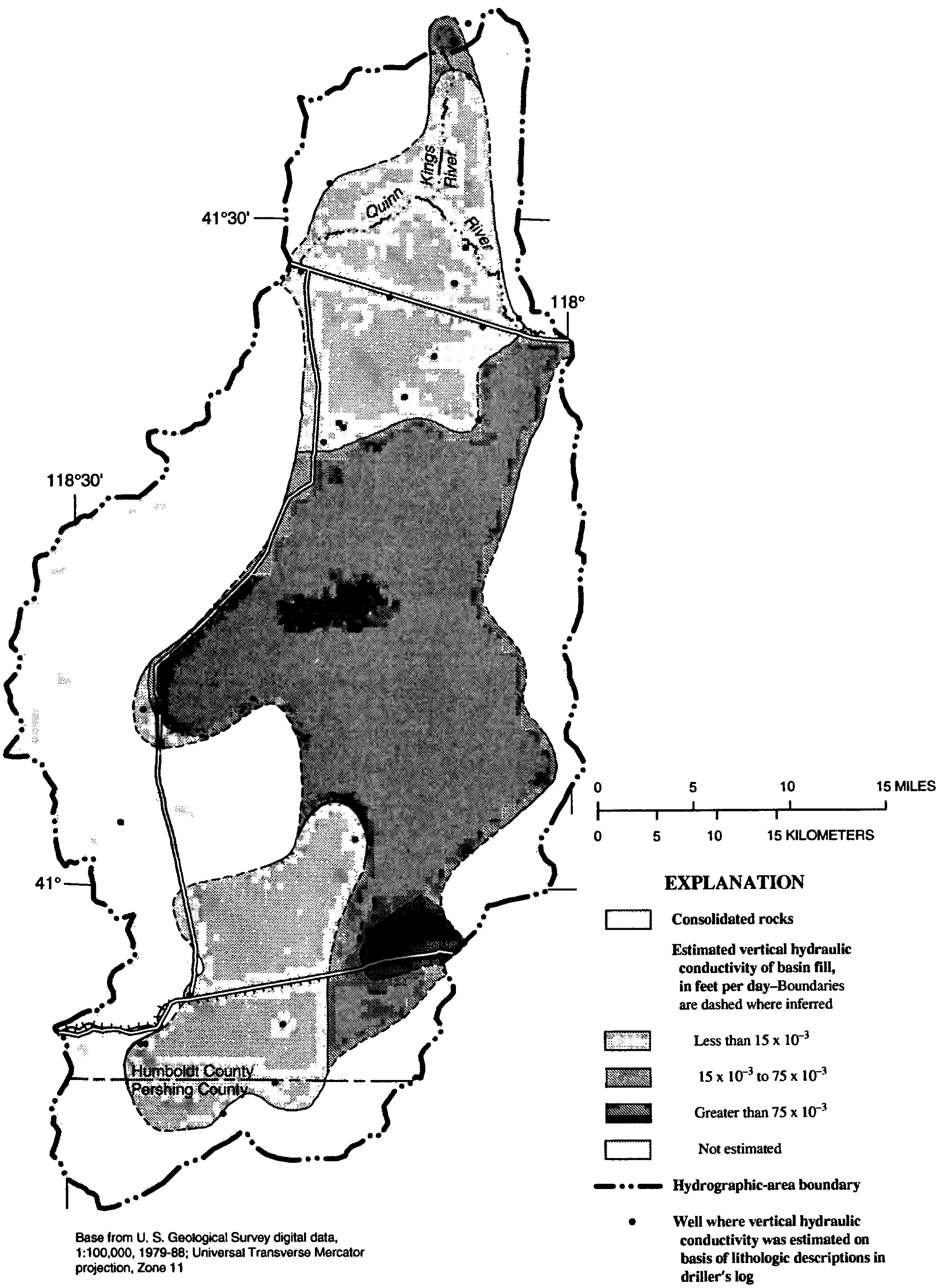


Figure 7. Distribution of estimated vertical hydraulic conductivity in upper 180 feet of saturated basin fill, Desert Valley, Nevada.

In general, specific yields of basin-fill deposits range from 5 percent for clay to about 30 percent for well-sorted sands (Morris and Johnson, 1967, tables 5 and 6). Estimates of average specific yield for the upper 180 ft of saturated basin fill in the study area were made from lithologic descriptions in drillers' logs. The lithologic descriptions were subdivided into five categories and assigned specific-yield values on the basis of the results of Cohen (1963, pl. 2), Morris and Johnson (1967, tables 5 and 6), and Harrill and Moore (1970, p. 27). Table 5 presents the five lithologic categories and their assigned specific yields.

The general distribution of estimated specific yield for the upper 180 ft of saturated basin fill is shown in figure 8. Areas underlain by fine-grained deposits, such as the large hardpan near Jungo, have specific yields of less than 10 percent. The arithmetic mean of specific-yield values estimated from 35 drillers' logs is about 15 percent. Using the distribution of specific yield shown in figure 8, estimated storage for the upper 180 ft of saturated basin fill would have been greater than 10 million acre-ft under predevelopment conditions. This estimation indicates that a large volume of ground water is stored within the basin-fill aquifer beneath the study area.

For deeper parts of the aquifer system, storage coefficients were estimated by multiplying the thickness of the deposits (in feet) by 1×10^{-6}, as suggested by Lohman (1972, p. 53). In the study area, saturated basin fill ranges from 0 to about 7,000 ft thick. If water yield is entirely from the expansion of stored water in the confined aquifer and none is from the compaction of fine-grained material, the storage coefficient for confined deposits 500-7,000 ft thick would range from 0.007 to 0.0005 percent.

Water Quality and Geochemistry

Chemical analyses were made of water from 18 wells scattered throughout the study area and 3 streams that issue from the Jackson Mountains (pl. 1*F*). Water-quality analyses for sites 70 and 76 are from the Sleeper Mine hydrochemistry data base (Geoffrey Beale, Water Management Consultants Inc., written commun., 1990). The analyses included determination of specific conductance, pH, water temperature, dissolved oxygen, calcium, magnesium, sodium, potassium, bicarbonate, carbonate, sulfate, chloride, fluoride, silica, nitrate, orthophosphate, arsenic, boron, iron, manganese, selenium, deuterium, oxygen-18, and radon-222. Most of the ground water sampled is from shallow depths (less than 200 ft) and is used for stock watering. The streams sampled are generally perennial in the upper reaches and become ephemeral after they leave the mountains. The results of these analyses are presented in table 6. Of the 16 wells sampled during this study period—1988-91—6 wells (sites 53, 86, 88, 100, 102, and 119) also were sampled during 1954-61 (Sinclair, 1962b, table 3) and the results for those samples are also presented in table 6 for comparison. During this study, each site was sampled only once, except for site 123, where a second sample was collected for deuterium and oxygen-18 analyses (table 7).

Table 5. Specific yield of lithologic units described in drillers' logs, Desert Valley, Nevada

Lithologic unit described by drillers	Assigned specific yield [1] (percent)
Sand	30
Gravel; sand and gravel	25
Sand, gravel, and clay; gravel and clay cemented; gravel	15
Sand and clay; sandy clay, silt	10
Clay, silt	5

[1] Based on Cohen (1963), Morris and Johnson (1967), and Harrill and Moore (1970).

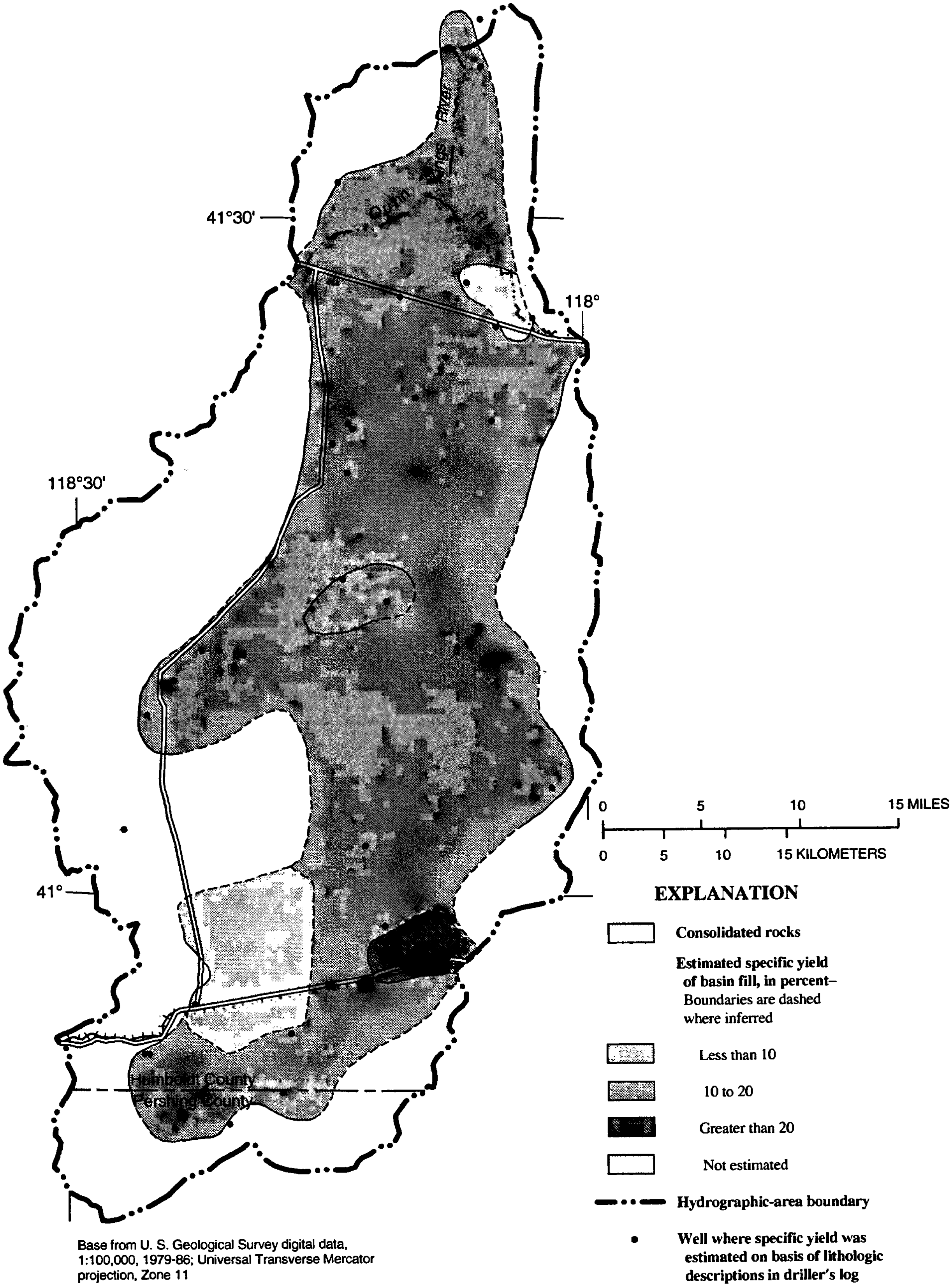


Figure 8. Distribution of estimated specific yield in upper 180 feet of saturated basin fill, Desert Valley, Nevada.

Table 6. Results of chemical analyses for water samples from selected stream and well sites, Desert Valley, Nevada

[Abbreviations and symbols: L, measured in laboratory (all other specific-conductance, pH alkalinity, and bicarbonate values are field measurements); mg/L, milligrams per liter; µS/cm, microsiemens per centimeter at 25°C; °C, degrees Celsius; µg/L, micrograms per liter; <, less than; pCi/L, picocuries per liter; --, not determined. Deuterium and oxygen are relative to Vienna Standard Mean Ocean Water. Earlier (1954-61) analyses for sites 53, 86, 88, 100, 102, and 119 are from Sinclair (1962b, table 3)]

Site number (plate 1*F*)	Date sampled	Time	Specific conduct-ance (µS/cm)	pH (stand-ard units)	Water temper-ature (°C)	Oxygen, dis-solved (mg/L)	Hard-ness (mg/L as $CaCO_3$)	Calcium, dis-solved (mg/L as Ca)	Magne-sium, dissolved (mg/L as Mg)	Sodium, dis-solved (mg/L as Na)
					Stream sites					
35	09-24-90	1315	424	8.1	14.5	--	170	43	15	23
36	09-25-90	0815	312	7.5	14.0	--	110	31	8.1	24
39	09-25-90	1300	928	8.7	19.0	--	220	56	19	100
					Well sites					
44	02-14-90	1115	473	8.1	9.5	2.3	180	46	15	34
50	06-26-91	1500	7,290	7.7 L	12.0	--	1,000	190	130	1,200
53	10-26-54	--	941	9.0	26.6	--	9	2.2	.8	197
	02-13-90	1515	744	7.8	21.0	3.5	79	22	5.9	130
62	02-14-90	1530	628	7.9	8.5	.8	92	25	7.1	100
[1]70	06-17-88	0815	--	7.9	--	--	61	18	4	195
[1]76	03-30-90	0005	2,000	8.0	--	--	490	178	11	144
86	08-06-61	--	566 L	7.8 L	11.5	--	215	58	17	30
	07-24-90	0900	787	7.4	12.5	--	330	91	25	37
88	02-26-61	--	1,000 L	7.8 L	19.5	--	154	46	9.7	146
	07-24-90	1800	975	7.7	20.0	2.9	150	44	9.4	140
89	06-26-91	1030	1,020	7.7	14.0	--	190	51	14	120
94	07-24-90	1120	394	7.2	13.0	5.2	140	38	11	26
100	[2]02-27-61	--	675 L	7.8 L	15.5	--	124	38	7.1	98
	[3]02-27-61	--	589 L	7.7 L	15.5	--	95	30	4.6	90
	[4]02-27-61	--	425 L	8.0 L	19.0	--	38	14	1.0	78
	07-24-90	1300	938	7.5	14.0	--	290	89	16	87
102	02-26-61	--	925 L	7.7 L	13.5	--	155	48	8.5	136
	02-12-90	1630	1,040	7.8	11.0	.5	150	45	9.2	150
113	02-15-90	0950	703	7.9	14.0	4.1	150	40	11	100
117	02-15-90	1400	1,620	7.7	14.0	.8	240	64	19	240
119	02-27-61	--	1,370 L	7.6 L	15.0	--	304	55	41	164
	02-16-90	0945	3,700	7.6	13.0	.8	1,200	200	170	290
123	07-25-90	0845	1,890	7.6	6.0	--	480	75	72	210
	06-25-91	1050	2,120	7.7	17.0	--	--	--	--	--
131	02-13-90	0930	3,050	8.2	11.0	1.5	340	100	22	530
133	06-25-91	1430	821	7.5	14.0	--	87	22	7.7	150

Table 6. Results of chemical analyses for water samples from selected stream and well sites, Desert Valley, Nevada—Continued

Site number (plate 1*F*)	Potassium, dissolved (mg/L as K)	Alkalinity dissolved (mg/L as $CaCO_3$)	Bicarbonate, dissolved (mg/L as HCO_3)	Carbonate, dissolved (mg/L as CO_3)	Sulfate, dissolved (mg/L as SO_4)	Chloride, dissolved (mg/L as Cl)	Fluoride, dissolved (mg/L as F)	Silica, dissolved (mg/L as SiO_2)	Dissolved solids, sum of constituents (mg/L)
				Stream sites					
35	1.4	170 L	210 L	--	28	15	0.2	--	230
36	1.3	140 L	170 L	--	14	12	.2	--	170
39	5.2	170 L	210 L	--	87	140	.3	--	510
				Well sites					
44	4.0	150	180	0	51	48	0.2	58	340
50	39	520	630	0	1,600	1,400	2.0	12	4,900
53	18	--	211	36	70	106	1.4	4.8	541
	14	199	240	0	79	88	.9	71	530
62	13	180	220	0	30	90	.5	67	440
[1]70	10	168	205	--	119	140	.9	31	725
[1]76	27	154	188	--	38	435	.4	48	1,070
86	1.5	--	276	0	32	22	--	--	--
	1.9	270	330	0	46	72	.2	20	460
88	12	--	204	0	94	157	.3	63	640
	12	150	190	0	87	160	.3	63	610
89	13	130	160	0	34	210	.6	48	570
94	4.0	150	180	0	26	24	.2	39	260
100	8.8	--	224	0	43	80	.8	46	431
	9.4	--	215	0	31	61	1.0	55	385
	10	--	208	0	17	22	1.1	52	301
	2.7	250	300	0	83	120	.2	22	570
102	10	--	222	0	126	90	.9	49	606
	9.5	180	220	0	140	97	1.0	49	610
113	8.4	190	230	0	89	76	.5	31	470
117	16	210	260	0	200	270	.4	55	990
119	5.9	--	233	0	88	274	.5	16	773
	20	150	190	0	330	890	.4	55	2,100
123	3.2	160	200	0	320	370	.3	21	1,200
	--	--	--	--	--	--	--	--	--
131	1.3	150	180	0	270	730	.6	52	1,800
133	10	250	310	0	98	42	.5	21	500

Table 6. Chemical analyses of water samples from selected surface- and ground-water sites, Desert Valley, Nevada—Continued

Site number (plate 1*F*)	Nitrogen, nitrate, dissolved (mg/L as N)	Ortho-phosphate, dissolved (mg/L as P)	Arsenic, dis-solved (µg/L as As)	Boron, dis-solved (µg/L as B)	Iron, dis-solved (µg/L as Fe)	Manga-nese, dissolved (µg/L as Mn)	Sele-nium, dissolved (µg/L as Se)	Delta deuterium (permil)	Delta oxygen-18 (permil)	Radon-222, total (pCi/L)
					Surface-water sites					
35	--	--	--	--	--	--	--	-116	-15.2	--
36	--	--	--	--	--	--	--	-118	-15.5	--
39	--	--	--	--	--	--	--	-114	-14.2	--
					Ground-water sites					
44	0.26	0.04	11	100	38	26	<1	-124	-16.1	740
50	--	--	--	3,100	7,900	2,900	--	-108	-12.6	--
53	--	--	--	--	--	<1	--	--	--	--
	.3	.02	26	530	6	<1	1	-125	-16.0	1,000
62	<.1	.10	22	460	160	240	<1	-126	-16.2	600
[1]70	.4	--	46	--	210	<1	<5	--	--	--
[1]76	0	--	30	500	210	1.2	<5	--	--	--
86	--	--	--	--	--	0	--	--	--	--
	1.9	.02	2	110	5	<1	1	-118	-15.5	500
88	--	--	--	870	--	--	--	--	--	--
	1.2	.02	<1	720	86	5	2	-121	-14.7	1,000
89	--	--	--	300	310	940	--	-121	-15.8	--
94	.7	.01	3	90	6	<1	<1	-121	-15.8	730
100	--	--	--	560	--	--	--	--	--	--
	--	--	--	530	--	--	--	--	--	--
	--	--	--	670	--	--	--	--	--	--
	1.6	.03	3	270	9	2	<1	-118	-15.2	910
102	21	--	--	890	--	--	--	--	--	--
	9.3	.07	22	700	37	39	10	-124	-14.3	760
113	.3	.06	10	600	97	2	2	-121	-15.2	900
117	<.1	.07	29	1,100	98	340	<1	-122	-14.6	350
119	--	--	--	810	--	--	--	--	--	--
	22	.02	4	630	120	370	36	-125	-15.2	1,100
123	2.4	.01	3	480	13	<1	2	-131	-16.6	500
	--	--	--	--	--	--	--	-129	-16.4	--
131	.1	.08	70	720	40	140	<1	-122	-15.9	1,000
133	--	--	--	350	99	270	--	-122	-15.2	--

[1] Data from Water Management Consultants Inc., written commun., 1990.

[2] Site 100 sampled at 100 feet.

[3] Site 100 sampled at 250 feet.

[4] Site 100 sampled at 500 feet.

Surface-water samples were collected during base-flow conditions, near the bedrock–basin-fill contact at the apex of the alluvial fans. Base flow is water that has infiltrated the rock and thin soil in the mountains and reemerges in stream channels as ground-water discharge. Chemical analyses of base flow (sites 35, 36 and 39) are assumed to be characteristic of water entering the basin-fill aquifer from the recharge areas. Most ground-water samples were collected using the existing pump at each site; however, samples from four wells (sites 50, 62, 89, and 133) were obtained using either a peristaltic or submersible pump. Specific conductance, pH, and temperature of the ground water were monitored during pumping to ensure that samples represented ground-water conditions within the aquifer and not borehole water. Samples were collected after these measured properties stabilized. Also determined onsite were alkalinity, measured by incremental-pH titration, and dissolved oxygen, measured with a dissolved-oxygen meter and probe. Samples collected for chemical analyses were filtered onsite using a pre-rinsed 0.45-µm filter and preserved according to standard U. S. Geological Survey methods (Fishman and Friedman, 1989). Samples were shipped to the U. S. Geological Survey Laboratory in Arvada, Colo., for analysis. The types of containers and preservation procedures used for the various samples are those specified by the U.S. Geological Survey (Timme, 1994). As an indication of the accuracy of the chemical analyses, an ionic balance was calculated for each sample. One sample (from site 50) had a calculated balance error of nearly 6 percent; all other samples had ionic balance errors of less than 5 percent.

Plate 1*F* presents water-quality diagrams that illustrate the relative milliequivalent-per-liter proportions of major ionic species for each chemical analysis made during this study. Predominant ionic species include sodium, potassium, magnesium, calcium, chloride, sulfate, bicarbonate, and carbonate. The water quality at sites 35 and 36 (stream baseflow in recharge-source areas) represents the most dilute water sampled in the study area (dissolved solids less than 250 mg/L) and has pH values of 8.1 and 7.5, respectively. Calcium is the most abundant cation, and bicarbonate is the most abundant anion at both sites. In contrast, the sample from Louse Creek (site 39) in the southern part of the Jackson Mountains has a dissolved-solids concentration of 511 mg/L and is dominated by sodium (cation) and chloride (anion) in nearly equal proportions. Ground water sampled during this study ranges from slightly to moderately alkaline (pH ranges from 7.2 to 8.2), and most samples have dissolved-solids concentrations between 500 and 1,000 mg/L. Sites 50, 76, 119, 123, and 131 have dissolved-solids concentrations that exceed 1,000 mg/L, with a maximum of 4,900 mg/L at site 50 (table 6).

Nevada water-quality standards for selected constituents are shown in table 7 and are used herein as a basis for comparing reported concentrations with respect to beneficial use for human consumption, aquatic life, irrigation, and watering livestock. In 1988, the State of Nevada adopted these standards from the U.S. Environmental Protection Agency (1986). On the basis of the State standards for 10 inorganic constituents and properties, most ground water sampled during this study is suitable for each designated beneficial use. However, a sample from site 131, which is within Quinn River Valley (pl. 1*C*), exceeded the primary drinking-water standard for arsenic and the secondary maximum standard for chloride and dissolved solids. The primary drinking-water standard was exceeded for selenium and nitrate (as nitrogen) in ground water at site 119, and at site 102 the sample contained selenium at the primary standard value. Secondary maximum drinking-water standards for chloride and dissolved solids are exceeded at sites 50, 76, 119, and 123 (dissolved solids only). In addition, site 50 exceeds secondary standards for fluoride, iron, and sulfate. Water-quality standards for aquatic life are exceeded for boron at sites 50, 88, 102, 113, 117, 119, and 131. Aquatic-life standards are also exceeded for iron at site 50 and for selenium at site 119. Irrigation standards are exceeded for manganese at sites 50, 62, 89, 117, 119, and 133 and for boron at sites 50, 88, and 117. Site 133 is located just outside the southeast part of the study area. Fluoride and iron standards for irrigation use meet or exceed at sites 50 and 102, and site 119 exceeds the selenium standard for irrigation. Standards for watering of livestock is exceeded in fluoride at site 50. Samples for radon-222 were analyzed for 13 sites and all exceeded the proposed standard of 300 pCi/L, having concentrations ranging from 350 to 1,100 pCi/L. Ground-water samples from near and within the Sleeper Mine generally exceed all standards for arsenic (Hydrotechnica, written commun., 1988). Hydrotechnica hydrologists believe that the arsenic concentrations are associated with the solution of arsenic minerals within the ore body, rather than the overlying basin fill.

Table 7. Selected water-quality standards for designated beneficial use

[Values in micrograms per liter, except as noted. Abbreviations and symbol: mg/L, milligrams per liter; pCi/L, picocuries per liter; --, standard does not exist for indicated constituent. Standards set by U.S. Environmental Protection Agency and adopted by State of Nevada (Nevada Bureau of Health Protection Services, 1992).]

Constituent	Public water systems		Aquatic life	Irrigation	Watering of livestock
	Primary standard[1]	Secondary maximum standard[2]			
Arsenic	50	--	[3]360	100	200
Boron	--	--	550	750	5,000
Chloride (mg/L)	--	400	--	--	--
Dissolved solids (mg/L)	--	1,000	--	--	--
Fluoride (mg/L)	4	2	--	1	2
Iron	--	600	1,000	5,000	--
Manganese	--	--	--	200	--
Selenium	10	--	[4]20	20	50
Sulfate (mg/L)	--	500	--	--	--
Nitrate, as N (mg/L)	10	--	--	--	--
Radon-222 (pCi/L)	[5]300	--	--	--	--

[1] Primary standards are health related and federally mandated.

[2] Secondary maximum standards are based on esthetic qualities and are enforceable by State of Nevada.

[3] Standard based on more toxic dissolved arsenic species (arsenic III).

[4] One-hour average; may be exceeded only once every 3 years.

[5] Proposed but not promulgated.

Trilinear diagrams are used to show the chemical character of water in terms of milliequivalent-per-liter percentages of major dissolved constituents (Hem, 1985). The trilinear diagram in figure 9 is subdivided into four general water types on the basis of major constituents making up more than 50 percent of the sample. The diagram indicates that the water sampled in the study area was overall a mixture of constituents; however, type-3 water (sodium plus potassium, sulfate plus chloride) represents nearly half the samples. The pH of ground-water ranged from 7.2 to 8.7; consequently, the bicarbonate-plus-carbonate component of the trilinear diagram is dominated by bicarbonate. Calcium was the dominant cation in all sites with water types 1 and 4 except for sites 119 and 123, where magnesium was slightly greater. Sodium was the dominant cation in water types 2 and 3 and was generally greater than 50 percent. Bicarbonate was the dominant anion in water types 1 and 2 and makes up more than 50 percent of the anions. In water types 3 and 4, chloride represents the largest percentage of anions except in samples from sites 53, 102, and 100, where sulfate is slightly greater.

Samples of water originating in the recharge-source area in the northern part of the Jackson Mountains and in the adjacent basin fill represent the most dilute water (average dissolved-solids concentration at sites 35, 36, 86, and 94 was 280 mg/L) and are a calcium-dominated bicarbonate water. This water evolves along ground-water flow paths to a more concentrated sodium chloride water (average dissolved-solids concentrations at sites 70, 88, and 89 was 640 mg/L). Similar geochemical evolution of ground water in a closed basin in central Nevada has been documented by Thomas and others (1989b).

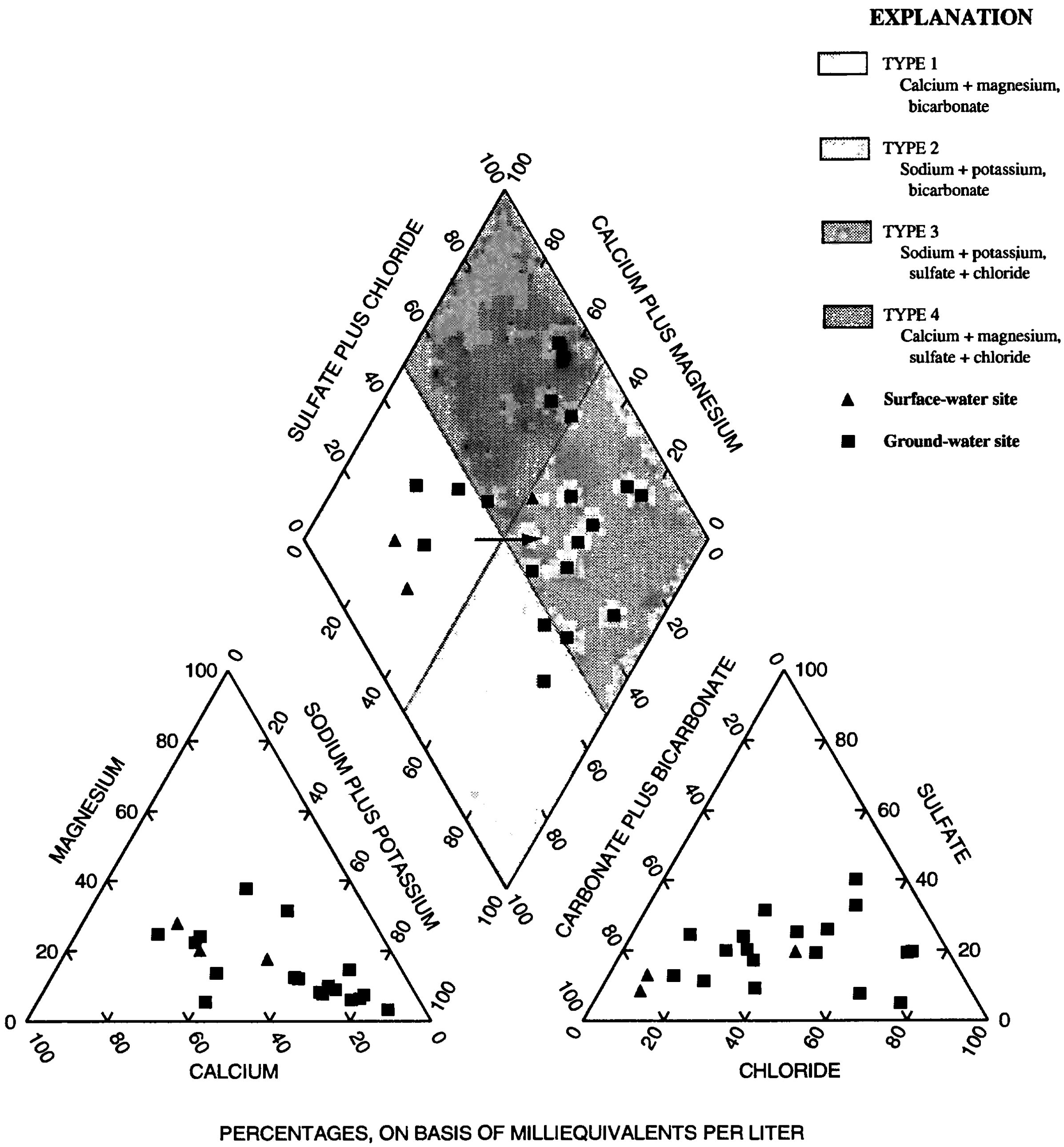


Figure 9. Proportions of major dissolved constituents in sampled stream water (sites 35, 36, and 39) and well water, Desert Valley, Nevada. Arrow indicates path of generalized chemical evolution, from recharge areas to discharge areas.

The relation between the stable hydrogen isotope of water (deuterium) and chloride concentration has been used to indicate processes concentrating ions in ground water (Welch and Preissler, 1990, p. 31; Thomas and others, 1989, fig. 16). On the basis of a plot of deuterium as a function of chloride concentration, the increase in concentration of dissolved solids in the ground water appears to be related to the dissolution of evaporative salts, or transpiration, or both, rather than evaporation (fig. 10). Salt dissolution and transpiration increase ion concentrations in solution while producing no appreciable change in deuterium composition. In contrast, evaporation results in greater proportions of deuterium relative to hydrogen (less negative delta-deuterium values) with increasing ion concentration because the ground water lost to the atmosphere by evaporation is enriched in hydrogen relative to deuterium (more negative delta-deuterium values). Water from site 50 shows approximately a 10-permil increase in deuterium above that of most ground water in the study area and has the highest chloride concentration of all the samples. This suggests that the high concentrations of chloride and other dissolved solids at this sampling site is due to evaporative processes.

GROUND-WATER RECHARGE FROM PRECIPITATION

The principal source of water that recharges the basin-fill aquifer system in the study area originates as precipitation that falls within the mountains surrounding the valley floor. Mountain-block estimates of recharge were made using an empirical method developed by Maxey and Eakin (1949) and a chloride-balance technique (Dettinger, 1989). Both methods are based on the total precipitation that falls within the recharge-source areas where annual precipitation is greater than 8 in. Recharge that occurs by direct infiltration of precipitation on the valley floor in areas covered by sand dunes was estimated using a deep-percolation model (Bauer and Vaccaro, 1987).

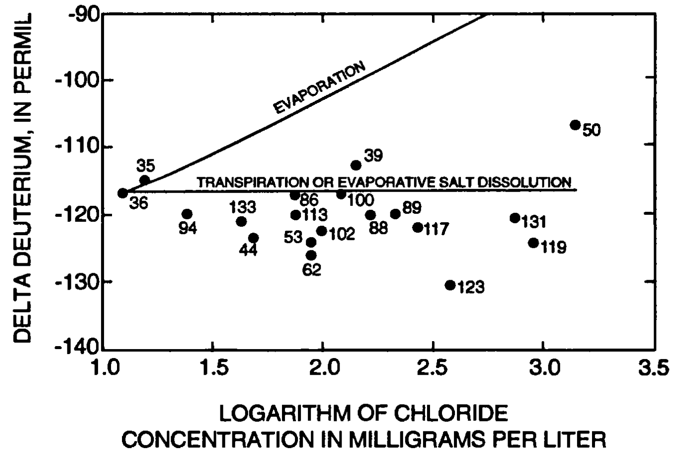


Figure 10. Relation between delta deuterium and logarithm of chloride concentrations in sampled water, Desert Valley, Nevada (site numbers listed in table 6).

Estimates of average annual precipitation within the study area were made on the basis of the relation between altitude and average annual precipitation at 26 sites with 5 or more years of data (table 2). The average annual precipitation for altitude zones within the basin (fig. 2) was constructed from the relation shown in figure 3. The residual plot of predicted and measured average annual precipitation (fig. 11) indicates that the simple linear relation used in this analysis appears to be appropriate and generally fits the observed data. On the basis of this information, the total average annual precipitation that falls within the study area is estimated to be on the order of 410,000 acre-ft. Estimated precipitation, by altitude zone, is given in table 8. The average annual precipitation estimated in each corresponding altitude zone was multiplied by the area within that zone and summed to determine the total average annual precipitation within the entire basin. The areas in each altitude zone were obtained from 7.5- and 15-minute topographic maps. This annual total is about 37 percent larger then the 300,000 acre-ft originally estimated by Sinclair (1962b) and reflects the inclusion of the Sod House subarea in this study, use of an updated precipitation-altitude relation, and the better resolution of the more recent maps used in the present study to define altitude zones.

Estimates Using Maxey-Eakin Method

The Maxey-Eakin method for estimating ground-water recharge from precipitation uses a percentage of total precipitation within a specified altitude zone that potentially would become ground-water recharge. The percentages for each altitude zone are based on estimates developed by Maxey and Eakin (1949) from 13 valleys in east-central Nevada. The percentages of estimated recharge for each altitude zone and associated average annual precipitation are given in table 8. An estimated average annual recharge rate of about 6,800 acre-ft/yr was calculated using this method for the study area (table 8). This is about 26 percent greater than the estimated 5,000 acre-ft/yr of Sinclair (1962b), due to the higher rates of precipitation estimated by the current study and differences in delineation of altitude zones. More than half (about 55 percent) of the total recharge to the ground-water system is estimated to originate in the Jackson Mountains north of Trout Creek (pl. 1*A*). Over most of the valley floor, precipitation is less than 8 in. annually and is assumed to be a negligible source of recharge (Maxey and Eakin, 1949; Sinclair, 1962b; Huxel and others, 1966), although some recharge may occur in areas covered by sand dunes. Approximately 6 percent of the total precipitation that falls within the recharge-source areas (altitudes greater than 5,000 ft) is estimated to become ground-water recharge.

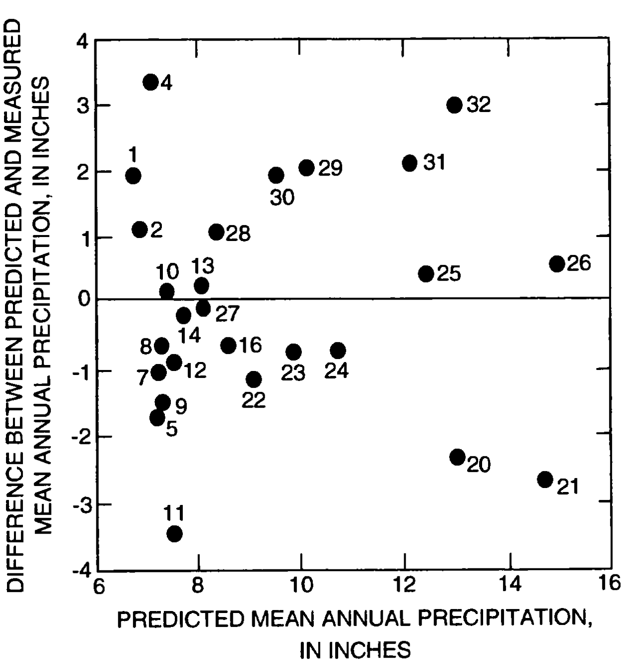


Figure 11. Difference between predicted and measured mean annual precipitation, Desert Valley area, Nevada (site numbers listed in table 2).

Table 8. Estimated annual average ground-water recharge from precipitation, Desert Valley area, Nevada

Altitude zone (feet above sea level)	Area (acres)	Estimated annual precipitation			Estimated recharge	
		Range (inches)	Average (feet)	Average (acre-feet)	Assumed percentage of precipitation	Acre-feet per year
Above 8,000	2,800	18-22	1.7	4,800	25	1,200
7,000-8,000	7,700	15-18	1.4	11,000	15	1,600
6,000-7,000	21,500	12-15	1.1	24,000	7	2,000
5,000-6,000	78,200	8-12	.9	70,000	3	2,000
Below 5,000	635,000	4-8	.5	300,000	0	0
Total (rounded)	745,000			400,000		7,000

Estimates Using Chloride-Balance Technique

The chloride-balance technique for estimating ground-water recharge has been applied in several basins within the Basin and Range Province (Dettinger, 1989; Thomas and others, 1989a; and Harrill and Preissler, 1994). This technique is based on the balance between total chloride concentration in bulk precipitation that falls in recharge-source areas and chloride concentration in water that represents ground-water recharge. The technique assumes that precipitation is the only source of chloride in the recharge water. A more detailed discussion of the assumptions and application of the chloride-balance technique is presented by Dettinger (1989). On the basis of the chloride-balance technique, the volume of recharge can be approximated as follows:

$$R = P(Cl_p/Cl_r) \quad ,$$

where R is recharge (in acre-feet per year),
P is total precipitation that falls in recharge-source area (in acre-feet per year),
Cl_p is chloride concentration in bulk precipitation (in milligrams per liter), and
Cl_r is chloride concentration of recharge water (in milligrams per liter).

Using 110,000 acre-ft/yr as the total precipitation estimated to fall in recharge-source areas (altitudes greater than 5,000 ft; table 8), 0.4 mg/L as the average chloride concentration (Dettinger, 1989) in bulk precipitation that falls in the recharge-source areas, and 13.5 mg/L as the average chloride concentration of recharge water from sites 35 and 36 sampled during base-flow conditions, the recharge is estimated to be about 3,300 acre-ft/yr. That amount is about half of the recharge estimated using the Maxey-Eakin method and may represent a minimum. However, the chloride-balance estimate is more likely to be low because of the assumption that precipitation is the only source of chloride in the recharge waters. Chloride-laden dust blown into the recharge-source areas from playas of the Black Rock Desert to the west may account for the relatively high concentration of chloride in the recharge water. Dettinger (1989) reports that chloride concentration in bulk-precipitation may be as high as 0.9 mg/L, which suggests that a larger recharge estimate could therefore be obtained due to dry fall-out of additional chloride. If an average chloride concentration of 6.6 mg/L, as reported by Malmberg and Worts (1966) from three streams sampled in the northern Bilk Creek Mountains (pl. 1*A*) is used to represent typical chloride concentrations in recharge waters, an estimate of 6,600 acre-ft/yr is calculated. These samples were taken during base-flow conditions (September) from streams that drain predominantly east-facing slopes similar to sites 35 and 36 of this study. The Bilk Creek Mountains are the northern extension of the Jackson Mountains and make up the western boundary of Kings River Valley. However, they are a considerable distance north of the Black Rock Desert and probably receive less blowing dust.

Estimates of Recharge Through Active Sand Dunes

The methods previously discussed for estimating ground-water recharge assumed an altitude below which precipitation does not contribute to the ground-water reservoir. An altitude of 5,000 ft was assumed to be the "cutoff" altitude used in the recharge estimates, which corresponds to an average annual precipitation of less than 8 in. and generally includes the entire valley floor. Because of the high evapotranspiration rates and low amounts of precipitation associated with valley floors in arid areas, annual precipitation is mostly consumed by vegetation and evaporation, resulting in negligible quantities of ground-water recharge. However, studies in other arid to semiarid areas have documented the potential for ground-water recharge to occur through sparsely or unvegetated sandy environments, such as dune fields (Allison and others, 1985; Stephens and Knowlton, 1986).

A deep percolation model (DPM), developed by Bauer and Vaccaro (1987), was used to estimate potential recharge through about 12,000 acres of valley floor in the south-central part of the study area covered by active sand dunes (Berger, 1992). The model used daily climatic data collected from the nearest weather station (Winnemucca) and soil characteristics, vegetative cover, and land use typical of the modeled region. Long-term estimates of deep percolation (recharge) are determined as the difference between precipitation and the sum of evapotranspiration and surface-water runoff simulated at the site by the DPM.

The results of the DPM indicate that ground water may recharge through unvegetated sand dunes within the study area during each month of a given year; however, the maximum rates are during December through February. Estimated recharge rates calculated by the DPM range between 0.04 and 0.11 ft/yr. Applying these rates to the area of the dune field results in an estimated range of about 500-1,000 acre-ft/yr of ground-water recharge. The observed ground-water divide in the south-central part of the valley may be produced in part by the dune field acting as a conduit for ground-water recharge.

GROUND-WATER DISCHARGE BY EVAPOTRANSPIRATION

Ground-water discharge by evapotranspiration includes losses by bare-soil evaporation and transpiration by native vegetation. In areas where the water table is only a few feet below land surface, ground water can discharge through direct evaporation. In clayey soils, typical of those in the study area, ground water can evaporate directly from the water table from a depth of almost 8 ft (Lee, 1912, p. 53). Native vegetation that grows in areas where the water table or the capillary fringe above the water table lies within reach of their roots, and thus provides a perennial source of water, are called phreatophytes (Meinzer, 1927, p. 1). Phreatophytic vegetation has been documented to consume large quantities of ground water in several sparsely vegetated basins in Nevada (Huxel and others, 1966, p. 28; Malmberg and Worts, 1966, p. 29; Harrill and Moore, 1970, p. 66; Thomas and others, 1989a, table 8). In Desert Valley, the principal phreatophyte is greasewood, which grows randomly in areas on the valley floor where the depth to water is less than about 35 ft.

The distribution and density of phreatophyte communities in Desert Valley were determined by incorporating Landsat remotely sensed satellite data with field observations. Landsat Multispectral Scanner (MSS) data from August 19, 1988, was used to map general land-cover classes on the basis of spectral-pattern recognition. The land-cover classifications that related to potential evapotranspiration zones were then compared with previous phreatophyte-distribution maps of Zones (1963, pl. 1) and Huxel and others (1966, pl. 3) and field notes made during the course of this study. Of approximately 70,000 acres of phreatophyte vegetation identified on the valley floor (fig. 12), about half the area consists primarily of low-density greasewood (plant cover, about 12 percent) and the other half consists primarily of sparse greasewood mounds (plant cover, about 5 percent). About 1,600 acres, in the northern part of the study area, were identified as bare soil where the depth to water is less than 8 ft. The area of phreatophytes outside the modeled area is assumed to be negligible.

In an effort to determine evapotranspiration for different greasewood densities, micrometeorological instruments commonly used to measure and calculate an energy budget were placed in a field-study site in the northern part of the study area (Nichols, 1992). The site, in a sparsely vegetated area approximately 100 ft west of site 43 (fig. 12, pl. 1*C*), was occupied June 6 through June 17, 1991. Data collection consisted of measurements of temperature and vapor pressure of the air at two heights above the vegetation canopy, incident and reflected short-wave radiation, incident and emitted long-wave radiation, soil heat flux, and soil temperature. The data were used to estimate evapotranspiration rates using the Bowen-ratio method (Tanner, 1960). The Bowen-ratio method estimates actual evapotranspiration, is based on the energy balance, and is dependent on temperature and humidity gradients (Gay and Fritschen, 1979; Van Hylckama, 1980). Data from similar field-study sites, together with the results from this study, were used to generate evapotranspiration rates as a function of plant-cover density and depth to water (W.D. Nichols, U.S. Geological Survey, written commun., 1992). Assuming an average depth to water of about 20 ft beneath areas identified as vegetated by phreatophytes, the evapotranspiration rate for low-density cover is estimated to be about 0.17 ft/yr. The evapotranspiration rate for sparse greasewood mounds was estimated to be about 0.07 ft/yr. Evaporation rates for bare soil having an average depth to water of about 5 ft is estimated to be about 1.1 ft/yr (W.D. Nichols, written commun., 1992). Applying these rates to the acreage of identified phreatophytes and bare soil gives an estimated 10,000 acre-ft annually consumed by evapotranspiration in Desert Valley.

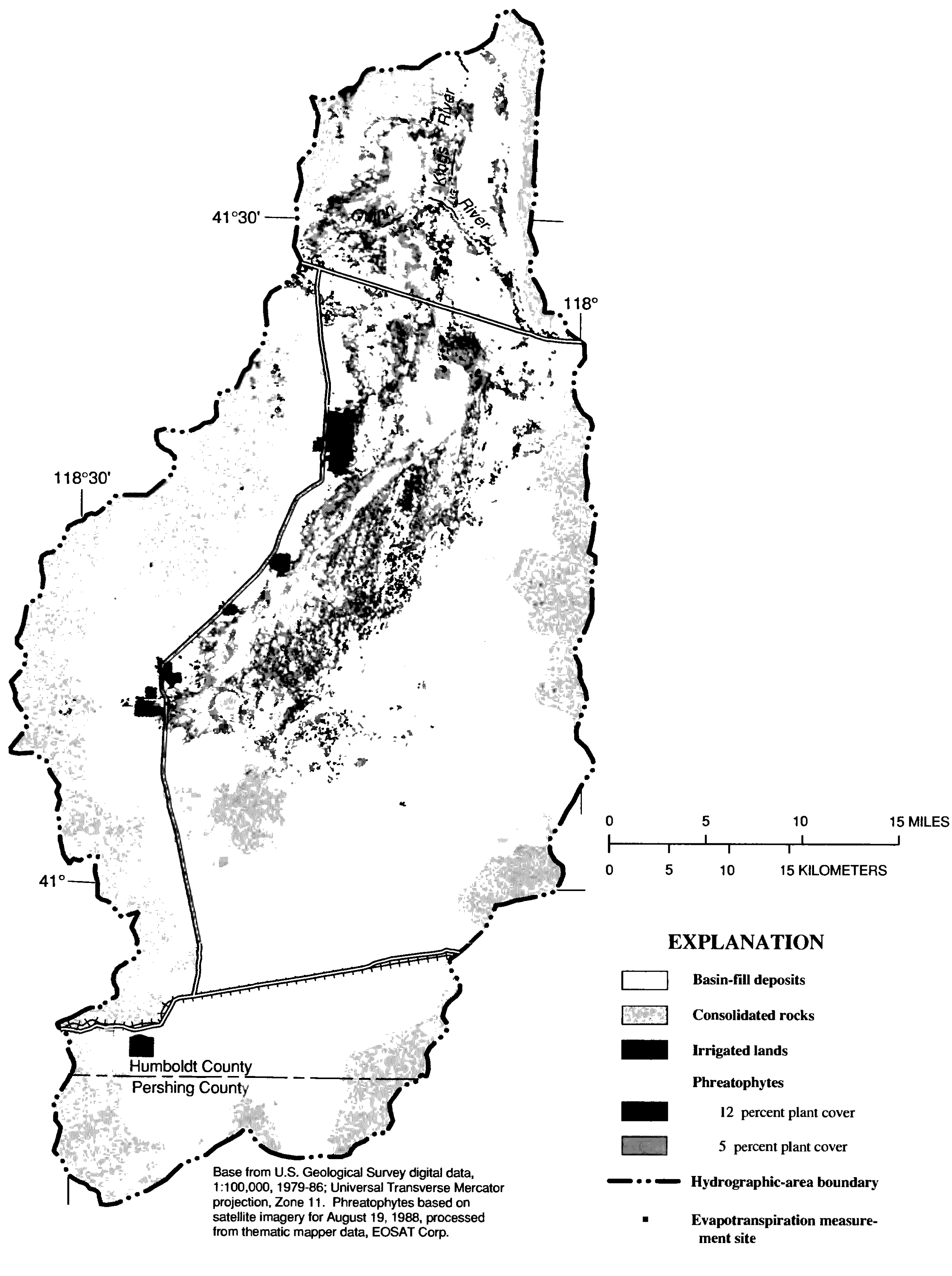


Figure 12. Distribution of phreatophytes in August 1988 and irrigated land for 1981-91, Desert Valley, Nevada

PREDEVELOPMENT GROUND-WATER BUDGET

Estimates of ground-water inflow and outflow for the study area under predevelopment conditions (pre-1962) are summarized in table 9. Ground-water withdrawals prior to 1962 are considered negligible and were not included in the predevelopment budget. In addition, surface-water diversions from major streams issuing from the Jackson Mountains, which began many years ago, are assumed to have only a slight effect on the balance of the hydrologic system and are not considered in the budget. Estimates of individual budget components, as discussed in preceding sections, are presented as a range representing minimum and maximum quantities. The long-term average is assumed to fall within the given range. Those components listed as a single value are considered to represent the long-term annual average. The water budget reflects natural (steady-state) conditions that are assumed to have existed before human development began in the area. Ground-water inflow and outflow are assumed equal under these conditions; however, each independently estimated component of the budget is subject to some uncertainty.

Recharge from precipitation in the mountains accounts for most of the ground-water inflow to the study area. Ground-water discharge by evapotranspiration accounts for more than 75 percent of the outflow. The distribution of phreatophytic vegetation determined from Landsat Multispectral Scanner data for August 1988 and recent field observations may be somewhat different than under predevelopment conditions, due to changes in depth to water since development began. The most uncertain components of the predevelopment water budget are the quantities of infiltration from rivers and subsurface outflow to the southwest. The ground-water flow model, discussed in the following sections of this report, was used to help quantify these components and select values representing the average annual predevelopment ground-water inflow and outflow for the study area.

Table 9. Estimated ground-water budget for predevelopment conditions (pre-1962), Desert Valley, Nevada

[All values in acre-feet per year]

Budget component	Estimated predevelopment conditions
Inflow	
Recharge from precipitation:	
From mountain block (p. 33, p. 34)	3,300 - 6,800
From sand dunes (p. 35)	500 - 1,000
Infiltration from rivers (p. 19)	700 - 4,700
Subsurface inflow:	
From Kings River Valley (p. 16)	900
From Quinn River Valley (p. 16)	300
Total inflow (rounded)	5,700 - 14,000
Outflow	
Evapotranspiration (p. 35)	10,000
Subsurface outflow:	
To Pine Valley (p. 19)	100 - 400
To Southwest (p. 19)	120 - 1,200
Total outflow (rounded)	10,000 - 12,000

GROUND-WATER DEVELOPMENT

Prior to open-pit mine dewatering in 1985, ground-water withdrawals were primarily for crop irrigation, with lesser amounts for domestic use and livestock watering. Prior to 1962, ground-water pumpage in the entire valley was about 700 acre-ft/yr and was assumed to have only a slight effect on the basin-fill aquifer system in Desert Valley (Sinclair, 1962b, p. 10). About 400-500 acre-ft/yr was pumped to supplement streamflow from the Jackson Mountains along the west side of the valley near the Bottle Creek Ranch area. As a result of extensive interviews with many long-time Desert Valley residents, a fairly detailed account of the agricultural history of the valley was compiled for the period 1962-91 and is summarized in the following paragraphs. Table 10 lists the estimated acreage of irrigated land and estimates of the gross and net ground-water pumpage for irrigation over the 30-yr period.

Table 10. Estimated irrigated acreage and ground-water pumpage, Desert Valley, Nevada, 1962-91

Year	Estimated irrigated land (acres)	Estimated ground-water pumpage (acre-feet)		
		Irrigation		Mine dewatering[1] (reported gross pumpage)
		Gross	Net[2]	
1962	2,100	3,700	2,600	
1963	2,100	3,700	2,600	
1964	2,100	3,700	2,600	
1965	2,600	5,200	3,500	
1966	2,600	5,200	3,500	
1967	3,000	6,500	4,200	
1968	3,000	6,500	4,200	
1969	3,000	6,500	4,200	
1970	3,000	6,500	4,200	
1971	3,000	6,500	4,200	
1972	3,000	6,500	4,200	
1973	3,500	8,000	5,100	
1974	3,500	8,000	5,100	
1975	6,400	18,000	11,000	
1976	6,400	18,000	11,000	
1977	6,400	18,000	11,000	
1978	6,400	18,000	11,000	
1979	6,400	18,000	11,000	
1980	5,300	15,000	8,800	
1981	5,300	15,000	8,800	
1982	5,300	15,000	8,800	
1983	5,300	15,000	8,800	
1984	5,300	15,000	8,800	
1985	5,600	15,000	8,700	2,100
1986	5,400	15,000	8,700	6,200
1987	5,700	15,000	8,900	8,100
1988	5,200	13,000	8,000	14,000
1989	4,900	13,000	7,600	15,000
1990	5,100	13,000	7,900	22,000
1991	5,500	14,000	8,600	23,000

[1] Mine dewatering did not begin until 1985; data from Nevada Gold Mining, Inc., written commun., 1992.

[2] Net pumpage estimated as 60 percent of gross pumpage.

During the period 1962-74, an average of about 2,900 acres were irrigated annually in four general areas along the west side of the valley floor and southwest of Jungo. From 1975 to about 1980, the area of irrigated land increased to an annual average of about 6,400 acres, mostly because of an increase of nearly 2,000 irrigated acres in the southeastern part of the valley. By 1980, the farmed area in the southeast was abandoned and the annual irrigated area had decreased to 5,300 acres and has remained at about that level through 1991. The general distribution of irrigated land for the period 1981-91 is shown in figure 12.

Estimates of ground-water pumpage for irrigation were made on the basis of the distribution of irrigated land, number of irrigation wells, percent of surface-water supplement, and cultivation practices during the years 1962-91. Most of the pumped water is consumed by evapotranspiration; however, some infiltrates beyond the plant-root systems and recharges the aquifer. The net pumpage, which is that amount of ground water completely removed from the system, is estimated to be about 60 percent of the gross pumpage (Thomasson and others, 1960, p. 235; Cohen and others, 1963, p. 93; and Harrill and Moore, 1970, p. 10). Over the period 1962-74, annual net pumpage increased from about 2,600 acre-ft to about 5,100 acre-ft and averaged about 3,900 acre-ft. Because the increased acreage in the southeastern part of the valley was irrigated solely by ground water during the period 1975-80, estimates of annual net pumpage were nearly 11,000 acre-ft. In 1980, net ground-water withdrawals for irrigation decreased to about 8,800 acre-ft, and since 1985 have averaged about 8,300 acre-ft annually.

Reported gross pumpage at the Sleeper Mine for the years 1985 through 1991 is shown in table 10 (Nevada Gold Mining, Inc., written commun., 1992). During this 7-year period, total ground-water withdrawals at the mine were about 90,000 acre-ft. About 2-3 percent of the total pumped water from the dewatering operation is consumed at the site for mining, milling, and domestic uses (Nevada Gold Mining, Inc., written commun., 1992). All the water removed from the site was channeled to a discharge area on the valley floor northwest of the mine where the ponded water created an artificial wetlands. On the basis of MSS data collected in August 1988, the wetlands covered about 1,400 acres. The average depth of water in the wetlands was about 1.5 ft (Nevada Gold Mining, Inc., written commun., 1991). An estimated 8,000 acre-ft, or about 59 percent of the total 13,600 acre-ft channeled to the wetlands during 1988, infiltrated to the ground-water system and nearly 4,700 acre-ft was lost by direct evaporation. About 900 acre-ft is estimated to have remained within the wetlands area at the end of 1988. Due to the proximity of the wetlands to pumping influences created at the mine, the potential for recirculation of infiltration from the wetlands back into the dewatering well field became a concern. As a result, a new artificial wetlands area, farther west of the dewatering operations, was created in 1991 (pl. 1*A*). The new wetlands are part of the Sleeper Mine Temporary Wetlands Enhancement Project and are managed in cooperation with the Nevada Department of Wildlife and the Bureau of Land Management. The total area covered by the new wetlands project is about 4,700 acres and incorporates the initial wetlands area.

Water-Level Changes

Water-level contours used to determine present-day (1991) conditions were constructed from measurements collected during the Spring of 1991 (pl. 1*E*). Additional control was provided by eight measurements made in 1990 and two made in 1989. Water-level measurements used to construct contours within the influence of the dewatering operation at the Sleeper Mine, including those adjacent to the wetlands, were made during the same time period in 1991. Depths to water below land surface are also shown on plate 1*E*.

The general distribution of net declines in ground-water levels between predevelopment and present-day (1991) conditions was determined by comparing the difference between lines of equal water levels constructed from measurements made during the late 1950's to early 1960's (predevelopment) and Spring 1991 (figure 13). The measured differences at 38 wells for the same period also are shown in figure 13. Three wells measured in 1961, sites 68, 73, and 122 (table 15), have since been destroyed; however, water levels in nearby sites 69, 74, and 121 were used to estimate the water-level differences in those areas. In general, ground-water levels measured during Spring 1991 are lower than those representing predevelopment conditions. Water-level declines are less than 5 ft throughout the south-central part of the valley in areas generally unaffected by substantial ground-water withdrawals. These declines may show the magnitude of effect caused by the trend of below-average precipitation over the last several years. Declines greater than 10 ft are observed just north of the study-area boundary in the area of site 42; in the southwest, near sites 122 and 124; in the northeast part near the dewatering operation; and along the western margin of the valley floor near irrigation pumping centers (sites 85, 91, and 100). Water-level declines near site 42 are probably a result of continued irrigation pumping in the Rio King subarea to the north (Malmberg and Worts, 1960, p. 41-42). Maximum water-level declines beneath the open pits at the Sleeper Mine, as of Spring 1991, range from 295 to 315 ft (Nevada Gold Mining, Inc., written commun., 1992). Elevated ground-water levels beneath and adjacent to the discharge area have produced net declines of less than 5 ft since predevelopment.

Hydraulic-head measurements from two piezometers that are separated and screened at different depths within the same well were used to indicate the vertical direction of ground-water flow. Hydrographs of water levels for wells OH-50 (sites 60 and 61) and OH-49 (sites 80 and 81) are presented in figure 14. Well OH-50 has one piezometer (site 60) perforated between 150 and 200 ft below land surface, and another piezometer (site 61) perforated between 630 and 680 ft below land surface (Nevada Gold Mining, Inc., written commun., 1989). Water-level measurements made at sites 60 and 61 (pl. 1*C*), during the later part of 1989 through 1990, indicate an upward ground-water gradient between 200 and 630 ft below land surface (fig. 14). This well (OH-50) is north of the new wetlands area. Early in 1991, the vertical gradient reversed, indicating downward movement of ground water. This change in direction appears to correspond with the relocation of the wetlands and the resulting increase in recharge to the ground-water system. Well OH-49 (sites 80 and 81; pl. 1*C*) is adjacent to the initial discharge lake. The well casing at site 80 is perforated between 70 and 90 ft below land surface and at site 81 is perforated between 325 and 490 ft below land surface. Hydrographs of water levels at these sites indicate downward ground-water flow with the vertical gradient increasing with time. The water level in site 80 is rising in response to infiltrating water from the initial discharge lake, whereas water levels measured in site 81 show a declining trend. The declining trend is a result of the dewatering operation at the mine, which is affecting the deeper part of the basin-fill aquifer in the immediate area.

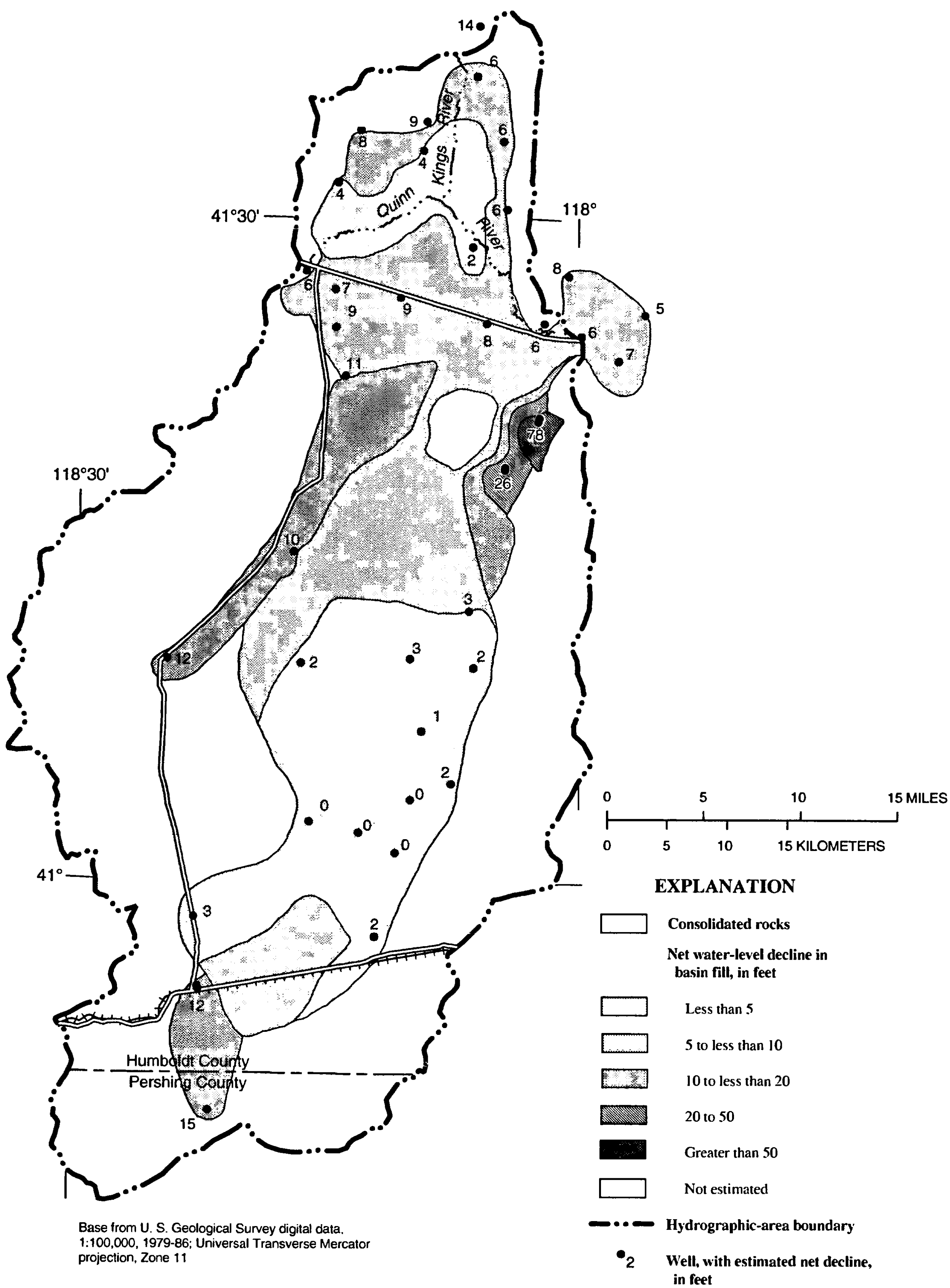


Figure 13. General distribution of estimated net declines in ground-water levels from predevelopment through Spring 1991, Desert Valley, Nevada.

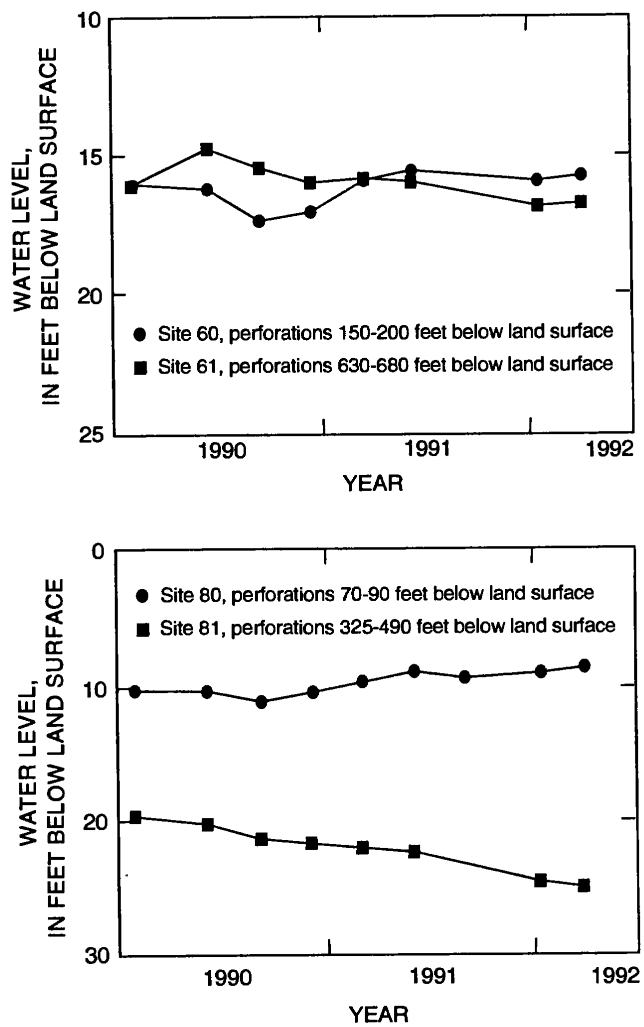


Figure 14. Water levels for wells OH-50 and OH-49 at sites 60, 61, 80, and 81, 1990-92, Desert Valley, Nevada.

Changes in the ground-water flow regime between predevelopment and present day are observed mainly in areas affected by the pit dewatering at the Sleeper Mine. Water-level contours for Spring 1991 (pl. 1*E*) suggest that some subsurface flow entering Desert Valley from Quinn River Valley is captured by wells at the mine. The general shape of the dewatering cone, created by pumping at the mine, is elongated with the long axis trending just west of north. The cone is bounded by the impermeable Slumbering Hills to the east and the wetlands area to the west. Water infiltrating beneath the wetlands has produced a ground-water divide between the Sleeper Mine and the area to the west. In addition, the Spring 1991 water-level contours also suggest that subsurface flow continues to exit the basin to the southwest. The broad ground-water divide, originally northeast of the Jungo Hills during predevelopment conditions, has migrated southward and has become somewhat more defined.

Changes in Water Quality

Changes in water quality between predevelopment and present-day conditions were determined by comparing data from six wells (sites 53, 86, 88, 100, 102, and 119; locations shown on pl. 1*F*) sampled before 1962 and again in 1990. Samples were taken at three depth intervals in 1960 by Sinclair (1962b) at site 100 and were averaged for comparison to the present-day integrated analysis. The three major water types reported by Sinclair—calcium bicarbonate, sodium bicarbonate, and sodium chloride—had a similar distribution in the basin-fill aquifer during the present study.

Present-day analyses (1990) indicate that the concentration of major ionic species has generally increased since predevelopment time at three of the six resampled sites (sites 86, 100, and 119; table 6). Results of analyses for site 119 exhibit the largest increase in total dissolved solids (about a three-fold increase), and magnesium has replaced sodium as the dominant cation. Major ion concentrations at sites 88 and 102 are nearly the same in 1990 as in 1961. Boron concentrations have decreased in samples from sites 88, 100, 102, and 119 since 1961; however, concentrations still remain above the aquatic-life criteria in all resampled sites except those from site 100.

HYDROLOGIC SIMULATIONS USING A GROUND-WATER FLOW MODEL

Flow-Model Development

A mathematical ground-water flow model was developed to simulate predevelopment conditions and used to evaluate the response of the basin-fill aquifer to ground-water development in Desert Valley. The flow model provides a means to test the conceptual model of the hydrologic system developed during this study and to estimate effects of hypothetical future ground-water development. Calibration of the flow model was done by matching simulated and measured water levels representing pre-1962 conditions and simulating water-level declines due to estimated ground-water pumpage from 1962 to 1991. Probable long-term effects of hypothetical ground-water withdrawals were then evaluated using the calibrated flow model.

The accuracy with which the flow model simulates an actual ground-water system depends on how well the hydrologic processes of the system are understood and then simulated. The quality and distribution of the input data used to describe these processes are the determining factors that limit the model in simulating the actual system. A ground-water flow model is not necessarily a unique representation of a flow system; however, by using reasonable hydraulic properties and boundary conditions, the flow model can closely simulate the natural flow system of the study area.

Mathematical Basis

The numerical technique used in this study to analyze ground-water flow and yield of the aquifer system is a finite-difference ground-water flow model written by McDonald and Harbaugh (1988). The model solves the three-dimensional equation of ground-water flow by using finite-difference approximations; the equation can be written as follows:

$$d/dx\,(K_{xx}dh/dx) + d/dy\,(K_{yy}dh/dy) + d/dz\,(K_{zz}dh/dz) - W = S_s dh/dt \quad ,$$

where K_{xx}, K_{yy} are hydraulic conductivities in the principal horizontal directions (in length per time),

K_{zz} is hydraulic conductivity in the vertical direction (in length per time),

h is hydraulic head (in length),

W is volumetric flux of recharge or discharge per unit volume (in time^{-1}),

S_s is specific storage (in length^{-1}),

t is time, and

x, y, z are Cartesian coordinates aligned along the major axes of hydraulic conductivity.

The finite-difference method is used to obtain approximate solutions to the three-dimensional flow equation by replacing the continuous partial derivatives with systems of simultaneous algebraic difference equations. The difference equations are then solved in terms of the unknown hydraulic head at discrete points, or nodes, and time. The strongly implicit procedure (McDonald and Harbaugh, 1988, p. 12-1) was used to solve the system of difference equations by iteration. Solution for each node is achieved when the head change between each iteration is less than a specified value. The value specified for the model simulations for Desert Valley was 0.001 ft. Each node is centered in a model cell that has dimensions of x, y, and z. Hydraulic properties within each cell are assumed to be homogeneous, so that the model-derived hydraulic head represents the average head over the entire cell.

General Features of the Model

To translate the conceptual model of the hydrologic system to the mathematical flow model and solve the ground-water flow equation by finite differences, a block-centered grid was superimposed over a map view of the study area. The grid is used to divide the basin-fill aquifer into discrete model cells and layers. A diagrammatic representation, shown in figure 15, illustrates the model's representation of the aquifer system and its relation to the conceptualization of the flow model.

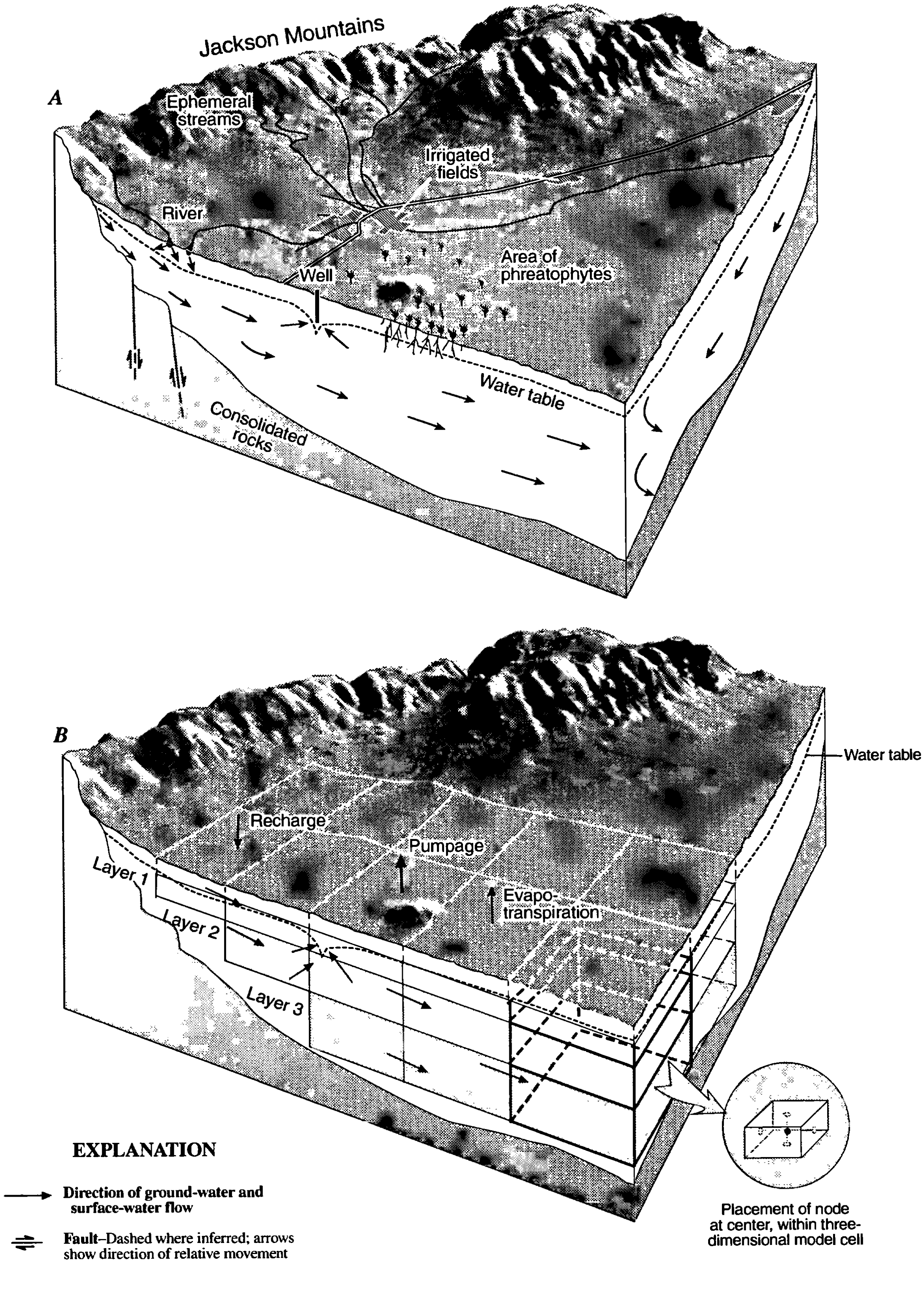


Figure 15. Three-dimensional conceptualization of ***(A)*** basin-fill aquifer and ***(B)*** computer model of aquifer, Desert Valley, Nevada.

The model grid used in this study contains 26 columns, 58 rows, and three layers. The grid is oriented so that a minimum number of cells are outside the modeled region (fig. 16). The grid lies parallel to the general direction of ground-water flow and each cell has horizontal dimensions of 1 mi on a side. The grid consists of 746 active cells in layers 1 and 2 and 207 active cells in layer 3. Processes of evapotranspiration, recharge from precipitation, and the interaction between surface water and ground water were simulated within layer 1. The top 100 ft of saturated basin fill is generally unconfined and is represented by layer 1. The middle layer (layer 2) has a maximum thickness of 500 ft and is present wherever the saturated basin-fill deposits exceed 100 ft. Ground-water discharge by wells and subsurface flows in and out of the basin-fill aquifer are simulated in both layers 1 and 2. Because of the complex interbedded nature of the basin-fill deposits determined from a limited number of drillers' logs, thicknesses were arbitrarily assigned to layers 1 and 2. Pumping stresses assigned during simulations of water-resources development were distributed between layers 1 and 2 on the basis of available data on depth of the screened intervals in pumping wells. Layer 3 represents the zone that extends from 600 ft below the water table to consolidated rock. Only a few wells, mainly near the Sleeper Mine, penetrate this interval, and the layer is used primarily to account for stored water and deep ground-water flow. Layer 2 was simulated by the model as a confined aquifer, but is allowed to convert to unconfined conditions if water levels drop below the bottom of layer 1 due to pumping. Layer 3 was treated as a confined aquifer.

Boundary Conditions

The ground-water flow equation applied in the flow model has an infinite number of solutions. To develop a more basin-specific model, additional information about the conditions at the boundary of the flow system was required. Boundary conditions were specified in the model on the basis of ground-water-flow concepts developed during this study. Model cells that represent basin-fill deposits were designated as active, whereas inactive cells were used to represent less-permeable consolidated rock. The boundary between active and inactive cells represents the model boundary, as illustrated in figure 16.

No-flow and head-dependent flow boundaries were used in the model to simulate flow conditions along the periphery of the basin. Lateral and vertical boundaries between the basin fill and consolidated rock, where ground-water flow is assumed to be negligible, were specified as no-flow boundaries. The alluvial divides in the southern part of the study area represent ground-water divides and were also simulated as no-flow boundaries.

Head-dependent flow boundaries were used to simulate subsurface inflow from the Kings River and Quinn River Valleys, and subsurface outflow to Pine Valley and the southwest in the vicinity of the northern Antelope Range (fig. 1, fig. 16). Inflow and outflow conditions were simulated in layers 1 and 2 at head-dependent flow boundaries by extending external cells beyond the modeled region and assigning head values to those cells. A conductance term provides the link between the source and external cell and is a function of the cross-sectional area of the cell perpendicular to ground-water flow and the horizontal hydraulic conductivity of the basin fill at the boundary. The assigned heads for the three areas simulated as head-dependent flow boundaries in the northern part of the study area represent water levels measured during the early 1960's. The values used for the external heads in the southwestern part were specified on the basis of the estimated hydraulic gradient in the area during predevelopment time.

Recharge was simulated in layer 1 as constant-flow boundaries in active cells along the edge of the model grid. Figure 17 shows the distribution and rate of recharge used in the model simulations. The volume of recharge simulated in the model was calculated by using the rates for each cell, as shown in figure 17, and multiplying by cell area. Not all cells along this boundary receive recharge. The amount of recharge introduced to each cell depends on its position adjacent to a particular recharge-source area. The distribution of recharge was determined for each drainage recharge source area on the basis of the Maxey-Eakin method, as previously discussed. Model cells superimposed over the area of active sand dunes (fig. 1) were also treated as constant-flow cells. Recharge was distributed to these cells on the basis of the results from the DPM.

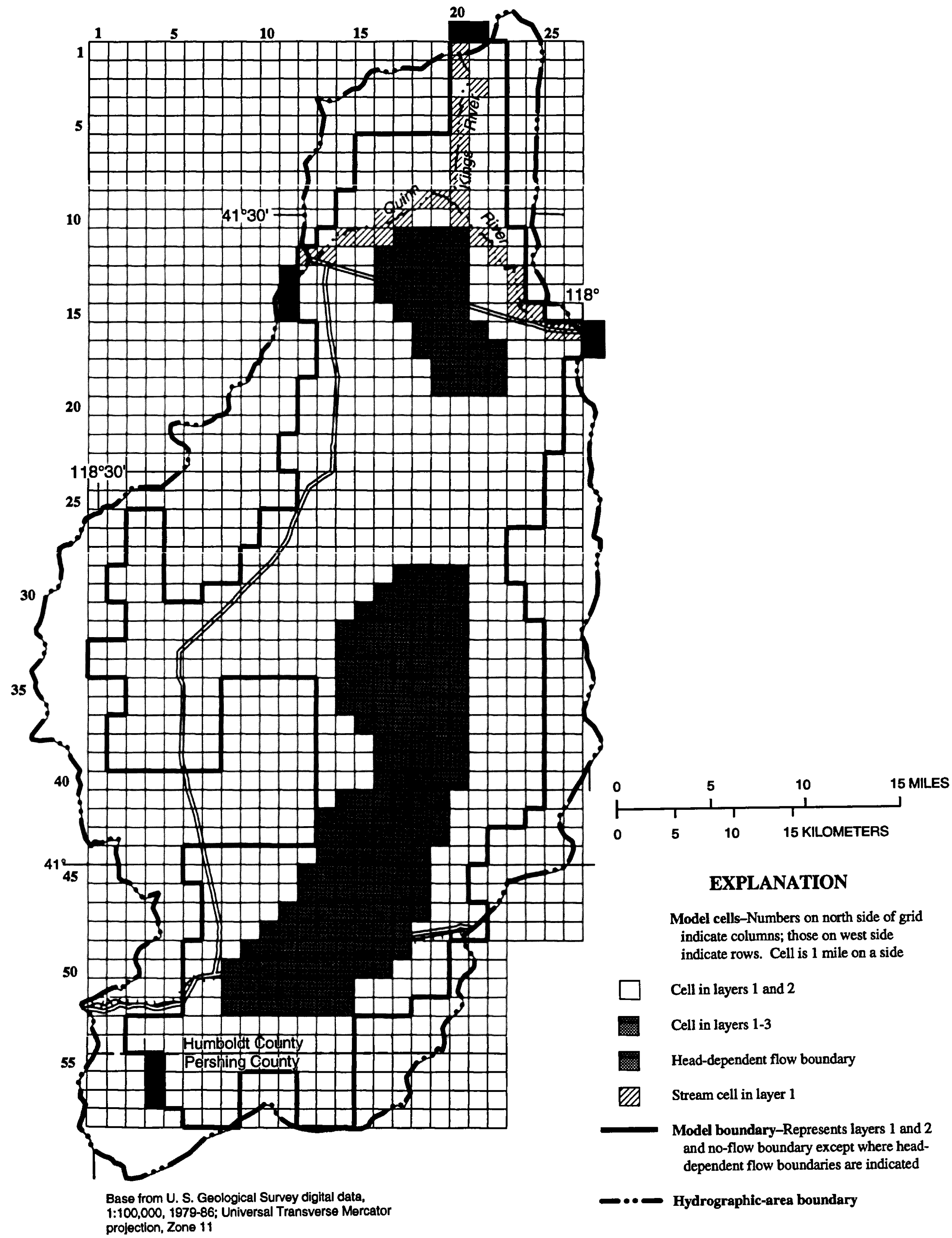


Figure 16. Block-centered finite-difference grid used for ground-water flow model of Desert Valley, Nevada.

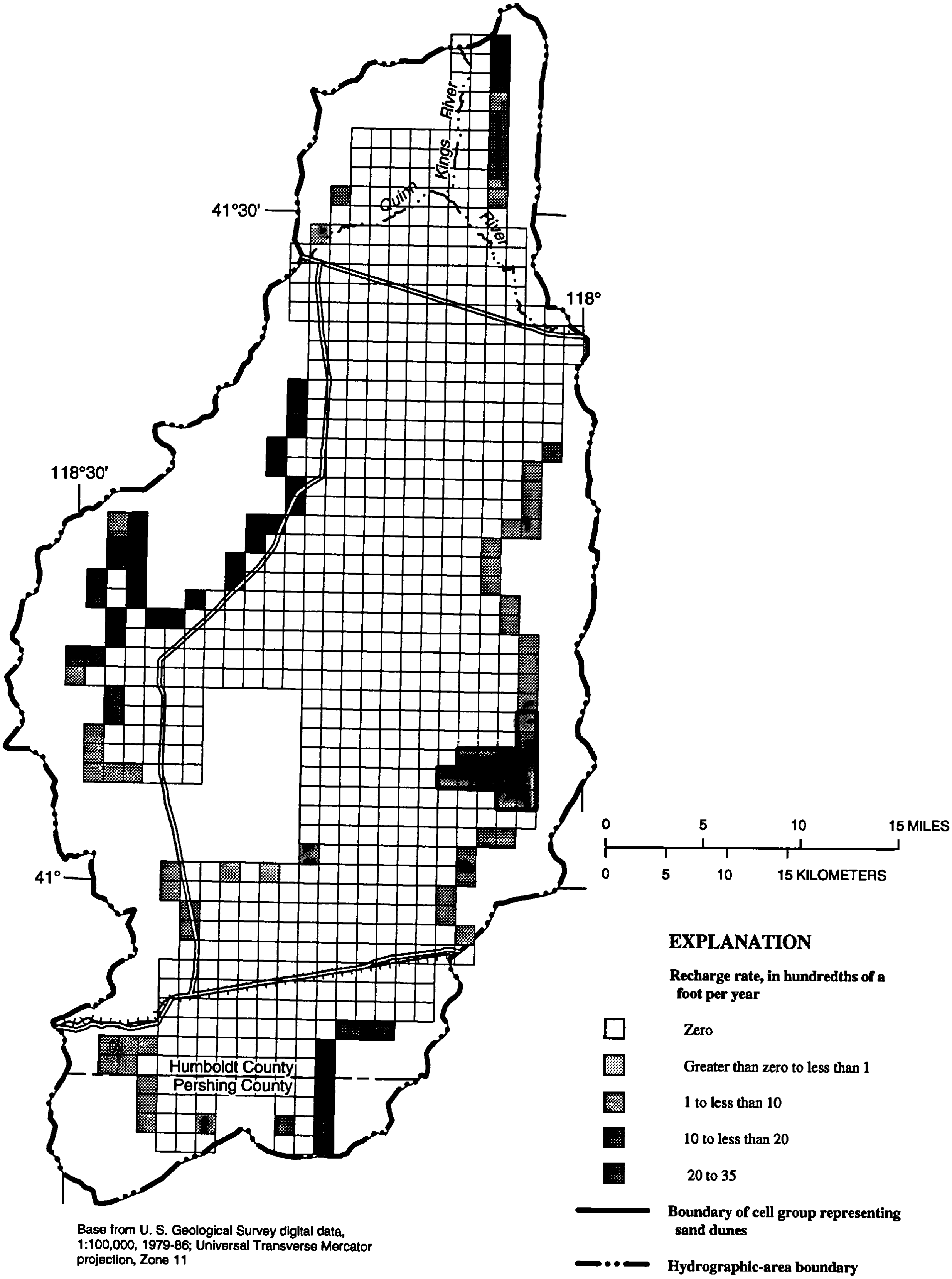


Figure 17. Distribution of model cells used to simulate recharge, and annual recharge rates used in simulation, Desert Valley, Nevada.

Interactions between surface water and ground water, including the infiltration beneath the Sleeper Mine wetlands and associated canals, which will be discussed in the section titled "Changes in Flow-Boundary Conditions," were evaluated in the model using a program to simulate stream-aquifer relations written by Prudic (1989). This computer program is a modification of the River Package described by McDonald and Harbaugh (1988, p. 6-1) and can be used in their ground-water flow model. The Quinn and Kings Rivers were simulated using 27 cells in layer 1 of the model grid (fig. 16). Leakage in or out of each cell is calculated on the basis of the head difference between the stream and aquifer in that cell and a conductance value.

Ground-water discharge by evapotranspiration was specified in layer 1 of the flow model as a head-dependent flow boundary. Evapotranspiration was simulated as a linear function of depth, and was computed from a maximum rate at land surface to the extinction depth at which evapotranspiration is assumed to cease. The model grid was digitally superimposed on the land-cover distribution shown in figure 12, and the percentage of plant cover and bare soil area was determined for each cell. In areas simulated to have evapotranspiration, the depth to water was generally 35 ft or less. Because water levels are generally several feet below the land surface, the maximum evapotranspiration rate at the surface is based on a linear extrapolation from rates at the depths where shrubs commonly are obtaining water. The maximum evapotranspiration rate assigned to each cell was then calculated on the basis of the percentage of area covered by the two different plant densities and bare soil in each cell. The distribution of cells specified to have ground-water discharge from evapotranspiration, and the maximum evapotranspiration rates simulated by the model, are shown in figure 18. Maximum evapotranspiration rates used in this report are those compiled from field studies for this project and other areas of the Great Basin by W.D. Nichols (U.S. Geological Survey, written commun., 1992): 0.38 ft/yr for low-density greasewood cover, 0.16 ft/yr for sparse greasewood mounds, and 2.5 ft/yr for bare soil. Extinction depths used were 35 ft and 8 ft for phreatophytes and bare soil, respectively.

Initial Conditions and Aquifer Properties

Prior to 1962, the ground-water system in Desert Valley was in a state of dynamic equilibrium (steady state), the long-term averages for recharge and discharge were balanced, and change in storage was negligible. Ground-water levels shown on plate *1D* for predevelopment are considered to represent steady-state conditions, and were used as initial water levels for model-layer 1. Analyses of limited water-level data suggest that only small vertical gradients existed during predevelopment time; consequently, the initial head distribution for model-layer 2 was assumed to be the same as for model-layer 1. Results of water-level measurements made at sites 60 and 61 (table 15) in 1990 suggest that the potential for upward vertical flow exists; however, it is not known if this condition was present during predevelopment time. No water-level data were available for model-layer 3 during predevelopment time, so water levels in this layer were also set equal to those in model-layer 1.

The initial distribution of transmissivity for the three layers was estimated as the product of the thickness of that layer and a hydraulic-conductivity value. The average thicknesses of saturated basin fill represented by layers 1 and 2 are 100 and 500 ft, respectively. Thickness values assigned to layer 3 varied according to the distance between the bottom of layer 2 and consolidated rock. Horizontal hydraulic-conductivity values for layers 1 and 2 were estimated from the distribution shown in figure 6. A similar distribution of horizontal hydraulic conductivity was assumed for layer 3, but values were decreased 50 percent for every 1,200 ft of depth to account for overburden pressure. During development simulations, transmissivity values in layers 1 and 2 were recalculated by the model to account for changes in the saturated thickness due to ground-water withdrawal. Transmissivity values for layer 3 were held constant.

Vertical flow between layers was simulated as an equivalent leakance term representing numerous discontinuous lenses of fine-grained deposits within the basin fill. Leakance, as defined by Lohman (1972, p. 30), is the ratio of vertical hydraulic conductivity of the confining beds to the thickness. Leakance was estimated from the distribution of vertical hydraulic conductivity, shown in figure 7, divided by the vertical distance to the centers of adjacent model layers. Initial values of leakance specified in the model did not need adjustment during calibration to obtain a best fit.

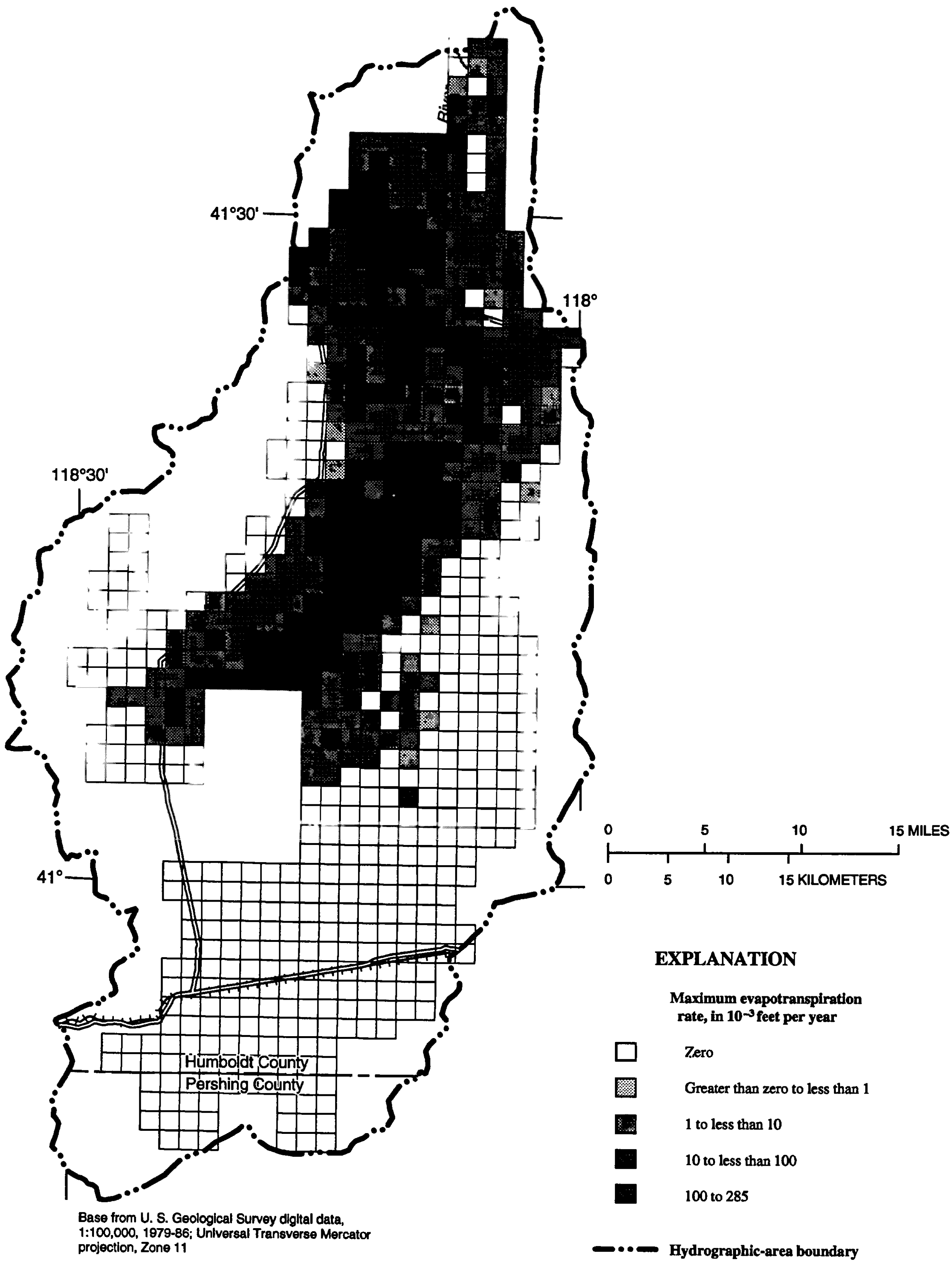


Figure 18. Distribution of model cells used to simulate evapotranspiration, and maximum evapotranspiration rates used in simulation, Desert Valley, Nevada.

Specific yields shown in figure 8 were used as the initial storage values for layer 1. Because layer 2 has the potential to go from confined to unconfined conditions during pumping, both storage-coefficient and specific-yield values were added to the flow model for layer 2. The specific-yield values used for layer 1 were also used as initial storage values for layer 2 during unconfined conditions. For confined conditions in layers 2 and 3, storage coefficients were estimated by using the approximate relation given by Lohman (1972, p. 9), multiplied by cell thickness. Storage values are required data for development (transient) simulations and are not needed for simulations of predevelopment conditions (steady state).

Simulation of Predevelopment Conditions

The predevelopment ground-water flow model was constructed by incorporating the previously discussed boundary and initial conditions that describe the hydrologic system in Desert Valley before the onset of significant ground-water development. The simulation of predevelopment conditions provides a base-line flow model that was used as initial input for simulations of ground-water development for the period of 1962-91.

Calibration and Results

Calibration of the predevelopment flow model was based on the relation between simulated and measured or estimated head values, subsurface inflow and outflow, discharge by evapotranspiration, and Quinn River outflow to Pine Valley. The model was considered calibrated when:

1. mean absolute departure of simulated heads from measured heads and the associated standard deviation were minimal for 35 model cells containing wells (see next paragraph),
2. simulated subsurface inflow and outflow at the head-dependent flow boundaries agreed with estimated values,
3. the total amount of simulated discharge by evapotranspiration agreed with the estimated amount,
4. the simulated Quinn River flow out of the modeled region matched the estimated value, and
5. the simulated mass balance of water into and out of the entire flow system had a minimal error.

Predevelopment water-level measurements at 35 wells were compared to model-derived heads computed for corresponding cells where the wells are located. Nearly 80 percent of these model-computed heads were within 5 ft or less of the measured value and all were less than 10 ft (fig. 19). The absolute departure of the simulated heads from measured heads for the 35 cells in layer 1 containing wells was 3.40 ft, with a standard deviation of 2.76 ft. The simulated and measured potentiometric surface for layer 1 and the location of the 35 cells used for comparison to the calculated potentiometric surface are shown in figure 20.

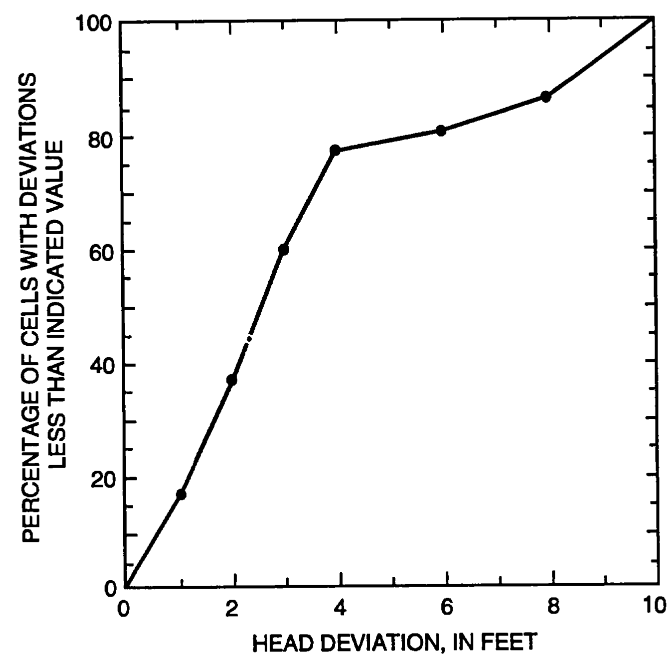


Figure 19. Frequency distribution of deviations between measured and simulated hydraulic heads for predevelopment simulation, Desert Valley, Nevada.

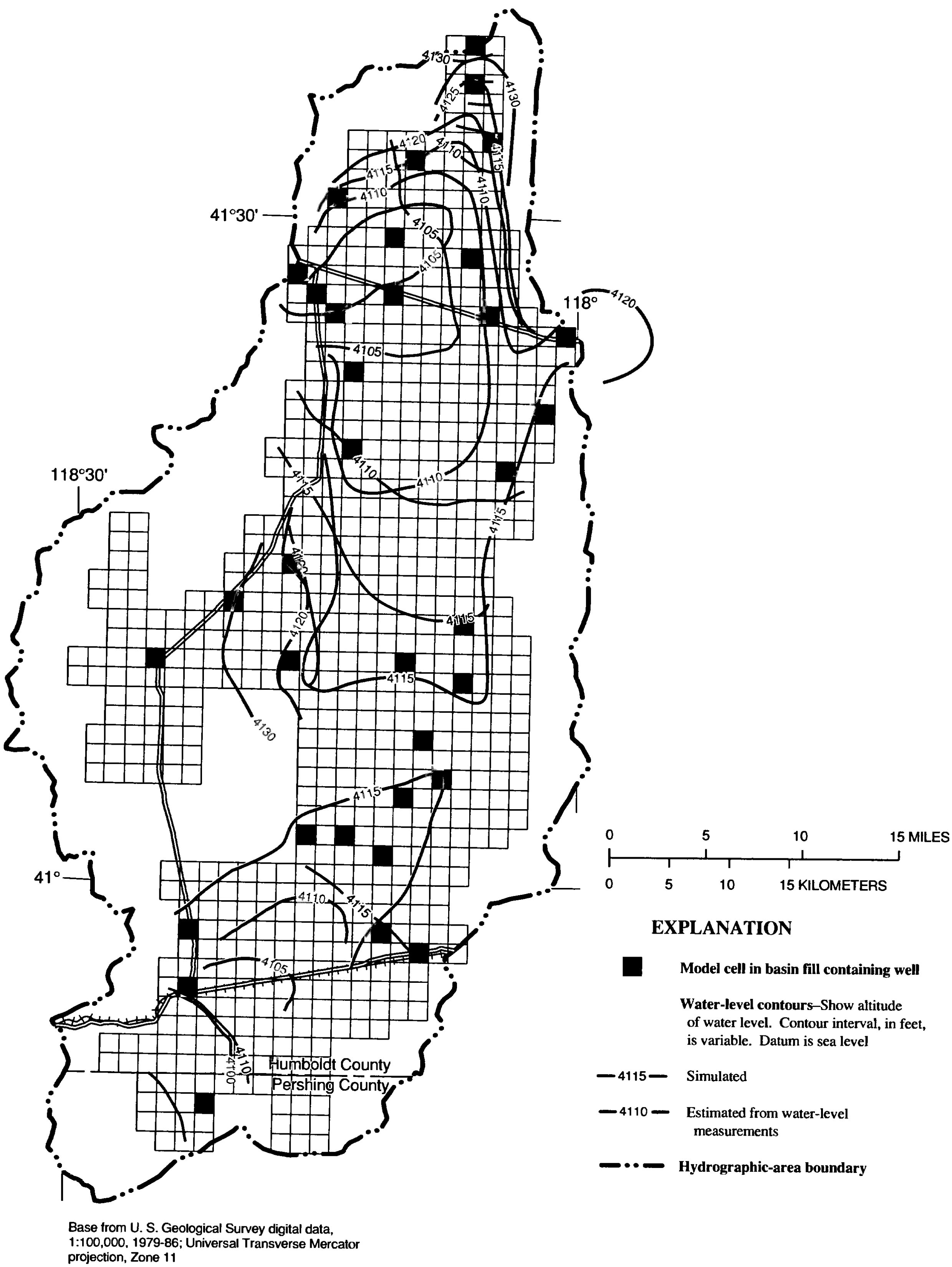


Figure 20. Simulated potentiometric surface for layer 1 and water levels estimated on basis of field data, predevelopment conditions, Desert Valley, Nevada.

The predevelopment potentiometric surface simulated for layer 1 is in reasonable agreement with the potentiometric surface describing predevelopment conditions based on field data. The potentiometric surface for layer 2, derived from the model, is generally similar to that of layer 1. Heads simulated in cells in the area southeast of the Quinn River as it exits the study area are as much as 1 ft higher in layer 2 than in layer 1, suggesting that the potential for upward flow of ground water exists. Although predevelopment water-level data are insufficient to verify the existence of upward ground-water movement, upward movement is indicated from water-level data collected at sites 60 and 61 before effects from the wetlands were observed.

Areas of greater-than-5-ft difference between simulated and estimated (predevelopment) heads were generally along the boundary of the model. Simulated and estimated heads may differ because the model-computed head is specified at the center of the cell, representing an average head, whereas the estimated head may be anywhere in that square-mile cell.

The initial distribution of hydraulic conductivity was adjusted until the best fit was obtained between measured and computed heads. The distribution of the calibrated hydraulic conductivity for layer 1 is shown in figure 21. During model calibration, hydraulic conductivities for layer 2 were decreased to one-half the calibrated values for layer 1. Transmissivity values for layer 3 were not adjusted from initial estimates. Calibrated hydraulic conductivities ranged from less than 25 ft/d along the west-central model boundary and north of the Quinn River to greater than 76 ft/d within a north-south corridor through the center of the basin. Because of the lack of lithologic information from wells, this apparent transmissive corridor was not detected. The distribution of the highest computed values in the center of the basin is similar to the distribution of hydraulic conductivity determined in Paradise Valley (Prudic and Herman, in press), where the higher values are attributed to well-sorted stream deposits. The distribution determined from this study, in part, supports the interpretation by Davis (1982, 1990) that the Humboldt River may have flowed northward through Desert Valley 22,000-35,000 years ago.

Values of total inflow and outflow calculated by the model (table 11) for predevelopment conditions are within the ranges estimated by empirical techniques (table 9). However, the simulated mountain-block recharge is slightly larger (6,900 acre-ft/yr) and sand-dune recharge is slightly smaller (440 acre-ft/yr) than the estimated values. Model-derived values of infiltration from rivers, subsurface fluxes, and evapotranspiration fall within the estimated ranges.

Table 11. Simulated ground-water budget for predevelopment conditions (pre-1962), Desert Valley, Nevada

[All values in acre-feet per year, rounded to two significant figures]

Budget component	Simulated predevelopment conditions
Inflow	
Recharge from precipitation:	
From mountain block	6,900
From sand dunes	440
Infiltration from rivers:	
Quinn River	2,600
Kings River	110
Subsurface inflow:	
From Kings River Valley	820
From Quinn River Valley	310
Total inflow	11,000
Outflow	
Evapotranspiration	9,100
Subsurface outflow:	
To Pine Valley	400
To Southwest	1,700
Total outflow	11,000

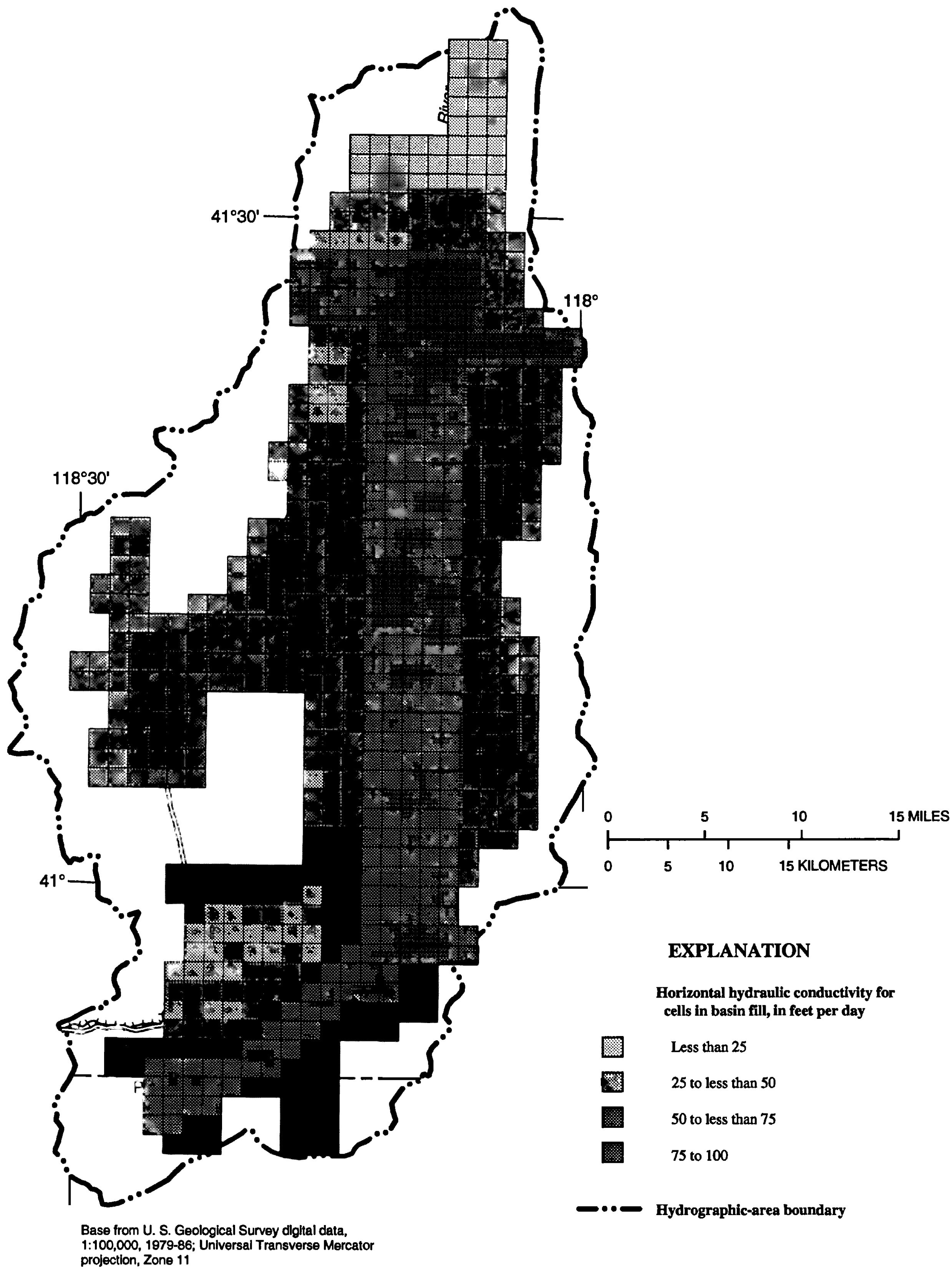


Figure 21. Distribution of hydraulic conductivity in layer 1 used in best-fit predevelopment simulation, Desert Valley, Nevada.

Sensitivity Analysis

Model sensitivity to the uncertainty in the estimates of five hydrologic properties was evaluated on the basis of 14 model simulations for predevelopment conditions (table 12). Each property was varied to determine the effects on the differences between measured and simulated head for 35 model cells (fig. 20) and the final calibrated flux rates at head-dependent boundaries. Each time the model was run, one property was uniformly varied by doubling or reducing by one-half its calibrated value while the other properties remained constant. Because solution to the predevelopment model is not unique, the sensitivity analysis cannot be used to verify the accuracy of the model; however, the analysis can be used to test the response of the model to a range of values used for initial conditions.

The results of the sensitivity analyses presented in table 12, in general, indicate that the water-level distribution and flux at head-dependent boundaries simulated by the model are not highly sensitive to uncertainties in values of transmissivity and vertical-hydraulic conductivity (average change, 12.6 percent). Simulated water levels and subsurface flux at head-dependent boundaries are most sensitive to uncertainties in recharge and ground-water discharge by evapotranspiration. Although a large percentage of change is calculated, the absolute difference in mean head is generally about 10 ft or less. Variations in recharge and discharge are equally compensated in the model by balancing subsurface inflow and outflow with discharge by evapotranspiration.

Simulation of Development, 1962-91

Hydrologic stresses on the ground-water flow system caused by pumping for irrigation along the west side of the valley floor and dewatering operations at the Sleeper Mine were simulated for the period 1962-91. Hydrologic properties, boundary conditions, distribution of evapotranspiration and recharge, and simulated heads determined from the best-fit predevelopment model were used as initial conditions for the development model. Rates of inflow, such as recharge from precipitation and surface-water inflow from the Quinn and Kings Rivers, were adjusted to reflect the percentage of the long-term average during the 30-year development simulation.

Selection of Stress Periods

The development simulation (1962-91) was divided into 10 stress periods on the basis of estimated ground-water pumpage within the Desert Valley study area. The division of stress periods and their relation to estimated annual ground-water withdrawals is illustrated in figure 22. Time intervals that could be represented by fairly constant irrigation pumpage before mine dewatering began were specified as separate stress periods. At the beginning of mine dewatering in 1985, corresponding with stress-period 4, yearly stress periods were specified. Stress periods were further subdivided into time steps which form a geometric progression that increases in length according to a specified multiplier. For the development simulation, the initial time step and each subsequent step was increased by 1.5 times the length of the preceding time step. During the simulation, all external stresses to the system were held constant throughout each stress period.

Stress-period 1 was specified as 13 years with six time steps, over the period 1962-74. Simulated net pumpage for irrigation was specified as 3,900 acre-ft annually during this period. Stress-periods 2 and 3 were both specified as 5 years with five annual time steps during 1975-79 and 1980-84. Simulated net irrigation pumpages for stress periods 2 and 3 were about 11,000 and 8,800 acre-ft/yr, respectively. Stress-periods 4 through 10, beginning in 1985 and ending in 1991, were 1 year in length and divided into four time steps. Ground-water withdrawals for both net irrigation and mine dewatering were simulated in stress-periods 4 through 10. The pumping stresses used in the simulation are presented in table 13. The distribution of model cells assigned as irrigation pumping, mine dewatering, and wetlands and canals is shown in figure 23.

Table 12. Summary of model-sensitivity simulations for Desert Valley, Nevada

[Abbreviation and symbol: ET, evapotranspiration; <, less than]

Property varied	Part of model affected	Change applied to property (percent)	Absolute mean difference, in feet, between measured and simulated head for 35 model cells (percent change in parentheses)[1]	Flux at head-dependent boundaries, in acre-feet per year (percent change in parentheses)[1]				
				Outflow to Pine Valley	Outflow to southwest	Inflow from Quinn River Valley	Inflow from Kings River Valley	Evapotranspiration
Calibrated predevelopment simulation results								
None	All layers	0	3.4	400	1,700	310	820	9,100
Sensitivity analysis								
Transmissivity	All layers	+100	3.64 (7)	486 (21)	1,955 (15)	332 (7)	1,365 (67)	8,731 (4)
		-50	6.34 (87)	257 (36)	1,393 (18)	286 (8)	475 (42)	9,178 (<1)
Do.	Layer 1	+100	3.12 (8)	434 (8)	1,793 (6)	323 (4)	985 (20)	8,999 (1)
		-50	3.80 (12)	369 (8)	1,613 (5)	305 (2)	728 (11)	9,117 (<1)
Do.	Layer 2	+100	3.42 (<1)	472 (18)	1,899 (12)	320 (3)	1,224 (49)	8,796 (3)
		-50	5.01 (45)	303 (24)	1,499 (12)	306 (1)	576 (30)	9,158 (<1)
Vertical hydraulic conductivity	Interface between layers 1 and 2	+100	3.39 (<1)	396 (1)	1,683 (1)	316 (2)	819 (<1)	9,110 (<1)
		-50	3.41 (<1)	399 (<1)	1,686 (<1)	307 (<1)	815 (<1)	9,074 (<1)
Recharge	All layers	+100	10.56 (210)	506 (26)	2,952 (74)	41 (87)	682 (17)	13,675 (50)
		-50	6.93 (104)	298 (26)	996 (41)	496 (60)	912 (11)	6,535 (28)
Maximum ET rate	Layer 1	+100	7.28 (114)	80 (80)	1,405 (17)	771 (149)	1,107 (35)	10,475 (15)
		-50	5.13 (51)	553 (38)	1,992 (17)	-17 (106)	671 (18)	6,058 (33)
Maximum ET depth	Corresponding depth in layer 1	+100	5.77 (70)	535 (34)	2,067 (22)	21 (93)	701 (14)	6,575 (28)
		-50	10.53 (210)	21 (95)	1,086 (36)	895 (188)	1,069 (30)	10,943 (20)

[1] Percent change is relative to predevelopment results.

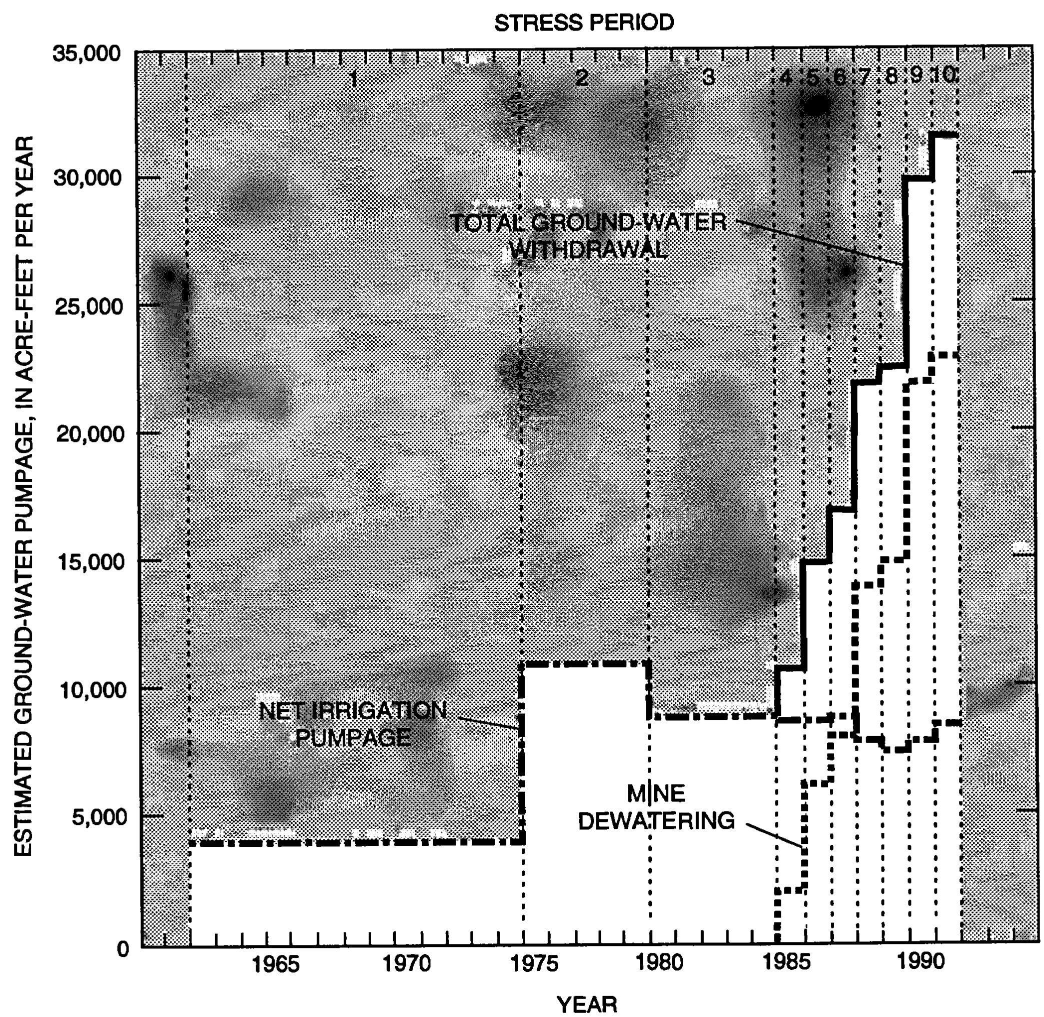


Figure 22. Estimates of net irrigation pumpage, mine-dewatering pumpage, and total ground-water withdrawals, by stress period, specified for development simulation, Desert Valley, Nevada.

Table 13. Simulated ground-water withdrawals for irrigation and mine dewatering, by stress period and corresponding year(s), Desert Valley, Nevada

Stress period	Simulated annual ground-water withdrawal			
	Years	Irrigation (acre-feet)	Mine dewatering (acre-feet)	Total average withdrawal (acre-feet)
1	1962-1974	3,900	0	3,900
2	1975-1979	11,000	0	11,000
3	1980-1984	8,800	0	8,800
4	1985	8,700	2,100	10,800
5	1986	8,700	6,200	14,900
6	1987	8,900	8,100	17,000
7	1988	8,000	14,000	22,000
8	1989	7,600	15,000	22,600
9	1990	7,900	22,000	29,900
10	1991	8,600	23,000	31,600

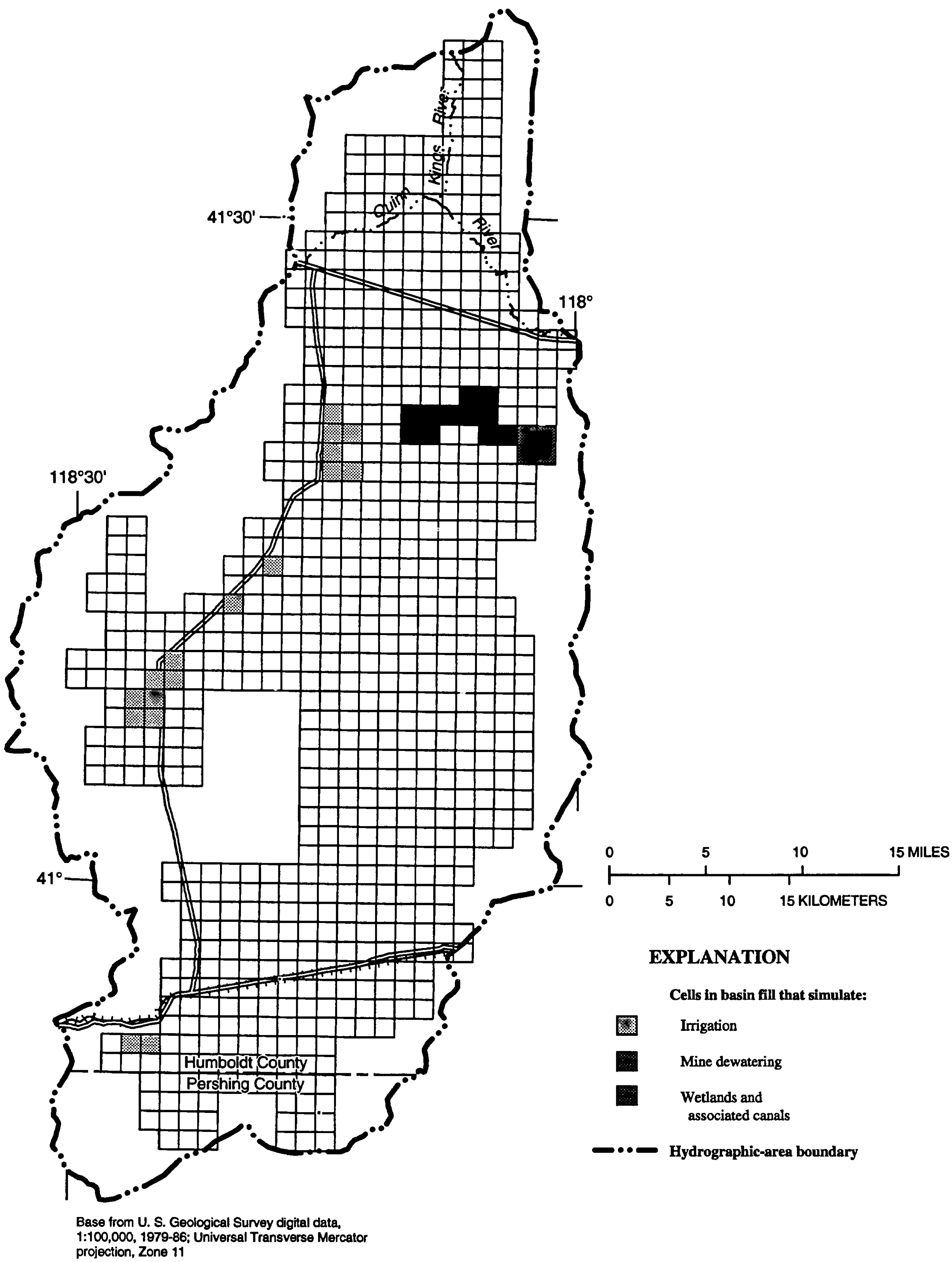


Figure 23. Distribution of model cells used to simulate irrigation pumping, mine dewatering, and discharge lakes and associated canals, Desert Valley, Nevada.

Changes in Flow-Boundary Conditions

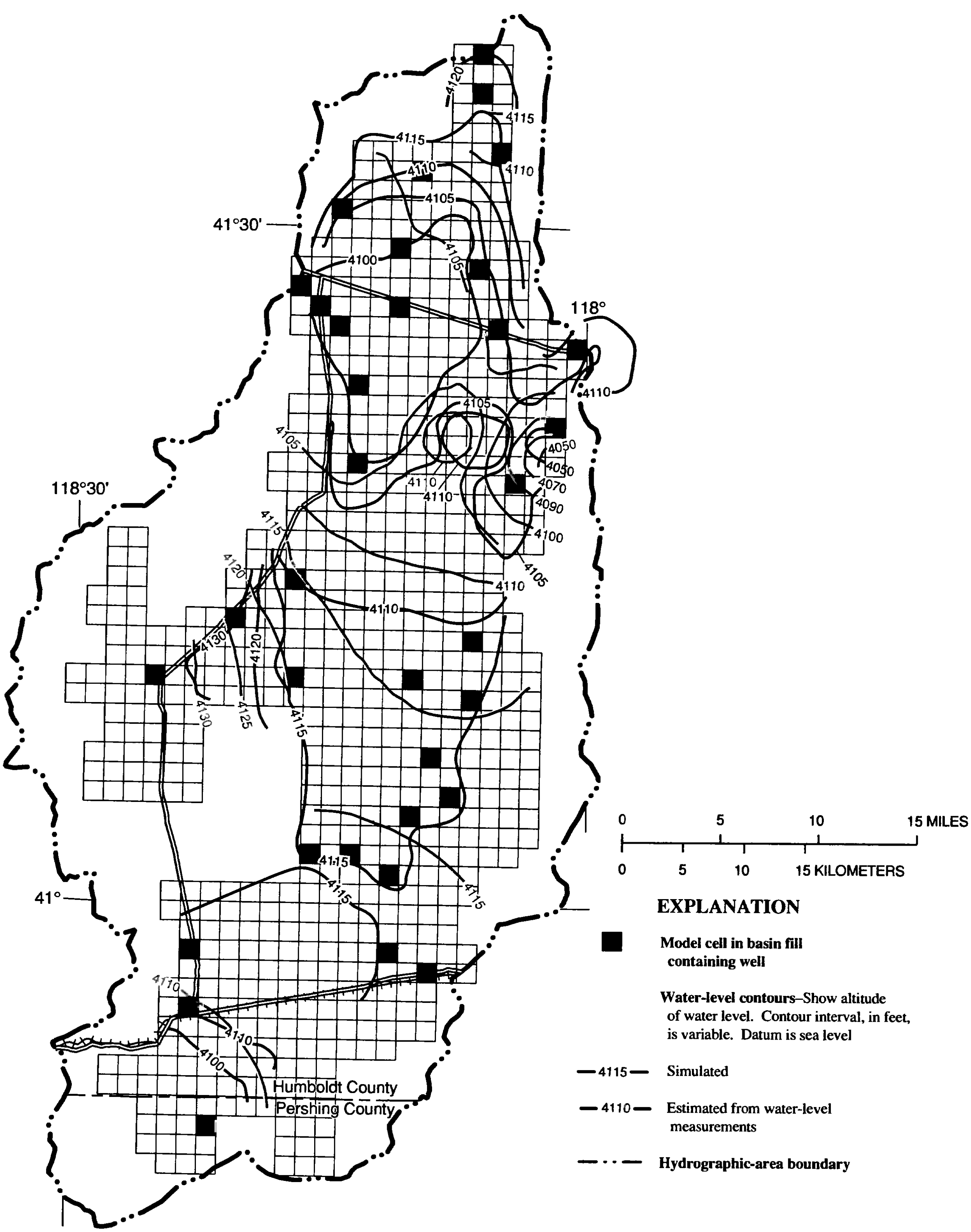
Changes in flow-boundary conditions between predevelopment and development simulations were made at the head-dependent flow boundaries used to simulate subsurface flow in the northern part of the study area. Head values assigned to external cells used to simulate subsurface flow were adjusted for each stress period on the basis of a linear relation between predevelopment head values and 1991 water-level measurements. The simulation of infiltration from the artificial wetlands and associated canals was made by modifying the input data sets for the stream-aquifer program (Prudic, 1989). In addition to the 27 stream cells for the Quinn and Kings Rivers (fig. 16), five stream cells were included in stress-periods 4 through 9 (1985 through 1990) to simulate the effects of the initial wetlands area. During stress-period 10 (1991), nine stream cells were specified to simulate the infiltration of water beneath the second wetlands area. The amount of water introduced to these cells is equal to the gross discharge from the mine minus the amount of water consumed at the mine and the estimated evaporation from the wetlands. The locations of cells containing the additional stream reaches used to simulate the artificial wetlands are shown in figure 23. Model cells that were used to simulate the original wetlands area (1985-90; stress periods 4-9) remained as active stream cells during stress-period 10 to allow infiltration of water that remained impounded at the end of stress-period 9. Recharge and streamflow rates in the model were either increased or decreased depending on the estimated departure from the long-term average (normal) during each stress period.

Calibration and Results

Calibration of the development simulation consisted of adjusting the streambed conductance values of active stream cells that were specified to represent the artificial wetlands. Streambed conductances were adjusted, within reason, until the quantity of water that remained impounded in the artificial wetlands at the end of each stress period matched the quantity that was estimated or measured at the start of the corresponding year. After evaporation losses and the water impounded within the artificial wetlands were accounted for during each stress period, the remaining water was assumed to be ground-water recharge. The final stream-bed conductance values were then held constant throughout the development simulation. Additional calibration was done by comparing simulated water- level contours to contours constructed from Spring 1991 water-level measurements and comparing simulated water-level declines with measured declines over the 30-year period of development simulation.

The configuration of the model-computed potentiometric surface for layer 1 at the end of stress-period 10 (fig. 24) is in good agreement with the measured Spring 1991 potentiometric surface. The potentiometric surface simulated for layer 2 at the end of stress-period 10 is similar to that of layer 1; however, basin-wide water-level data are insufficient to determine the quality of the match for layer 2.

Modeled water-level declines for the 30-year development simulation (1962 to 1991), shown for layer 1 in figure 25, match fairly well with the general distribution of net declines determined from field data over the same time period (fig. 13). Comparison between figures 13 and 25 indicates that the model simulation was generally able to approximate the measured water-level declines throughout the entire basin, including the area of declines due to the dewatering operation at the mine and the area of less-than-5-ft declines near the artificial wetlands. Maximum simulated declines at the four cells representing mine dewatering were about 70 ft, compared with measured declines of nearly 300 ft beneath the mine pits. This is because the simulated declines represent values averaged over each of four 1-mile-square model cells compared with measurements in wells located at the maximum points of drawdown within the pits. To more closely approximate the total drawdown beneath the pits, model cells would have to be closer in size to the area covered by the pits.



Base from U. S. Geological Survey digital data, 1:100,000, 1979-86; Universal Transverse Mercator projection, Zone 11

Figure 24. Model-simulated potentiometric surface for layer 1 at end of stress-period 10 (1991) for development simulation, Desert Valley, Nevada.

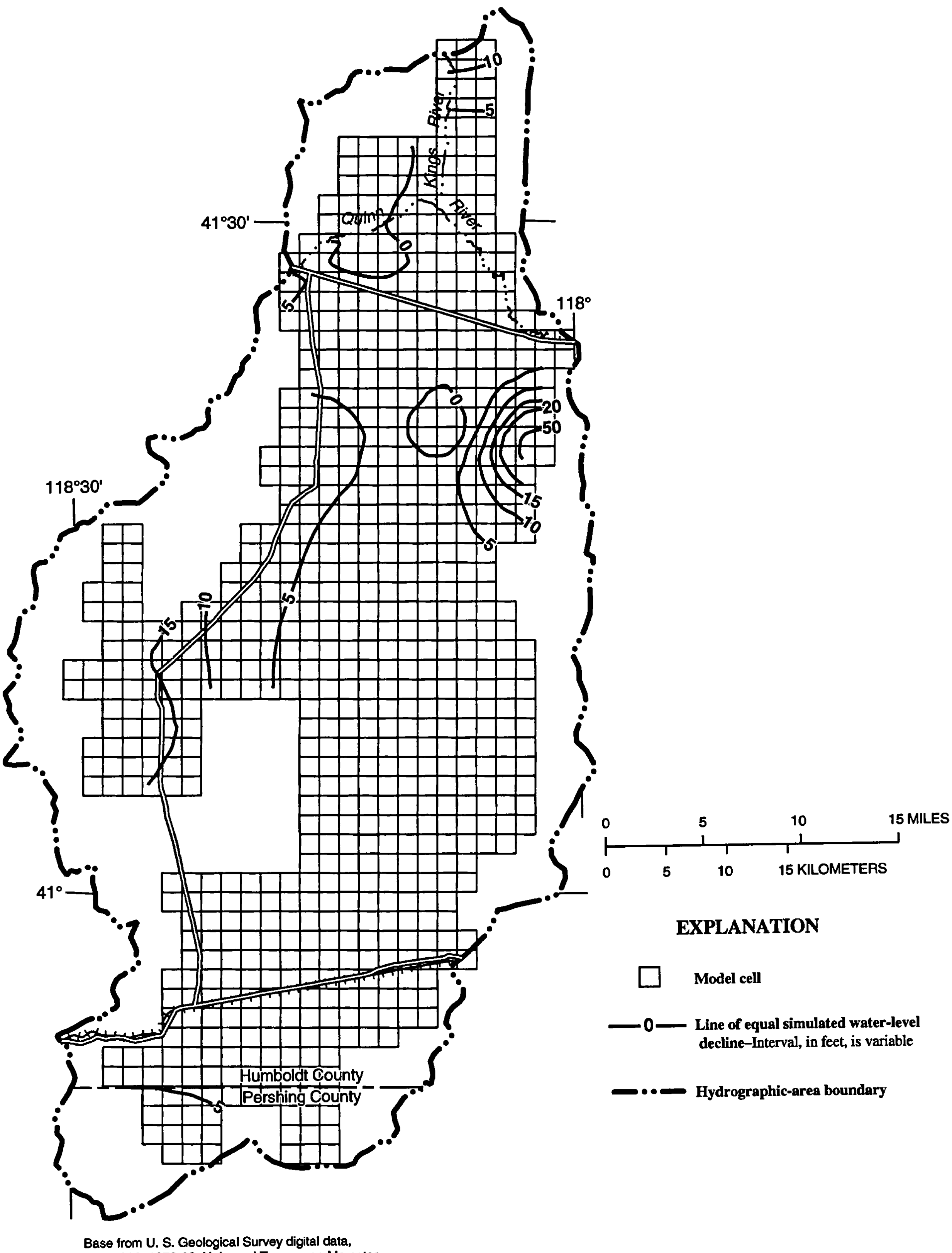


Figure 25. Model-simulated water-level declines for layer 1 at end of stress-period 10 (1991) for development simulation, Desert Valley, Nevada.

Hydrographs of measured and simulated water levels for eight wells that are screened within the equivalent of layer 1, and for the corresponding model cells, are shown in figure 26. The hydrographs show that simulated water levels closely match measured water levels on a basin-wide scale. Model-simulated hydrographs for cells unaffected by the dewatering operation (cells 3/21, 13/12, 40/18, and 47/7 [row/column]) closely match the observed hydrographs for the corresponding sites (sites 44, 62, 104, and 119). The remaining four hydrographs represent measured and simulated water-level changes associated with the mine dewatering. The general trend of water-level declines simulated for sites 67 and 69 (cells 20/25 and 21/24) are comparable to the observed trends. However, well-site 69 (cell 21/24) is closer to the mine than to the cell center, resulting in greater observed drawdowns than those simulated. The measured water-level decline at site 130 (cell 16/26) reflects the decrease in infiltration from the Quinn River due to 8 years of below-normal precipitation (fig. 4*B*), superimposed on the effects of the mine dewatering. Surface-water inflow is simulated by the model as an average daily value over one year, and is not modeled seasonally. Thus, the hydrograph of simulated water levels for the corresponding cell shows some net decline, but not as much as that measured. Site 80 (cell 20/22) is in the wetlands area where measured water levels increased slightly through 1990 (fig. 26). Simulated water levels at cell 20/22 gradually increased from 1985 to 1990 in response to simulated infiltration of water from the wetlands. In February 1991, mine discharge was rechanneled to the new wetlands area farther west, which allowed the original wetlands to dry. The effect of this change was observed in site 80 as a slight decline in water level at the end of 1991 (fig. 26). The simulated response in cell 20/22 during 1991 shows a larger water-level decline than that measured. This difference is because the cell center is closer to the original wetlands area and the dewatering at the mine than site 80.

Hydrographs for four wells screened at depths the equivalent of layer 2 (sites 60, 71, 81, and 109), two wells in layer 3 (sites 60 and 72), and the corresponding model cells are shown in figure 27. Five of the six hydrographs have simulated water levels greater than measured levels due to the location of the well in relation to the cell center. This effect is greatest where hydraulic gradients are steepest. In general, the simulated water-level trends derived from the model approximate the observed trends.

The ground-water budget summarizing the inflow to and outflow from the basin-fill aquifer of Desert Valley for 1991 conditions (end of stress-period 10) determined from the development simulation is given in table 14. On the basis of long-term streamflow data and the general trend of below-average precipitation (fig. 4*B*), 1991 ground-water recharge and surface-water flow were estimated to be about 64 percent of the long-term average. This below-average condition is reflected in the simulated decrease of inflow to the ground-water system from predevelopment time. Decreases in subsurface inflow from the Kings River and Quinn River Valleys were calculated by assigning Spring 1991 water-level values to the associated external cells.

Table 14. Simulated ground-water budget for development conditions at end of stress-period 10 (1991), Desert Valley, Nevada

[All values in acre-feet per year, rounded to two significant figures]

Budget component	Simulated 1991 conditions
Inflow	
Recharge from precipitation:	
From mountain block	4,400
From sand dunes	280
Infiltration from rivers	2,400
Infiltration from dewatering lakes	[1]16,000
Subsurface inflow:	
From Kings River Valley	240
From Quinn River Valley	160
Total inflow	23,000
Outflow	
Evapotranspiration	7,800
Subsurface outflow:	
To Pine Valley	400
To Southwest	1,800
Groundwater pumpage [2]:	8,600
For irrigation	
For mine dewatering	23,000
Total outflow	42,000
Net results	
Outflow minus inflow	19,000
Storage depletion (simulated by model)	18,000

[1] Includes about 1,200 acre-feet simulated to remain impounded in initial wetlands at end of stress-period 9.

[2] Simulated pumpage for irrigation is estimated net pumpage and simulated pumpage for mine dewatering is estimated gross pumpage.

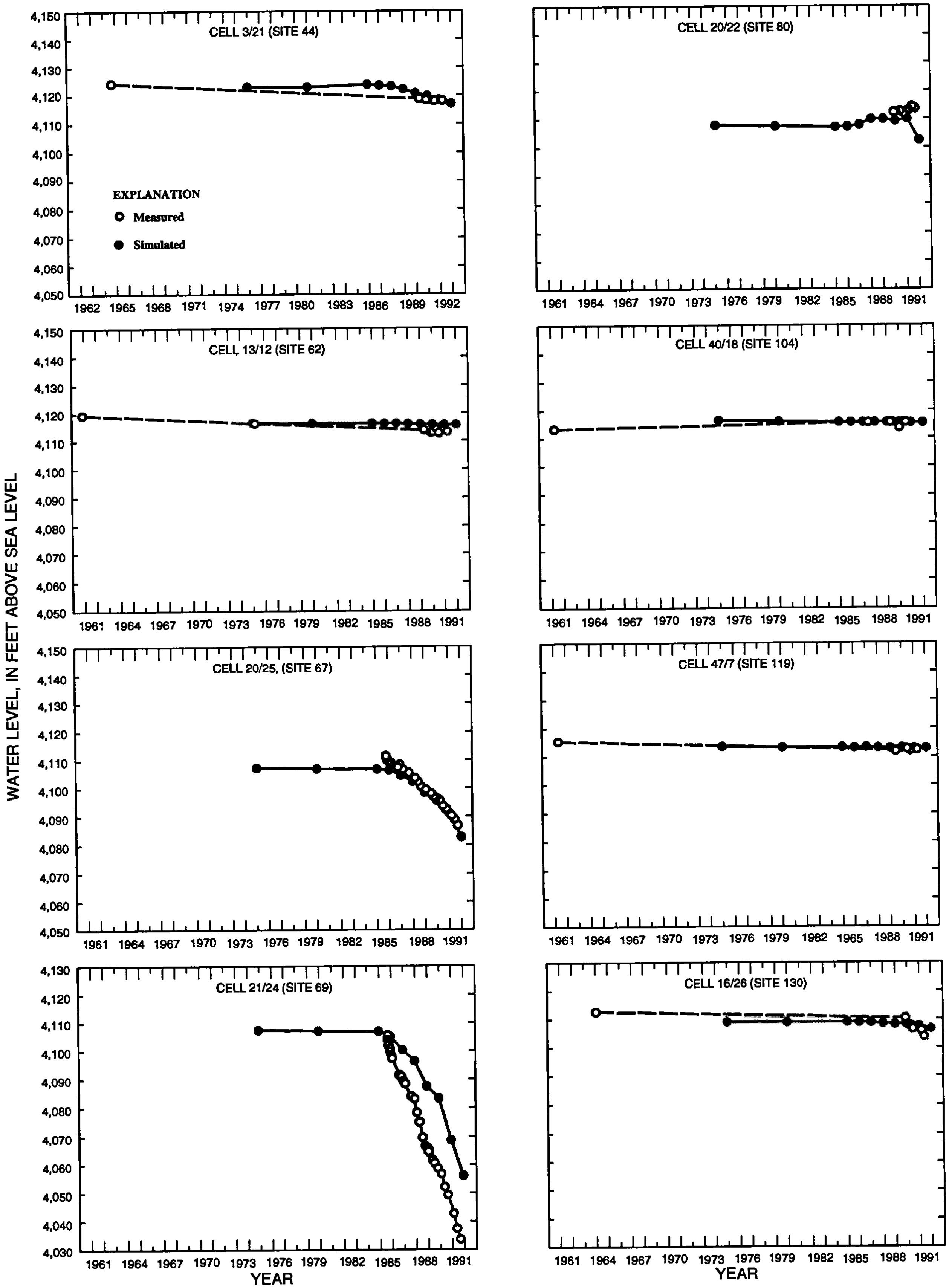


Figure 26. Measured and simulated ground-water levels for selected cells, layer 1, during development simulation, Desert Valley, Nevada. Cell location is indicated by row and column (for example, 21/24 indicates row 21, column 24).

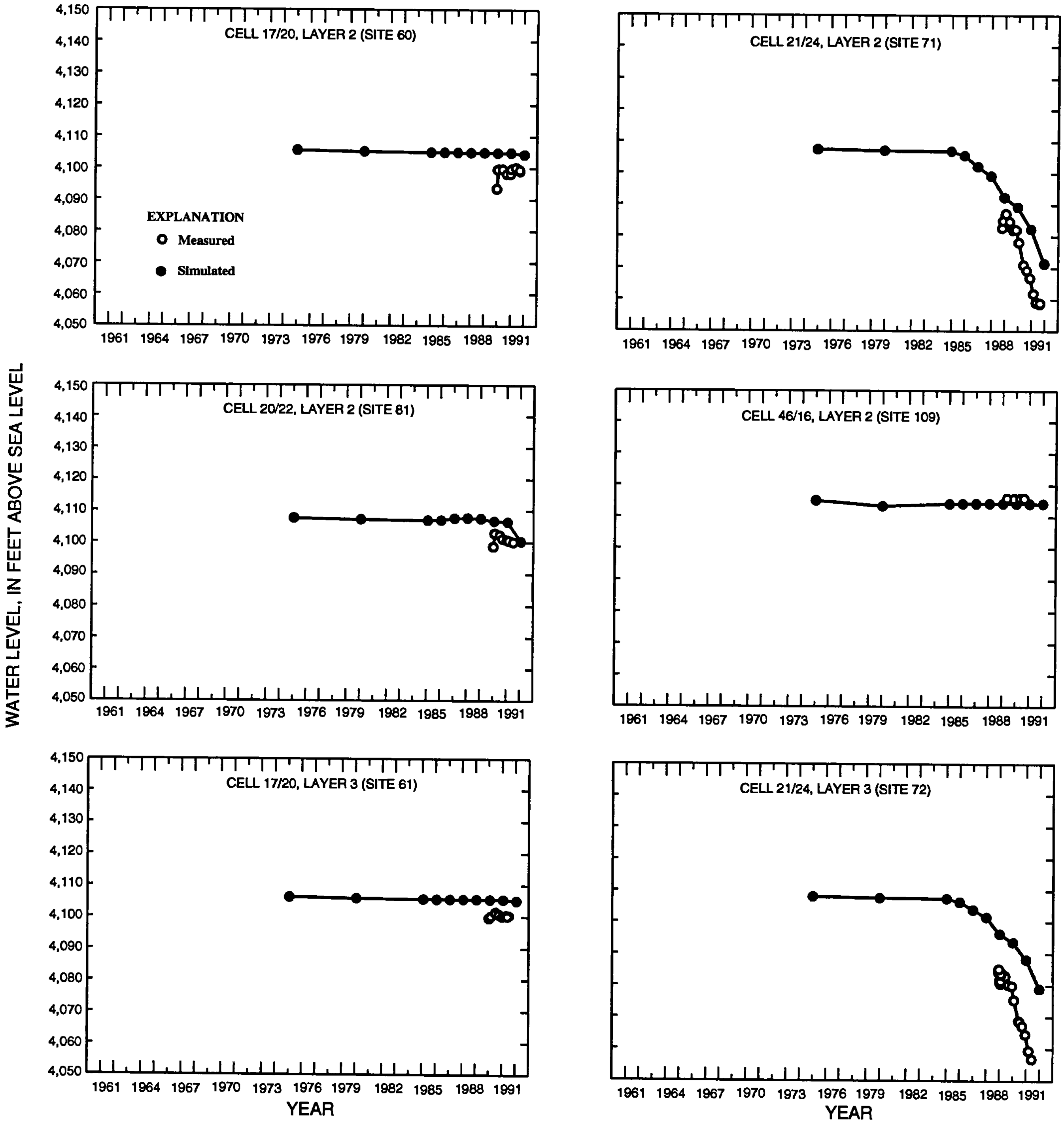


Figure 27. Measured and simulated ground-water levels for selected cells, layers 2 and 3, during development simulation, Desert Valley, Nevada. Cell location is indicated by row and column (for example, 21/24 indicates row 21, column 24).

Simulated surface-water outflow to Pine Valley by way of the Quinn River decreased from the estimated long-term average of 1,400 acre-ft/yr to about 100 acre-ft/yr for 1991. Infiltration beneath the artificial wetlands and the depletion in ground-water storage supplied nearly all the pumpage simulated at the Sleeper Mine. Declines in ground-water levels near the mine, shown in figure 25, are a result of depletion in storage. A small amount of mine discharge water may be supplied by a decrease in evapotranspiration and an increase in infiltration beneath the Quinn River. Simulated infiltration from all rivers for 1991 was only about 310 acre-ft, less than that simulated under predevelopment conditions despite the greatly reduced streamflows during 1991.

Simulation of Response to Hypothetical Mine-Dewatering Scenarios

To evaluate the probable long-term effects of ground-water withdrawals, three hypothetical dewatering scenarios were simulated using the calibrated flow model. The hypothetical scenarios were developed on the basis of the life expectancy of the Sleeper Mine and discussions with representatives from the Nevada Division of Water Resources. The results from simulated aquifer responses to the hypothetical dewatering scenarios are intended to indicate general basin-wide trends. Figures showing the distribution of model-computed water-level declines since predevelopment (figs. 28, 29, 31, 32, 34, and 35) for selected stress periods, are used to illustrate probable long-term effects of ground-water withdrawals on the basis of results from the dewatering scenarios. Simulated ground-water budgets are used to describe the overall effects of ground-water development on the recharge and discharge of the aquifer systems and changes in the cumulative depletion of ground-water storage with time (figs. 30, 33, and 36). Estimates of these elements made for predevelopment conditions are used as the initial point (where elapsed time = 0) for evaluating simulated changes since predevelopment time. The hypothetical dewatering scenarios provide a means of evaluating various management alternatives for the ground-water supply within Desert Valley. The concept of optimal yield (Bear and Levin, 1967), as a function of time and hydrologic conditions of the aquifer system may not necessarily meet sustained-yield requirements for a particular ground-water basin. However, the dewatering scenarios, in a sense, test the optimal-yield concept in terms of ground-water development in excess of equilibrium conditions for a limited length of time.

The hypothetical dewatering scenarios were constrained in regard to the model-layer assignments specified for mine dewatering, for the distribution of irrigation pumping, and for the inflow and outflow quantities. To avoid dewatering cells from going dry during the simulations, all pumping for mine dewatering was reassigned from layer 1 to layer 2. This modification in vertical- pumping distribution at the mine is not unreasonable considering the probable pumping conditions as the pits become deeper and the depth of ground-water withdrawal increases. Because Desert Valley is a Designated Basin, variations in future ground-water withdrawals for irrigation and in the general distribution of irrigation pumpage were assumed to remain virtually the same as those in 1991. Long-term estimates of streamflow, recharge from precipitation, and evapotranspiration, which were determined for predevelopment conditions and used in the predevelopment flow model, also were used for the hypothetical dewatering scenarios. The effect of this constraint is evident mostly in the discontinuity of the curve representing simulated change in subsurface inflow (bottom plot in figs. 30, 33, and 36). For each dewatering scenario, a 100-year recovery period follows the termination of simulated mine dewatering, to allow the ground-water system to approach a new equilibrium. During the recovery period, mine dewatering is specified as zero in the model and irrigation pumping continues for the entire simulation at 1991 levels. Hydraulic properties of the basin-fill aquifer determined from the calibrated flow model were used for all scenarios.

Scenario A—Continued Dewatering at Projected Rates, 1991-98

The first dewatering scenario (scenario A) was used to evaluate effects of continued mine dewatering at projected increasing rates for an additional 7 years, from 1991 through 1998 (fig. 30*A*). Annual dewatering volumes are projected to increase steadily from 24,000 acre-ft in 1992 to 32,000 acre-ft in 1998 (Nevada Gold Mining, Inc., written commun., 1992).

During scenario A, the pumped water is allowed to continue infiltrating beneath the artificial wetlands, as specified in stress-period 10 of the development model. Seven 1-year stress periods, each with four time steps, were added to the calibrated development model to simulate the additional mine dewatering. At the end of the dewatering period (stress-period 17), the 100-year recovery period is specified as stress-period 18, with 25 time steps.

The distribution of water-level declines since predevelopment computed by the model at the end of the simulated dewatering period for scenario A (stress-period 17; fig. 28) is similar to the distribution of declines exhibited in stress-period 10 (figure 25). By steadily increasing the ground-water withdrawal at the mine for an additional 7 years, simulated water-level declines continued to expand, generally farther south and southwest of the mine than to the north. Expansion of simulated water-level declines north of the mine is constrained by the availability of recharge to be captured from head-dependent flow boundaries and stream cells. To the south and southwest, in contrast, pumped water is obtained by depletion of ground-water storage, which causes a larger area of simulated water-level declines. At the end of the 100-year recovery period (stress-period 18), water levels have nearly recovered to predevelopment conditions in the area of the mine, and water levels in the wetlands area have returned to nearly predevelopment levels (fig. 29). Some residual effects appear to have propagated away from the mine area; these declines may be solely a result of the dewatering or, more likely, a combination of dewatering and continued pumping for irrigation. Figure 30 shows changes in budget components, with time, determined from the results of simulating continued mine dewatering for 7 years beginning in 1991 (scenario A). Large changes in the budget values during mine dewatering (elapsed time, between 24 and 36 years) indicate that the aquifer system is out of equilibrium. After mine dewatering ceases (elapsed time, 37 years), smaller changes in budget values suggest that the aquifer may be gradually approaching a new equilibrium with little or no change in storage.

Scenarios B and C—Continued Dewatering at 1991 Rate, 1991-2016

The second and third scenarios (scenarios B and C) were developed to evaluate the basin-wide effects of constant mine dewatering at the 1991 rate for 25 years (1991-2016), followed by the 100-year recovery period (fig. 33*A*, 36*A*). As in scenario A, the pumped water is allowed to infiltrate beneath the wetlands area during scenario B; however, during scenario C the pumped water is not allowed to infiltrate beneath the wetlands areas and is entirely removed from the model. For scenarios B and C, 25 additional 1-year stress periods were added to the calibrated development model (stress-periods 11-35), each with 4 time steps. Stress-period 36, with 25 time steps, is used to represent the 100-year recovery period.

Water-level declines since predevelopment, simulated by 25 years of continuous mine dewatering beginning in 1991, expand considerable distance away from the mine in both scenarios (figs. 31 and 34). However, water-level declines simulated in scenario B are similar to declines simulated in scenario A, which are both vastly different from declines simulated in scenario C. This suggest that the infiltration beneath the wetlands has a large effect on the distribution of water-level declines to the west of the mine. The additional recharge provided by the wetlands attenuates the westward propagation of effects from the mine dewatering. At the end of the 100-year simulated recovery period, the distribution of water-level declines on a basin-wide scale for scenarios B and C is similar to that for scenario A (figs. 29, 32, and 35). As a result of not allowing the mine discharge water to infiltrate beneath the wetlands area (scenario C), the pumpage for dewatering captures water from other sources, including the depletion of ground water in storage and the reduction of evapotranspiration due to lowered water levels. This difference in the source of recharge between scenarios B and C is evident in the budget-component curves shown in figures 33 and 36. Over the same time interval (elapsed time, between 30 and 56 years), the slopes of the cumulative depletion in storage and evapotranspiration curves for scenario C are steeper than those for scenario B. The steeper slope indicates that more water is obtained from storage and reduction of evapotranspiration in scenario C than in scenario B because of the absence of infiltration beneath the wetlands area. The model results also suggest that infiltration from the rivers does not increase during scenario C simulations. This lack of increase suggests that the infiltration from beneath the Quinn River was probably at its maximum prior to mine dewatering. By the end of the 100-year recovery period, the simulated aquifer system appears to be approaching a new equilibrium.

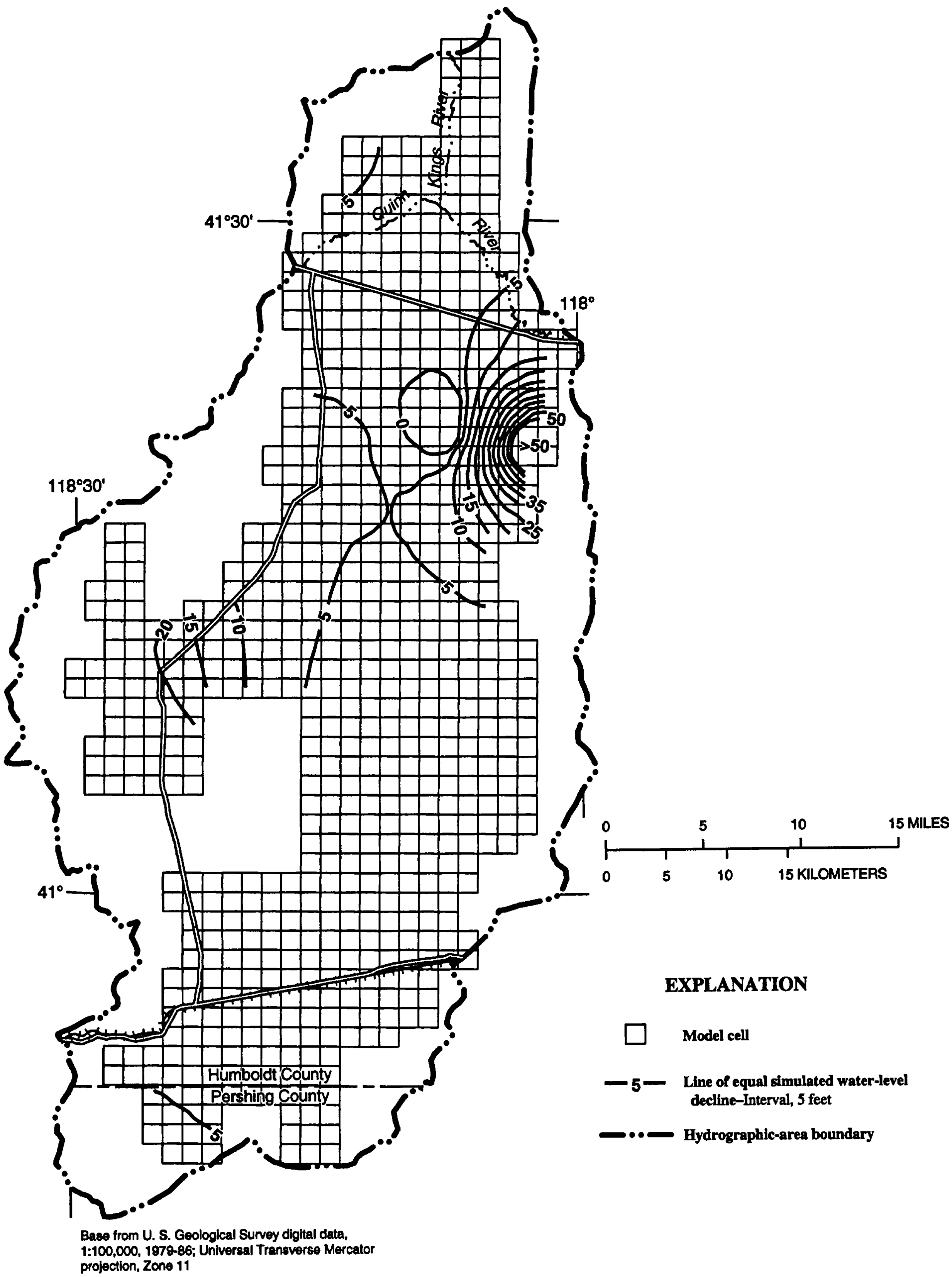


Figure 28. Model-simulated water-level declines since predevelopment at end of 7 years (stress-period 17) for hypothetical mine-dewatering period, scenario A (continued dewatering at projected rates, 1991-98), Desert Valley, Nevada.

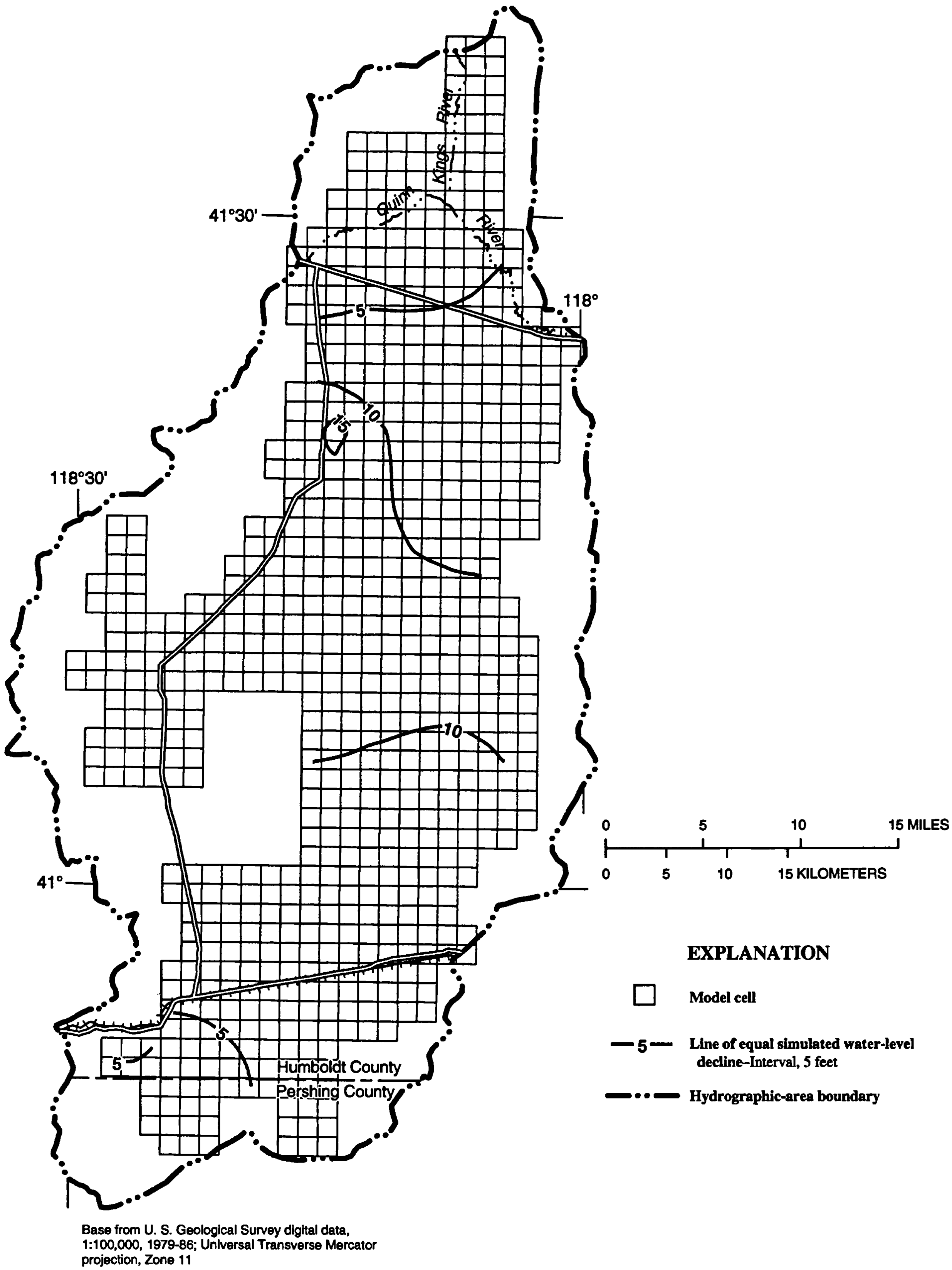


Figure 29. Model-simulated water-level declines since predevelopment at end of 100-year recovery (stress-period 18) for hypothetical mine-dewatering period, scenario A (continued dewatering at projected rates, 1991-98), Desert Valley, Nevada.

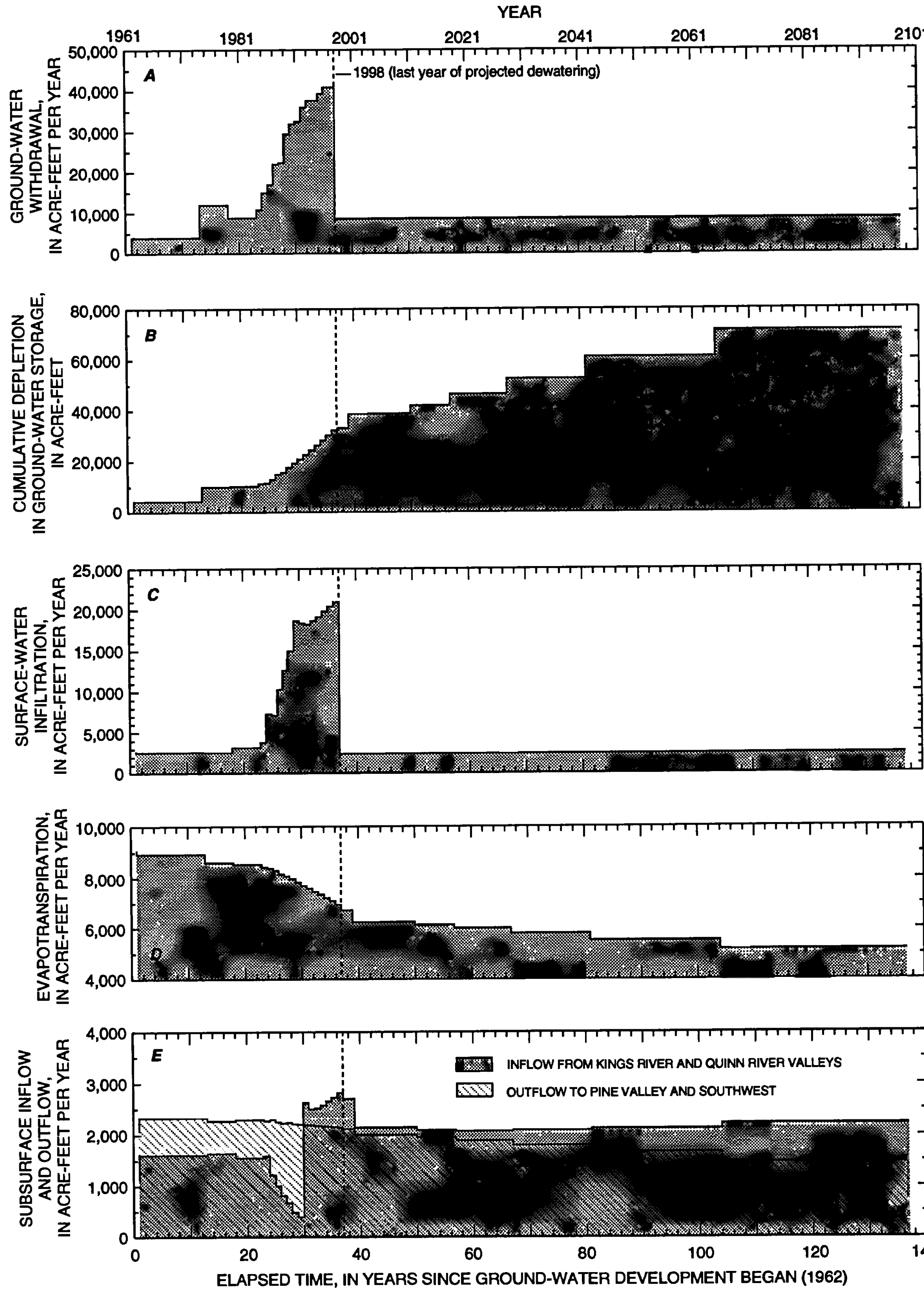


Figure 30. Scenario A, simulated response with continued mine dewatering at projected increasing rates followed by a 100-year recovery period, Desert Valley, Nevada. Mine-dewatering rate increase from 24,000 acre-feet in 1992 to 32,000 acre-feet in 1998. ***A,*** Rate of total ground-water withdrawal. ***B,*** Cumulative depletion in ground-water storage. ***C,*** Surface-water infiltration rate. ***D,*** Evapotranspiration rate. ***E,*** Rates of subsurface inflow and outflow.

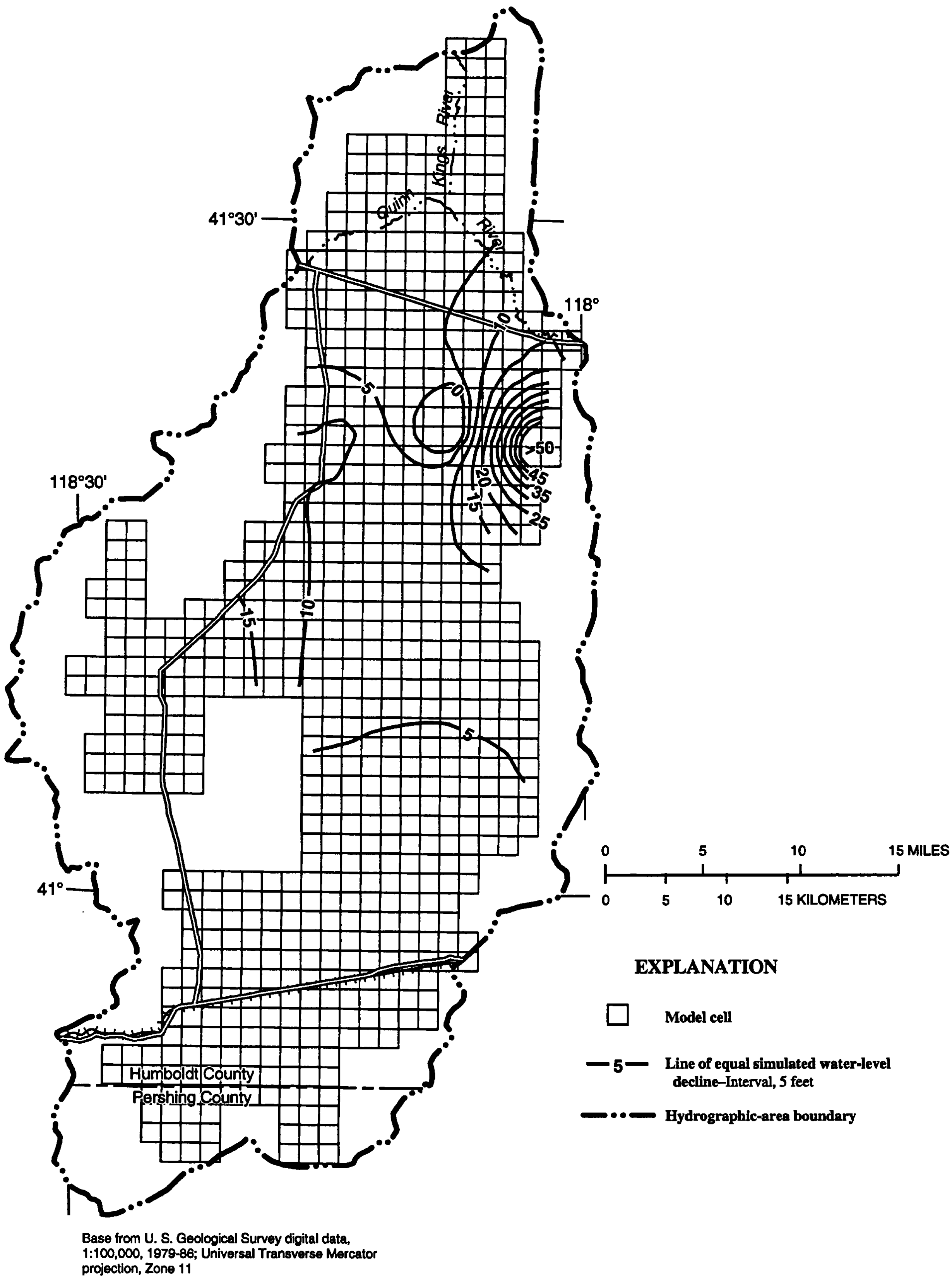


Figure 31. Model-simulated water-level declines since predevelopment at end of 25 years (stress-period 35) for hypothetical mine-dewatering period, scenario B (continued dewatering at 1991 rate), Desert Valley, Nevada.

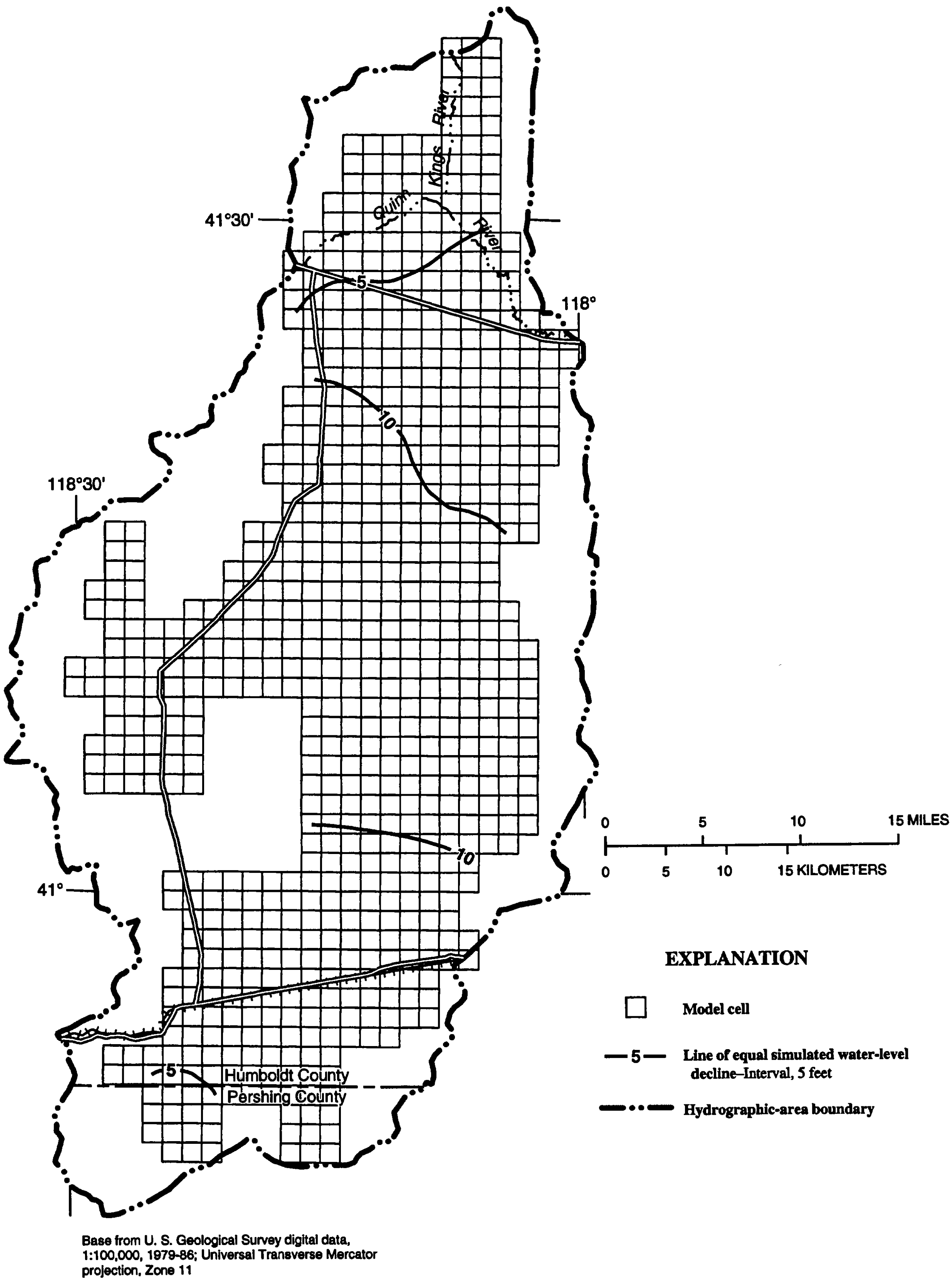


Figure 32. Model-simulated water-level declines since predevelopment at end of 100-year recovery (stress-period 36) for hypothetical mine-dewatering period, scenario B (continued dewatering at 1991 rate), Desert Valley, Nevada.

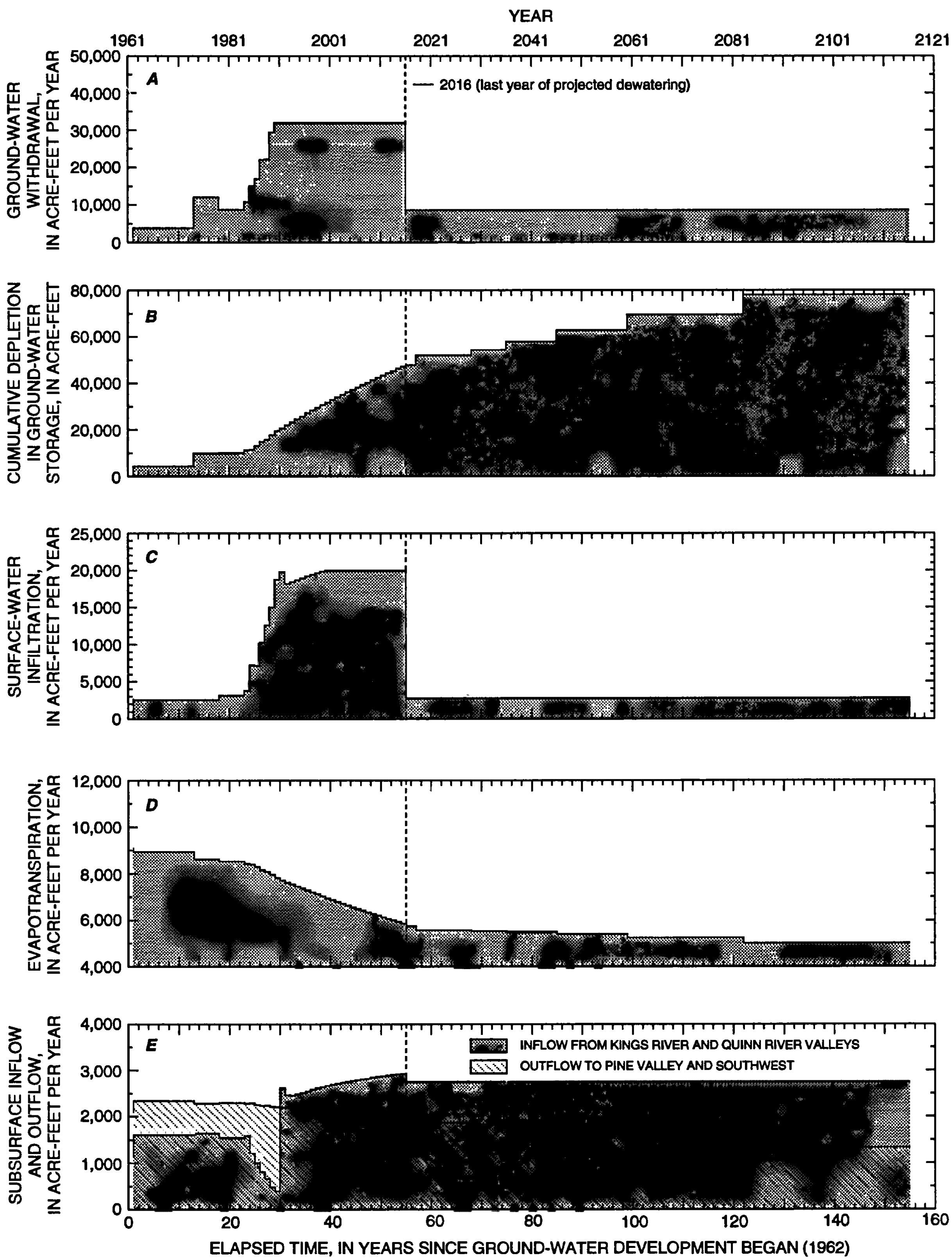


Figure 33. Scenario B, simulated response with mine dewatering at 1991 rate (23,000 acre-feet) for 25 years followed by a 100-year recovery period, Desert Valley, Nevada. Pumped mine water is allowed to infiltrate beneath wetlands area. ***A,*** Rate of total ground-water withdrawal. ***B,*** Cumulative depletion in ground-water storage. ***C,*** Surface-water infiltration rate. ***D,*** Evapotranspiration rate. ***E,*** Rates of subsurface inflow and outflow.

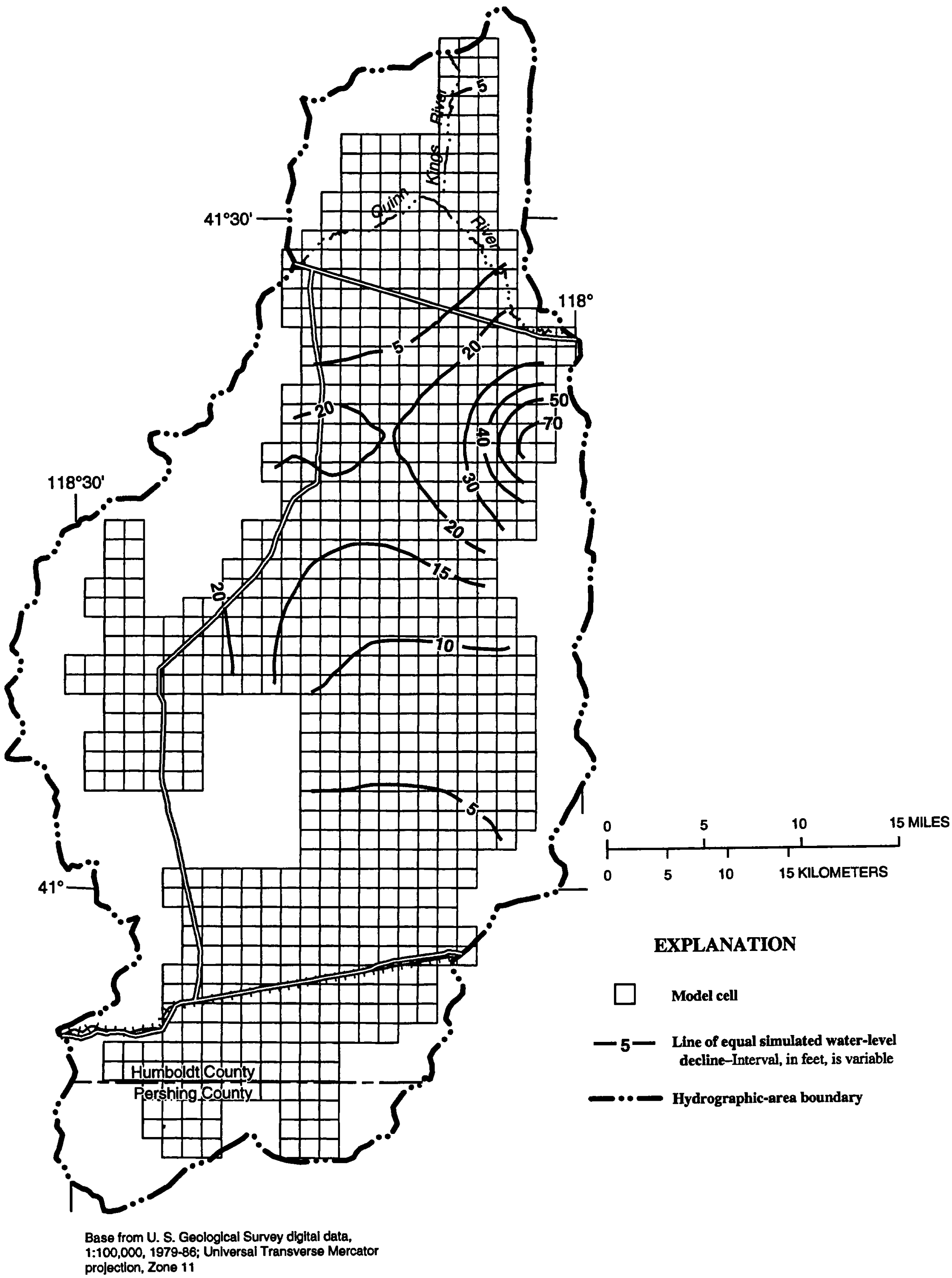


Figure 34. Model-simulated water-level declines at end of 25 years (stress-period 35) for hypothetical mine-dewatering period, scenario C (continued dewatering at 1991 rate), Desert Valley, Nevada.

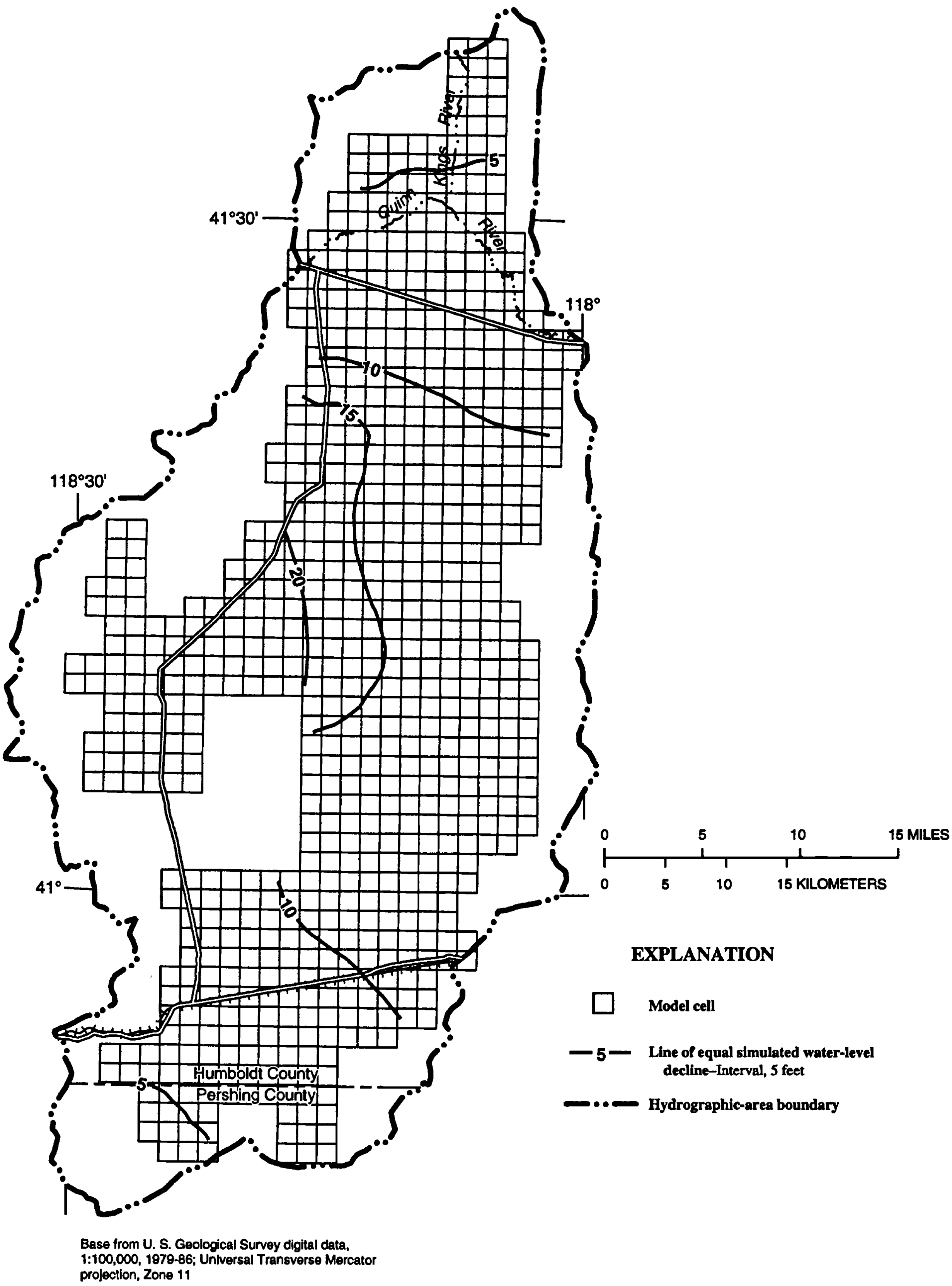


Figure 35. Model-simulated water-level declines at end of 100-year recovery (stress-period 36) for hypothetical mine-dewatering period, scenario C (continued dewatering at 1991 rate), Desert Valley, Nevada.

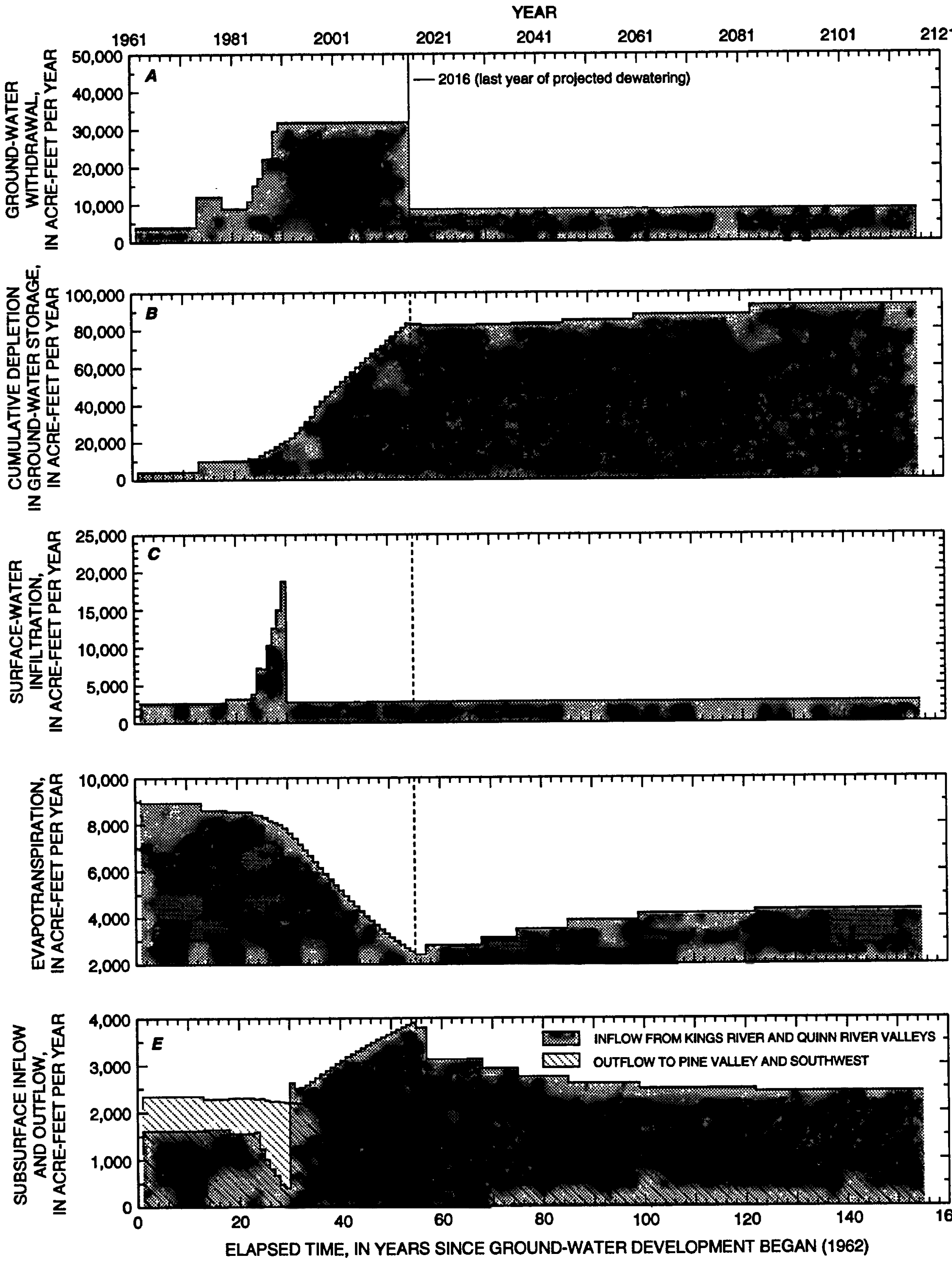


Figure 36. Scenario C, simulated response with mine dewatering at 1991 rate (23,000 acre-feet) for 25 years followed by a 100-year recovery period, Desert Valley, Nevada. Pumped mine water is not allowed to infiltrate beneath wetlands area and is entirely removed from model. ***A,*** Rate of total ground-water withdrawal. ***B,*** Cumulative depletion in ground-water storage. ***C,*** Surface-water infiltration rate. ***D,*** Evapotranspiration rate. ***E,*** Rates of subsurface inflow and outflow.

Evaluation of Hypothetical Dewatering Scenarios

Simulation results from the three hypothetical dewatering scenarios indicate that water-level declines from long-term mine dewatering would not be localized and probably would affect a large area in Desert Valley. However, water-level declines of greater than 50 ft are simulated at a distance of only 1 mi or less from the mine in scenarios A and B, and about 2 mi from the mine in scenario C. The practice of discharging mine waters to the wetlands site where infiltration recharges the ground-water system, and the position of the artificial wetlands relative to the mine, effectively retard the expansion of water-level declines westward from the mine. Additional subsurface inflow from the adjacent Quinn River Valley is induced in response to dewatering at the mine; in contrast, the simulated infiltration beneath the Quinn River was not greatly increased. On the basis of simulated changes of inflow and outflow budget components with time and the change of cumulative depletion in ground-water storage, a new equilibrium may be approached slowly after 100 years of recovery from the time mine dewatering ceases.

Limitations on Use of Flow Model

To represent the ground-water flow system of Desert Valley using a mathematical flow model, many simplifying assumptions about the system were necessary. Hydraulic properties of basin-fill deposits and distributions of water levels within basin-fill aquifers are seldom known accurately. Available hydrologic information within the study area on a basin-wide scale was sparse; however, more detailed data were available in the Sleeper Mine area. Those data provided limited, localized insight into the depositional textures of the basin fill. Thus, most of the hydrologic conditions in the basin-fill aquifer had to be inferred, especially along the edges of the valley floor and at depths greater than about 200 ft.

Streamflow in the Quinn and Kings Rivers was simulated by the model as a constant daily rate during each stress period. That constant rate allowed streamflow infiltration to recharge the ground-water system uniformly over a given year. Limited discharge data suggest that actual streamflow and associated recharge generally are limited to short periods during Spring runoff. Ephemeral streamflow would cause seasonal water-level fluctuations in wells near the rivers. This seasonality was not modeled; however, an attempt was made to adjust the specified annual streamflow in the model to be proportional to the estimated long-term normal. Depending on the amount of streamflow available during any given year and the irrigation practices associated with the two rivers upstream from the study area, actual streamflow during a particular year may never enter the study area.

The calibration process was constrained by the amount of data available to determine how closely the measured data can be matched by simulation. The predevelopment model was calibrated using sparse water-level data collected during the late 1950's and early 1960's and was assumed to represent predevelopment conditions. Model calibration for the development simulation was made against changes in water levels over a 30-year period and estimated storage volumes within the artificial wetlands beginning in 1985. If the areal distribution of current ground-water pumpage remains about the same and the general location of the artificial wetlands does not change, effects of future pumping and infiltration beneath the wetlands could be simulated with about the same degree of accuracy as for the development period (1962-91). Increased pumping rates at the mine can be evaluated, but effects on the basin-fill aquifer system should be considered reliable only as general changes and trends.

SUMMARY AND CONCLUSIONS

In the Spring of 1985, open-pit mine dewatering began at the Sleeper Mine in the northeastern part of Desert Valley. Dewatering in 1991 totalled 23,000 acre-ft—more than three times the estimated annual recharge from precipitation. The mining operation is planned to continue through 1998 at a projected dewatering rate of nearly 32,000 acre-ft/yr. Unlined canals are used to convey the pumped water to an artificial wetlands northwest of the mine, where the water creates areas for wildlife habitat. The mine discharge either is consumed by evapotranspiration or infiltrates back to the basin-fill aquifer. In 1991, the discharge area was moved farther west and away from the mine because water infiltrating beneath the wetlands was recirculating back to the dewatering operation at the mine.

As a result of the apparent potential for ground-water overdraft due to mine dewatering, the U.S. Geological Survey, in cooperation with the Nevada Division of Water Resources, began a study in 1989 to evaluate the hydrologic conditions of Desert Valley. The objectives of the study were to document 1991 hydrologic conditions and determine whether these conditions had changed since predevelopment time (pre-1962). In addition, a reappraisal of the basin's ground-water budget was made on the basis of hydrologic information collected since predevelopment. A ground-water flow model was then developed and used to simulate predevelopment and 1991 conditions and evaluate probable long-term effects of ground-water withdrawals on a basin-wide scale.

The study area, which includes both the Desert Valley hydrographic area and the Sod House hydrographic subarea in northwestern Nevada, encompasses about 1,200 mi^2, of which about 70 percent is underlain by unconsolidated basin-fill deposits. Annual precipitation on the valley floor is generally less than 8 in., increasing to more than 18 in. in the higher altitudes of the Jackson Mountains. The estimated total precipitation that falls within the study area is approximately 400,000 acre-ft annually.

The geologic history of the Desert Valley area is complex and includes deposition of large volumes of volcanic rocks and marine sediments, intense mountain-building activity, basin-and-range extensional faulting, and cyclic fluctuations of a large, closed-basin lake. The unconsolidated basin-fill deposits, which may be as much as 7,000 ft thick in the south-central part of the basin, make up the principal ground-water reservoir. These deposits consist of lenticular units of gravel, sand, silt, and clay, which function as a single aquifer system. Ground water within the basin fill is generally unconfined at shallow depths and under slightly confined conditions at grater depths. Estimates of hydraulic conductivity range between 5 ft/d for fine-grained deposits to as much as 320 ft/d for coarse-grained deposits. The amount of ground water stored in the upper 180 ft of saturated basin fill is estimated to total about 10 million acre-ft.

On the basis of Nevada State standards for 10 selected inorganic constituents and properties, most ground water sampled during this study is suitable for beneficial use for human consumption, aquatic life, irrigation, and watering livestock. Although most ground water sampled contains more than 500 mg/L of dissolved solids, water at only five sites exceeded secondary maximum drinking-water standards. The concentration of dissolved solids appears to be related primarily to the dissolution of evaporative salts and transpiration, rather than to the direct evaporation of ground water. Results of chemical analyses suggest that the overall composition of the ground water is a mixture of the major dissolved constituents; however, sodium-plus-potassium and sulfate-plus-chloride-type water represent nearly half the samples collected. General water types have a distribution similar to that documented by data for 1954-61. Geochemical evolution of the ground water follows a logical sequence along estimated flow paths from recharge source areas to discharge areas.

The inflow and outflow components of the ground-water budget for the aquifer system within the study area were estimated by using empirical techniques and refined by calibration of a ground-water flow model (table 11). Under predevelopment (natural) conditions, the total flow through the aquifer system was about 11,000 acre-ft/yr. The estimate of annual recharge by precipitation is 7,300 acre-ft—about 2,000 acre-ft greater than the 1962 reconnaissance estimate. This estimate includes about 440 acre-ft of recharge to the areas covered by sand dunes. Ground-water inflow to the basin-fill aquifer from infiltration beneath rivers was about 2,700 acre-ft/yr, and subsurface inflow from adjacent Quinn River and Kings River Valleys was about 1,100 acre-ft/yr. Natural discharge was estimated to be about 9,100 acre-ft/yr by evapotranspiration and about 2,100 acre-ft/yr by subsurface outflow. Under predevelopment conditions, ground water flowed toward the center of the basin from the recharge source areas in adjacent mountains. Ground water enters the basin-fill aquifer from the adjacent Quinn River and Kings River Valleys and exits to Pine Valley beneath low alluvial divides in the northern part of the study area. The existence of a ground-water divide west of the Jungo Hills suggests that some ground water, perhaps about 1700 acre-ft/yr, exits the study area to the south near the northern Antelope Range.

During 1991, about 5,500 acres of land, generally along the western margin of the valley floor, was irrigated with ground water, supplemented by local streamflow from the Jackson Mountains. Net ground-water withdrawals for irrigation were about 8,600 acre-ft annually, which appears to have resulted in 10-20 ft of water-level declines near the irrigated areas since predevelopment time. Water levels in areas unaffected by ground-water development have declined less than 5 ft since predevelopment time, probably as a result of the recent trend of below-average precipitation. Maximum water-level declines beneath the open pits at the Sleeper Mine, as of Spring 1991, ranged from 295 to 315 ft. In contrast, water levels beneath the wetlands receiving mine discharge rose 5-10 ft. Changes in the ground-water flow regime between predevelopment and 1991 conditions are predominantly near the dewatering operations and associated wetlands. Subsurface flow continues to enter and exit beneath the low alluvial divides in the north and to the south, similar to predevelopment conditions. However, the natural flow directions are interrupted by the dewatering operations, causing capture of ground water as it enters from the Quinn River Valley and moves toward the exit point to Pine Valley. The ground-water budget, as simulated by the ground-water flow model for 1991 conditions, indicates that nearly all the water pumped at the mine is supplied by infiltration beneath the artificial wetlands and the depletion of ground water in storage. A small amount of mine discharge water may be supplied by a decrease in evapotranspiration and an increase in infiltration beneath the Quinn River Valley.

The calibrated flow model was used to evaluate the probable long-term effects of ground-water withdrawal on a basin-wide scale. On the basis of the life expectancy of the Sleeper Mine and discussions with representatives from the Nevada Division of Water Resources, three hypothetical dewatering scenarios were developed. Scenario A was used to evaluate effects of continued mine dewatering at projected increasing rates for an additional 7 years from 1991 through 1998, followed by a 100-year recovery period at which time mine dewatering is discontinued and irrigation pumping is held constant at 1991 levels. During this scenario, the mine discharge water was allowed to infiltrate beneath the wetlands area similar to the conditions used in the predevelopment model. Scenarios B and C simulated constant mine dewatering at the 1991 rate for a period of 25 years (1991-2016), followed by a 100-year recovery period with similar pumping conditions as in scenario A. Infiltration beneath the wetlands area was simulated in scenario B, but in scenario C was removed from the flow model and not allowed to recharge the system. The results of the hypothetical dewatering scenarios suggest that water level-declines from long-term mine dewatering would not be localized and probably would affect a large area in Desert Valley. Local recharge to the mine, in scenarios A and B, was predominantly from infiltration beneath the wetlands area. In contrast, recharge to the mine in scenario C was obtained by depletion of ground-water storage and reduction in evapotranspiration. In addition, the distribution of simulated water-level declines suggests that the relative position of the current wetlands area in the ground-water flow system can attenuate the westward propagation of effects from the mine dewatering. By the end of the 100-year recovery period, the simulated aquifer system in all three scenarios has not reached a new equilibrium.

REFERENCES CITED

Allison, G.B., Stone, W.J., and Hughes, M.W., 1985, Recharge in karst and dune elements of a semi-arid landscape as indicated by natural isotopes and chloride: Journal of Hydrology, v. 76, p. 1-25.

Arteaga, F.E., 1978, Appraisal of water resources in the Fort McDermitt Indian Reservation, Humboldt County, Nevada: U.S. Geological Survey Open-File Report 78-139, 50 p.

Bauer, H.H., and Vaccaro, J.J., 1987, Documentation of a deep percolation model for estimating ground-water recharge: U.S. Geological Survey Open-File Report 86-536, 83 p.

Bear, J., and Levin, O., 1967, The optimal yield of an aquifer, *in* Artificial recharge and management of aquifers: International Association of Scientific Hydrology, Proceedings, Symposium of Haifa, Publication 72, p. 401-412.

Berger, D.L., 1992, Ground-water recharge through active sand dunes in northwestern Nevada: Water Resources Bulletin, v. 28, no. 5, p. 959-965.

Calkins, F.C., 1938, Gold deposits of Slumbering Hills, Nevada: University of Nevada Bulletin 3, 26 p.

Carlson, H.S., 1974, Nevada place names—A geographical dictionary: Reno, University of Nevada Press, 282 p.

Cohen, Philip, 1963, Specific-yield and particle-size relations of Quaternary alluvium, Humboldt River Valley, Nevada: U.S. Geological Survey Water-Supply Paper 1669-M, 24 p.

Cohen, Philip, and others, 1965, Water resources of the Humboldt River Valley near Winnemucca, Nevada: U.S. Geological Survey Water-Supply Paper 1795, 143 p.

Cordell, Lindrith, and Henderson, R.G., 1968, Iterative three-dimensional selection of gravity anomaly data using digital computer: Geophysics, v. 33, no. 4, p. 596-601.

Davis, J.O., 1982, Bits and pieces—Environmental history of the Western Great Basin during the last 35,000 years, *in* Madsen, David, and O'Connell, James, eds., Man and environment in the Great Basin: Society for American Archaeology Paper 2, p. 53-75.

Dettinger, M.D., 1989, Reconnaissance estimates of natural recharge to desert basins in Nevada, U.S.A., by using chloride-balance calculations: Journal of Hydrology, v. 106, p. 55-78.

Durbin, T.J., Kapple, G.W., and Freckleton, J.R., 1978, Two-dimensional and three-dimensional digital flow models of the Salinas Valley ground-water basin, California: U.S. Geological Survey Water-Resources Investigations Report 78-113, 134 p.

Ferguson, H.G., Muller, S.W., and Roberts, R.J., 1951, Geologic map of the Winnemucca quadrangle, Nevada: U.S. Geological Survey, Geologic Quadrangle Map GQ-11, scale 1:125,000.

Fishman, M.J., and Friedman, L.C., eds., 1989, Methods for determination of inorganic substances in water and fluvial sediments: U.S. Geological Survey Techniques of Water-Resources Investigations, book 5, chap. A1, 545 p.

Garcia, K.T., Gortsema, G.C., Pennington, R.N., and Preissler, A.M., 1992, Water resources data, Nevada, water year 1991: U.S. Geological Survey Water-Data Report NV-91-1, 481 p.

Gay, L.W., and Fritschen, L.J., 1979, An energy budget analysis of water use by saltcedar: Water Resources Research, v. 15, no. 6, p. 1589-1591.

Hardman, George, 1965, Nevada precipitation map, adapted from map prepared by George Hardman, Victor Kral, and others, 1936: University of Nevada, Reno, Agricultural Experiment Station Bulletin 185, 27 p.

Harrill, J.R., and Moore, D.O., 1970, Effects of ground-water development on the water regimen of Paradise Valley, Humboldt County, Nevada, 1948-68, and hydrologic reconnaissance of the tributary areas: Nevada Division of Water Resources, Bulletin 39, 123 p.

Harrill, J.R., and Preissler, A.M., 1994, Ground-water flow and simulated effects of development in Stagecoach Valley, a small, partly drained basin in Lyon and Storey Counties, western Nevada: U.S. Geological Survey Professional Paper 1409-H, 74 p.

Hem, J.D., 1985, Study and interpretation of the chemical characteristics of natural water (3d ed.): U.S. Geological Survey Water-Supply Paper 2254, 283 p.

Huxel, C.J., Jr., Parkes, J.E., and Everett, D.E., 1966, Effects of irrigation development on the water supply of Quinn River Valley area, Nevada and Oregon, 1950-64: Nevada Department of Conservation and Natural Resources, Water Resources Bulletin 34, 80 p.

Hydrotechnica, 1988, Sleeper Mine dewatering design: consultant's Status Report, Phase 1, v. 1-2.

———1989, The geology of Sleeper Mine with special reference to dewatering: consultant's report, 28 p.

Johnson, M.G., 1977, Geology and mineral deposits of Pershing County, Nevada: Nevada Bureau of Mines and Geology Bulletin 89, 115 p.

Lee, C.H., 1912, An intensive study of the water resources of a part of Owens Valley, California: U.S. Geological Survey Water-Supply Paper 294, 135 p.

Lohman, S.W., 1972, Ground-water hydraulics: U.S. Geological Survey Professional Paper 708, 70 p.

Malmberg, G.T., and Worts, G.F., Jr., 1966, The effects of pumping on the hydrology of Kings River Valley, Humboldt County, Nevada, 1957-64: Nevada Department of Conservation and Natural Resources, Water Resources Bulletin 31, 57 p.

Maxey, G.B., and Eakin, T.E., 1949, Ground water in White River Valley, White Pine, Nye, and Lincoln Counties, Nevada: Nevada State Engineer, Water Resources Bulletin 8, 59 p.

McDonald, M.G., and Harbaugh, A.W., 1988, A modular three-dimensional finite-difference ground-water flow model: U.S. Geological Survey Techniques of Water-Resources Investigations, book 6, chap. A-1, 586 p.

Meinzer, O.E., 1927, Plants as indicators of ground water: U.S. Geological Survey Water-Supply Paper 577, 95 p.

Mifflin, M.D., and Wheat, M.W., 1979, Pluvial lakes and estimated pluvial climates of Nevada: Nevada Bureau of Mines and Geology Bulletin 94, 57 p.

Morris, D.A., and Johnson, A.I., 1967, Summary of hydrologic properties of rock and soil materials, as analyzed by the hydrologic laboratory of the U.S. Geological Survey, 1948-60: U.S. Geological Survey Water-Supply Paper 1839-D, 42 p.

Morrison, R.B., 1964, Lake Lahontan—Geology of southern Carson Desert, Nevada: U.S. Geological Survey Professional Paper 401, 156 p.

Nash, J.T., Utterback, W.C., and Saunders, J.A., 1989, Geology and geochemistry of the Sleeper gold-silver deposit, Humboldt County, Nevada—An interim report: U.S. Geological Survey Open-File Report 89-476, 39 p.

Nevada Bureau of Health Protection Services, 1992, Public water systems—Quality: Nevada Administrative Code, Chapter 445, p. 49-52.

Nevada Commission on Economic Development, 1987, State of Nevada's response to Department of Energy's invitation for site proposals for the Superconducting Super Collider (SSC): Carson City, Nev., 12 volumes.

Nevada Division of Water Resources, 1993, Underground water and wells: Nevada Administrative Code, Chapters 534 and 535, p. 12781-12782.

Nichols, W.D., 1992, Energy budgets and resistances to energy transport in sparsely vegetated rangeland: Agricultural and Forest Meteorology, v. 60, p. 221-247.

Prudic, D.E., 1989, Documentation of a computer program to simulate stream-aquifer relations using a modular, finite-difference, ground-water flow model: U.S. Geological Survey Open-File Report 88-729, 113 p.

Prudic, D.E., and Herman, M.E., in press, Ground-water hydrology and simulated effects of development in Paradise Valley, a basin tributary to the Humboldt River in Humboldt County, Nevada: U.S. Geological Survey Professional Paper 1409-F.

Rush, F.E., 1968, Index of hydrographic areas in Nevada: Nevada Division of Water Resources, Information Report 6, 38 p.

Russell, B.J., 1984, Mesozoic geology of the Jackson Mountains, northwestern Nevada: Geological Society of America Bulletin, v. 95, p. 313-328.

Russell, I.C., 1885, Geological history of Lake Lahontan—A quaternary lake of northwestern Nevada: U.S. Geological Survey Monograph 11, 288 p.

Saltus, R.W., 1988, Nevada gravity data: Sioux Falls, S. D., EROS Data Center, magnetic tape.

Sinclair, W.C., 1962a, Ground-water resources of Pine Forest Valley, Humboldt County, Nevada: Nevada Department of Conservation and Natural Resources, Ground-Water Resources - Reconnaissance Report 4, 22 p.

———1962b, Ground-water resources of Desert Valley, Humboldt and Pershing Counties, Nevada: Nevada Division of Water Resources, Ground-Water Resources - Reconnaissance Report 7, 23 p.

Skougstad, M.W., Fishman, N.J., Friedman, L.C., Erdmann, D.E., and Duncan, S.S., eds., 1979, Methods for determination of inorganic substances in water and fluvial sediments: U.S. Geological Survey Techniques of Water-Resources Investigations, book 5, chap. A1, 626 p.

Stephens, D.B., and Knowlton, R., Jr., 1986, Soil water movement and recharge through sand at a semiarid site in New Mexico: Water Resources Research, v. 22, no. 6, p. 881-889.

Stewart, J.H., 1980, Geology of Nevada—Discussion to accompany the geologic map of Nevada: Nevada Bureau of Mines and Geology Special Publication 4, 136 p.

Tanner, C.B., 1960, Energy balance approach to evapotranspiration from crops: Soil Science Society of America, v. 24, p. 1-9.

Theis, C.V., 1963, Estimating the transmissibility of a water-table aquifer from the specific capacity of a well, *in* Bentall, Ray, comp., Methods of determining permeability, transmissibility, and drawdown: U.S. Geological Survey Water-Supply Paper 1536-I, p. 332-336.

Thomas, J.M., Carlton, S.M., and Hines, L.B., 1989a, Ground-water hydrology and simulated effects of development in Smith Creek Valley, a hydrologically closed basin in Lander County, Nevada: U.S. Geological Survey Professional Paper 1409-E, 57 p.

Thomas, J.M., Welch, A.H., and Preissler, A.M., 1989b, Geochemical evolution of ground water in Smith Creek Valley—A hydrologically closed basin in central Nevada, U.S.A.: Applied Geochemistry, v. 4, p. 493-510.

Thomasson, H.G., Jr., Olmsted, F.H., and LeRoux, E.F., 1960, Geology, water resources, and usable ground-water storage capacity of part of Solano County, California: U.S. Geological Survey Water-Supply Paper 1464, 693 p.

Timme, P.J., 1994, National Water Quality Laboratory, 1994 services catalog: U.S. Geological Survey Open-File Report 94-304, 72 p.

U.S. Environmental Protection Agency, 1986, Quality criteria for water, 1986: Office of Water Regulations and Standards, U.S. Environmental Protection Agency Report EPA-440/5-86-061, 504 p.

U.S. Geological Survey, 1962-65, Surface water records of Nevada, 1961-64: Carson City, Nev., U.S. Geological Survey Water-Data Reports (published annually).

———1966-75, Water resources data for Nevada, 1965-74: Carson City, Nev., U.S. Geological Survey Water-Data Reports (published annually).

———1976-82, Water resources data, Nevada, water years 1975-81: U.S. Geological Survey Water-Data Reports NV-75-1 to NV-81-1 (published annually).

Van Hylckama, T.E.A., 1980, Weather and evapotranspiration studies in a saltcedar thicket, Arizona: U.S. Geological Survey Professional Paper 491-F, 51 p.

Welch, A.H., and Preissler, A.M., 1990, Geothermal resources of the western arm of the Black Rock Desert, northwestern Nevada—Part II, Aqueous geochemistry and hydrology: U.S. Geological Survey Water-Resources Investigations Report 87-4062, 91 p.

Willden, Ronald, 1958, Cretaceous and Tertiary orogeny in Jackson Mountains, Humboldt County, Nevada: American Association of Petroleum Geologists Bulletin, v. 42, no. 10, p. 2801-2825.

———1963, General geology of the Jackson Mountains, Humboldt County, Nevada: U.S. Geological Survey Bulletin 1141-D, 65 p.

———1964, Geology and mineral deposits of Humboldt County, Nevada: Nevada Bureau of Mines and Geology Bulletin 59, 154 p.

Zones, C.P., 1963, Ground water in the alluvium of Kings River Valley, Humboldt County, Nevada: U.S. Geological Survey Water-Supply Paper 1619-L, 38 p.

BLANK

Table 15. Water-level measurements and other information for wells, Desert Valley, Nevada

[**Water use**: H, domestic; I, irrigation; N, industrial; S, stock; U, unused. **Site status**: O, obstruction in well above water surface; R, well had been pumped recently; X, water level was affected by stage in nearby surface-water body. **Method**: S, steel tape; T, electric tape; NR, method not recorded (sites 55-57, 59-61, 66, 67, 69-72, 75-84, and 130 measured by Nevada Gold Mining, Inc.; site 53 measured by Sinclair (1962, table 1); sites 129 and 131 measured by Huxel and others (1966, table 20); sites 57, 110, 115, and 132-134 first measured by driller). **Symbol**: --, unknown]

Site number (plate 1C)	Water use	Well depth (feet)	Well diameter (inches)	Land-surface altitude (feet above sea level)	Perforated interval (feet below land surface)	Water-level measurement			
						Date	Depth (feet below land surface)	Site status	Method
42	S	76	6	4,156	12-62	09/01/59	21.10		S
						04/19/89	33.26		S
						11/14/89	34.14		S
						08/01/90	34.62		S
						04/03/91	34.72	R	S
43	S	236	10	4,135	--	09/16/63	9.51		S
						04/19/89	14.77	R	S
						11/14/89	15.18		S
						02/13/90	15.25		S
						05/08/90	15.32	R	S
						07/31/90	15.52		S
						04/03/91	16.01		S
44	S	76	6	4,135	22-76	09/19/63	10.51		S
						04/19/89	16.22	R	S
						11/14/89	16.60		S
						02/13/90	16.53		S
						08/01/90	16.91		S
						04/03/91	16.93		S
45	S	--	8	4,125	--	09/19/63	0.48		S
						04/19/89	7.85	R	S
						11/14/89	7.93		S
						05/08/90	8.11	R	S
						08/01/90	8.41		S
						04/03/91	8.56		S
46	S	--	6	4,165	--	09/19/63	41.98		S
						--/--/76	47.96		S
						04/18/89	50.50		S
						11/14/89	49.79		S
						05/08/90	49.91		S
						08/01/90	50.00		S
						04/03/91	50.35		S
47	S	182	10	4,132	--	09/19/63	12.98		S
						04/19/89	17.41	R	S
						11/14/89	17.67		S
						07/31/90	18.29		S
						04/03/91	18.87		S
48	U	22	2	4,114	--	09/19/63	0.34		S
						--/--/76	0.25		S
						05/09/89	2.58		S
						11/14/89	3.48		S
						05/08/90	3.24		S
						07/31/90	3.62		S
						04/03/91	3.94		S

Table 15. Water-level measurements and other information for wells, Desert Valley, Nevada—Continued

Site number (plate 1*C*)	Water use	Well depth (feet)	Well diameter (inches)	Land-surface altitude (feet above sea level)	Perforated interval (feet below land surface)	Water-level measurement			
						Date	Depth (feet below land surface)	Site status	Method
49	S	202	6	4,143	52-220	09/19/63	31.68		S
						--/--/64	26.38		S
						--/--/76	28.70		S
						11/14/89	35.26	R	S
						08/01/90	35.95		S
						04/03/91	35.9	R	T
50	S	52	10	4,113	--	11/13/89	10.53	S	S
						05/09/90	10.76		S
						07/31/90	12.88		S
						04/03/91	12.98		S
						06/26/91	12.97		
51	S	--	8	4,113	--	--/--/76	8.49		S
						04/18/89	9.89		S
						11/14/89	13.33	R	S
						05/09/90	10.82		S
						04/03/91	12.13		S
52	S	229	8	4,118	--	05/04/61	11.8		S
						03/09/76	11.95		S
						04/18/89	12.46		S
						05/09/90	13.20		S
						08/01/90	13.47		S
						08/22/90	13.60		S
						04/03/91	14.00		S
53	S	112	16	4,121	--	04/21/51	3.1		NR
						05/09/89	8.89	X,R	S
54	S	27	6	4,124	--	06/29/89	9.46	X	S
						05/09/90	11.92		S
						07/31/90	12.57		S
55	U	525	--	4,126	--	09/05/89	17.85		NR
						11/28/89	18.15		NR
						02/28/90	18.01		NR
						06/06/90	19.41		NR
						12/10/90	20.00	O	NR
						06/06/91	20.00	O	NR
56	U	600	--	4,126	--	11/28/89	17.00		NR
						02/28/90	16.08		NR
						06/06/90	16.16		NR
						09/12/90	17.42		NR
						12/10/90	16.84		NR
						03/07/91	16.62		NR
						06/06/91	16.46		NR
						01/15/92	17.12		NR
						04/01/92	17.43		NR

Table 15. Water-level measurements and other information for wells, Desert Valley, Nevada—Continued

Site number (plate 1*C*)	Water use	Well depth (feet)	Well diameter (inches)	Land-surface altitude (feet above sea level)	Perforated interval (feet below land surface)	Water-level measurement			
						Date	Depth (feet below land surface)	Site status	Method
57	U	80	2	4,114	64-69	08/22/90	21		NR
						09/13/90	14.29		NR
						04/03/91	14.32		S
						06/06/91	14.89		NR
						01/14/92	15.24		NR
						04/01/92	15.52		NR
58	U	166	8	4,117	--	04/27/61	7.90		S
						03/--/76	13.03		S
						04/18/89	16.53		S
						11/13/89	17.75		S
						02/14/90	17.24		S
						05/09/90	17.03		S
						07/31/90	17.82		S
						04/03/91	17.34		S
59	U	248	8	4,121	--	04/27/61	10.9		S
						03/--/76	17.74		S
						05/09/90	15.46		S
						07/31/90	16.10		S
						09/13/90	17.0		NR
						04/03/91	16.64		S
						09/04/91	17.74		NR
						01/15/92	18.61		NR
						04/01/92	18.70		NR
60	U	200	2	4,116	150-200	12/13/89	22.22		NR
						02/01/90	16.01		NR
						06/13/90	16.22		NR
						09/12/90	17.36		NR
						12/10/90	17.05		NR
						03/13/91	15.90		NR
						06/06/91	15.57		NR
						09/04/91	16.65		NR
						01/15/92	15.94		NR
						04/01/92	15.78		NR
61	U	700	2	4,116	630-680	12/13/89	16.67		NR
						02/01/90	16.13		NR
						06/13/90	14.75		NR
						09/12/90	15.49		NR
						12/10/90	15.98		NR
						03/13/91	15.79		NR
						06/06/91	15.97		NR
						01/14/92	16.89		NR
						04/01/92	16.76		NR
62	U	30	6	4,109	--	11/10/60	2.60		S
						03/15/75	5.7		S
						04/18/89	8.25		S
						11/13/89	9.21		S
						02/14/90	8.94		S
						05/08/90	8.36		S
						08/01/90	9.45		S
						04/03/91	8.86		S

Table 15. Water-level measurements and other information for wells, Desert Valley, Nevada—Continued

Site number (plate 1*C*)	Water use	Well depth (feet)	Well diameter (inches)	Land-surface altitude (feet above sea level)	Perforated interval (feet below land surface)	Water-level measurement			
						Date	Depth (feet below land surface)	Site status	Method
63	U	39	2	4,115	--	09/19/63	12.04		S
						--/--/76	15.28		S
						04/18/89	18.24		S
						11/13/89	19.45		S
						05/08/90	18.70		S
						08/01/90	19.63		S
						04/03/91	19.23		S
64	S	--	6	4,127	--	05/04/61	20.9		S
						05/09/89	29.29	R	S
						11/14/89	30.08	R	S
						05/08/90	30.65	R	S
						04/03/91	30.35		S
65	S	270	10	4,232	130-270	05/11/89	125.63		S
						11/13/89	128.21	R	S
66	U	600	--	4,132	--	08/23/89	29.43		NR
						11/28/89	29.82		NR
						02/28/90	30.42		NR
						06/20/90	32.35		NR
						09/12/90	33.41		NR
						12/10/90	34.00		NR
						03/07/91	35.00		NR
						06/06/91	35.90		NR
						01/15/92	38.70		NR
						04/01/92	39.54		NR

Table 15. Water-level measurements and other information for wells, Desert Valley, Nevada—Continued

Site number (plate 1*C*)	Water use	Well depth (feet)	Well diameter (inches)	Land-surface altitude (feet above sea level)	Perforated interval (feet below land surface)	Water-level measurement			
						Date	Depth (feet below land surface)	Site status	Method
67	U	125	2	4,138	115-125	10/13/85	26.58		NR
						10/20/85	26.74		NR
						10/27/85	26.85		NR
						11/03/85	27.75		NR
						11/11/85	27.15		NR
						11/23/85	27.27		NR
						12/15/85	27.73		NR
						12/22/85	27.88		NR
						12/29/85	27.90		NR
						01/05/86	28.13		NR
						01/12/86	28.50		NR
						01/19/86	28.50		NR
						01/26/86	28.50		NR
						02/02/86	28.50		NR
						02/09/86	28.31		NR
						02/23/86	28.50		NR
						09/23/86	30.00		NR
						11/13/86	29.68		NR
						02/05/87	30.77		NR
						03/11/87	31.00		NR
						09/18/87	32.35		NR
						02/29/88	34.03		NR
						05/31/88	35.27		NR
						08/15/88	36.84		NR
						08/29/88	37.04		NR
						11/29/88	38.17		NR
						02/13/89	38.58		NR
						02/28/89	38.90		NR
						05/30/89	39.41		NR
						08/29/89	40.40		NR
						11/27/89	41.14		NR
						02/28/90	41.81		NR
						06/21/90	44.01		NR
						09/12/90	45.18		NR
						12/10/90	46.22		NR
						03/07/91	47.39		NR
						06/06/91	48.65		NR
						09/09/91	50.78		NR
						01/15/92	51.46		NR
						04/01/92	53.39		NR
68	S	--	8	4,146	--	04/11/61	30.4		S

Table 15. Water-level measurements and other information for wells, Desert Valley, Nevada—Continued

Site number (plate 1C)	Water use	Well depth (feet)	Well diameter (inches)	Land-surface altitude (feet above sea level)	Perforated interval (feet below land surface)	Water-level measurement			
						Date	Depth (feet below land surface)	Site status	Method
69	U	250	2	4,138	100-110	10/13/85	32.30		NR
						10/20/85	33.00		NR
						10/27/85	33.60		NR
						11/03/85	34.25		NR
						11/11/85	34.85		NR
						11/17/85	35.29		NR
						11/23/85	35.55		NR
						12/01/85	36.44		NR
						12/15/85	37.35		NR
						12/22/85	37.87		NR
						12/29/85	38.27		NR
						01/05/86	38.63		NR
						01/12/86	38.92		NR
						01/19/86	39.09		NR
						01/26/86	39.35		NR
						02/02/86	39.60		NR
						02/09/86	39.82		NR
						02/23/86	40.40		NR
						09/23/86	46.00		NR
						11/13/86	46.90		NR
						02/05/87	48.70		NR
						03/11/87	49.37		NR
						09/18/87	53.75		NR
						11/30/87	54.42		NR
						02/29/88	59.39		NR
						05/31/88	62.56		NR
						08/15/88	68.08		NR
						08/17/88	68.18		NR
						08/29/88	68.06		NR
						11/29/88	71.45		NR
						02/13/89	72.42		NR
						02/27/89	73.48		NR
						05/30/89	75.83		NR
						08/05/89	77.10		NR
						08/28/89	77.55		NR
						11/29/89	79.20		NR
						02/28/90	81.01		NR
						06/06/90	85.59		NR
						09/12/90	88.42		NR
						03/07/91	94.95		NR
						06/06/91	100.30		NR
						09/11/91	104.05		NR
						01/15/92	135.86		NR

Table 15. Water-level measurements and other information for wells, Desert Valley, Nevada—Continued

Site number (plate 1*C*)	Water use	Well depth (feet)	Well diameter (inches)	Land-surface altitude (feet above sea level)	Perforated interval (feet below land surface)	Water-level measurement			
						Date	Depth (feet below land surface)	Site status	Method
70	U	555	--	4,137	--	05/31/88	51.92		NR
						08/16/88	56.00		NR
						08/17/88	56.05		NR
						08/22/88	57.30		NR
						08/29/88	55.14		NR
						09/21/88	55.10		NR
						11/29/88	58.22		NR
						01/31/89	59.37		NR
						02/06/89	54.48		NR
						02/13/89	53.68		NR
						02/14/89	57.03		NR
						02/27/89	58.02		NR
						05/30/89	59.00		NR
						08/05/89	62.00		NR
						08/28/89	62.10		NR
						11/28/89	62.62		NR
						02/28/90	66.64		NR
						06/06/90	73.41		NR
						03/07/91	82.90		NR
						06/06/91	85.29		NR
						09/11/91	86.46		NR
						01/15/92	90.11		NR
						04/01/92	91.10		NR
71	U	540	2	4,133	420-540	12/05/88	49.68		NR
						12/12/88	47.65		NR
						12/19/88	47.38		NR
						01/03/89	47.75		NR
						01/09/89	47.93		NR
						01/16/89	47.99		NR
						01/23/89	48.23		NR
						01/30/89	48.14		NR
						02/06/89	46.06		NR
						02/13/89	45.50		NR
						02/14/89	46.63		NR
						02/20/89	47.45		NR
						02/27/89	47.15		NR
						03/06/89	47.98		NR
						04/10/89	48.42		NR
						05/30/89	47.96		NR
						08/05/89	50.11		NR
						08/28/89	50.24		NR
						11/29/89	50.61		NR
						02/01/90	54.52		NR
						06/12/90	61.65		NR
						09/06/90	63.38		NR
						12/10/90	65.96		NR
						03/12/91	70.92		NR
						06/06/91	73.49		NR
						09/05/91	74.10		NR
						01/15/92	74.10		NR
						04/01/92	76.26		NR

Table 15. Water-level measurements and other information for wells, Desert Valley, Nevada—Continued

Site number (plate 1*C*)	Water use	Well depth (feet)	Well diameter (inches)	Land-surface altitude (feet above sea level)	Perforated interval (feet below land surface)	Water-level measurement			
						Date	Depth (feet below land surface)	Site status	Method
72	U	820	2	4,133	740-810	12/05/88	48.17		NR
						12/12/88	49.00		NR
						12/19/88	48.33		NR
						01/03/89	51.31		NR
						01/09/89	52.14		NR
						01/16/89	52.23		NR
						01/23/89	51.81		NR
						01/30/89	51.78		NR
						02/06/89	49.45		NR
						02/13/89	48.92		NR
						02/14/89	50.05		NR
						02/20/89	51.00		NR
						02/27/89	50.55		NR
						03/06/89	51.40		NR
						04/10/89	50.40		NR
						05/30/89	49.93		NR
						08/05/89	52.73		NR
						08/28/89	52.84		NR
						11/29/89	53.26		NR
						02/01/90	57.67		NR
						06/12/90	64.20		NR
						09/12/90	65.85		NR
						12/10/90	68.49		NR
						03/12/91	73.66		NR
						06/06/91	76.29		NR
						01/15/92	76.98		NR
						04/01/92	77.32		NR
73	S	50	--	4,152	--	04/11/61	39.2		S
74	S	--	6	4,143	--	05/08/89	45.56		S
						11/15/89	47.26		S
						05/08/90	49.82		S
						07/31/90	51.72		S
						04/04/91	56.28		S
75	U	90	2	4,115	25-80	12/13/89	18.65		NR
						03/02/90	18.63		NR
						06/21/90	19.09		NR
						09/12/90	19.59		NR
						12/10/90	19.09		NR
						03/13/91	18.12		NR
						06/06/91	18.87		NR
						09/04/91	18.59		NR
						01/14/92	17.39		NR
						04/01/92	16.50		NR

Table 15. Water-level measurements and other information for wells, Desert Valley, Nevada—Continued

Site number (plate 1*C*)	Water use	Well depth (feet)	Well diameter (inches)	Land-surface altitude (feet above sea level)	Perforated interval (feet below land surface)	Water-level measurement			
						Date	Depth (feet below land surface)	Site status	Method
76	U	650	2	4,115	100-150	12/13/89	17.80		NR
						03/02/90	16.75		NR
						06/21/90	17.95		NR
						09/12/90	19.02		NR
						12/10/90	18.22		NR
						03/13/91	17.08		NR
						06/06/91	18.12		NR
						01/14/92	16.42		NR
						04/01/92	15.23		NR
77	U	640	2	4,115	600-640	12/13/89	17.28		NR
						03/02/90	16.22		NR
						06/21/90	17.50		NR
						09/12/90	19.30		NR
						12/10/90	18.39		NR
						03/13/91	17.22		NR
						06/06/91	17.62		NR
						01/14/92	18.05		NR
						04/01/92	17.31		NR
78	U	40	2	4,118	5-40	06/25/91	15.96		NR
						09/04/91	16.38		NR
						01/14/92	15.48		NR
						04/01/92	14.80		NR
79	U	40	2	4,118	5-40	06/25/91	4.46		NR
						09/04/91	4.32		NR
						01/14/92	2.76		NR
						04/01/92	1.83		NR
80	U	90	2	4,122	70-90	12/13/89	10.73		NR
						02/01/90	10.55		NR
						06/11/90	10.51		NR
						09/12/90	11.12		NR
						12/10/90	10.51		NR
						03/07/91	9.81		NR
						06/06/91	9.00		NR
						09/04/91	9.42		NR
						01/15/92	9.03		NR
						04/01/92	8.62		NR
81	U	510	2	4,122	325-490	12/13/89	23.79		NR
						02/01/90	19.60		NR
						06/11/90	20.33		NR
						09/12/90	21.40		NR
						12/10/90	21.72		NR
						03/07/91	22.02		NR
						06/06/91	22.41		NR
						01/15/92	24.53		NR
						04/01/92	25.02		NR
82	U	40	2	4,119	5-40	06/25/91	14.04		NR
						09/04/91	14.95		NR
						01/14/92	15.58		NR
						04/01/92	11.88		NR

Table 15. Water-level measurements and other information for wells, Desert Valley, Nevada—Continued

Site number (plate 1*C*)	Water use	Well depth (feet)	Well diameter (inches)	Land-surface altitude (feet above sea level)	Perforated interval (feet below land surface)	Water-level measurement			
						Date	Depth (feet below land surface)	Site status	Method
83	U	40	2	4,119	5-40	06/25/91	15.71		NR
						09/04/91	15.64		NR
						01/14/92	13.92		NR
						04/01/92	8.29		NR
84	U	40	2	4,122	5-40	06/25/91	5.62		NR
						09/04/91	5.23		NR
						01/15/92	4.80		NR
						04/01/92	4.45		NR
85	S	--	6	4,146	--	04/--/61	38		S
						05/09/89	48.01		S
						11/14/89	50.03	R	S
						05/08/90	48.42		S
						04/03/91	48.62		S
87	S	--	8	4,134	--	04/27/61	33.3		S
						05/08/90	40.35		S
						08/01/90	44.62		S
						04/03/91	32.88		S
88	S	--	6	4,218	--	05/08/89	110.50	R	S
						11/15/89	111.21		S
						05/08/90	112.13		S
						07/31/90	112.30	R	S
						04/04/91	114.28	R	S
89	U	59	2	4,140	48-52	08/24/90	30.00		S
						04/04/91	29.53		S
						06/26/91	29.87		S
90	S	87	--	4,138	60-85	04/26/61	23.4		S
91	S	130	10	4,149	83-153	04/26/61	30.4		S
						04/18/89	38.17		S
						11/14/89	40.38	R	S
						05/08/90	43.51		S
						08/01/90	44.22	R	S
						04/03/91	40.25		S
92	S	87	6	4,145	65-85	04/26/61	27.3		S
93	S	95	--	4,150	70-80	04/26/61	28.3		S
94	S,H	620	16	4,196	63-620	11/14/89	65.32		S
						04/04/91	63.56		S
95	S	360	10	4,579	330-360	08/07/66	305		S
						06/15/87	303		--
						11/15/89	302.07		S
						04/04/91	302.3		T

Table 15. Water-level measurements and other information for wells, Desert Valley, Nevada—Continued

Site number (plate 1*C*)	Water use	Well depth (feet)	Well diameter (inches)	Land-surface altitude (feet above sea level)	Perforated interval (feet below land surface)	Water-level measurement			
						Date	Depth (feet below land surface)	Site status	Method
96	S	--	6	4,167	--	04/11/61	52		S
						05/08/89	54.67		S
						11/15/89	54.83		S
						05/08/90	54.90		S
						07/31/90	54.91		S
97	S	55	8	4,147	--	04/16/60	32.5		S
						06/15/87	36		--
						04/20/89	34.60	R	S
						11/15/89	34.82		S
						07/16/90	34.82		S
						04/04/91	35.02	R	S
98	S	116	6	4,179	--	04/11/61	66.20		S
						06/15/87	69		--
						05/08/89	68.02		S
						11/15/89	68.02		S
						05/08/90	68.20		S
						07/31/90	68.16		S
						04/04/91	68.60	R	S
99	S	--	6	4,150	--	04/26/61	34.8		S
						06/27/89	36.74		S
						11/16/89	36.94		S
						05/10/90	36.85		S
						08/01/90	37.10		S
						04/04/91	37.09		S
100	I	300	18	4,207	--	04/14/60	62.1		S
						05/10/89	65.02		S
						11/14/89	69.67		S
						08/24/90	73.63		S
101	S	53	6	4,170	--	04/08/61	31.3		S
						04/21/89	30.7	O	S
102	S	--	8	4,132	--	04/08/61	16.5		S
						06/16/87	17.00		--
						05/08/89	17.79	R	S
						11/15/89	17.88		S
						01/18/90	17.76		S
						05/08/90	17.85		S
						07/31/90	17.79		S
						04/04/91	17.83	R	S
103	S	50	8	4,139	--	06/03/61	24.20		S
						05/08/89	25.80		S
						11/15/89	25.88		S
						05/08/90	25.93		S
						07/16/90	25.94		S
						04/04/91	26.14	R	S

Table 15. Water-level measurements and other information for wells, Desert Valley, Nevada—Continued

Site number (plate 1*C*)	Water use	Well depth (feet)	Well diameter (inches)	Land-surface altitude (feet above sea level)	Perforated interval (feet below land surface)	Water-level measurement			
						Date	Depth (feet below land surface)	Site status	Method
104	S	77	8	4,148	--	04/08/61	34.8		S
						06/16/87	32.7		--
						04/20/89	32.53	R	S
						05/08/89	32.62		S
						06/26/89	32.57		S
						11/15/89	32.66		S
						01/18/90	32.64		S
						05/08/90	32.63		S
						07/31/90	32.63		S
105	S	--	6	4,156	--	06/16/87	43		--
						04/21/89	42.74		S
						11/16/89	42.77		S
						02/15/90	43.77		S
						05/10/90	42.80		S
						08/02/90	42.87		S
						04/04/91	42.89		S
106	S	--	6	4,149	--	04/08/61	34.80		S
						04/21/89	46.22	R	S
						06/27/89	34.36		S
						11/16/89	34.38		S
						05/10/90	34.44		S
						08/02/90	34.50		S
						04/04/91	34.51		S
107	S	89	6	4,148	--	01/01/67	34		S
						04/20/89	33.58		S
						11/15/89	33.66		S
						05/07/90	33.72		S
						07/31/90	33.68		S
108	S	75	6	4,166	--	04/08/61	53		S
						06/16/87	53		--
						4/20/89	52.22	R	S
						11/15/89	52.29		S
						05/07/90	52.32		S
						07/31/90	52.33		S
						04/04/91	52.55	R	S
109	U	288	14	4,169	168-288	04/20/89	53.47		S
						11/15/89	53.52		S
						05/07/90	53.50		S
						07/31/90	53.51		S
110	U	310	14	4,171	142-310	03/--/75	57		NR
						04/20/89	56.68		S
111	U	288	14	4,192	144-288	04/20/89	75.82		S
112	S	--	14	4,186	--	11/15/89	71.29		S
						05/07/90	71.32		S
						07/31/90	71.31		S
						04/04/91	71.7	R	T

Table 15. Water-level measurements and other information for wells, Desert Valley, Nevada—Continued

Site number (plate 1*C*)	Water use	Well depth (feet)	Well diameter (inches)	Land-surface altitude (feet above sea level)	Perforated interval (feet below land surface)	Water-level measurement			
						Date	Depth (feet below land surface)	Site status	Method
113	S	--	6	4,175	--	04/08/61	58.8		S
						04/20/89	60.35	R	S
						06/27/89	60.39		S
						11/15/89	60.45		S
						05/07/90	60.42		S
						07/31/90	60.45		S
114	U	284	14	4,192	164-284	04/20/89	76.45		S
115	U	287	14	4,185	143-287	03/--/75	71		R
						04/20/89	72.15		S
116	N	--	8	4,194	--	04/20/89	76.38		S
						11/15/89	76.53		S
						01/17/90	76.54		S
						06/04/90	76.55		S
						08/02/90	76.67		S
						04/03/91	76.66	R	S
117	S	86	6	4,160	--	04/21/89	45.40	R	S
						06/27/89	45.41		S
						11/16/89	45.43		S
						05/10/90	45.43		S
						08/02/90	45.51		S
118	S	63	8	4,159	--	04/20/89	42.78	R	S
						11/15/89	42.82		S
						05/07/90	42.83		S
						07/31/90	42.81		S
119	S	140	8	4,169	--	04/--/61	54.5		S
						06/16/89	58		--
						11/14/89	57.48	R	S
						05/10/90	57.29	R	S
						08/01/90	57.54		S
						04/03/91	57.60	R	S
120	U	91	2	4,170	76-81	08/26/90	83.00		S
						08/27/90	68.95		S
						04/05/91	58.95		S
121	U	98	2	4,160	93-98	04/03/91	47.94		S
122	I	500	--	4,160	336-348	--/--/61	60	R	--
123	I	260	24	4,195	--	05/10/89	115.0		T
						11/16/89	113.14		S
						05/07/90	114.91		S
						04/03/91	114.44		S
124	S	153	8	4,178	83-153	04/--/61	72.2		S
						06/26/89	87.26		S
						11/16/89	87.32		S
						02/14/90	87.17		S
						05/07/90	87.19		S
						07/31/90	87.35		S

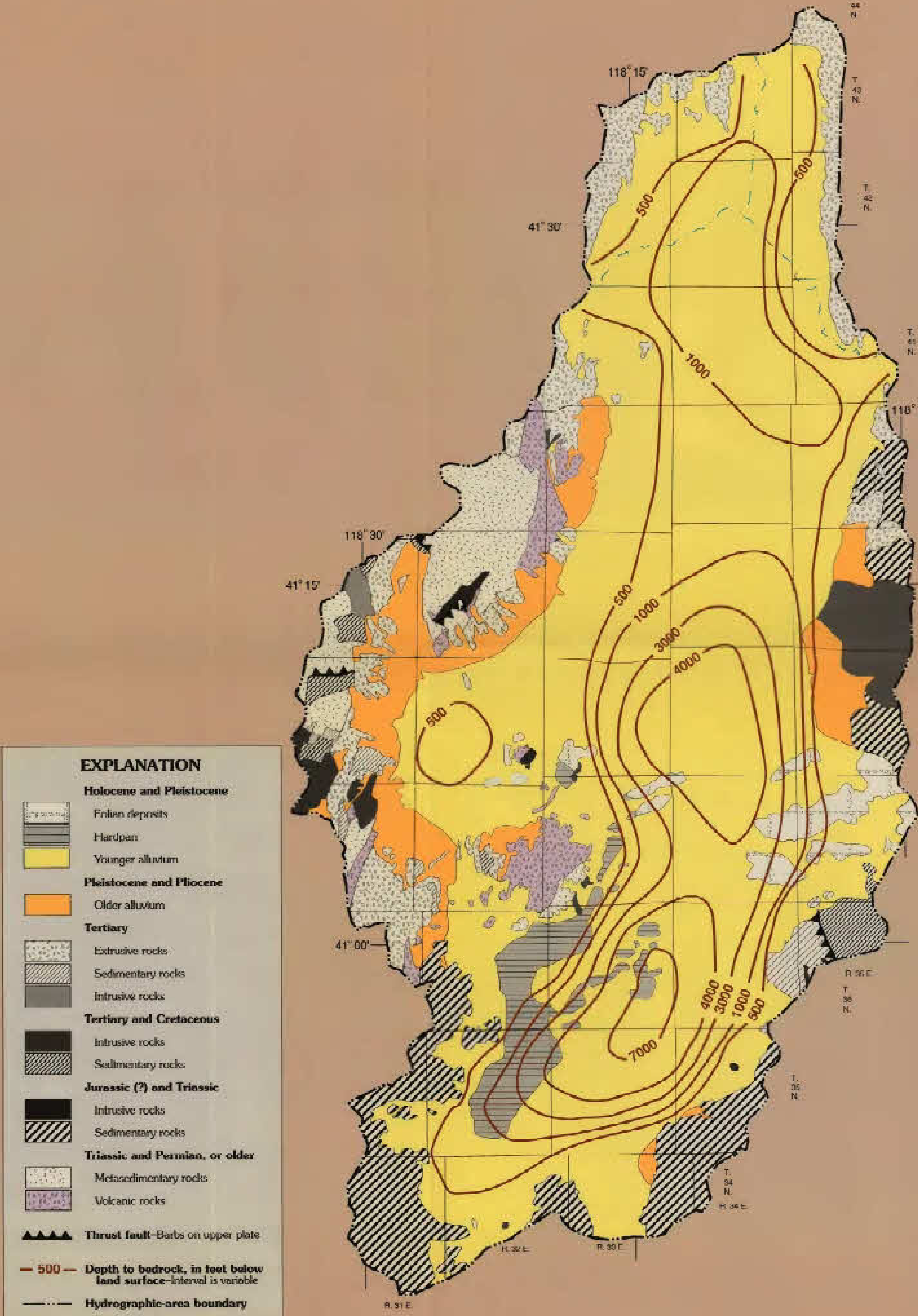
Table 15. Water-level measurements and other information for wells, Desert Valley, Nevada—Continued

Site number (plate 1*C*)	Water use	Well depth (feet)	Well diameter (inches)	Land-surface altitude (feet above sea level)	Perforated interval (feet below land surface)	Water-level measurement			
						Date	Depth (feet below land surface)	Site status	Method
125	U	152	2	4,210	147-152	11/11/90	83.20		S
						04/03/91	111.75		S
						04/04/91	111.75		S
126	S	--	10	4,154	--	02/26/64	38.34		S
						11/14/89	42.77	R	S
						05/09/90	43.40		S
						04/03/91	45.23		S
127	S	--	8	4,321	--	06/26/89	16.49		S
						11/16/89	23.28	R	S
						07/25/90	17.13	R	S
128	S	--	8	4,168	--	06/26/89	24.11		S
						11/16/89	24.22		S
129	S	300	8	4,258	--	09/26/47	134.1		NR
						04/19/89	138.64		S
						11/14/89	141.27		S
						02/13/90	141.76		S
130	U	32	2	4,123	--	02/27/64	10.26		S
						05/11/89	12.64		S
						11/13/89	14.54		S
						02/14/90	14.88		S
						05/08/90	15.19		S
						07/31/90	15.78		S
						09/13/90	16.1		NR
						04/03/91	17.16		S
						06/06/91	19.45		NR
						01/15/92	18.04		NR
						04/01/92	20.51		NR
131	S	63	8	4,127	--	09/28/47	8.70		NR
						11/14/89	12.75	R	S
						04/03/91	13.67		S
132	S	160	6	4,333	140-160	07/--/58	125		NR
						11/15/89	125.89		S
						05/07/90	125.83		S
						04/04/91	125.50	R	S
133	U	58	2	4,232	53-58	11/08/90	40		NR
						11/11/90	28.26		S
						04/04/91	28.10		S
						06/25/91	28.23		S
134	U	52	2	4,232	48-52	11/09/90	22		NR
						11/10/90	24.06		S
						11/11/90	20.30		S
						04/04/91	19.80		S

☆U.S. GOVERNMENT PRINTING OFFICE: 1995-686-114

EXHIBIT 5

EXHIBIT 5



B. Generalized geology.

EXHIBIT 6

EXHIBIT 6

Desert Valley Aquifer Depth

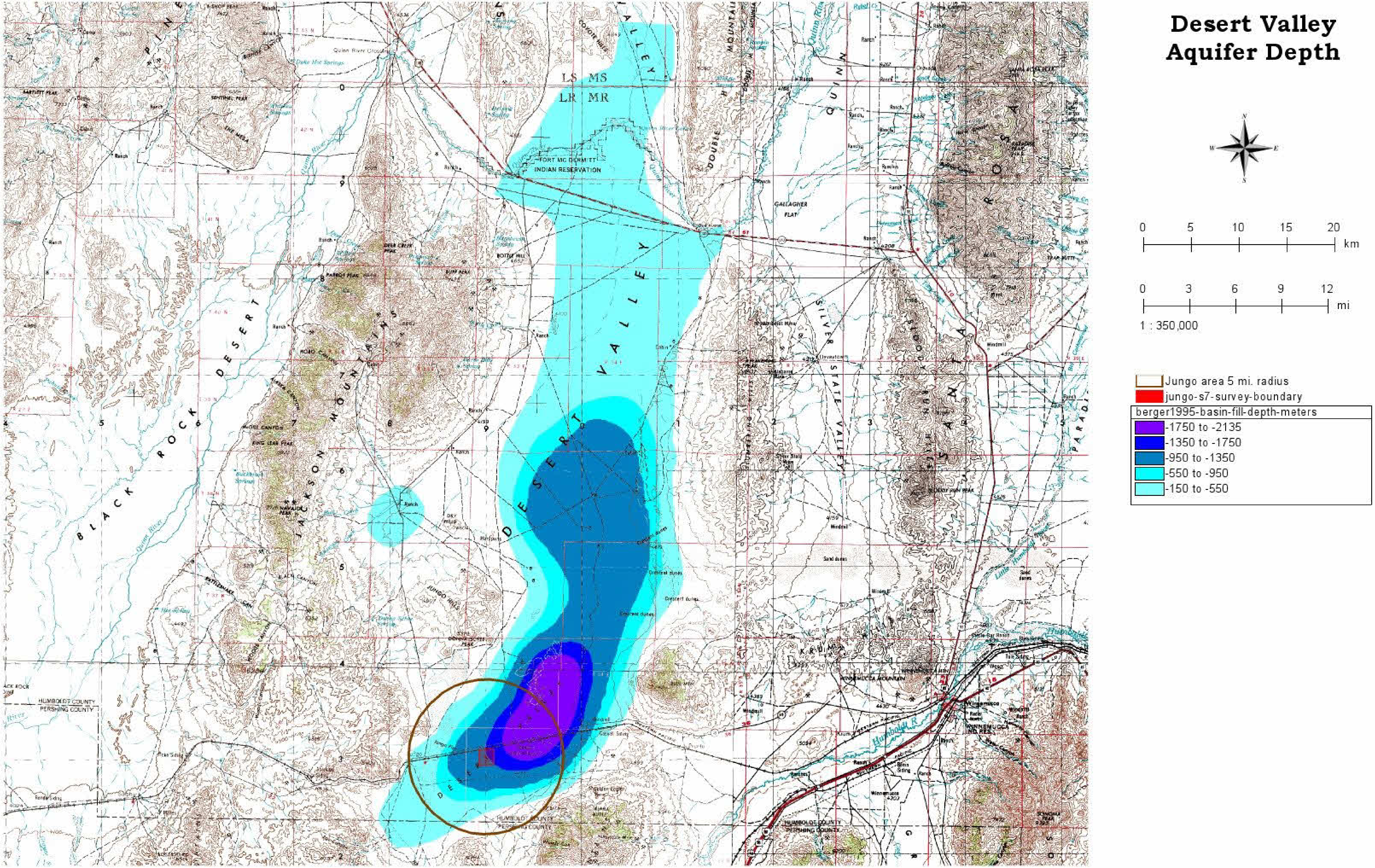
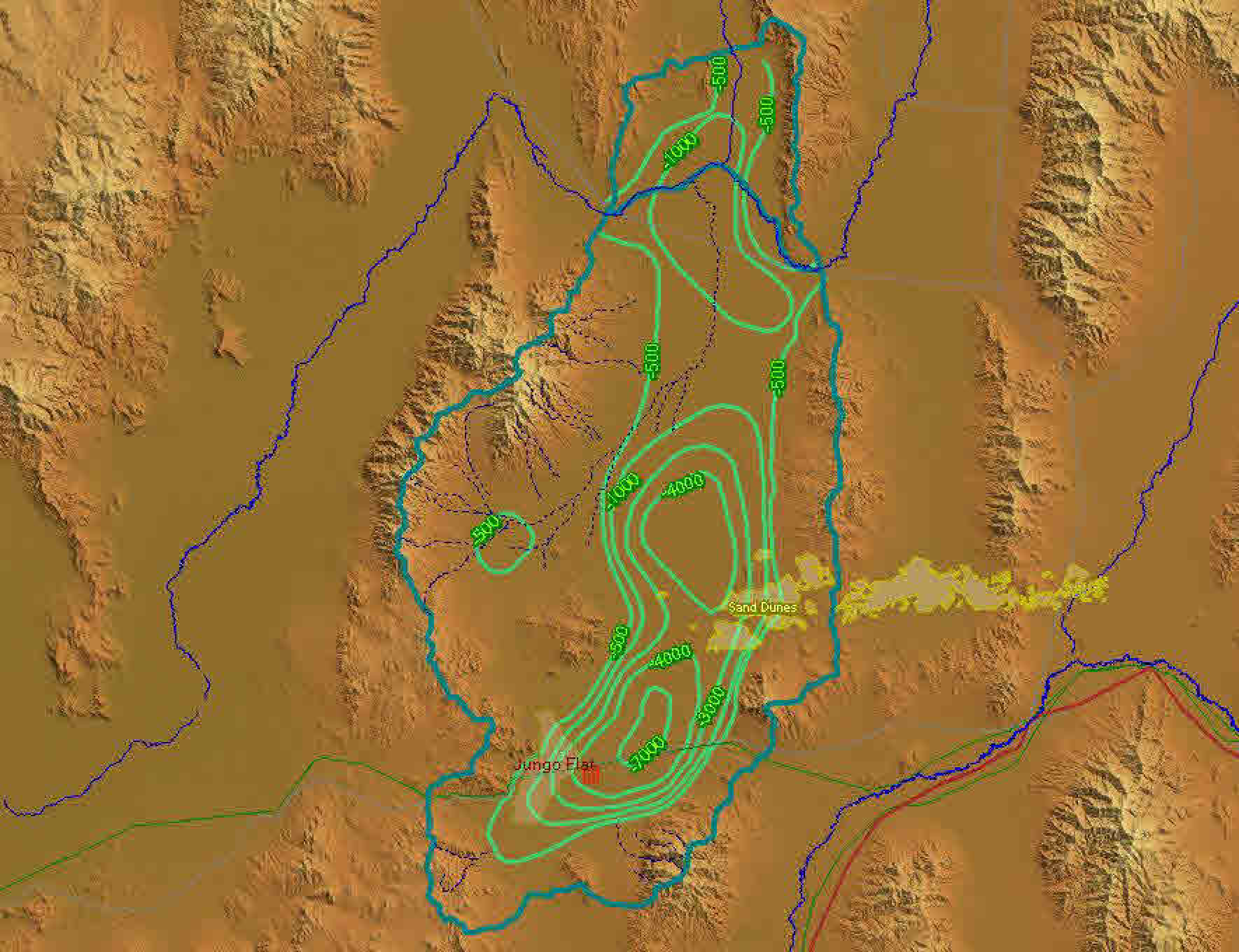


EXHIBIT 7

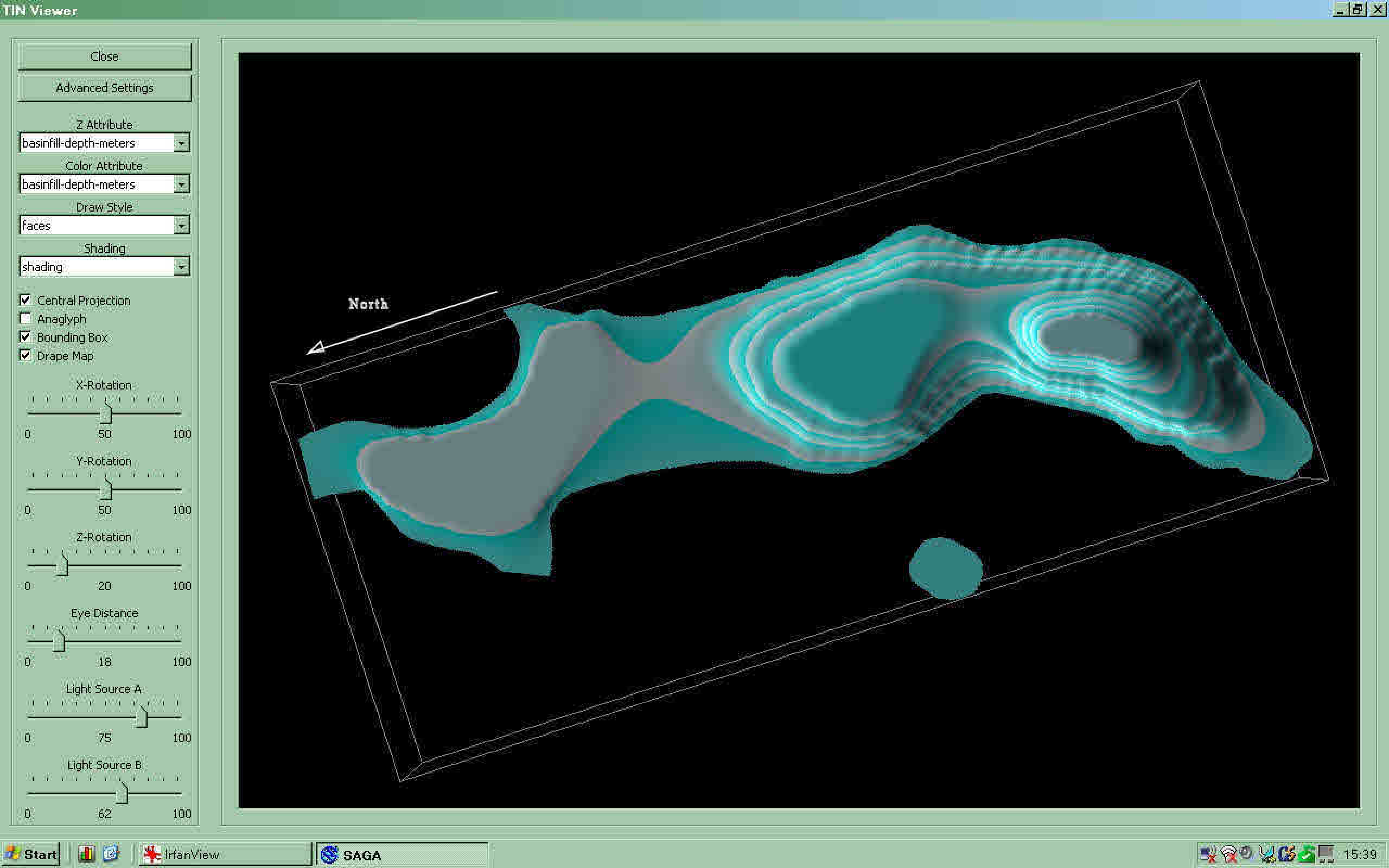
EXHIBIT 7

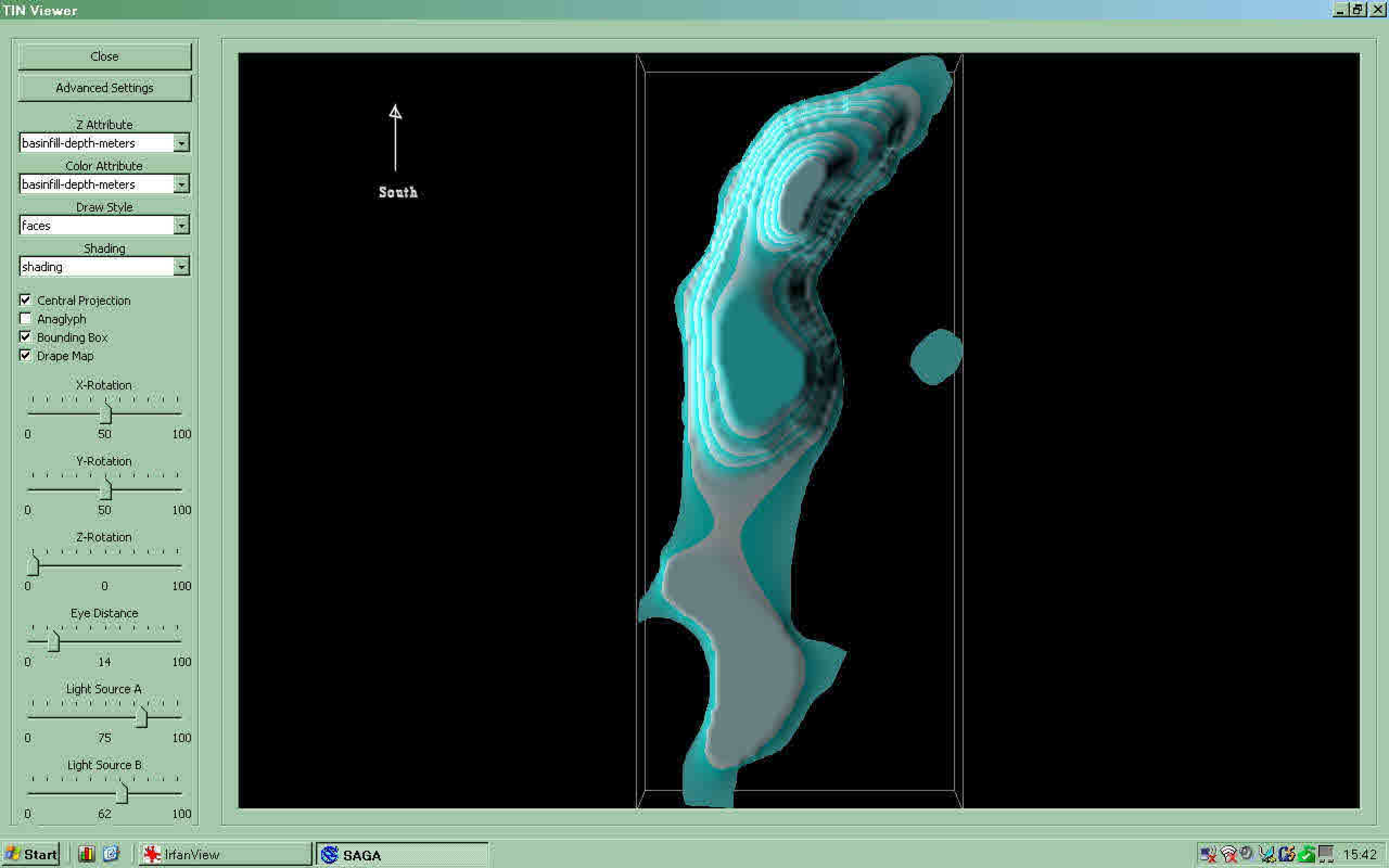


-500
-500
-1000
-500
-500
-1000
-4000
500
Sand Dunes
-500
-4000
-3000
-7000
Jungo Flat

EXHIBIT 8

EXHIBIT 8


TIN Viewer
Close
Advanced Settings
Z Attribute
basinfill-depth-meters
Color Attribute
basinfill-depth-meters
Draw Style
faces
Shading
shading
Central Projection
Anaglyph
Bounding Box
Drape Map
X-Rotation
0 50 100
Y-Rotation
0 50 100
Z-Rotation
0 20 100
Eye Distance
0 18 100
Light Source A
0 75 100
Light Source B
0 62 100
North
Start
IrfanView
SAGA
15:39


TIN Viewer
Close
Advanced Settings
Z Attribute
basinfill-depth-meters
Color Attribute
basinfill-depth-meters
Draw Style
faces
Shading
shading
Central Projection
Anaglyph
Bounding Box
Drape Map
X-Rotation
0 50 100
Y-Rotation
0 50 100
Z-Rotation
0 0 100
Eye Distance
0 14 100
Light Source A
0 75 100
Light Source B
0 62 100
South
Start
IrfanView
SAGA
15:42

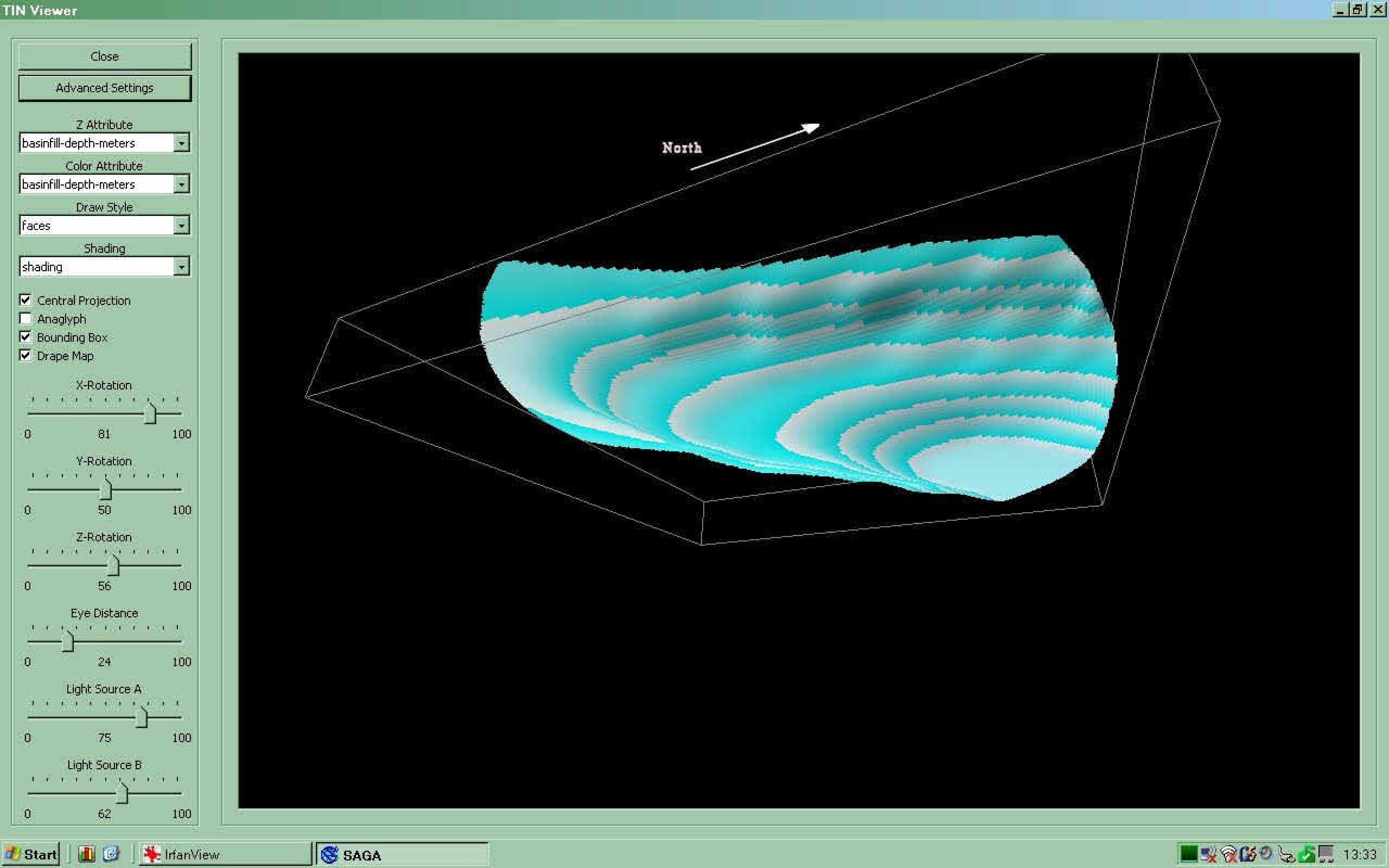

TIN Viewer
Close
Advanced Settings
Z Attribute
basinfill-depth-meters
Color Attribute
basinfill-depth-meters
Draw Style
faces
Shading
shading
Central Projection
Anaglyph
Bounding Box
Drape Map
X-Rotation
0 81 100
Y-Rotation
0 50 100
Z-Rotation
0 56 100
Eye Distance
0 24 100
Light Source A
0 75 100
Light Source B
0 62 100
North
Start
IrfanView
SAGA
13:33

EXHIBIT 9

EXHIBIT 9

Deficiencies in Subtitle D Landfill Liner Failure and Groundwater Pollution Monitoring

G. Fred Lee, PhD, PE, DEE, President Anne Jones-Lee, PhD, Vice President

G. Fred Lee & Associates

El Macero, CA 95618

Abstract

The US EPA (1991) MSW Subtitle D landfill regulations require a groundwater monitoring system based on vertical monitoring wells located at a point of compliance for monitoring that is no more than 150 meters from the down groundwater gradient edge of the landfill. The regulations specify that a detection monitoring program be implemented which has a high reliability of determining when leachate-polluted groundwaters reach the point of compliance. A critical review of the implementation of the Subtitle D landfill liner failure detection approach using the typical current groundwater monitoring approach shows that minimum Subtitle D landfills are being permitted with monitoring wells spaced one hundred to one thousand feet apart. The 1990 work of Dr. J. Cherry showed that plastic sheeting lined landfills such as a minimum Subtitle D landfill, will initially produce narrow plumes of groundwater pollution that arise through leachate leakage through the plastic sheeting liner that could readily pass by the typical point of compliance groundwater monitoring well array without being detected by the monitoring wells. This paper reviews the deficiencies in the Subtitle D groundwater monitoring approach in detecting groundwater pollution associated with the inevitable liner failure before widespread, off-site pollution occurs. Also presented is information on alternative monitoring approaches that have a high reliability of detecting liner failure before significant groundwater pollution occurs. The recommended monitoring system involves the use of a double composite liner with a leak detection system between the two liners where the lower composite liner functions as a pan lysimeter for the upper composite liner.

Introduction

In 1988, the US EPA-proposed RCRA Subtitle D municipal solid waste landfilling regulations recognized that a single composite liner for a landfill would not prevent groundwater pollution by landfill leachate for as long as the wastes in the landfill would be a threat. The US EPA Solid Waste Disposal Criteria (August 30, 1988a) stated,

> *"First, even the best liner and leachate collection system will ultimately fail due to natural deterioration, and recent improvements in MSWLF (municipal solid waste landfill) containment technologies suggest that releases may be delayed by many decades at some landfills."*

The US EPA Criteria for Municipal Solid Waste Landfills (July 1988b) stated,

> *"Once the unit is closed, the bottom layer of the landfill will deteriorate over time and, consequently, will not prevent leachate transport out of the unit."*

While in 1988, the US EPA developed the conclusion that a single composite liner would not protect groundwaters from impaired use for as long as the wastes in the landfill represent a threat, the general understanding by professionals of the significant shortcomings associated with the use of high density polyethylene liners or, for that matter, other plastic liner (flexible membrane liner–FML) systems were just beginning to be understood. Today, these deficiencies are well understood. Lee and Jones-Lee (1997,1998) have published a comprehensive review of the fundamentally flawed nature of minimum Subtitle D landfill containment systems to prevent groundwater pollution for as long as the wastes in a "dry tomb" type landfill will be a threat.

The wastes in a Subtitle D "dry tomb" type landfill will be a threat to pollute groundwaters, effectively forever. The flexible membrane layer in the composite liner has a finite period of time when it can be expected to function effectively to collect leachate. While no one can predict the length of this time before groundwater pollution will occur associated with a minimum Subtitle D single composite landfill liner system, there is increasing evidence that it could be as short as a few decades, even if high quality liner construction occurs and the placement of wastes in the landfill is done in such a way as to prevent penetrating the liner by waste constituents. This situation has been understood in

the landfill field for a number of years. There are eight states or parts of states that will not allow the construction of a single composite lined municipal solid waste (MSW) landfill.

Detection of Liner Failure

The US EPA, as part of developing Subtitle D landfill regulations, established monitoring requirements which were, in principle, designed to detect at the point of compliance for monitoring, the pollution of groundwaters by landfill leachate before off-site pollution occurs. The point of compliance for groundwater monitoring for Subtitle D landfills must be on the landfill owner's property and be no more than 150 meters from the downgradient edge of the waste management unit. It was the Agency's position at the time of the adoption of Subtitle D regulations that the inevitable failure of the single composite liner in preventing leachate from passing through it while the wastes in the landfill are still a threat would be detected by the groundwater monitoring system before off-site pollution occurred.

The Subtitle D monitoring approach requires that the landfill owner implement an extensive groundwater monitoring program once leachate-polluted groundwaters are detected at the point of compliance. Further, Subtitle D regulations require that once the extent of groundwater pollution has been defined, the landfill owner must initiate a groundwater remediation program to stop the spread of the pollution and start to clean up the polluted aquifer to the extent that it is possible. It is understood, however, that it will never be possible to clean up an MSW leachate-polluted aquifer system so the groundwaters associated with such a system would ever be considered safe for domestic consumption and many other purposes.

Reliability of Groundwater Monitoring Under Subtitle D

The US EPA in developing its groundwater monitoring system for Subtitle D landfills did not critically analyze the ability of groundwater monitoring wells of the type that are typically used to monitor groundwater pollution at classical unlined sanitary landfills to be able to detect the leachate-polluted groundwaters that would occur when the flexible membrane liner in a composite liner for a Subtitle D landfill first starts to degrade/deteriorate. The classical unlined sanitary landfill can be reliably monitored by placing groundwater monitoring wells at about any location down groundwater gradient from the landfill since the classical sanitary landfills produce large plumes of polluted groundwaters. However, the plastic sheeting-lined landfills, such as the minimum Subtitle D landfills, will first start to leak leachate through the liner system in small areas compared to the total area of the landfill.

The US EPA (1991) in Subtitle D groundwater monitoring system requirements stated:

> *"The design must ensure that the concentration values listed in Table 1 of this section will not be exceeded in the uppermost aquifer at the relevant point of compliance..."*

and specify that

"(a) A ground-water monitoring system must be installed that consists of a sufficient number of wells, installed at appropriate locations and depths, to yield ground-water samples from the uppermost aquifer (as defined in §258.2) that: (2) Represent the quality of ground water passing the relevant point of compliance..."

"(c) The sampling procedures and frequency must be protective of human health and the environment."

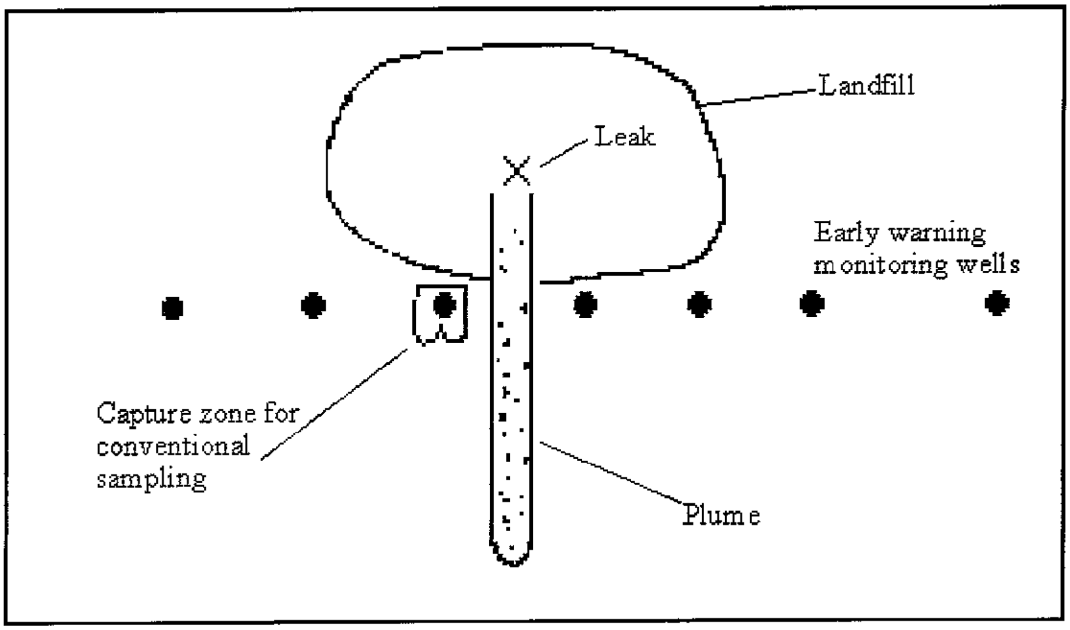
Further, the State of California Water Resources Control Board Chapter 15 regulations governing the landfilling of municipal solid wastes require that a sufficient number of monitoring wells be located so that they *"...provide for the best assurance of the* ***earliest possible*** *detection of a release from a waste management unit."* (emphasis added).

The Agency did not anticipate that the implementation of this requirement at the state and regional regulatory agency level would be based on mechanical application of the approach that had been used to monitor classical unlined sanitary landfills, i.e. a few downgradient monitoring wells spaced hundreds to a thousand or more feet apart. Dr. John Cherry (1990) was the first to point out that the approaches that were being adopted for monitoring plastic sheeting-lined landfills had a low probability of detecting landfill leachate-polluted groundwaters at the point of compliance before off-site pollution occurs. Cherry and his associates at the University of Waterloo, Ontario, Canada conducted a number of field experiments in which dyes were injected into a sand aquifer system at a specific source and the lateral spread of the dyed groundwater was assessed. It was found that the lateral spread of groundwater pollution plumes were limited near the source of pollution.

While Cherry's original publication on this topic was in a conference proceedings that was not widely read by hydrogeologists who work in the landfill field, he discussed these issues at the American Society for Testing and Materials symposium, Current Practices in Ground Water and Vadose Zone Investigations, held in San Diego, CA in January 1991 where he indicated that the typical groundwater monitoring systems that are being used for lined landfills involving vertical monitoring wells spaced hundreds to a thousand or more feet apart at the point of compliance for groundwater monitoring have a low probability of detecting leachate-polluted groundwaters at this point before widespread, off-site groundwater pollution occurs by landfill leachate. Based on the work of Cherry and his associates, a two-foot long line source of leachate, such as would occur from a rip, tear or point of deterioration in an FML, would be expected in a sand aquifer system to spread laterally to about ten feet within 150 meters of the source.

[CLI wells are approximately 150 meters from the center of the LF, probabilistically between 50 and 100 meters horizontally and 7 meters below a leak. A 2 foot rip would produce a leachate plume 2-5 feet across if the plume moved in sand. However, it does not. Moving through clay the same leak would produce an irregular plume consisting of small veinlets and disseminations. The leak would take much longer to move the 50-100 meters laterally and the 7 meters vertically. Its geometric configuration would be unpredictable and would follow construction layering and natural fissure cracking. Upon entering a monitored sand body such as the Lower Radnor Till Sand, the leading edges of the veinlet-based plume would tend to coalesce and disperse into the sand body assuming a more conventional plume configuration but would not be detectable unless some part of it passes within the area of influence (about a foot) of the existing 200-300 foot wide-spaced well-point array.smj]

The typical leachate-polluted groundwater plumes developed initially from an FML-lined landfill liner failure would be finger-like with limited lateral spread near the landfill. This means that since the typical groundwater monitoring well used for monitoring groundwater pollution by landfill leachate where three borehole volumes are purged prior to sampling, that the monitoring well samples groundwater only within about a foot of the well. If the monitoring wells are spaced 200 feet apart, which is close for many groundwater monitoring systems for Subtitle D landfills, there are 198 feet between each well where leachate plumes generated by initial leakage through the landfill liner system can pass without being detected by the wells. Cherry developed Figure 1 to show this relationship.



After Cherry 1990

Figure 1

Therefore, the basic premise of the US EPA Subtitle D regulations that the inevitable failure of the single composite liner from preventing leachate from passing through it for as long as the wastes represent a threat would be detected with a high degree of reliability before widespread off-site groundwater pollution occurs is fundamentally flawed. The groundwater monitoring systems that are used today at Subtitle D landfills with monitoring wells spaced hundreds or more feet apart are highly unreliable in detecting the pollution of groundwaters by landfill leachate at off-site properties where there is an inadequate landfill owner-owned bufferland between the edge of the waste management unit and adjacent properties.

The US EPA in developing Subtitle D and most state landfilling regulations allow landfilling of waste essentially up to the property line. This means there is no bufferland space between where the initial leakage of leachate through the liner system occurs and off-site/adjacent property groundwaters are located that can be polluted by landfill leachate. The authors are involved in several classical sanitary landfill investigations where small area sources of constituents, such as the dumping of chloroform into the landfill for waste disposal, has occurred. These landfills have produced chloroform plumes that extend over a mile from the landfill. These plumes exist in sand and gravel aquifer systems which are not atypical of many aquifers where Subtitle D landfills are located.

The situation could be much worse in a fractured rock aquifer system, where as described by Haitjema (1991)

> *"An extreme example of Equation (1) (aquifer heterogeneity) is flow through fractured rock. The design of monitoring well systems in such an environment is a nightmare and usually not more than a blind gamble."*

* * *

> *"Monitoring wells in the regional aquifer are unreliable detectors of local leaks in a landfill."*

While the initial work of Cherry, pointing out the deficiencies in groundwater monitoring of lined landfills was not widely recognized, today, as a result of subsequent publications by a number of individuals such as Parsons and Davis (1991), Lee and Jones-Lee (1994a) and others, the highly significant deficiencies in the typical groundwater monitoring approach that is proposed by landfill applicants and allowed by regulatory agencies is well understood. It has been the authors' experience that typically the regulatory agency personnel and boards have chosen to ignore this situation and proceed as though flexible membrane lined-landfills leachate leakage occurs throughout the entire bottom area of the landfill and a few groundwater monitoring wells spaced hundreds to a thousand or more feet apart can be expected to comply with Subtitle D requirements of ensuring that the concentrations of constituents in the US EPA "Table 1" are not exceeded in the uppermost aquifer at the point of compliance.

Adequacy of Landfill Permit Review

The current landfill groundwater monitoring program development approach is basically the ostrich approach in which the professional consultants who recommend this type of monitoring and the regulatory agencies who approve such monitoring are carrying out their responsibilities in a technically inadequate manner. Both consultants to landfill applicants and regulatory agency staff are required to use high-quality science and engineering in carrying out the responsibilities with respect to the development of a landfill. To ignore, as is typically done, the grossly inadequate groundwater monitoring that is occurring at Subtitle D landfills will ultimately represent significant liabilities to the consultants and to the regulatory agencies. This consultant liability arises from the fact that the consultant is signing off on the landfill projects as complying with regulations when they only meet minimum prescriptive standards for design, but obviously do not conform to the US EPA Subtitle D requirements of protecting groundwaters from impaired use for as long as the wastes in municipal solid waste "dry tomb" landfills will be a threat–effectively, forever. The liner, cover and groundwater monitoring systems will not prevent leachate from being generated in the landfill and leaving the landfill and detected at the point of compliance for groundwater monitoring for as long as the wastes will be a threat.

While some consultants for landfill applicants indicate that "*...groundwater monitoring programs are routinely designed to reflect the specific subsurface conditions and probable mechanisms of contaminant migration at each site,*" the authors have been involved in review of over 50 landfills located in various parts of the US and have yet to find a single case where the groundwater monitoring system that is used reflects the issues raised by Cherry (1990) that the initial leakage through a plastic sheeting-lined landfill will produce finger plumes of leachate of limited dimension at the point of compliance where groundwater monitoring occurs. Further, we have yet to find a single case where the fact that the groundwater monitoring wells at the point of compliance often have zones of capture of a foot or so around each well is considered in developing well spacing at the point of compliance. With monitoring wells spaced hundreds of feet apart, it is obvious that the groundwater monitoring systems being used for many Subtitle D landfills is a fundamentally flawed approach for assessing the inevitable groundwater pollution that will occur at essentially all minimum Subtitle D landfills sited at geologically unsuitable sites, i.e., lacking natural protection, when the flexible membrane liner systems being used fail to prevent leachate from passing through them for as long as the wastes in the landfill represent a threat.

Landfill applicants, through their consultants, should be required to conduct a site-specific evaluation of the potential characteristics of the leachate plumes generated through initial leakage through the FML when it reaches the point of compliance for groundwater monitoring. This requires a site-specific statistical/hydrogeological assessment of the dimensions of the leachate-polluted groundwater plume at the point of compliance relative to the zones of capture of the monitoring wells and the well spacing, for a failure of the landfill liner system that could occur at any location under the landfill footprint. This information should be part of the standard landfill design documentation that is made available to the regulatory agency and the public as part of reviewing the appropriateness of developing a particular landfill at a particular location.

Some landfill applicant consultants assert, in defense of their somewhat arbitrary approach for developing a groundwater monitoring system based on the typical approach that is being used today, that there has been no documentation that this approach has failed to detect landfill-liner leakage that results in groundwater pollution. Such assertions, however, fail to provide a discussion of the situation that exists today with respect to failure of minimum Subtitle D landfill liner systems and groundwater monitoring systems to function as required in Subtitle D requirements for as long as the wastes represent a threat. Lee and Jones-Lee (1996) have developed a review of this topic where they point out that minimum Subtitle D landfills have only been required since 1993. It would be highly unusual in this short period of time to have demonstrated proof that eventually during the infinite period of time that the wastes would be a threat at a minimum Subtitle D landfill, that the liner will fail and that the groundwater monitoring systems with monitoring wells spaced hundreds to a thousand or so feet apart at the point of compliance have failed to detected the liner failure.

In most cases, liner failure that would have occurred in the past four years would be due to grossly inadequate construction and waste placement. Further, the transport rates of leachate and leachate-polluted groundwaters are such that it would be unlikely that leachate that had passed through the failed liner system would have reached the point of compliance at this time, which can be located, under Subtitle D requirements, at 150 meters from the edge of the waste management unit. Because of the fundamentally flawed nature of the groundwater monitoring approach, involving the use of monitoring wells with limited zones of capture compared to well spacing, it would be a pure fluke that the initial liner leakage groundwater pollution plumes would be detected by a groundwater monitoring well at the point of compliance as required by US EPA and Chapter 15 requirements of detecting leachate-polluted groundwaters at the earliest possible time. Some have characterized minimum Subtitle D landfills as a "time bomb." If the approach advocated by some landfill applicant consultants is followed, there would be need to wait until the bomb goes off before action can be taken to address the obvious issues that the groundwater monitoring approach as being implemented today is fundamentally flawed and does not consider the issues raised by Cherry and others on the inadequacies of groundwater monitoring to detect pollution at minimum Subtitle D landfills.

It is reasonable to expect that a groundwater monitoring system would have a high probability of detecting leachate-polluted groundwaters at the point of compliance, for any plausible landfill liner leak that could occur for as long as the wastes in the landfill will be a threat that could lead to the pollution of off-site groundwaters impairing their use for domestic or other purposes. Certainly, a situation where a substantial part of the leachate associated with liner leakage can pass by the point of compliance for groundwater monitoring without being detected by the monitoring wells does not comply with either Subtitle D or Chapter 15 requirements of adequate and reliable groundwater monitoring.

The current approach for development and implementation of groundwater monitoring systems for minimum Subtitle D landfills focuses considerable resources on collection and analysis of chemicals in vertical monitoring wells at the point of compliance as well as upgradient from the landfill. Comprehensive statistical procedures have been developed to determine when an increase in a waste-derived constituent above background has occurred. While such approaches are appropriate, they fail to address the fundamental issue of the overall reliability of the groundwater monitoring system being used. The issue that should be first addressed is whether the groundwater monitoring well array is a reliable array for a particular site to detect leachate-polluted groundwaters at the point of compliance with a high degree of reliability when the leachate pollution of groundwaters at this point first occurs. The approach that is used today of ignoring this essential step in developing groundwater monitoring programs for lined landfills is highly inadequate and technically invalid.

The problems with landfill applicants and their consultants failing to provide adequate and reliable information on the ability of a proposed landfill groundwater monitoring system to comply with regulatory requirements is part of a significant problem than exists today in the regulation/permitting of landfills. Typically, landfill applicants and their consultants follow the approach of doing the least possible in order to get the landfill permitted. Lee and Jones-Lee (1995a) have discussed the significant, well-known problems that exist today where landfill applicants and their consultants fail to provide full disclosure of the potential problems associated with a proposed landfill in protecting public health, groundwater resources, the environment and the interest of those within the sphere of influence of the landfill for as long as the wastes in the landfill will be a threat.

The codes of ethics for the National Society for Professional Engineers and the American Society of Civil Engineers require that any registered engineer provide full disclosure with respect to public health and environmental protection of their proposed projects. The typical approach used today by landfill applicants and their consultants follows the legal-adversary system used in the courts, where only the merits of a proposed project are discussed, without informing the public or regulatory agencies of the significant deficiencies in the proposed project in complying with Subtitle D requirements of protecting groundwaters from pollution by landfill leachate for as long as the waste in the landfill will be a threat. It is well known that many consultants who work for landfill applicants and, for that matter, many other project proponents that have the potential to be adverse to the environment, must, if they want to continue to obtain business, only report on the positive aspects of a particular project and fail to report on the well-known significant negative aspects. It is also well known in the field that any consultants who normally work with landfill applicants who fully discuss in a public arena, such as a landfill permitting hearing, the long-term problems associated with the proposed landfill will do this only once, since they will not obtain further work with landfill applicants.

Lee and Jones-Lee (1995a) recommend that an independent, interactive full public peer review of technical issues, such as the adequacy of a groundwater monitoring system for a proposed landfill be conducted in which the landfill applicants and their consultants are required to provide detailed information/documentation on their evaluation of the reliability of the groundwater monitoring system that they propose to use in detecting, at the earliest possible time, leachate polluted groundwater at the point of compliance. Adoption of this peer review process would eventually lead to a situation where engineering consultants would not have to violate the NSPE and ASCE codes of ethics for protection of public health and the environment in order to gain additional work with landfill applicants.

Recommended Approach

There is need to immediately terminate the facade that exists today in the permitting of Subtitle D landfills with respect to the reliability of the groundwater monitoring systems that are being allowed in detecting leachate-polluted groundwaters before they cause off-site groundwater pollution. It will be necessary to immediately change how groundwater monitoring programs are developed for lined landfills. The current seat-of-the-pants approach for designing monitoring systems in which a few monitoring wells are arbitrarily installed along the point of compliance must be terminated. Regulatory agencies must start requiring that landfill applicants, through their consultants, develop an estimate of the reliability of the groundwater monitoring system proposed for a landfill in detecting leachate-polluted groundwaters at the point of compliance. These estimates should be based on a site-specific evaluation of the initial size and lateral spread of the leachate pollution plumes that could be produced from leaks at any location through the landfill liner system, including near the downgradient edge of the waste management unit. Development of this type of information will show that the typical groundwater monitoring system being permitted today for minimum Subtitle D landfills cannot comply with Subtitle D groundwater monitoring requirements.

The state of Michigan addressed this problem several years ago and adopted a double composite liner for municipal solid waste landfills in which there is a leak detection system between the two composite liners. The lower composite liner is not a containment liner, but is the base of the leak detection system for the upper composite liner. As discussed by Lee and Jones-Lee (a), this approach can be an effective approach for preventing groundwater pollution by Subtitle D landfills provided that the landfill owner is required to take the necessary action to stop leachate leaking through the upper composite liner when it occurs. Because of the impossibility of repairing the liner, this action would likely involve repairing the landfill cover. Since Subtitle D landfill covers are not designed to prevent moisture from entering the wastes and since their ability to control moisture input to the landfill will deteriorate significantly over time where this deterioration cannot be observed through visual inspection of the landfill surface, the approach that should be followed is to install a leak detectible cover over the landfill that the landfill owner operates and maintains in perpetuity, i.e. for as long as the wastes in the landfill will be a threat. Lee and Jones-Lee (1995b) have discussed the issue that should be considered in developing long term protection of groundwater quality associated with the closure of a Subtitle D landfill. The key to developing groundwater quality protection associated with the use of a leak detectible cover is the development, from disposal fees, of a dedicated trust fund of sufficient magnitude to operate and maintain the leak detectible cover for as long as the wastes represent a threat to groundwater quality. Lee and Jones-Lee (1994a,b) recommend that if a landfill owner is unable or unwilling to stop leachate from occurring in the leak detection layer between the two composite liners, then the landfill owner must exhume (mine) the wastes and properly manage them at a geologically suitable site where there are either no groundwaters or natural protection of the groundwaters that could be polluted by landfill leachate is present.

The additional costs of these systems compared to the conventional minimum Subtitle D MSW landfilling is estimated to be from 10 to 20 cents per person per day more for solid waste management than is being paid under minimum Subtitle D landfilling. This is a small cost compared to the large Superfund-like costs that will ultimately have to be borne by future generations in groundwater clean-up at minimum Subtitle D landfills, potential damage to public health of those within the sphere of influence of the landfill and the lost groundwater resources that will occur because of leachate pollution.

Summary

Today's minimum Subtitle D groundwater monitoring systems are fundamentally flawed in complying with Subtitle D requirements of protecting groundwaters from impaired use by MSW landfill leachate for as long as the wastes in a "dry tomb" landfill will be a threat. The typical groundwater monitoring well array being allowed at Subtitle D landfills today has a low probability of detecting landfill leachate-polluted groundwaters at the point of compliance before trespass of leachate-polluted groundwaters occurs under adjacent properties. There is immediate need to require, as part of permitting a Subtitle D landfill, that the landfill applicant critically analyze the expected reliability of the groundwater monitoring system in complying with regulatory requirements of preventing groundwater pollution beyond the point of compliance. Such an analysis would show, for many Subtitle D landfills, that vertical monitoring wells spaced more than about ten feet apart for most hydrogeologic settings at the point of compliance cannot comply with Subtitle D groundwater monitoring requirements.

Alternative, more reliable groundwater monitoring approaches are available, such as those adopted by the state of Michigan, in which a double composite liner is used where the lower composite liner is a leak detection system for the upper composite liner. This approach, if properly funded and implemented in perpetuity, could significantly improve the monitoring of landfill liner failure over that being achieved today. The cost of this approach is from 10 to 20 cents per person per day more for waste disposal than is being paid now for minimum Subtitle D landfilling. Payment of these costs now will be highly cost-effective in terms of protecting groundwater resources for use by future generations and preventing Subtitle D Superfund site clean-up costs that will evolve from most of the Subtitle D landfills that are being developed today.

Additional Information

Additional information on these topic areas is available from the authors' web site (http://members.aol.com/gfredlee/gfl.htm). The papers by the authors listed in the Literature Cited, are available from this web site.

Acknowledgment

This paper is adapted from a review of these topics by the authors that was published in the California Groundwater Resources Association newsletter, HydroVisions.

Literature Cited

Cherry, J. 1990. "Groundwater Monitoring: Some Deficiencies and Opportunities," In: Hazardous Waste Site Investigations: Towards Better Decisions, Proc. 10th ORNL Life Sciences Symposium, Gatlinburg, TN, May 1990, Lewis Publishers.

Haitjema, H. 1991. "Ground Water Hydraulics Considerations Regarding Landfills," Water Res. Bull. 27(5):791-796.

Lee, G.F. and Jones-Lee, A. 1993. "Groundwater Quality Monitoring at Lined Landfills: Adequacy of Subtitle D Approaches," Report of G. Fred Lee & Associates, El Macero, CA, 28pp.

Lee, G.F. and Jones-Lee, A. 1994a. "A Groundwater Protection Strategy for Lined Landfills," Environmental Science & Technology, 28:584-5.

Lee, G.F. and Jones-Lee, A. April, 1994b. "Landfilling of Solid & Hazardous Waste: Facing Long-Term Liability," In: Proc. 1994 Federal Environmental Restoration III & Waste Minimization II Conference, Hazardous Materials Control Resources Institute, Rockville, MD, pp. 1610-1618.

Lee, G.F. and Jones-Lee, A. 1995a. "Practical Environmental Ethics: Is There an Obligation to Tell the Whole Truth?," Published in condensed form "Environmental Ethics: The Whole Truth" Civil Engineering, Forum, 65:6.

Lee, G.F. and Jones-Lee, A. October,1995b. "Overview of Landfill Post Closure Issues," Presented at American Society of Civil Engineers Convention session devoted to "Landfill Closures - Environmental Protection and Land Recovery," San Diego, CA.

Lee, G.F. and Jones-Lee, A. 1996. "Detection of the Failure of Landfill Liner Systems," Report of G. Fred Lee & Associates, El Macero, CA, 13pp.

Lee, G.F. and Jones-Lee, A. 1997. "Deficiencies in US EPA Subtitle D Landfills in Protecting Groundwater Quality for as Long as MSW is a Threat: Recommended Alternative Approaches," Report of G. Fred Lee & Associates, El Macero, CA.

Lee, G.F. and Jones-Lee, A. June, 1998a. "Assessing the Potential of Minimum Subtitle D Lined Landfills to Pollute: Alternative Landfilling Approaches," Proc. of Air and Waste Management Association national meeting, San Diego, CA.

Parsons, A. and Davis, P. 1992. "A Proposed Strategy for Assessing Compliance with the RCRA Groundwater Monitoring Regulations," In: Current Practices in Ground Water and Vadose Zone Investigations, STP 1118, pp. 39-56, ASTM, Philadelphia, PA.

US EPA. August 30, 1988a. "Solid Waste Disposal Facility Criteria; Proposed Rule," Federal Register 53(168):33314-33422, 40 CFR Parts 257 and 258, US EPA, Washington, D.C.

US EPA. July, 1988b. "Criteria for Municipal Solid Waste Landfills," US EPA Washington D.C.

US EPA. October 9, 1991. "Solid Waste Disposal Facility Criteria; Final Rule," 40 CFR Parts 257 and 258, Federal Register 56(196):50978-51119.

EPA National Library Network

OLS : Record

RECORD NUMBER: 5 OF 22

New Search | Query Summary | Previous Item | Next Item | Bibliography | Item Status | Search History

Main Title	Closure/post-closure care and financial responsibility requirements (Subpart C, 258.30-258.32) : criteria for municipal solid waste landfills (40 CFR Part 258) : Subtitle D of Resource Conservation and Recovery Act (RCRA) /
CORP Author	Environmental Protection Agency, Washington, DC. Office of Solid Waste.
Publisher	The Office,
Place Published	Washington, D.C. :
Year Published	1988
Report Number	EPA/530-SW-88-041
Stock Number	PB88-242474
OCLC Number	18999303
Subjects	Regulations; Economic models; Earth fills; Post closures; Municipal **solid wastes**; Fines (Charges); Sanitary landfills; **Solid waste** management; **Solid waste disposal**; **Solid Waste Disposal Act**
Subject Added Ent	Sanitary landfills--Law and legislation--United States
Holdings	**Library** / **Call Number** / **Additional Info** / **Location** / **Date Modified** EKAM / TD795.C7434 1988 / / Region 4 Library/Atlanta,GA / 06/05/1998 NTIS / PB88-242474 / Most EPA libraries have a fiche copy filed under the call number shown. Check with individual libraries about paper copy. / NTIS / 01/01/1988
Collation	1 v. (various pagings) ; 28 cm.
Abstract	In August 1988, the U.S. Environmental Protection Agency proposed Solid Waste Disposal Facilities Criteria (40 CFR Part 258) for municipal solid waste landfills. The background document provides the technical support for the closure, post- closure core and financial responsibility requirements. The requirements are part of the operating requirements of Part 258. The document contains a discussion of background information and provides detailed information on the revised closure, post-closure, and financial responsibility requirements. The document addresses; (1) closure and post-closure performance stand; (2) closure and post-closure plans; (3) financial assurance

	criteria for closure, post-closure and corrective action for known releases; and (4) financial assurance mechanisms that are available to owners or operators of municipal solid waste landfills.
Notes	"Draft background document" "July 1988"
Corporate Au Added Ent	United States. Office of Solid Waste.
PUB Date Free Form	{1988}.
Ti Tra Differently	Criteria for municipal solid waste landfills (40 CFR Part 258).
NTIS Prices	PC A07/MF A01
BIB Level	m
OCLC Time Stamp	19980529161856
Cataloging Source	OCLC/T
Language	eng
Origin	OCLC
Type	MERGE
OCLC Rec Leader	01026nam 2200229Ka 45020

New Search | Query Summary | Previous Item | Next Item | Bibliography | Item Status | Search History

EXHIBIT 10

EXHIBIT 10

United States Department of Agriculture

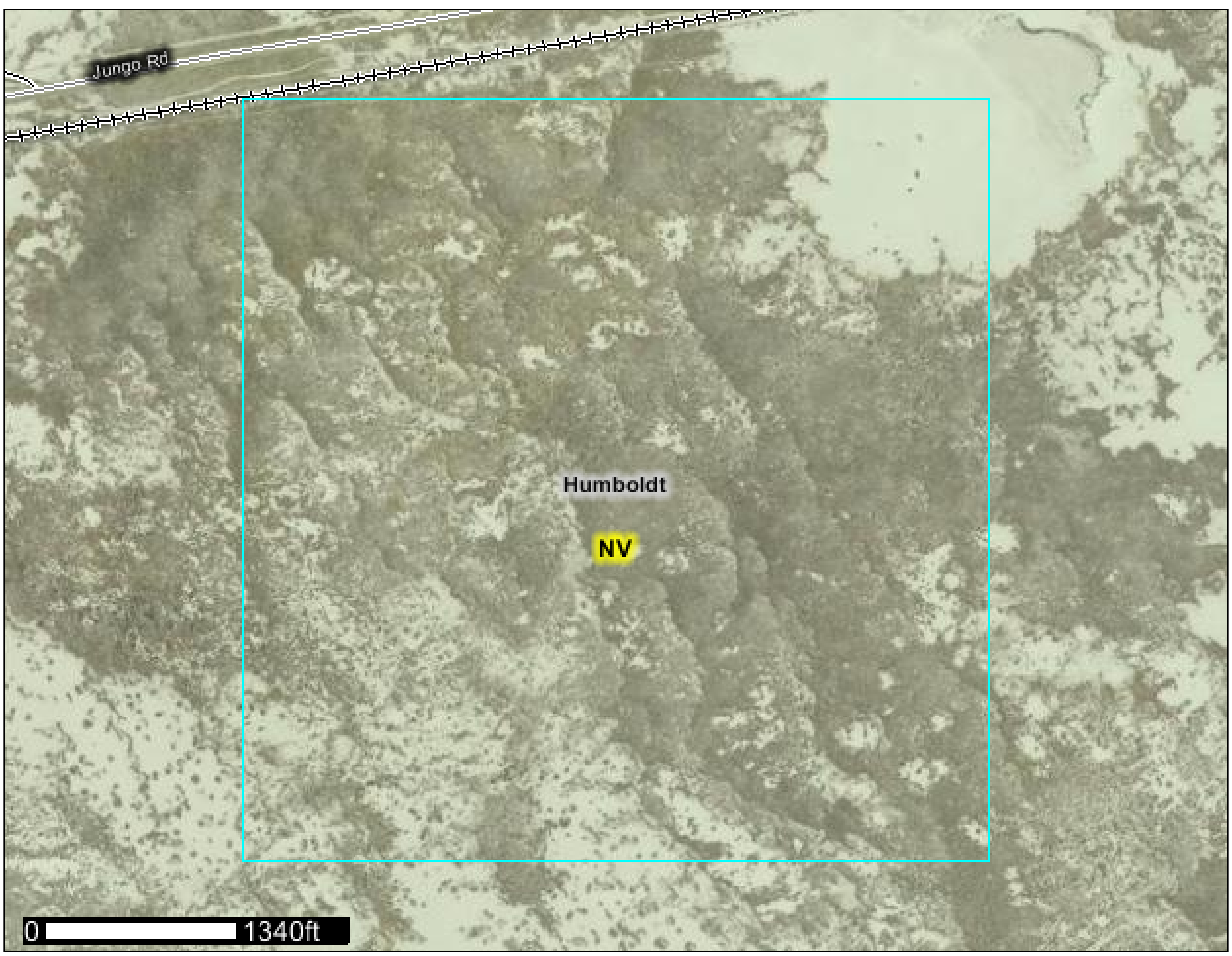
NRCS

Natural Resources Conservation Service

A product of the National Cooperative Soil Survey, a joint effort of the United States Department of Agriculture and other Federal agencies, State agencies including the Agricultural Experiment Stations, and local participants

Custom Soil Resource Report for

Humboldt County, Nevada, East Part



October 13, 2009

Preface

Soil surveys contain information that affects land use planning in survey areas. They highlight soil limitations that affect various land uses and provide information about the properties of the soils in the survey areas. Soil surveys are designed for many different users, including farmers, ranchers, foresters, agronomists, urban planners, community officials, engineers, developers, builders, and home buyers. Also, conservationists, teachers, students, and specialists in recreation, waste disposal, and pollution control can use the surveys to help them understand, protect, or enhance the environment.

Various land use regulations of Federal, State, and local governments may impose special restrictions on land use or land treatment. Soil surveys identify soil properties that are used in making various land use or land treatment decisions. The information is intended to help the land users identify and reduce the effects of soil limitations on various land uses. The landowner or user is responsible for identifying and complying with existing laws and regulations.

Although soil survey information can be used for general farm, local, and wider area planning, onsite investigation is needed to supplement this information in some cases. Examples include soil quality assessments (http://soils.usda.gov/sqi/) and certain conservation and engineering applications. For more detailed information, contact your local USDA Service Center (http://offices.sc.egov.usda.gov/locator/app?agency=nrcs) or your NRCS State Soil Scientist (http://soils.usda.gov/contact/state_offices/).

Great differences in soil properties can occur within short distances. Some soils are seasonally wet or subject to flooding. Some are too unstable to be used as a foundation for buildings or roads. Clayey or wet soils are poorly suited to use as septic tank absorption fields. A high water table makes a soil poorly suited to basements or underground installations.

The National Cooperative Soil Survey is a joint effort of the United States Department of Agriculture and other Federal agencies, State agencies including the Agricultural Experiment Stations, and local agencies. The Natural Resources Conservation Service (NRCS) has leadership for the Federal part of the National Cooperative Soil Survey.

Information about soils is updated periodically. Updated information is available through the NRCS Soil Data Mart Web site or the NRCS Web Soil Survey. The Soil Data Mart is the data storage site for the official soil survey information.

The U.S. Department of Agriculture (USDA) prohibits discrimination in all its programs and activities on the basis of race, color, national origin, age, disability, and where applicable, sex, marital status, familial status, parental status, religion, sexual orientation, genetic information, political beliefs, reprisal, or because all or a part of an individual's income is derived from any public assistance program. (Not all prohibited bases apply to all programs.) Persons with disabilities who require alternative means for communication of program information (Braille, large print, audiotape, etc.) should contact USDA's TARGET Center at (202) 720-2600 (voice and TDD). To file a complaint of discrimination, write to USDA, Director, Office of Civil Rights, 1400 Independence Avenue, S.W., Washington, D.C. 20250-9410 or call (800) 795-3272 (voice) or (202) 720-6382 (TDD). USDA is an equal opportunity provider and employer.

Contents

How Soil Surveys Are Made

Soil surveys are made to provide information about the soils and miscellaneous areas in a specific area. They include a description of the soils and miscellaneous areas and their location on the landscape and tables that show soil properties and limitations affecting various uses. Soil scientists observed the steepness, length, and shape of the slopes; the general pattern of drainage; the kinds of crops and native plants; and the kinds of bedrock. They observed and described many soil profiles. A soil profile is the sequence of natural layers, or horizons, in a soil. The profile extends from the surface down into the unconsolidated material in which the soil formed or from the surface down to bedrock. The unconsolidated material is devoid of roots and other living organisms and has not been changed by other biological activity.

Currently, soils are mapped according to the boundaries of major land resource areas (MLRAs). MLRAs are geographically associated land resource units that share common characteristics related to physiography, geology, climate, water resources, soils, biological resources, and land uses (USDA, 2006). Soil survey areas typically consist of parts of one or more MLRA.

The soils and miscellaneous areas in a survey area occur in an orderly pattern that is related to the geology, landforms, relief, climate, and natural vegetation of the area. Each kind of soil and miscellaneous area is associated with a particular kind of landform or with a segment of the landform. By observing the soils and miscellaneous areas in the survey area and relating their position to specific segments of the landform, a soil scientist develops a concept, or model, of how they were formed. Thus, during mapping, this model enables the soil scientist to predict with a considerable degree of accuracy the kind of soil or miscellaneous area at a specific location on the landscape.

Commonly, individual soils on the landscape merge into one another as their characteristics gradually change. To construct an accurate soil map, however, soil scientists must determine the boundaries between the soils. They can observe only a limited number of soil profiles. Nevertheless, these observations, supplemented by an understanding of the soil-vegetation-landscape relationship, are sufficient to verify predictions of the kinds of soil in an area and to determine the boundaries.

Soil scientists recorded the characteristics of the soil profiles that they studied. They noted soil color, texture, size and shape of soil aggregates, kind and amount of rock fragments, distribution of plant roots, reaction, and other features that enable them to identify soils. After describing the soils in the survey area and determining their properties, the soil scientists assigned the soils to taxonomic classes (units). Taxonomic classes are concepts. Each taxonomic class has a set of soil characteristics with precisely defined limits. The classes are used as a basis for comparison to classify soils systematically. Soil taxonomy, the system of taxonomic classification used in the United States, is based mainly on the kind and character of soil properties and the arrangement of horizons within the profile. After the soil scientists classified and named the soils in the survey area, they compared the individual soils with similar soils in the same taxonomic class in other areas so that they could confirm data and assemble additional data based on experience and research.

The objective of soil mapping is not to delineate pure map unit components; the objective is to separate the landscape into landforms or landform segments that have similar use and management requirements. Each map unit is defined by a unique combination of soil components and/or miscellaneous areas in predictable proportions. Some components may be highly contrasting to the other components of the map unit. The presence of minor components in a map unit in no way diminishes the usefulness or accuracy of the data. The delineation of such landforms and landform segments on the map provides sufficient information for the development of resource plans. If intensive use of small areas is planned, onsite investigation is needed to define and locate the soils and miscellaneous areas.

Soil scientists make many field observations in the process of producing a soil map. The frequency of observation is dependent upon several factors, including scale of mapping, intensity of mapping, design of map units, complexity of the landscape, and experience of the soil scientist. Observations are made to test and refine the soil-landscape model and predictions and to verify the classification of the soils at specific locations. Once the soil-landscape model is refined, a significantly smaller number of measurements of individual soil properties are made and recorded. These measurements may include field measurements, such as those for color, depth to bedrock, and texture, and laboratory measurements, such as those for content of sand, silt, clay, salt, and other components. Properties of each soil typically vary from one point to another across the landscape.

Observations for map unit components are aggregated to develop ranges of characteristics for the components. The aggregated values are presented. Direct measurements do not exist for every property presented for every map unit component. Values for some properties are estimated from combinations of other properties.

While a soil survey is in progress, samples of some of the soils in the area generally are collected for laboratory analyses and for engineering tests. Soil scientists interpret the data from these analyses and tests as well as the field-observed characteristics and the soil properties to determine the expected behavior of the soils under different uses. Interpretations for all of the soils are field tested through observation of the soils in different uses and under different levels of management. Some interpretations are modified to fit local conditions, and some new interpretations are developed to meet local needs. Data are assembled from other sources, such as research information, production records, and field experience of specialists. For example, data on crop yields under defined levels of management are assembled from farm records and from field or plot experiments on the same kinds of soil.

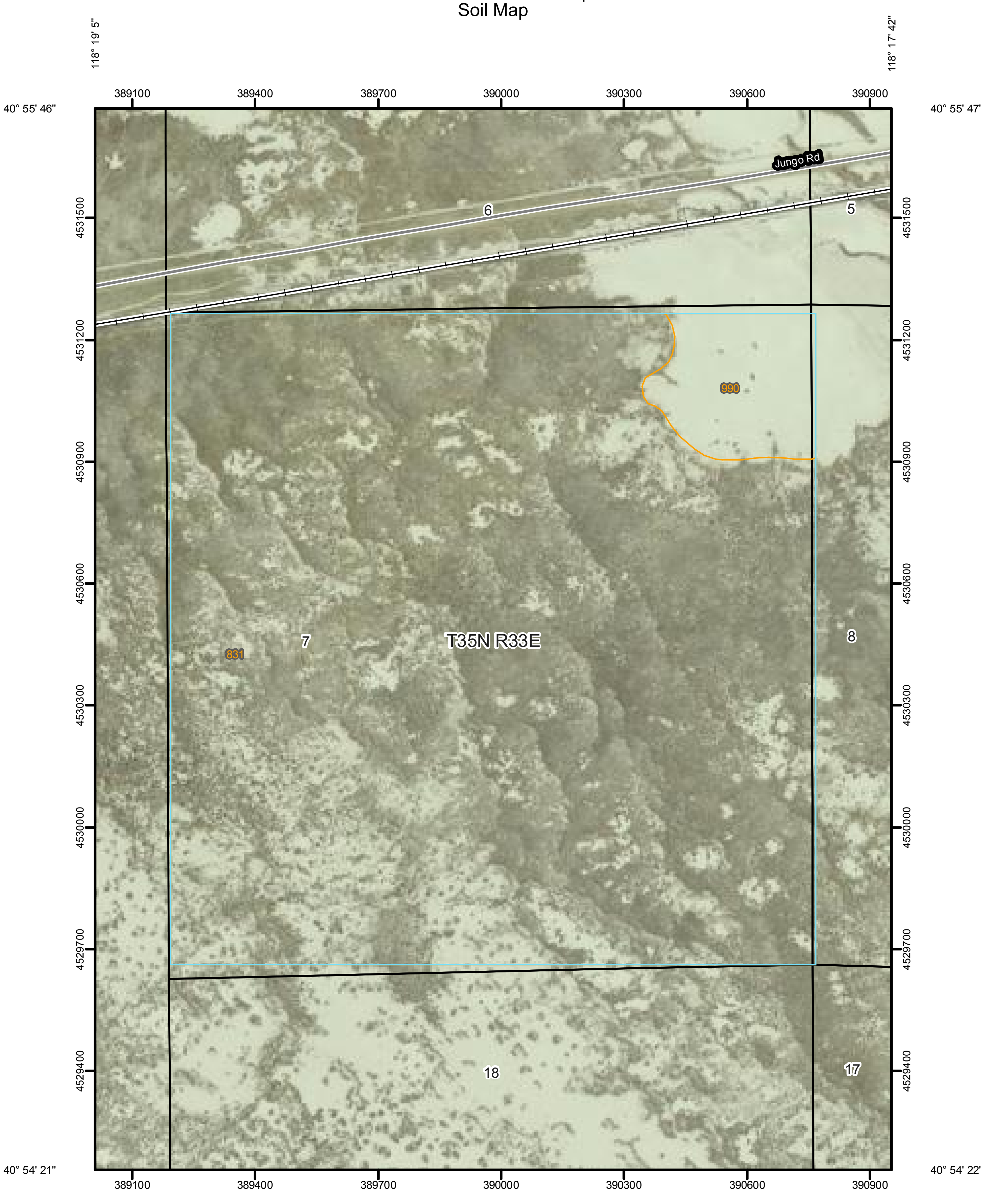
Predictions about soil behavior are based not only on soil properties but also on such variables as climate and biological activity. Soil conditions are predictable over long periods of time, but they are not predictable from year to year. For example, soil scientists can predict with a fairly high degree of accuracy that a given soil will have a high water table within certain depths in most years, but they cannot predict that a high water table will always be at a specific level in the soil on a specific date.

After soil scientists located and identified the significant natural bodies of soil in the survey area, they drew the boundaries of these bodies on aerial photographs and identified each as a specific map unit. Aerial photographs show trees, buildings, fields, roads, and rivers, all of which help in locating boundaries accurately.

Soil Map

The soil map section includes the soil map for the defined area of interest, a list of soil map units on the map and extent of each map unit, and cartographic symbols displayed on the map. Also presented are various metadata about data used to produce the map, and a description of each soil map unit.

Soil Map



Map Scale: 1:12,500 if printed on A size (8.5" x 11") sheet.

N

Meters: 0, 100, 200, 400, 600

Feet: 0, 450, 900, 1,800, 2,700

MAP LEGEND

Area of Interest (AOI)

Area of Interest (AOI)

Soils

Soil Map Units

Special Point Features

- Blowout
- Borrow Pit
- Clay Spot
- Closed Depression
- Gravel Pit
- Gravelly Spot
- Landfill
- Lava Flow
- Marsh or swamp
- Mine or Quarry
- Miscellaneous Water
- Perennial Water
- Rock Outcrop
- Saline Spot
- Sandy Spot
- Severely Eroded Spot
- Sinkhole
- Slide or Slip
- Sodic Spot
- Spoil Area
- Stony Spot
- Very Stony Spot
- Wet Spot
- Other

Special Line Features

- Gully
- Short Steep Slope
- Other

Political Features

- Cities
- PLSS Township and Range
- PLSS Section

Water Features

- Oceans
- Streams and Canals

Transportation

- Rails
- Interstate Highways
- US Routes
- Major Roads
- Local Roads

MAP INFORMATION

Map Scale: 1:12,500 if printed on A size (8.5" × 11") sheet.

The soil surveys that comprise your AOI were mapped at 1:24,000.

Please rely on the bar scale on each map sheet for accurate map measurements.

Source of Map: Natural Resources Conservation Service
Web Soil Survey URL: http://websoilsurvey.nrcs.usda.gov
Coordinate System: UTM Zone 11N NAD83

This product is generated from the USDA-NRCS certified data as of the version date(s) listed below.

Soil Survey Area: Humboldt County, Nevada, East Part
Survey Area Data: Version 4, Dec 12, 2006

Date(s) aerial images were photographed: 7/14/2006

The orthophoto or other base map on which the soil lines were compiled and digitized probably differs from the background imagery displayed on these maps. As a result, some minor shifting of map unit boundaries may be evident.

Map Unit Legend

Humboldt County, Nevada, East Part (NV777)			
Map Unit Symbol	**Map Unit Name**	**Acres in AOI**	**Percent of AOI**
831	Boton-Playas association	592.4	94.9%
990	Playas	32.0	5.1%
Totals for Area of Interest		**624.5**	**100.0%**

Map Unit Descriptions

The map units delineated on the detailed soil maps in a soil survey represent the soils or miscellaneous areas in the survey area. The map unit descriptions, along with the maps, can be used to determine the composition and properties of a unit.

A map unit delineation on a soil map represents an area dominated by one or more major kinds of soil or miscellaneous areas. A map unit is identified and named according to the taxonomic classification of the dominant soils. Within a taxonomic class there are precisely defined limits for the properties of the soils. On the landscape, however, the soils are natural phenomena, and they have the characteristic variability of all natural phenomena. Thus, the range of some observed properties may extend beyond the limits defined for a taxonomic class. Areas of soils of a single taxonomic class rarely, if ever, can be mapped without including areas of other taxonomic classes. Consequently, every map unit is made up of the soils or miscellaneous areas for which it is named and some minor components that belong to taxonomic classes other than those of the major soils.

Most minor soils have properties similar to those of the dominant soil or soils in the map unit, and thus they do not affect use and management. These are called noncontrasting, or similar, components. They may or may not be mentioned in a particular map unit description. Other minor components, however, have properties and behavioral characteristics divergent enough to affect use or to require different management. These are called contrasting, or dissimilar, components. They generally are in small areas and could not be mapped separately because of the scale used. Some small areas of strongly contrasting soils or miscellaneous areas are identified by a special symbol on the maps. If included in the database for a given area, the contrasting minor components are identified in the map unit descriptions along with some characteristics of each. A few areas of minor components may not have been observed, and consequently they are not mentioned in the descriptions, especially where the pattern was so complex that it was impractical to make enough observations to identify all the soils and miscellaneous areas on the landscape.

The presence of minor components in a map unit in no way diminishes the usefulness or accuracy of the data. The objective of mapping is not to delineate pure taxonomic classes but rather to separate the landscape into landforms or landform segments that have similar use and management requirements. The delineation of such segments on the map provides sufficient information for the development of resource plans. If intensive use of small areas is planned, however, onsite investigation is needed to define and locate the soils and miscellaneous areas.

An identifying symbol precedes the map unit name in the map unit descriptions. Each description includes general facts about the unit and gives important soil properties and qualities.

Soils that have profiles that are almost alike make up a *soil series*. Except for differences in texture of the surface layer, all the soils of a series have major horizons that are similar in composition, thickness, and arrangement.

Soils of one series can differ in texture of the surface layer, slope, stoniness, salinity, degree of erosion, and other characteristics that affect their use. On the basis of such differences, a soil series is divided into *soil phases*. Most of the areas shown on the detailed soil maps are phases of soil series. The name of a soil phase commonly indicates a feature that affects use or management. For example, Alpha silt loam, 0 to 2 percent slopes, is a phase of the Alpha series.

Some map units are made up of two or more major soils or miscellaneous areas. These map units are complexes, associations, or undifferentiated groups.

A *complex* consists of two or more soils or miscellaneous areas in such an intricate pattern or in such small areas that they cannot be shown separately on the maps. The pattern and proportion of the soils or miscellaneous areas are somewhat similar in all areas. Alpha-Beta complex, 0 to 6 percent slopes, is an example.

An *association* is made up of two or more geographically associated soils or miscellaneous areas that are shown as one unit on the maps. Because of present or anticipated uses of the map units in the survey area, it was not considered practical or necessary to map the soils or miscellaneous areas separately. The pattern and relative proportion of the soils or miscellaneous areas are somewhat similar. Alpha-Beta association, 0 to 2 percent slopes, is an example.

An *undifferentiated group* is made up of two or more soils or miscellaneous areas that could be mapped individually but are mapped as one unit because similar interpretations can be made for use and management. The pattern and proportion of the soils or miscellaneous areas in a mapped area are not uniform. An area can be made up of only one of the major soils or miscellaneous areas, or it can be made up of all of them. Alpha and Beta soils, 0 to 2 percent slopes, is an example.

Some surveys include *miscellaneous areas*. Such areas have little or no soil material and support little or no vegetation. Rock outcrop is an example.

Humboldt County, Nevada, East Part

831—Boton-Playas association

Map Unit Setting

Elevation: 4,100 to 4,200 feet
Mean annual precipitation: 6 to 8 inches
Mean annual air temperature: 50 to 52 degrees F
Frost-free period: 120 to 140 days

Map Unit Composition

Boton and similar soils: 50 percent
Playas: 35 percent

Description of Boton

Setting

Landform: Lake plains
Down-slope shape: Linear
Across-slope shape: Linear
Parent material: Volcanic ash and loess over lacustrine deposits

Properties and qualities

Slope: 0 to 2 percent
Depth to restrictive feature: More than 80 inches
Drainage class: Well drained
Capacity of the most limiting layer to transmit water (Ksat): Moderately high (0.20 to 0.57 in/hr)
Depth to water table: More than 80 inches
Frequency of flooding: None
Frequency of ponding: None
Calcium carbonate, maximum content: 20 percent
Gypsum, maximum content: 5 percent
Maximum salinity: Moderately saline to strongly saline (16.0 to 32.0 mmhos/cm)
Sodium adsorption ratio, maximum: 99.0
Available water capacity: High (about 12.0 inches)

Interpretive groups

Land capability classification (irrigated): 4s
Land capability (nonirrigated): 7s
Ecological site: SODIC TERRACE 6-8 P.Z. (R024XY003NV)

Typical profile

0 to 15 inches: Silt loam
15 to 21 inches: Silt loam
21 to 60 inches: Silt loam

Description of Playas

Setting

Landform: Playas
Down-slope shape: Concave
Across-slope shape: Concave

Properties and qualities

Slope: 0 to 1 percent

Capacity of the most limiting layer to transmit water (Ksat): Very low to moderately low (0.00 to 0.06 in/hr)
Depth to water table: About 0 inches
Frequency of ponding: Frequent
Calcium carbonate, maximum content: 10 percent
Gypsum, maximum content: 10 percent
Maximum salinity: Moderately saline to strongly saline (16.0 to 32.0 mmhos/cm)
Sodium adsorption ratio, maximum: 90.0
Available water capacity: Very low (about 1.8 inches)

Interpretive groups

Land capability (nonirrigated): 8w

Typical profile

0 to 6 inches: Silty clay
6 to 60 inches: Silty clay loam

990—Playas

Map Unit Setting

Elevation: 3,890 to 4,600 feet

Map Unit Composition

Playas: 95 percent

Description of Playas

Setting

Landform: Playas
Down-slope shape: Concave
Across-slope shape: Concave

Properties and qualities

Slope: 0 to 1 percent
Drainage class: Very poorly drained
Capacity of the most limiting layer to transmit water (Ksat): Very low to moderately low (0.00 to 0.06 in/hr)
Depth to water table: About 0 inches
Frequency of ponding: Frequent
Calcium carbonate, maximum content: 10 percent
Gypsum, maximum content: 10 percent
Maximum salinity: Moderately saline to strongly saline (16.0 to 32.0 mmhos/cm)
Sodium adsorption ratio, maximum: 90.0
Available water capacity: Very low (about 1.8 inches)

Interpretive groups

Land capability (nonirrigated): 8w

Typical profile

0 to 6 inches: Silty clay loam
6 to 60 inches: Silty clay

Soil Information for All Uses

Suitabilities and Limitations for Use

The Suitabilities and Limitations for Use section includes various soil interpretations displayed as thematic maps with a summary table for the soil map units in the selected area of interest. A single value or rating for each map unit is generated by aggregating the interpretive ratings of individual map unit components. This aggregation process is defined for each interpretation.

Building Site Development

Building site development interpretations are designed to be used as tools for evaluating soil suitability and identifying soil limitations for various construction purposes. As part of the interpretation process, the rating applies to each soil in its described condition and does not consider present land use. Example interpretations can include corrosion of concrete and steel, shallow excavations, dwellings with and without basements, small commercial buildings, local roads and streets, and lawns and landscaping.

Local Roads and Streets

Local roads and streets have an all-weather surface and carry automobile and light truck traffic all year. They have a subgrade of cut or fill soil material; a base of gravel, crushed rock, or soil material stabilized by lime or cement; and a surface of flexible material (asphalt), rigid material (concrete), or gravel with a binder. The ratings are based on the soil properties that affect the ease of excavation and grading and the traffic-supporting capacity. The properties that affect the ease of excavation and grading are depth to bedrock or a cemented pan, hardness of bedrock or a cemented pan, depth to a water table, ponding, flooding, the amount of large stones, and slope. The properties that affect the traffic-supporting capacity are soil strength (as inferred from the AASHTO group index number), subsidence, linear extensibility (shrink-swell potential), the potential for frost action, depth to a water table, and ponding.

The ratings are both verbal and numerical. Rating class terms indicate the extent to which the soils are limited by all of the soil features that affect the specified use. "Not limited" indicates that the soil has features that are very favorable for the specified use. Good performance and very low maintenance can be expected. "Somewhat limited" indicates that the soil has features that are moderately favorable for the specified use. The limitations can be overcome or minimized by special planning, design, or installation. Fair performance and moderate maintenance can be expected. "Very limited" indicates that the soil has one or more features that are unfavorable for the specified use. The limitations generally cannot be overcome without major soil reclamation, special design, or expensive installation procedures. Poor performance and high maintenance can be expected.

Numerical ratings indicate the severity of individual limitations. The ratings are shown as decimal fractions ranging from 0.01 to 1.00. They indicate gradations between the point at which a soil feature has the greatest negative impact on the use (1.00) and the point at which the soil feature is not a limitation (0.00).

The map unit components listed for each map unit in the accompanying Summary by Map Unit table in Web Soil Survey or the Aggregation Report in Soil Data Viewer are determined by the aggregation method chosen. An aggregated rating class is shown for each map unit. The components listed for each map unit are only those that have the same rating class as listed for the map unit. The percent composition of each component in a particular map unit is presented to help the user better understand the percentage of each map unit that has the rating presented.

Other components with different ratings may be present in each map unit. The ratings for all components, regardless of the map unit aggregated rating, can be viewed by generating the equivalent report from the Soil Reports tab in Web Soil Survey or from the Soil Data Mart site. Onsite investigation may be needed to validate these interpretations and to confirm the identity of the soil on a given site.

Tables—Local Roads and Streets

Local Roads and Streets— Summary by Map Unit — Humboldt County, Nevada, East Part						
Map unit symbol	Map unit name	Rating	Component name (percent)	Rating reasons (numeric values)	Acres in AOI	Percent of AOI
831	Boton-Playas association	Very limited	Boton (50%)	Low strength (1.00)	592.4	94.9%
				Shrink-swell (0.50)		
			Playas (35%)	Depth to saturated zone (1.00)		
				Shrink-swell (1.00)		
				Ponding (1.00)		
990	Playas	Very limited	Playas (95%)	Depth to saturated zone (1.00)	32.0	5.1%
				Low strength (1.00)		
				Shrink-swell (1.00)		
				Ponding (1.00)		
Totals for Area of Interest					**624.5**	**100.0%**

Local Roads and Streets— Summary by Rating Value		
Rating	Acres in AOI	Percent of AOI
Very limited	624.4	100.0%
Totals for Area of Interest	**624.5**	**100.0%**

Rating Options—Local Roads and Streets

Aggregation Method: Dominant Condition

Aggregation is the process by which a set of component attribute values is reduced to a single value that represents the map unit as a whole.

A map unit is typically composed of one or more "components". A component is either some type of soil or some nonsoil entity, e.g., rock outcrop. For the attribute being aggregated, the first step of the aggregation process is to derive one attribute value for each of a map unit's components. From this set of component attributes, the next step of the aggregation process derives a single value that represents the map unit as a whole. Once a single value for each map unit is derived, a thematic map for soil map units can be rendered. Aggregation must be done because, on any soil map, map units are delineated but components are not.

For each of a map unit's components, a corresponding percent composition is recorded. A percent composition of 60 indicates that the corresponding component typically makes up approximately 60% of the map unit. Percent composition is a critical factor in some, but not all, aggregation methods.

The aggregation method "Dominant Condition" first groups like attribute values for the components in a map unit. For each group, percent composition is set to the sum of the percent composition of all components participating in that group. These groups now represent "conditions" rather than components. The attribute value associated with the group with the highest cumulative percent composition is returned. If more than one group shares the highest cumulative percent composition, the corresponding "tie-break" rule determines which value should be returned. The "tie-break" rule indicates whether the lower or higher group value should be returned in the case of a percent composition tie.

The result returned by this aggregation method represents the dominant condition throughout the map unit only when no tie has occurred.

Component Percent Cutoff: None Specified

Components whose percent composition is below the cutoff value will not be considered. If no cutoff value is specified, all components in the database will be considered. The data for some contrasting soils of minor extent may not be in the database, and therefore are not considered.

Tie-break Rule: Higher

The tie-break rule indicates which value should be selected from a set of multiple candidate values, or which value should be selected in the event of a percent composition tie.

Shallow Excavations

Shallow excavations are trenches or holes dug to a maximum depth of 5 or 6 feet for graves, utility lines, open ditches, or other purposes. The ratings are based on the soil properties that influence the ease of digging and the resistance to sloughing. Depth to bedrock or a cemented pan, hardness of bedrock or a cemented pan, the amount of large stones, and dense layers influence the ease of digging, filling, and compacting. Depth to the seasonal high water table, flooding, and ponding may restrict the period when excavations can be made. Slope influences the ease of using machinery. Soil texture, depth to the water table, and linear extensibility (shrink-swell potential) influence the resistance to sloughing.

The ratings are both verbal and numerical. Rating class terms indicate the extent to which the soils are limited by all of the soil features that affect the specified use. "Not limited" indicates that the soil has features that are very favorable for the specified use. Good performance and very low maintenance can be expected. "Somewhat limited" indicates that the soil has features that are moderately favorable for the specified use. The limitations can be overcome or minimized by special planning, design, or installation. Fair performance and moderate maintenance can be expected. "Very limited" indicates that the soil has one or more features that are unfavorable for the specified use. The limitations generally cannot be overcome without major soil reclamation, special design, or expensive installation procedures. Poor performance and high maintenance can be expected.

Numerical ratings indicate the severity of individual limitations. The ratings are shown as decimal fractions ranging from 0.01 to 1.00. They indicate gradations between the point at which a soil feature has the greatest negative impact on the use (1.00) and the point at which the soil feature is not a limitation (0.00).

The map unit components listed for each map unit in the accompanying Summary by Map Unit table in Web Soil Survey or the Aggregation Report in Soil Data Viewer are determined by the aggregation method chosen. An aggregated rating class is shown for each map unit. The components listed for each map unit are only those that have the same rating class as listed for the map unit. The percent composition of each component in a particular map unit is presented to help the user better understand the percentage of each map unit that has the rating presented.

Other components with different ratings may be present in each map unit. The ratings for all components, regardless of the map unit aggregated rating, can be viewed by generating the equivalent report from the Soil Reports tab in Web Soil Survey or from the Soil Data Mart site. Onsite investigation may be needed to validate these interpretations and to confirm the identity of the soil on a given site.

Tables—Shallow Excavations

Shallow Excavations— Summary by Map Unit — Humboldt County, Nevada, East Part						
Map unit symbol	**Map unit name**	**Rating**	**Component name (percent)**	**Rating reasons (numeric values)**	**Acres in AOI**	**Percent of AOI**
831	Boton-Playas association	Somewhat limited	Boton (50%)	Cutbanks cave (0.10)	592.4	94.9%
990	Playas	Very limited	Playas (95%)	Depth to saturated zone (1.00)	32.0	5.1%
				Ponding (1.00)		
				Too clayey (0.72)		
				Cutbanks cave (0.10)		
Totals for Area of Interest					**624.5**	**100.0%**

Shallow Excavations— Summary by Rating Value		
Rating	**Acres in AOI**	**Percent of AOI**
Somewhat limited	592.4	94.9%
Very limited	32.0	5.1%
Totals for Area of Interest	**624.5**	**100.0%**

Rating Options—Shallow Excavations

Aggregation Method: Dominant Condition

Aggregation is the process by which a set of component attribute values is reduced to a single value that represents the map unit as a whole.

A map unit is typically composed of one or more "components". A component is either some type of soil or some nonsoil entity, e.g., rock outcrop. For the attribute being aggregated, the first step of the aggregation process is to derive one attribute value for each of a map unit's components. From this set of component attributes, the next step of the aggregation process derives a single value that represents the map unit as a whole. Once a single value for each map unit is derived, a thematic map for soil map units can be rendered. Aggregation must be done because, on any soil map, map units are delineated but components are not.

For each of a map unit's components, a corresponding percent composition is recorded. A percent composition of 60 indicates that the corresponding component typically makes up approximately 60% of the map unit. Percent composition is a critical factor in some, but not all, aggregation methods.

The aggregation method "Dominant Condition" first groups like attribute values for the components in a map unit. For each group, percent composition is set to the sum of the percent composition of all components participating in that group. These groups now represent "conditions" rather than components. The attribute value associated with the group with the highest cumulative percent composition is returned. If more than one group shares the highest cumulative percent composition, the corresponding "tie-break" rule determines which value should be returned. The "tie-break" rule indicates whether the lower or higher group value should be returned in the case of a percent composition tie.

The result returned by this aggregation method represents the dominant condition throughout the map unit only when no tie has occurred.

Component Percent Cutoff: None Specified

Components whose percent composition is below the cutoff value will not be considered. If no cutoff value is specified, all components in the database will be considered. The data for some contrasting soils of minor extent may not be in the database, and therefore are not considered.

Tie-break Rule: Higher

The tie-break rule indicates which value should be selected from a set of multiple candidate values, or which value should be selected in the event of a percent composition tie.

Construction Materials

Construction materials interpretations are tools designed to provide guidance to users in selecting a site for potential source of various materials. Individual soils or groups of soils may be selected as a potential source because they are close at hand, are the only source available, or they meets some or all of the physical or chemical properties required for the intended application. Example interpretations include roadfill, sand and gravel, topsoil and reclamation material.

Gravel Source

Gravel consists of natural aggregates (2 to 75 millimeters in diameter) suitable for commercial use with a minimum of processing. It is used in many kinds of construction. Specifications for each use vary widely. Only the probability of finding material in suitable quantity is evaluated. The suitability of the material for specific purposes is not evaluated, nor are factors that affect excavation of the material.

The properties used to evaluate the soil as a source of gravel are gradation of grain sizes (as indicated by the Unified classification of the soil), the thickness of suitable material, and the content of rock fragments. If the bottom layer of the soil contains gravel, the soil is considered a likely source regardless of thickness. The assumption is that the gravel layer below the depth of observation exceeds the minimum thickness. The ratings are for the whole soil, from the surface to a depth of about 6 feet. Coarse fragments of soft bedrock, such as shale and siltstone, are not considered to be gravel.

The soils are rated "good," "fair," or "poor" as potential sources of gravel. A rating of "good" or "fair" means that the source material is likely to be in or below the soil. The bottom layer and the thickest layer of the soils are assigned numerical ratings. These ratings indicate the likelihood that the layer is a source of gravel. The number 0.00 indicates that the layer is a poor source. The number 1.00 indicates that the layer is a good source. A number between 0.00 and 1.00 indicates the degree to which the layer is a likely source.

The map unit components listed for each map unit in the accompanying Summary by Map Unit table in Web Soil Survey or the Aggregation Report in Soil Data Viewer are determined by the aggregation method chosen. An aggregated rating class is shown for each map unit. The components listed for each map unit are only those that have the same rating class as listed for the map unit. The percent composition of each component in a particular map unit is presented to help the user better understand the percentage of each map unit that has the rating presented.

Other components with different ratings may be present in each map unit. The ratings for all components, regardless of the map unit aggregated rating, can be viewed by generating the equivalent report from the Soil Reports tab in Web Soil Survey or from the Soil Data Mart site. Onsite investigation may be needed to validate these interpretations and to confirm the identity of the soil on a given site.

Tables—Gravel Source

Gravel Source— Summary by Map Unit — Humboldt County, Nevada, East Part						
Map unit symbol	Map unit name	Rating	Component name (percent)	Rating reasons (numeric values)	Acres in AOI	Percent of AOI
831	Boton-Playas association	Poor	Boton (50%)	Bottom layer (0.00)	592.4	94.9%
				Thickest layer (0.00)		
			Playas (35%)	Bottom layer (0.00)		
				Thickest layer (0.00)		
990	Playas	Poor	Playas (95%)	Bottom layer (0.00)	32.0	5.1%
				Thickest layer (0.00)		
Totals for Area of Interest					**624.5**	**100.0%**

Gravel Source— Summary by Rating Value		
Rating	Acres in AOI	Percent of AOI
Poor	624.4	100.0%
Totals for Area of Interest	**624.5**	**100.0%**

Rating Options—Gravel Source

Aggregation Method: Dominant Condition

Component Percent Cutoff: None Specified

Tie-break Rule: Lower

Roadfill Source

Roadfill is soil material that is excavated in one place and used in road embankments in another place. The soils are rated as a source of roadfill for low embankments, generally less than 6 feet high and less exacting in design than higher embankments. The ratings are for the whole soil, from the surface to a depth of about 5 feet. It is assumed that soil layers will be mixed when the soil material is excavated and spread.

The soils are rated "good," "fair," or "poor" as potential sources of roadfill. The ratings are based on the amount of suitable material and on soil properties that affect the ease of excavation and the performance of the material after it is in place. The thickness of the suitable material is a major consideration. The ease of excavation is affected by large stones, depth to a water table, and slope. How well the soil performs in place after it has been compacted and drained is determined by its strength (as inferred from the AASHTO classification of the soil) and linear extensibility (shrink-swell potential). Normal compaction, minor processing, and other standard construction practices are assumed.

Numerical ratings between 0.00 and 0.99 are given after the specified features. These numbers indicate the degree to which the features limit the soils as sources of roadfill. The lower the number, the greater the limitation.

The map unit components listed for each map unit in the accompanying Summary by Map Unit table in Web Soil Survey or the Aggregation Report in Soil Data Viewer are determined by the aggregation method chosen. An aggregated rating class is shown for each map unit. The components listed for each map unit are only those that have the same rating class as listed for the map unit. The percent composition of each component in a particular map unit is presented to help the user better understand the percentage of each map unit that has the rating presented.

Other components with different ratings may be present in each map unit. The ratings for all components, regardless of the map unit aggregated rating, can be viewed by generating the equivalent report from the Soil Reports tab in Web Soil Survey or from the Soil Data Mart site. Onsite investigation may be needed to validate these interpretations and to confirm the identity of the soil on a given site.

Tables—Roadfill Source

Roadfill Source— Summary by Map Unit — Humboldt County, Nevada, East Part						
Map unit symbol	**Map unit name**	**Rating**	**Component name (percent)**	**Rating reasons (numeric values)**	**Acres in AOI**	**Percent of AOI**
831	Boton-Playas association	Poor	Boton (50%)	Low strength (0.00)	592.4	94.9%
				Shrink-swell (0.92)		
			Playas (35%)	Wetness depth (0.00)		
				Shrink-swell (0.12)		
990	Playas	Poor	Playas (95%)	Wetness depth (0.00)	32.0	5.1%
				Low strength (0.00)		
				Shrink-swell (0.12)		
Totals for Area of Interest					**624.5**	**100.0%**

Roadfill Source— Summary by Rating Value		
Rating	**Acres in AOI**	**Percent of AOI**
Poor	624.4	100.0%
Totals for Area of Interest	**624.5**	**100.0%**

Rating Options—Roadfill Source

Aggregation Method: Dominant Condition

Component Percent Cutoff: None Specified

Tie-break Rule: Lower

Sand Source

Sand is a natural aggregate (0.05 millimeter to 2 millimeters in diameter) suitable for commercial use with a minimum of processing. It is used in many kinds of construction. Specifications for each use vary widely. Only the probability of finding material in suitable quantity is evaluated. The suitability of the material for specific purposes is not evaluated, nor are factors that affect excavation of the material.

The properties used to evaluate the soil as a source of sand are gradation of grain sizes (as indicated by the Unified classification of the soil), the thickness of suitable material, and the content of rock fragments. If the bottom layer of the soil contains sand, the soil is considered a likely source regardless of thickness. The assumption is that the sand layer below the depth of observation exceeds the minimum thickness. The ratings are for the whole soil, from the surface to a depth of about 6 feet.

The soils are rated "good," "fair," or "poor" as potential sources of sand. A rating of "good" or "fair" means that sand is likely to be in or below the soil. The bottom layer and the thickest layer of the soil are assigned numerical ratings. These ratings indicate the likelihood that the layer is a source of sand. The number 0.00 indicates that the layer is a "poor source." The number 1.00 indicates that the layer is a "good source." A number between 0.00 and 1.00 indicates the degree to which the layer is a likely source.

The map unit components listed for each map unit in the accompanying Summary by Map Unit table in Web Soil Survey or the Aggregation Report in Soil Data Viewer are determined by the aggregation method chosen. An aggregated rating class is shown for each map unit. The components listed for each map unit are only those that have the same rating class as listed for the map unit. The percent composition of each component in a particular map unit is presented to help the user better understand the percentage of each map unit that has the rating presented.

Other components with different ratings may be present in each map unit. The ratings for all components, regardless of the map unit aggregated rating, can be viewed by generating the equivalent report from the Soil Reports tab in Web Soil Survey or from the Soil Data Mart site. Onsite investigation may be needed to validate these interpretations and to confirm the identity of the soil on a given site.

Tables—Sand Source

Sand Source— Summary by Map Unit — Humboldt County, Nevada, East Part						
Map unit symbol	**Map unit name**	**Rating**	**Component name (percent)**	**Rating reasons (numeric values)**	**Acres in AOI**	**Percent of AOI**
831	Boton-Playas association	Poor	Boton (50%)	Bottom layer (0.00)	592.4	94.9%
				Thickest layer (0.00)		
			Playas (35%)	Bottom layer (0.00)		
				Thickest layer (0.00)		
990	Playas	Poor	Playas (95%)	Bottom layer (0.00)	32.0	5.1%
				Thickest layer (0.00)		
Totals for Area of Interest					**624.5**	**100.0%**

Sand Source— Summary by Rating Value		
Rating	**Acres in AOI**	**Percent of AOI**
Poor	624.4	100.0%
Totals for Area of Interest	**624.5**	**100.0%**

Rating Options—Sand Source

Aggregation Method: Dominant Condition

Component Percent Cutoff: None Specified

Tie-break Rule: Lower

Source of Reclamation Material

Reclamation material is used in areas that have been drastically disturbed by surface mining or similar activities. When these areas are reclaimed, layers of soil material or unconsolidated geological material, or both, are replaced in a vertical sequence. The reconstructed soil favors plant growth. The ratings do not apply to quarries or other mined areas that require an offsite source of reconstruction material. The ratings are based on the soil properties that affect erosion and stability of the surface and the productive potential of the reclaimed soil. These properties include the content of sodium, salts, and calcium carbonate; reaction; available water capacity; erodibility; texture; content of rock fragments; and content of organic matter and other features that affect fertility.

The soils are rated "good," "fair," or "poor" as potential sources of reclamation material. The ratings are based on the amount of suitable material and on soil properties that affect the ease of excavation and the performance of the material after it is in place. The thickness of the suitable material is a major consideration. The ease of excavation is affected by large stones, depth to a water table, and slope. How well the soil performs in place after it has been compacted and drained is determined by its strength (as inferred from the AASHTO classification of the soil) and linear extensibility (shrink-swell potential). Normal compaction, minor processing, and other standard construction practices are assumed.

When the material is properly used in reclamation, a rating of "good" means that establishing and maintaining vegetation are relatively easy, that the surface is stable and resists erosion, and that the reclaimed soil has good potential productivity. A rating of "fair" means that vegetation can be established and maintained and the soil can be stabilized through modification of one or more properties. For satisfactory performance, it may be necessary to topdress with better suited material or add soil amendments. A rating of "poor" means that revegetation and stabilization are very difficult and costly. To establish and maintain vegetation, it is necessary to topdress with better suited material.

Numerical ratings between 0.00 and 0.99 are given after the specified features. These numbers indicate the degree to which the features limit the soils as sources of reclamation material. The lower the number, the greater the limitation.

The map unit components listed for each map unit in the accompanying Summary by Map Unit table in Web Soil Survey or the Aggregation Report in Soil Data Viewer are determined by the aggregation method chosen. An aggregated rating class is shown for each map unit. The components listed for each map unit are only those that have the same rating class as listed for the map unit. The percent composition of each component in a particular map unit is presented to help the user better understand the percentage of each map unit that has the rating presented.

Other components with different ratings may be present in each map unit. The ratings for all components, regardless of the map unit aggregated rating, can be viewed by generating the equivalent report from the Soil Reports tab in Web Soil Survey or from the Soil Data Mart site. Onsite investigation may be needed to validate these interpretations and to confirm the identity of the soil on a given site.

Tables—Source of Reclamation Material

Source of Reclamation Material— Summary by Map Unit — Humboldt County, Nevada, East Part						
Map unit symbol	**Map unit name**	**Rating**	**Component name (percent)**	**Rating reasons (numeric values)**	**Acres in AOI**	**Percent of AOI**
831	Boton-Playas association	Poor	Boton (50%)	Salinity (0.00)	592.4	94.9%
				Sodium content (0.00)		
				Too alkaline (0.00)		
				Organic matter content low (0.13)		
				Water erosion (0.37)		
			Playas (35%)	Droughty (0.00)		
				Salinity (0.00)		
				Sodium content (0.00)		
				Too clayey (0.00)		
				Too alkaline (0.00)		
990	Playas	Poor	Playas (95%)	Droughty (0.00)	32.0	5.1%
				Salinity (0.00)		
				Sodium content (0.00)		
				Too clayey (0.00)		
				Too alkaline (0.00)		
Totals for Area of Interest					**624.5**	**100.0%**

Source of Reclamation Material— Summary by Rating Value		
Rating	**Acres in AOI**	**Percent of AOI**
Poor	624.4	100.0%
Totals for Area of Interest	**624.5**	**100.0%**

Rating Options—Source of Reclamation Material

Aggregation Method: Dominant Condition

Component Percent Cutoff: None Specified

Tie-break Rule: Lower

Topsoil Source

Topsoil is used to cover an area so that vegetation can be established and maintained. The surface layer of most soils is generally preferred for topsoil because of its content of organic matter. Organic matter greatly increases the absorption and retention of moisture and nutrients for plant growth.

The upper 40 inches of a soil is evaluated for use as topsoil. Also evaluated is the reclamation potential of the borrow area. Normal compaction, minor processing, and other standard construction practices are assumed.

The soils are rated "good," "fair," or "poor" as potential sources of topsoil. The ratings are based on the soil properties that affect plant growth; the ease of excavating, loading, and spreading the material; and reclamation of the borrow area. Toxic substances, soil reaction, and the properties that are inferred from soil texture, such as available water capacity and fertility, affect plant growth. The ease of excavating, loading, and spreading is affected by rock fragments, slope, depth to a water table, soil texture, and thickness of suitable material. Reclamation of the borrow area is affected by slope, depth to a water table, rock fragments, depth to bedrock or a cemented pan, and toxic material.

Numerical ratings between 0.00 and 0.99 are given after the specified features. These numbers indicate the degree to which the features limit the soils as sources of topsoil. The lower the number, the greater the limitation.

The map unit components listed for each map unit in the accompanying Summary by Map Unit table in Web Soil Survey or the Aggregation Report in Soil Data Viewer are determined by the aggregation method chosen. An aggregated rating class is shown for each map unit. The components listed for each map unit are only those that have the same rating class as listed for the map unit. The percent composition of each component in a particular map unit is presented to help the user better understand the percentage of each map unit that has the rating presented.

Other components with different ratings may be present in each map unit. The ratings for all components, regardless of the map unit aggregated rating, can be viewed by generating the equivalent report from the Soil Reports tab in Web Soil Survey or from the Soil Data Mart site. Onsite investigation may be needed to validate these interpretations and to confirm the identity of the soil on a given site.

Tables—Topsoil Source

Topsoil Source— Summary by Map Unit — Humboldt County, Nevada, East Part						
Map unit symbol	**Map unit name**	**Rating**	**Component name (percent)**	**Rating reasons (numeric values)**	**Acres in AOI**	**Percent of AOI**
831	Boton-Playas association	Poor	Boton (50%)	Sodium content (0.00)	592.4	94.9%
				Salinity (0.00)		
			Playas (35%)	Wetness depth (0.00)		
				Sodium content (0.00)		
				Salinity (0.00)		
				Too clayey (0.00)		
990	Playas	Poor	Playas (95%)	Wetness depth (0.00)	32.0	5.1%
				Sodium content (0.00)		
				Salinity (0.00)		
				Too clayey (0.00)		
Totals for Area of Interest					**624.5**	**100.0%**

Topsoil Source— Summary by Rating Value		
Rating	**Acres in AOI**	**Percent of AOI**
Poor	624.4	100.0%
Totals for Area of Interest	**624.5**	**100.0%**

Rating Options—Topsoil Source

Aggregation Method: Dominant Condition

Component Percent Cutoff: None Specified

Tie-break Rule: Lower

Disaster Recovery Planning

Disaster recovery planning interpretations are tools for evaluating the suitability of soil for various aspects of recovery operations in response to catastrophic events such as hurricanes, earthquakes, large fires, or terrorist attacks. Example interpretations include burial of large numbers of dead cattle, disposal of large amounts of debris, and composting of vegetative materials.

Catastrophic Mortality, Large Animal Disposal, Pit

"Catastrophic mortality, large animal disposal, pit," is a method of disposing of dead animals by placing the carcasses in successive layers in an excavated pit. The carcasses are spread, compacted, and covered daily with a thin layer of soil that is excavated from the pit. When the pit is full, a final cover of soil material at least 2 feet thick is placed over the burial pit.

The interpretation is applicable to both heavily populated and sparsely populated areas. While some general observations may be made, onsite evaluation is required before the final site is selected. Improper site selection, design, or installation may cause contamination of ground water, seepage, and contamination of stream systems from surface drainage or floodwater. The risk of contamination can be reduced or eliminated by installing systems designed to eliminate or reduce the adverse effects of limiting soil properties. Ratings are for soils in their present condition. The present land use is not considered in the ratings.

Ratings are based on properties and qualities to the depth normally observed during soil mapping (approximately 6 or 7 feet). However, because pits may be as deep as 15 feet or more, geologic investigations are needed to determine the potential for pollution of ground water and to determine the design needed. These investigations, which are generally arranged by the pit developer, include examination of stratification, rock formations, and geologic conditions that might lead to the conducting of leachates to aquifers, wells, watercourses, and other water sources. The presence of hard, nonrippable bedrock, bedrock crevices, or highly permeable strata at or directly below the proposed pit bottom is undesirable because of the difficulty in excavation and the potential pollution of underground water.

Properties that influence the risk of pollution, ease of excavation, trafficability, and revegetation are major considerations. Soils that are flooded or have a water table within the depth of excavation present a potential pollution hazard and are difficult to excavate. Slope is an important consideration because it affects the work involved in road construction, the performance of the roads, and the control of surface water around the pit. It may also cause difficulty in constructing pits in which the pit bottom must be kept level and oriented to follow the contour of the land.

The ease with which the pit is dug and with which a soil can be used as daily and final cover is based largely on soil texture and consistence, which determine workability when the soil is dry and when it is wet. Soils that are plastic and sticky when wet are difficult to excavate, grade, or compact and difficult to place as a uniformly thick cover over a layer of carcasses. The uppermost part of the final cover should be soil material that favors the growth of plants. It should not contain excess sodium or salts and should not be too acid. In comparison with other horizons, the surface layer in most soils has the best workability and the highest content of organic matter. Thus, it may be desirable to stockpile the surface layer for use in the final blanketing of the filled pit area.

The ratings are both verbal and numerical. Rating class terms indicate the extent to which the soils are limited by all of the soil features that affect these uses. "Not limited" indicates that the soil has features that are very favorable for the specified use. Good performance and very low maintenance can be expected of a properly designed and installed system. "Somewhat limited" indicates that the soil has features that are moderately favorable for the specified use. The limitations can be overcome or minimized by special planning, design, or installation. Fair performance and moderate maintenance can be expected. "Very limited" indicates that the soil has one or more features that are unfavorable for the specified use. The limitations generally cannot be overcome without major soil reclamation, special design, or expensive installation procedures. Poor performance and high maintenance can be expected.

Numerical ratings indicate the severity of the individual limitations. The ratings are shown in decimal fractions ranging from 0.01 to 1.00. They indicate gradations between the point at which a soil feature has the greatest negative impact on the use (1.00) and the point at which the soil feature is not a limitation (0.00).

The map unit components listed for each map unit in the accompanying Summary by Map Unit table in Web Soil Survey or the Aggregation Report in Soil Data Viewer are determined by the aggregation method chosen. An aggregated rating class is shown for each map unit. The components listed for each map unit are only those that have the same rating class as listed for the map unit. The percent composition of each component in a particular map unit is presented to help the user better understand the percentage of each map unit that has the rating presented.

Other components with different ratings may be present in each map unit. The ratings for all components, regardless of the map unit aggregated rating, can be viewed by generating the equivalent report from the Soil Reports tab in Web Soil Survey or from the Soil Data Mart site. Onsite investigation may be needed to validate these interpretations and to confirm the identity of the soil on a given site.

Tables—Catastrophic Mortality, Large Animal Disposal, Pit

Catastrophic Mortality, Large Animal Disposal, Pit— Summary by Map Unit — Humboldt County, Nevada, East Part						
Map unit symbol	**Map unit name**	**Rating**	**Component name (percent)**	**Rating reasons (numeric values)**	**Acres in AOI**	**Percent of AOI**
831	Boton-Playas association	Very limited	Boton (50%)	Excess salt (1.00)	592.4	94.9%
				Water gathering (0.17)		
				Cutbanks cave (0.01)		
			Playas (35%)	Wetness (1.00)		
				Ponding (1.00)		
				Excess sodium (1.00)		
				Too clayey (1.00)		
				Excess salt (1.00)		
990	Playas	Very limited	Playas (95%)	Wetness (1.00)	32.0	5.1%
				Ponding (1.00)		
				Excess sodium (1.00)		
				Too clayey (1.00)		
				Excess salt (1.00)		
Totals for Area of Interest					**624.5**	**100.0%**

Catastrophic Mortality, Large Animal Disposal, Pit— Summary by Rating Value		
Rating	**Acres in AOI**	**Percent of AOI**
Very limited	624.4	100.0%
Totals for Area of Interest	**624.5**	**100.0%**

Rating Options—Catastrophic Mortality, Large Animal Disposal, Pit

Aggregation Method: Dominant Condition

Component Percent Cutoff: None Specified

Tie-break Rule: Higher

Catastrophic Mortality, Large Animal Disposal, Trench

"Catastrophic mortality, large animal disposal, trench," is a method of disposing of dead animals by placing the carcasses in successive layers in an excavated trench. The carcasses are spread, compacted, and covered daily with a thin layer of soil that is excavated from the trench. When the trench is full, a final cover of soil material at least 2 feet thick is placed over the filled trench area.

The interpretation is applicable to both heavily populated and sparsely populated areas. While some general observations may be made, onsite evaluation is required before the final site is selected. Improper site selection, design, or installation may cause contamination of ground water, seepage, and contamination of stream systems from surface drainage or floodwater. The risk of contamination can be reduced or eliminated by installing systems designed to eliminate or reduce the adverse effects of limiting soil properties. Ratings are for soils in their present condition. The present land use is not considered in the ratings.

Ratings are based on properties and qualities to the depth normally observed during soil mapping (approximately 6 or 7 feet). Because trenches may be as deep as 15 feet or more, however, geologic investigations are needed to determine the potential for pollution of ground water and to determine the design needed. These investigations, which are generally arranged by the trench developer, include examination of stratification, rock formations, and geologic conditions that might lead to the conducting of leachates to aquifers, wells, watercourses, and other water sources. The presence of hard, nonrippable bedrock, bedrock crevices, or highly permeable strata at or directly below the proposed trench bottom is undesirable because of the difficulty in excavation and the potential pollution of underground water.

Properties that influence the risk of pollution, ease of excavation, trafficability, and revegetation are major considerations. Soils that are flooded or have a water table within the depth of excavation present a potential pollution hazard and are difficult to excavate. Slope is an important consideration because it affects the work involved in road construction, the performance of the roads, and the control of surface water around the trench. It may also cause difficulty in constructing trenches in which the trench bottom must be kept level and oriented to follow the contour of the land.

The ease with which the trench is dug and with which a soil can be used as daily and final cover is based largely on soil texture and consistence, which determine workability when the soil is dry and when it is wet. Soils that are plastic and sticky when wet are difficult to excavate, grade, or compact and difficult to place as a uniformly thick cover over a layer of carcasses. The uppermost part of the final cover should be soil material that favors the growth of plants. It should not contain excess sodium or salts and should not be too acid. In comparison with other horizons, the surface layer in most soils has the best workability and the highest content of organic matter. Thus, it may be desirable to stockpile the surface layer for use in the final blanketing of the fill.

The ratings are both verbal and numerical. Rating class terms indicate the extent to which the soils are limited by all of the soil features that affect these uses. "Not limited" indicates that the soil has features that are very favorable for the specified use. Good performance and very low maintenance can be expected of a properly designed and installed system. "Somewhat limited" indicates that the soil has features that are moderately favorable for the specified use. The limitations can be overcome or minimized by special planning, design, or installation. Fair performance and moderate maintenance can be expected. "Very limited" indicates that the soil has one or more features that are unfavorable for the specified use. The limitations generally cannot be overcome without major soil reclamation, special design, or expensive installation procedures. Poor performance and high maintenance can be expected.

Numerical ratings indicate the severity of the individual limitations. The ratings are shown in decimal fractions ranging from 0.01 to 1.00. They indicate gradations between the point at which a soil feature has the greatest negative impact on the use (1.00) and the point at which the soil feature is not a limitation (0.00).

The map unit components listed for each map unit in the accompanying Summary by Map Unit table in Web Soil Survey or the Aggregation Report in Soil Data Viewer are determined by the aggregation method chosen. An aggregated rating class is shown for each map unit. The components listed for each map unit are only those that have the same rating class as listed for the map unit. The percent composition of each component in a particular map unit is presented to help the user better understand the percentage of each map unit that has the rating presented.

Other components with different ratings may be present in each map unit. The ratings for all components, regardless of the map unit aggregated rating, can be viewed by generating the equivalent report from the Soil Reports tab in Web Soil Survey or from the Soil Data Mart site. Onsite investigation may be needed to validate these interpretations and to confirm the identity of the soil on a given site.

Tables—Catastrophic Mortality, Large Animal Disposal, Trench

Catastrophic Mortality, Large Animal Disposal, Trench— Summary by Map Unit — Humboldt County, Nevada, East Part						
Map unit symbol	**Map unit name**	**Rating**	**Component name (percent)**	**Rating reasons (numeric values)**	**Acres in AOI**	**Percent of AOI**
831	Boton-Playas association	Very limited	Boton (50%)	Excess salt (1.00)	592.4	94.9%
				Water gathering (0.17)		
				Cutbanks cave (0.01)		
			Playas (35%)	Wetness (1.00)		
				Ponding (1.00)		
				Excess sodium (1.00)		
				Too clayey (1.00)		
				Excess salt (1.00)		
990	Playas	Very limited	Playas (95%)	Wetness (1.00)	32.0	5.1%
				Ponding (1.00)		
				Excess sodium (1.00)		
				Too clayey (1.00)		
				Excess salt (1.00)		
Totals for Area of Interest					**624.5**	**100.0%**

Catastrophic Mortality, Large Animal Disposal, Trench— Summary by Rating Value		
Rating	**Acres in AOI**	**Percent of AOI**
Very limited	624.4	100.0%
Totals for Area of Interest	**624.5**	**100.0%**

Rating Options—Catastrophic Mortality, Large Animal Disposal, Trench

Aggregation Method: Dominant Condition

Component Percent Cutoff: None Specified

Tie-break Rule: Higher

Clay Liner Material Source

Using natural clayey soil material to line the bottom of a landfill pit is a method of assist in the sealing the pit that may have excessively high water transmission capabilities in the soil layer below the excavation. This interpretation shows the degree and kinds of properties that make soil material suitable for use as a clay liner.

The soil is evaluated from the surface to 79 inches. The ratings are based on the soil properties that affect ease of excavation, compactability of the material, the thickness of the soil layer, reclamation of the area, and erosion from the site.

Soils that flood or have a water table within the depth of excavation present a potential pollution hazard and are difficult to excavate. Soils that are shallow to bedrock, ice, a cemented pan, or stones and boulders are limited because these features interfere with the excavation of the site or the suitability of the material. Slope is an important consideration because it affects the work involved in road construction, the performance of the roads, and the control of surface water around the borrow area.

The ratings are both verbal and numerical. Numerical ratings in the table indicate the level of suitability of the soil as a clay liner source. The ratings are shown in decimal fractions ranging from 1.00 to 0.01. They indicate gradations between the point at which a soil feature has the greatest positive impact on the use (1.00) and the point at which the soil feature has the greatest negative impact (0.00).

Rating class terms indicate the extent to which the soils are made suitable by all of the soil features that affect the suitability of soil material for this use. "Good" indicates that the soil has characteristics that are favorable for the specified use. The liner will have good performance and the material will not need any amendments to enhance its performance. "Fair" indicates that the soil has features that are moderately favorable for the specified use. The suitability as a liner may be enhanced by making a thicker layer, or adding bentonite to the soil material used for the liner. The soil may be difficult to work or contain rock fragments. "Poor" indicates that the soil has one or more features that are unfavorable for the specified use. While any material could be used as a clay liner, a poorly suited material will require large amounts of bentonite or other sealing material in order to achieve the expected level of performance.

The map unit components listed for each map unit in the accompanying Summary by Map Unit table in Web Soil Survey or the Aggregation Report in Soil Data Viewer are determined by the aggregation method chosen. An aggregated rating class is shown for each map unit. The components listed for each map unit are only those that have the same rating class as listed for the map unit. The percent composition of each component in a particular map unit is presented to help the user better understand the percentage of each map unit that has the rating presented.

Other components with different ratings may be present in each map unit. The ratings for all components, regardless of the map unit aggregated rating, can be viewed by generating the equivalent report from the Soil Reports tab in Web Soil Survey or from the Soil Data Mart site. Onsite investigation may be needed to validate these interpretations and to confirm the identity of the soil on a given site.

References:

USDA. Natural Resources Conservation Service. 1997. Agricultural Waste management Field Handbook. Chapter 10. 31 pages.

US Army Corps of Engineers. August 2004. Unified Facilities Guide Specifications No. 023377. 17 pages. http://www.ccb.org/docs/ufgshome/pdf/02377.pdf

Tables—Clay Liner Material Source

Clay Liner Material Source— Summary by Map Unit — Humboldt County, Nevada, East Part						
Map unit symbol	**Map unit name**	**Rating**	**Component name (percent)**	**Rating reasons (numeric values)**	**Acres in AOI**	**Percent of AOI**
831	Boton-Playas association	Poor	Boton (50%)	Area reclaim difficult (0.00)	592.4	94.9%
				Hard to pack (0.00)		
990	Playas	Poor	Playas (95%)	Wetness (0.00)	32.0	5.1%
				Area reclaim difficult (0.00)		
				Ponding (0.00)		
				Hard to pack (0.67)		
Totals for Area of Interest					**624.5**	**100.0%**

Clay Liner Material Source— Summary by Rating Value		
Rating	**Acres in AOI**	**Percent of AOI**
Poor	624.4	100.0%
Totals for Area of Interest	**624.5**	**100.0%**

Rating Options—Clay Liner Material Source

Aggregation Method: Dominant Condition

Component Percent Cutoff: None Specified

Tie-break Rule: Lower

Clay Liner Material Source

Using natural clayey soil material to line the bottom of a landfill pit is a method of assist in the sealing the pit that may have excessively high water transmission capabilities in the soil layer below the excavation. This interpretation shows the degree and kinds of properties that make soil material suitable for use as a clay liner.

The soil is evaluated from the surface to 79 inches. The ratings are based on the soil properties that affect ease of excavation, compactability of the material, the thickness of the soil layer, reclamation of the area, and erosion from the site.

Soils that flood or have a water table within the depth of excavation present a potential pollution hazard and are difficult to excavate. Soils that are shallow to bedrock, ice, a cemented pan, or stones and boulders are limited because these features interfere with the excavation of the site or the suitability of the material. Slope is an important consideration because it affects the work involved in road construction, the performance of the roads, and the control of surface water around the borrow area.

The ratings are both verbal and numerical. Numerical ratings in the table indicate the level of suitability of the soil as a clay liner source. The ratings are shown in decimal fractions ranging from 1.00 to 0.01. They indicate gradations between the point at which a soil feature has the greatest positive impact on the use (1.00) and the point at which the soil feature has the greatest negative impact (0.00).

Rating class terms indicate the extent to which the soils are made suitable by all of the soil features that affect the suitability of soil material for this use. "Good" indicates that the soil has characteristics that are favorable for the specified use. The liner will have good performance and the material will not need any amendments to enhance its performance. "Fair" indicates that the soil has features that are moderately favorable for the specified use. The suitability as a liner may be enhanced by making a thicker layer, or adding bentonite to the soil material used for the liner. The soil may be difficult to work or contain rock fragments. "Poor" indicates that the soil has one or more features that are unfavorable for the specified use. While any material could be used as a clay liner, a poorly suited material will require large amounts of bentonite or other sealing material in order to achieve the expected level of performance.

The map unit components listed for each map unit in the accompanying Summary by Map Unit table in Web Soil Survey or the Aggregation Report in Soil Data Viewer are determined by the aggregation method chosen. An aggregated rating class is shown for each map unit. The components listed for each map unit are only those that have the same rating class as listed for the map unit. The percent composition of each component in a particular map unit is presented to help the user better understand the percentage of each map unit that has the rating presented.

Other components with different ratings may be present in each map unit. The ratings for all components, regardless of the map unit aggregated rating, can be viewed by generating the equivalent report from the Soil Reports tab in Web Soil Survey or from the Soil Data Mart site. Onsite investigation may be needed to validate these interpretations and to confirm the identity of the soil on a given site.

References:

USDA. Natural Resources Conservation Service. 1997. Agricultural Waste management Field Handbook. Chapter 10. 31 pages.

US Army Corps of Engineers. August 2004. Unified Facilities Guide Specifications No. 023377. 17 pages. http://www.ccb.org/docs/ufgshome/pdf/02377.pdf

Tables—Clay Liner Material Source

Clay Liner Material Source— Summary by Map Unit — Humboldt County, Nevada, East Part						
Map unit symbol	**Map unit name**	**Rating**	**Component name (percent)**	**Rating reasons (numeric values)**	**Acres in AOI**	**Percent of AOI**
831	Boton-Playas association	Poor	Boton (50%)	Area reclaim difficult (0.00)	592.4	94.9%
				Hard to pack (0.00)		
990	Playas	Poor	Playas (95%)	Wetness (0.00)	32.0	5.1%
				Area reclaim difficult (0.00)		
				Ponding (0.00)		
				Hard to pack (0.67)		
Totals for Area of Interest					**624.5**	**100.0%**

Clay Liner Material Source— Summary by Rating Value		
Rating	**Acres in AOI**	**Percent of AOI**
Poor	624.4	100.0%
Totals for Area of Interest	**624.5**	**100.0%**

Rating Options—Clay Liner Material Source

Aggregation Method: Dominant Condition

Component Percent Cutoff: None Specified

Tie-break Rule: Lower

Composting Facility - Subsurface

Composting is a method of using natural processes to change vegetative debris into a useful product. This interpretation shows the degree and kind of limitations that affect the siting of a subsurface composting facility to stabilize vegetative debris produced as a result of a major disaster.

The soil is evaluated from the surface to a depth of 79 inches. The ratings are based on the soil properties that affect attenuation of suspended, soil solution, and gaseous decomposition products and microorganisms, construction and maintenance of the site, and public health. Improper site selection, design, or installation may cause contamination of ground water, seepage, and contamination of stream systems from surface drainage or floodwater.

Properties that influence the risk of pollution, ease of excavation, trafficability, and revegetation are major considerations. Soils that flood or have a water table within the depth of excavation present a potential pollution hazard and are difficult to excavate. Soils that have high saturated hydraulic conductivity (Ksat) are shallow to bedrock, ice, or a cemented pan, or have a high content of stones and boulders are limited because these features interfere with the installation, performance, and maintenance of the system. Slope is an important consideration because it affects the work involved in road construction, the performance of the roads, and the control of surface water around the excavation. It may also cause difficulty in constructing trenches which must be kept level and oriented to follow the ground contour.

Climatic factors influence the ease with which a composting facility can be maintained. Adequate precipitation to keep the mass moist, and sufficient heat to sustain biological activity are essential.

The ratings are both verbal and numerical. Numerical ratings indicate the severity of the individual limitations. The ratings are shown in decimal fractions ranging from 0.01 to 1.00. They indicate gradations between the point at which a soil feature has the greatest negative impact on the use (1.00) and the point at which the soil feature is not a limitation (0.00).

Rating class terms indicate the extent to which the soils are limited by all of the soil features that affect these uses. "Not limited" indicates that the soil has features that are very favorable for the specified use. Good performance and very low maintenance can be expected of a properly designed and installed system on these soils. "Somewhat limited" indicates that the soil has features that are moderately favorable for the specified use. The limitations can be overcome or minimized by special planning, design, or installation. Fair performance and moderate maintenance can be expected. "Very limited" indicates that the soil has one or more features that are unfavorable for the specified use. The limitations generally cannot be overcome without major soil reclamation, special design, or expensive installation procedures. Poor performance and high maintenance can be expected.

The map unit components listed for each map unit in the accompanying Summary by Map Unit table in Web Soil Survey or the Aggregation Report in Soil Data Viewer are determined by the aggregation method chosen. An aggregated rating class is shown for each map unit. The components listed for each map unit are only those that have the same rating class as listed for the map unit. The percent composition of each component in a particular map unit is presented to help the user better understand the percentage of each map unit that has the rating presented.

Other components with different ratings may be present in each map unit. The ratings for all components, regardless of the map unit aggregated rating, can be viewed by generating the equivalent report from the Soil Reports tab in Web Soil Survey or from the Soil Data Mart site. Onsite investigation may be needed to validate these interpretations and to confirm the identity of the soil on a given site.

Tables—Composting Facility - Subsurface

Composting Facility - Subsurface— Summary by Map Unit — Humboldt County, Nevada, East Part						
Map unit symbol	**Map unit name**	**Rating**	**Component name (percent)**	**Rating reasons (numeric values)**	**Acres in AOI**	**Percent of AOI**
831	Boton-Playas association	Somewhat limited	Boton (50%)	Low precipitation (0.25)	592.4	94.9%
				Water gathering (0.17)		
				Cutbanks cave (0.01)		
990	Playas	Not rated	Playas (95%)		32.0	5.1%
Totals for Area of Interest					**624.5**	**100.0%**

Composting Facility - Subsurface— Summary by Rating Value		
Rating	**Acres in AOI**	**Percent of AOI**
Somewhat limited	592.4	94.9%
Null or Not Rated	32.0	5.1%
Totals for Area of Interest	**624.5**	**100.0%**

Rating Options—Composting Facility - Subsurface

Aggregation Method: Dominant Condition

Component Percent Cutoff: None Specified

Tie-break Rule: Higher

Composting Facility - Surface

Composting is a method of using natural processes to change vegetative debris into a useful product. This interpretation evaluates the degree and kind of limitation(s) that affect the siting of a surface composting facility to stabilize vegetative debris produced as a result of a major disaster.

The soil is evaluated from the surface to a depth of 79 inches. The ratings are based on the soil properties that affect trafficability; attenuation of suspended, soil solution, and gaseous decomposition products and microorganisms; construction and maintenance of the site; and public health. Improper site selection, design, or installation may cause contamination of ground water, seepage, and contamination of stream systems from surface drainage or floodwater.

Properties that influence the risk of pollution, ease of excavation, trafficability, and revegetation are major considerations. Soils that flood or have a water table within the depth of excavation present a potential pollution hazard and are difficult to excavate. Soils that have high saturated hydraulic conductivity (Ksat), that are shallow to bedrock, ice, or a cemented pan, or that have a high content of stones and boulders are limited because these features interfere with the installation, performance, and maintenance of the system. Slope is an important consideration because it affects the work involved in road construction, the performance of the roads, and the control of surface water around the facility.

Climatic factors influence the ease with which a composting facility can be maintained. Adequate precipitation to keep the mass moist, and sufficient heat to sustain biological activity are essential.

The ratings are both verbal and numerical. Numerical ratings indicate the severity of the individual limitations. The ratings are shown in decimal fractions ranging from 0.01 to 1.00. They indicate gradations between the point at which a soil feature has the greatest limitation on the use (1.00) and the point at which the soil feature is not a limitation (0.00).

Rating class terms indicate the extent to which the soils are limited by all of the soil features that affect these uses. "Not limited" indicates that the soil has features that are very favorable for the specified use. Good performance and very low maintenance can be expected of a properly designed and installed system on these soils. "Somewhat limited" indicates that the soil has features that are moderately favorable for the specified use. The limitations can be overcome or minimized by special planning, design, or installation. Fair performance and moderate maintenance can be expected. "Very limited" indicates that the soil has one or more features that are unfavorable for the specified use. The limitations generally cannot be overcome without major soil reclamation, special design, or expensive installation procedures. Poor performance and high maintenance can be expected.

The map unit components listed for each map unit in the accompanying Summary by Map Unit table in Web Soil Survey or the Aggregation Report in Soil Data Viewer are determined by the aggregation method chosen. An aggregated rating class is shown for each map unit. The components listed for each map unit are only those that have the same rating class as listed for the map unit. The percent composition of each component in a particular map unit is presented to help the user better understand the percentage of each map unit that has the rating presented.

Other components with different ratings may be present in each map unit. The ratings for all components, regardless of the map unit aggregated rating, can be viewed by generating the equivalent report from the Soil Reports tab in Web Soil Survey or from the Soil Data Mart site. Onsite investigation may be needed to validate these interpretations and to confirm the identity of the soil on a given site.

Tables—Composting Facility - Surface

Composting Facility - Surface— Summary by Map Unit — Humboldt County, Nevada, East Part						
Map unit symbol	**Map unit name**	**Rating**	**Component name (percent)**	**Rating reasons (numeric values)**	**Acres in AOI**	**Percent of AOI**
831	Boton-Playas association	Very limited	Boton (50%)	Low strength (1.00)	592.4	94.9%
				Low precipitation (0.25)		
990	Playas	Not rated	Playas (95%)		32.0	5.1%
Totals for Area of Interest					**624.5**	**100.0%**

Composting Facility - Surface— Summary by Rating Value		
Rating	**Acres in AOI**	**Percent of AOI**
Very limited	592.4	94.9%
Null or Not Rated	32.0	5.1%
Totals for Area of Interest	**624.5**	**100.0%**

Rating Options—Composting Facility - Surface

Aggregation Method: Dominant Condition

Component Percent Cutoff: None Specified

Tie-break Rule: Higher

Composting Medium and Final Cover

Using natural soil material to assist in the biological degradation of organic material and as a capping for the mass of compost is common practice. This interpretation shows the degree and kinds of properties that make soil material suitable for use as composting medium and final cover material. Each soil is rated as a potential source of such material.

The soil is evaluated from the surface to 79 inches. The ratings are based on the soil properties that affect ease of excavation, workability of the material, the thickness of the soil layer, reclamation of the area, and erosion from the site.

Soils that flood or have a water table within the depth of excavation present a potential pollution hazard and are difficult to excavate. Soils that are shallow to bedrock, ice, a cemented pan, or stones and boulders are limited because these features interfere with the excavation of the site or the suitability of the material. Slope is an important consideration because it affects the work involved in road construction, the performance of the roads, and the control of surface water around the borrow area.

The ratings are both verbal and numerical. Numerical ratings in indicate the level of suitability of the soil as a composting medium and final cover material source. The ratings are shown in decimal fractions ranging from 1.00 to 0.01. They indicate gradations between the point at which a soil feature has the greatest positive impact on the use (1.00) and the point at which the soil feature has the greatest negative impact (0.00).

Rating class terms indicate the extent to which the soils are made suitable by all of the soil features that affect the suitability of soil material for this use. "Good" indicates that the soil has characteristics that are favorable for the specified use. The compost medium or final cover material will have good performance. "Fair" indicates that the soil has features that are moderately favorable for the specified use. The soil may be somewhat difficult to work or contain rock fragments. "Poor" indicates that the soil has one or more features that are unfavorable for the specified use. While any material could be used as a composting medium and final cover material, a poorly suited material will require large amounts of amendments or screening in order to achieve the expected level of performance.

The map unit components listed for each map unit in the accompanying Summary by Map Unit table in Web Soil Survey or the Aggregation Report in Soil Data Viewer are determined by the aggregation method chosen. An aggregated rating class is shown for each map unit. The components listed for each map unit are only those that have the same rating class as listed for the map unit. The percent composition of each component in a particular map unit is presented to help the user better understand the percentage of each map unit that has the rating presented.

Other components with different ratings may be present in each map unit. The ratings for all components, regardless of the map unit aggregated rating, can be viewed by generating the equivalent report from the Soil Reports tab in Web Soil Survey or from the Soil Data Mart site. Onsite investigation may be needed to validate these interpretations and to confirm the identity of the soil on a given site.

Tables—Composting Medium and Final Cover

Composting Medium and Final Cover— Summary by Map Unit — Humboldt County, Nevada, East Part						
Map unit symbol	**Map unit name**	**Rating**	**Component name (percent)**	**Rating reasons (numeric values)**	**Acres in AOI**	**Percent of AOI**
831	Boton-Playas association	Poor	Boton (50%)	Excess sodium (0.00)	592.4	94.9%
990	Playas	Poor	Playas (95%)	Too clayey (0.00)	32.0	5.1%
				Hard to reclaim (dense layer) (0.00)		
				Wetness depth (0.00)		
				Excess sodium (0.00)		
				Excess salt (0.00)		
Totals for Area of Interest					**624.5**	**100.0%**

Composting Medium and Final Cover— Summary by Rating Value		
Rating	**Acres in AOI**	**Percent of AOI**
Poor	624.4	100.0%
Totals for Area of Interest	**624.5**	**100.0%**

Rating Options—Composting Medium and Final Cover

Aggregation Method: Dominant Condition

Component Percent Cutoff: None Specified

Tie-break Rule: Lower

Rubble and Debris Disposal, Large-Scale Event

Burial of rubble and debris in an expeditiously constructed landfill is a method of disposing of material that has been rendered unsafe and unusable by the effects of a large-scale disaster, either natural or man-made, often affecting tens of counties or parishes. Many homes and business structures are rendered unfit for occupancy, either by destruction or contamination. Such a landfill involves excavating a large pit or trench, placing the rubble and debris in the trench, and covering each layer with a blanket of soil material. A final blanket of cover material is placed over the whole facility when completed.

This interpretation shows the degree and kind of limitations that affect a soil's use for such a landfill. The soil is evaluated from the surface to 79 inches. An on-site investigation to greater depth will be needed for final site acceptance. The ratings are based on the soil properties that affect attenuation of suspended, soil solution, and gaseous decomposition products and microorganisms; construction and maintenance of the site; and public health. Improper site selection, design, or installation may cause contamination of ground water, seepage, and contamination of stream systems from surface drainage or floodwater.

Properties that influence the risk of pollution, ease of excavation, trafficability, and revegetation are major considerations. Soils that flood or have a water table within the depth of excavation present a potential pollution hazard and are difficult to excavate. Soils that have high saturated hydraulic conductivity (Ksat) or are shallow to bedrock, ice, a cemented pan, or stones and boulders are limited because these features interfere with the installation, performance, and maintenance of the system. Slope is an important consideration because it affects the work involved in road construction, the performance of the roads, and the control of surface water around the excavation. It may also cause difficulty in constructing trenches for which the trench or pit bottom must be kept level and oriented to follow the ground contour.

The ease with which the trench or pit is dug and with which a soil can be used as daily and final covers is based largely on texture and consistence of the soil which affect the workability of the soil both when dry and when wet. Soils that are plastic and sticky when wet are difficult to excavate, grade, or compact and difficult to place as a uniformly thick cover over a layer of rubble or debris. The uppermost part of the final cover should be soil material that is favorable for the growth of plants. It should not contain excess sodium or salt and should not be too acid. In comparison with other horizons, the A horizon in most soils has the best workability and the highest content of organic matter. Thus, for a rubble and debris disposal operation it may be desirable to stockpile the surface layer for use in the final blanketing of the filled area.

The ratings are both verbal and numerical. Numerical ratings indicate the severity of the individual limitations. The ratings are shown in decimal fractions ranging from 0.01 to 1.00. They indicate gradations between the point at which a soil feature has the greatest negative impact on the use (1.00) and the point at which the soil feature is not a limitation (0.00).

Rating class terms indicate the extent to which the soils are limited by all of the soil features that affect these uses. "Not limited" indicates that the soil has features that are very favorable for the specified use. Good performance and very low maintenance can be expected of a properly designed and installed system on these soils. "Somewhat limited" indicates that the soil has features that are moderately favorable for the specified use. The limitations can be overcome or minimized by special planning, design, or installation. Fair performance and moderate maintenance can be expected. "Severely limited" indicates that the soil has one or more features that are unfavorable for the specified use. The limitations generally cannot be overcome without major soil reclamation, special design, or expensive installation procedures. Poor performance and high maintenance can be expected.

The map unit components listed for each map unit in the accompanying Summary by Map Unit table in Web Soil Survey or the Aggregation Report in Soil Data Viewer are determined by the aggregation method chosen. An aggregated rating class is shown for each map unit. The components listed for each map unit are only those that have the same rating class as listed for the map unit. The percent composition of each component in a particular map unit is presented to help the user better understand the percentage of each map unit that has the rating presented.

Other components with different ratings may be present in each map unit. The ratings for all components, regardless of the map unit aggregated rating, can be viewed by generating the equivalent report from the Soil Reports tab in Web Soil Survey or from the Soil Data Mart site. Onsite investigation may be needed to validate these interpretations and to confirm the identity of the soil on a given site.

Tables—Rubble and Debris Disposal, Large-Scale Event

Rubble and Debris Disposal, Large-Scale Event— Summary by Map Unit — Humboldt County, Nevada, East Part						
Map unit symbol	**Map unit name**	**Rating**	**Component name (percent)**	**Rating reasons (numeric values)**	**Acres in AOI**	**Percent of AOI**
831	Boton-Playas association	Severely limited	Boton (50%)	Excess salt (1.00)	592.4	94.9%
				Water gathering (0.17)		
				Cutbanks cave (0.01)		
			Playas (35%)	Wetness (1.00)		
				Ponding (1.00)		
				Excess sodium (1.00)		
				Too clayey (1.00)		
				Excess salt (1.00)		
990	Playas	Severely limited	Playas (95%)	Wetness (1.00)	32.0	5.1%
				Ponding (1.00)		
				Excess sodium (1.00)		
				Too clayey (1.00)		
				Excess salt (1.00)		
Totals for Area of Interest					**624.5**	**100.0%**

Rubble and Debris Disposal, Large-Scale Event— Summary by Rating Value		
Rating	**Acres in AOI**	**Percent of AOI**
Severely limited	624.4	100.0%
Totals for Area of Interest	**624.5**	**100.0%**

Rating Options—Rubble and Debris Disposal, Large-Scale Event

Aggregation Method: Dominant Condition

Component Percent Cutoff: None Specified

Tie-break Rule: Higher

Sanitary Facilities

Sanitary Facilities interpretations are tools designed to guide the user in site selection for the safe disposal of sewage and solid waste. Example interpretations include septic tank absorption fields, sewage lagoons, and sanitary landfills.

Daily Cover for Landfill

Daily cover for landfill is the soil material that is used to cover compacted solid waste in a sanitary landfill. The soil material is obtained offsite, transported to the landfill, and spread over the waste. The ratings also apply to the final cover for a landfill. They are based on the soil properties that affect workability, the ease of digging, and the ease of moving and spreading the material over the refuse daily during wet and dry periods. These properties include soil texture, depth to a water table, ponding, rock fragments, slope, depth to bedrock or a cemented pan, reaction, and content of salts, sodium, or lime.

Loamy or silty soils that are free of large stones and excess gravel are the best cover for a landfill. Clayey soils may be sticky and difficult to spread; sandy soils are subject to wind erosion.

Slope affects the ease of excavation and of moving the cover material. Also, it can influence runoff, erosion, and reclamation of the borrow area.

The soil material used as the final cover for a landfill should be suitable for plants. It should not have excess sodium, salts, or lime and should not be too acid. After soil material has been removed, the soil material remaining in the borrow area must be thick enough over bedrock, a cemented pan, or the water table to permit revegetation. Some damage to the borrow area is expected, however, and plant growth may not be optimum.

This information is intended for land use planning, for evaluating land use alternatives, and for planning site investigations prior to design and construction. The information, however, has limitations. For example, estimates and other data generally apply only to that part of the soil between the surface and a depth of 5 to 7 feet. Because of the map scale, small areas of different soils may be included within the mapped areas of a specific soil.

The information is not site specific and does not eliminate the need for onsite investigation of the soils or for testing and analysis by personnel experienced in the design and construction of engineering works.

Government ordinances and regulations that restrict certain land uses or impose specific design criteria were not considered in preparing the ratings. Local ordinances and regulations should be considered in planning, in site selection, and in design.

The ratings are both verbal and numerical. Rating class terms indicate the extent to which the soils are limited by all of the soil features that affect these uses. "Not limited" indicates that the soil has features that are very favorable for the specified use. Good performance and very low maintenance can be expected. "Somewhat limited" indicates that the soil has features that are moderately favorable for the specified use. The limitations can be overcome or minimized by special planning, design, or installation. Fair performance and moderate maintenance can be expected. "Very limited" indicates that the soil has one or more features that are unfavorable for the specified use. The limitations generally cannot be overcome without major soil reclamation, special design, or expensive installation procedures. Poor performance and high maintenance can be expected.

Numerical ratings in the table indicate the severity of individual limitations. The ratings are shown as decimal fractions ranging from 0.01 to 1.00. They indicate gradations between the point at which a soil feature has the greatest negative impact on the use (1.00) and the point at which the soil feature is not a limitation (0.00).

The map unit components listed for each map unit in the accompanying Summary by Map Unit table in Web Soil Survey or the Aggregation Report in Soil Data Viewer are determined by the aggregation method chosen. An aggregated rating class is shown for each map unit. The components listed for each map unit are only those that have the same rating class as listed for the map unit. The percent composition of each component in a particular map unit is presented to help the user better understand the percentage of each map unit that has the rating presented.

Other components with different ratings may be present in each map unit. The ratings for all components, regardless of the map unit aggregated rating, can be viewed by generating the equivalent report from the Soil Reports tab in Web Soil Survey or from the Soil Data Mart site. Onsite investigation may be needed to validate these interpretations and to confirm the identity of the soil on a given site.

Tables—Daily Cover for Landfill

Daily Cover for Landfill— Summary by Map Unit — Humboldt County, Nevada, East Part						
Map unit symbol	**Map unit name**	**Rating**	**Component name (percent)**	**Rating reasons (numeric values)**	**Acres in AOI**	**Percent of AOI**
831	Boton-Playas association	Very limited	Playas (35%)	Depth to saturated zone (1.00)	592.4	94.9%
				Sodium content (1.00)		
				Hard to compact (1.00)		
				Salinity (1.00)		
				Ponding (1.00)		
990	Playas	Very limited	Playas (95%)	Depth to saturated zone (1.00)	32.0	5.1%
				Sodium content (1.00)		
				Too clayey (1.00)		
				Hard to compact (1.00)		
				Salinity (1.00)		
Totals for Area of Interest					**624.5**	**100.0%**

Daily Cover for Landfill— Summary by Rating Value		
Rating	**Acres in AOI**	**Percent of AOI**
Very limited	624.4	100.0%
Totals for Area of Interest	**624.5**	**100.0%**

Rating Options—Daily Cover for Landfill

Aggregation Method: Most Limiting

Aggregation is the process by which a set of component attribute values is reduced to a single value that represents the map unit as a whole.

A map unit is typically composed of one or more "components". A component is either some type of soil or some nonsoil entity, e.g., rock outcrop. For the attribute being aggregated, the first step of the aggregation process is to derive one attribute value for each of a map unit's components. From this set of component attributes, the next step of the aggregation process derives a single value that represents the map unit as a whole. Once a single value for each map unit is derived, a thematic map for soil map units can be rendered. Aggregation must be done because, on any soil map, map units are delineated but components are not.

For each of a map unit's components, a corresponding percent composition is recorded. A percent composition of 60 indicates that the corresponding component

typically makes up approximately 60% of the map unit. Percent composition is a critical factor in some, but not all, aggregation methods.

The aggregation method "Most Limiting" is suitable only for attributes that correspond to a programmatically generated soil interpretation. Such an interpretation attempts to determine if a soil is suitable for a particular use. The results for such an interpretation can be ranked from least limiting (or most suitable) to most limiting (or least suitable). For this aggregation method, the most limiting result among all components of the map unit is returned.

The result returned by this aggregation method may or may not represent the dominant condition throughout the map unit. The result may well be based on the limitations of a map unit component of very minor extent. If one were making a decision based on this result, that decision would be based on the most conservative, or most pessimistic, result.

Component Percent Cutoff: None Specified

Components whose percent composition is below the cutoff value will not be considered. If no cutoff value is specified, all components in the database will be considered. The data for some contrasting soils of minor extent may not be in the database, and therefore are not considered.

Tie-break Rule: Higher

The tie-break rule indicates which value should be selected from a set of multiple candidate values, or which value should be selected in the event of a percent composition tie.

Sanitary Landfill (Area)

In an "area sanitary landfill," solid waste is placed in successive layers on the surface of the soil. The waste is spread, compacted, and covered daily with a thin layer of soil from a source away from the site. A final cover of soil material at least 2 feet thick is placed over the completed landfill. A landfill must be able to bear heavy vehicular traffic. It can result in the pollution of ground water. Ease of excavation and revegetation should be considered.

The ratings are based on the soil properties that affect trafficability and the risk of pollution. These properties include flooding, saturated hydraulic conductivity (Ksat), depth to a water table, ponding, slope, and depth to bedrock or a cemented pan. Flooding is a serious problem because it can result in pollution in areas downstream from the landfill. If Ksat is too rapid or if fractured bedrock, a fractured cemented pan, or the water table is close to the surface, the leachate can contaminate the water supply. Slope is a consideration because of the extra grading required to maintain roads in the steeper areas of the landfill. Also, leachate may flow along the surface of the soils in the steeper areas and cause difficult seepage problems.

The ratings are both verbal and numerical. Rating class terms indicate the extent to which the soils are limited by all of the soil features that affect the specified use. "Not limited" indicates that the soil has features that are very favorable for the specified use. Good performance and very low maintenance can be expected. "Somewhat limited" indicates that the soil has features that are moderately favorable for the specified use. The limitations can be overcome or minimized by special planning, design, or installation. Fair performance and moderate maintenance can be expected. "Very limited" indicates that the soil has one or more features that are unfavorable for the specified use. The limitations generally cannot be overcome without major soil reclamation, special design, or expensive installation procedures. Poor performance and high maintenance can be expected.

Numerical ratings indicate the severity of individual limitations. The ratings are shown as decimal fractions ranging from 0.01 to 1.00. They indicate gradations between the point at which a soil feature has the greatest negative impact on the use (1.00) and the point at which the soil feature is not a limitation (0.00).

The map unit components listed for each map unit in the accompanying Summary by Map Unit table in Web Soil Survey or the Aggregation Report in Soil Data Viewer are determined by the aggregation method chosen. An aggregated rating class is shown for each map unit. The components listed for each map unit are only those that have the same rating class as listed for the map unit. The percent composition of each component in a particular map unit is presented to help the user better understand the percentage of each map unit that has the rating presented.

Other components with different ratings may be present in each map unit. The ratings for all components, regardless of the map unit aggregated rating, can be viewed by generating the equivalent report from the Soil Reports tab in Web Soil Survey or from the Soil Data Mart site. Onsite investigation may be needed to validate these interpretations and to confirm the identity of the soil on a given site.

Tables—Sanitary Landfill (Area)

Sanitary Landfill (Area)— Summary by Map Unit — Humboldt County, Nevada, East Part						
Map unit symbol	Map unit name	Rating	Component name (percent)	Rating reasons (numeric values)	Acres in AOI	Percent of AOI
831	Boton-Playas association	Very limited	Playas (35%)	Depth to saturated zone (1.00)	592.4	94.9%
				Ponding (1.00)		
990	Playas	Very limited	Playas (95%)	Depth to saturated zone (1.00)	32.0	5.1%
				Ponding (1.00)		
Totals for Area of Interest					**624.5**	**100.0%**

Sanitary Landfill (Area)— Summary by Rating Value		
Rating	Acres in AOI	Percent of AOI
Very limited	624.4	100.0%
Totals for Area of Interest	**624.5**	**100.0%**

Rating Options—Sanitary Landfill (Area)

Aggregation Method: Most Limiting

Aggregation is the process by which a set of component attribute values is reduced to a single value that represents the map unit as a whole.

A map unit is typically composed of one or more "components". A component is either some type of soil or some nonsoil entity, e.g., rock outcrop. For the attribute being aggregated, the first step of the aggregation process is to derive one attribute value for each of a map unit's components. From this set of component attributes, the next step of the aggregation process derives a single value that represents the map unit as a whole. Once a single value for each map unit is derived, a thematic map for soil map units can be rendered. Aggregation must be done because, on any soil map, map units are delineated but components are not.

For each of a map unit's components, a corresponding percent composition is recorded. A percent composition of 60 indicates that the corresponding component typically makes up approximately 60% of the map unit. Percent composition is a critical factor in some, but not all, aggregation methods.

The aggregation method "Most Limiting" is suitable only for attributes that correspond to a programmatically generated soil interpretation. Such an interpretation attempts to determine if a soil is suitable for a particular use. The results for such an interpretation can be ranked from least limiting (or most suitable) to most limiting (or least suitable). For this aggregation method, the most limiting result among all components of the map unit is returned.

The result returned by this aggregation method may or may not represent the dominant condition throughout the map unit. The result may well be based on the limitations of a map unit component of very minor extent. If one were making a decision based on this result, that decision would be based on the most conservative, or most pessimistic, result.

Component Percent Cutoff: None Specified

Components whose percent composition is below the cutoff value will not be considered. If no cutoff value is specified, all components in the database will be considered. The data for some contrasting soils of minor extent may not be in the database, and therefore are not considered.

Tie-break Rule: Higher

The tie-break rule indicates which value should be selected from a set of multiple candidate values, or which value should be selected in the event of a percent composition tie.

Sanitary Landfill (Trench)

A "trench sanitary landfill" is an area where solid waste is placed in successive layers in an excavated trench. The waste is spread, compacted, and covered daily with a thin layer of soil excavated at the site. When the trench is full, a final cover of soil material at least 2 feet thick is placed over the landfill. A landfill must be able to bear heavy vehicular traffic. It can result in the pollution of ground water. Ease of excavation and revegetation should be considered.

The ratings are based on the soil properties that affect the risk of pollution, the ease of excavation, trafficability, and revegetation. These properties include saturated hydraulic conductivity (Ksat), depth to bedrock or a cemented pan, depth to a water table, ponding, slope, flooding, texture, stones and boulders, highly organic layers, soil reaction, and content of salts and sodium. Unless otherwise stated, the ratings apply only to that part of the soil within a depth of about 6 feet. For deeper trenches, onsite investigation may be needed.

Hard, nonrippable bedrock, creviced bedrock, or highly permeable strata at or directly below the proposed trench bottom can affect the ease of excavation and the hazard of ground-water pollution. Slope affects construction of the trenches and the movement of surface water around the landfill. It also affects the construction and performance of roads in areas of the landfill.

Soil texture and consistence affect the ease with which the trench is dug and the ease with which the soil can be used as daily or final cover. They determine the workability of the soil when dry and when wet. Soils that are plastic and sticky when wet are difficult to excavate, grade, or compact and are difficult to place as a uniformly thick cover over a layer of refuse.

The soil material used as the final cover for a trench landfill should be suitable for plants. It should not have excess sodium or salts and should not be too acid. The surface layer generally has the best workability, the highest content of organic matter, and the best potential for plants. Material from the surface layer should be stockpiled for use as the final cover.

The ratings are both verbal and numerical. Rating class terms indicate the extent to which the soils are limited by all of the soil features that affect the specified use. "Not limited" indicates that the soil has features that are very favorable for the specified use. Good performance and very low maintenance can be expected. "Somewhat limited" indicates that the soil has features that are moderately favorable for the specified use. The limitations can be overcome or minimized by special planning, design, or installation. Fair performance and moderate maintenance can be expected. "Very limited" indicates that the soil has one or more features that are unfavorable for the specified use. The limitations generally cannot be overcome without major soil reclamation, special design, or expensive installation procedures. Poor performance and high maintenance can be expected.

Numerical ratings indicate the severity of individual limitations. The ratings are shown as decimal fractions ranging from 0.01 to 1.00. They indicate gradations between the point at which a soil feature has the greatest negative impact on the use (1.00) and the point at which the soil feature is not a limitation (0.00).

The map unit components listed for each map unit in the accompanying Summary by Map Unit table in Web Soil Survey or the Aggregation Report in Soil Data Viewer are determined by the aggregation method chosen. An aggregated rating class is shown for each map unit. The components listed for each map unit are only those that have the same rating class as listed for the map unit. The percent composition of each component in a particular map unit is presented to help the user better understand the percentage of each map unit that has the rating presented.

Other components with different ratings may be present in each map unit. The ratings for all components, regardless of the map unit aggregated rating, can be viewed by generating the equivalent report from the Soil Reports tab in Web Soil Survey or from the Soil Data Mart site. Onsite investigation may be needed to validate these interpretations and to confirm the identity of the soil on a given site.

Tables—Sanitary Landfill (Trench)

Sanitary Landfill (Trench)— Summary by Map Unit — Humboldt County, Nevada, East Part						
Map unit symbol	Map unit name	Rating	Component name (percent)	Rating reasons (numeric values)	Acres in AOI	Percent of AOI
831	Boton-Playas association	Very limited	Boton (50%)	Excess salt (1.00)	592.4	94.9%
			Playas (35%)	Depth to saturated zone (1.00)		
				Excess sodium (1.00)		
				Excess salt (1.00)		
				Ponding (1.00)		
				Too clayey (0.50)		
990	Playas	Very limited	Playas (95%)	Depth to saturated zone (1.00)	32.0	5.1%
				Excess sodium (1.00)		
				Too clayey (1.00)		
				Excess salt (1.00)		
				Ponding (1.00)		
Totals for Area of Interest					**624.5**	**100.0%**

Sanitary Landfill (Trench)— Summary by Rating Value		
Rating	Acres in AOI	Percent of AOI
Very limited	624.4	100.0%
Totals for Area of Interest	**624.5**	**100.0%**

Rating Options—Sanitary Landfill (Trench)

Aggregation Method: Most Limiting

Aggregation is the process by which a set of component attribute values is reduced to a single value that represents the map unit as a whole.

A map unit is typically composed of one or more "components". A component is either some type of soil or some nonsoil entity, e.g., rock outcrop. For the attribute being aggregated, the first step of the aggregation process is to derive one attribute value for each of a map unit's components. From this set of component attributes, the next step of the aggregation process derives a single value that represents the map unit as a whole. Once a single value for each map unit is derived, a thematic map for soil map units can be rendered. Aggregation must be done because, on any soil map, map units are delineated but components are not.

For each of a map unit's components, a corresponding percent composition is recorded. A percent composition of 60 indicates that the corresponding component

typically makes up approximately 60% of the map unit. Percent composition is a critical factor in some, but not all, aggregation methods.

The aggregation method "Most Limiting" is suitable only for attributes that correspond to a programmatically generated soil interpretation. Such an interpretation attempts to determine if a soil is suitable for a particular use. The results for such an interpretation can be ranked from least limiting (or most suitable) to most limiting (or least suitable). For this aggregation method, the most limiting result among all components of the map unit is returned.

The result returned by this aggregation method may or may not represent the dominant condition throughout the map unit. The result may well be based on the limitations of a map unit component of very minor extent. If one were making a decision based on this result, that decision would be based on the most conservative, or most pessimistic, result.

Component Percent Cutoff: *None Specified*

Components whose percent composition is below the cutoff value will not be considered. If no cutoff value is specified, all components in the database will be considered. The data for some contrasting soils of minor extent may not be in the database, and therefore are not considered.

Tie-break Rule: Higher

The tie-break rule indicates which value should be selected from a set of multiple candidate values, or which value should be selected in the event of a percent composition tie.

Waste Management

Waste Management interpretations are tools designed to guide the user in evaluating soils for use of organic wastes and wastewater as productive resources. Example interpretations include land application of manure, food processing waste, and municipal sewage sludge, and disposal of wastewater by irrigation or overland flow process.

Disposal of Wastewater by Irrigation

Wastewater includes municipal and food-processing wastewater and effluent from lagoons or storage ponds. Municipal wastewater is the waste stream from a municipality. It contains domestic waste and may contain industrial waste. It may have received primary or secondary treatment. It is rarely untreated sewage. Food-processing wastewater results from the preparation of fruits, vegetables, milk, cheese, and meats for public consumption. In places it is high in content of sodium and chloride. The effluent in lagoons and storage ponds is from facilities used to treat or store food-processing wastewater or domestic or animal waste. Domestic and food-processing wastewater is very dilute, and the effluent from the facilities that treat or store it commonly is very low in content of carbonaceous and nitrogenous material; the content of nitrogen commonly ranges from 10 to 30 milligrams per liter. The wastewater from animal waste treatment lagoons or storage ponds, however, has much higher concentrations of these materials, mainly because the manure has not been diluted as much as the domestic waste. The content of nitrogen in this wastewater generally ranges from 50 to 2,000 milligrams per liter. When wastewater is applied, checks should be made to ensure that nitrogen, heavy metals, and salts are not added in excessive amounts.

Disposal of wastewater by irrigation not only disposes of municipal wastewater and wastewater from food-processing plants, lagoons, and storage ponds but also can improve crop production by increasing the amount of water available to crops. The ratings are based on the soil properties that affect the design, construction, management, and performance of the irrigation system. The properties that affect design and management include the sodium adsorption ratio, depth to a water table, ponding, available water capacity, saturated hydraulic conductivity (Ksat), slope, and flooding. The properties that affect construction include stones, cobbles, depth to bedrock or a cemented pan, depth to a water table, and ponding. The properties that affect performance include depth to bedrock or a cemented pan, bulk density, the sodium adsorption ratio, salinity, reaction, and the cation-exchange capacity, which is used to estimate the capacity of a soil to adsorb heavy metals. Permanently frozen soils are not suitable for disposal of wastewater by irrigation.

The ratings are both verbal and numerical. Rating class terms indicate the extent to which the soils are limited by all of the soil features that affect agricultural waste management. "Not limited" indicates that the soil has features that are very favorable for the specified use. Good performance and very low maintenance can be expected. "Somewhat limited" indicates that the soil has features that are moderately favorable for the specified use. The limitations can be overcome or minimized by special planning, design, or installation. Fair performance and moderate maintenance can be expected. "Very limited" indicates that the soil has one or more features that are unfavorable for the specified use. The limitations generally cannot be overcome without major soil reclamation, special design, or expensive installation procedures. Poor performance and high maintenance can be expected.

Numerical ratings indicate the severity of individual limitations. The ratings are shown as decimal fractions ranging from 0.01 to 1.00. They indicate gradations between the point at which a soil feature has the greatest negative impact on the use (1.00) and the point at which the soil feature is not a limitation (0.00).

The map unit components listed for each map unit in the accompanying Summary by Map Unit table in Web Soil Survey or the Aggregation Report in Soil Data Viewer are determined by the aggregation method chosen. An aggregated rating class is shown for each map unit. The components listed for each map unit are only those that have the same rating class as listed for the map unit. The percent composition of each component in a particular map unit is presented to help the user better understand the percentage of each map unit that has the rating presented.

Other components with different ratings may be present in each map unit. The ratings for all components, regardless of the map unit aggregated rating, can be viewed by generating the equivalent report from the Soil Reports tab in Web Soil Survey or from the Soil Data Mart site. Onsite investigation may be needed to validate these interpretations and to confirm the identity of the soil on a given site.

Tables—Disposal of Wastewater by Irrigation

Disposal of Wastewater by Irrigation— Summary by Map Unit — Humboldt County, Nevada, East Part						
Map unit symbol	**Map unit name**	**Rating**	**Component name (percent)**	**Rating reasons (numeric values)**	**Acres in AOI**	**Percent of AOI**
831	Boton-Playas association	Very limited	Boton (50%)	Sodium content (1.00)	592.4	94.9%
				Slow water movement (0.37)		
			Playas (35%)	Droughty (1.00)		
				Slow water movement (1.00)		
				Depth to saturated zone (1.00)		
				Salinity (1.00)		
				Sodium content (1.00)		
990	Playas	Very limited	Playas (95%)	Droughty (1.00)	32.0	5.1%
				Slow water movement (1.00)		
				Depth to saturated zone (1.00)		
				Salinity (1.00)		
				Sodium content (1.00)		
Totals for Area of Interest					**624.5**	**100.0%**

Disposal of Wastewater by Irrigation— Summary by Rating Value		
Rating	**Acres in AOI**	**Percent of AOI**
Very limited	624.4	100.0%
Totals for Area of Interest	**624.5**	**100.0%**

Rating Options—Disposal of Wastewater by Irrigation

Aggregation Method: Most Limiting

Aggregation is the process by which a set of component attribute values is reduced to a single value that represents the map unit as a whole.

A map unit is typically composed of one or more "components". A component is either some type of soil or some nonsoil entity, e.g., rock outcrop. For the attribute being aggregated, the first step of the aggregation process is to derive one attribute value for each of a map unit's components. From this set of component attributes, the next step of the aggregation process derives a single value that represents the map unit as a whole. Once a single value for each map unit is derived, a thematic map for soil map units can be rendered. Aggregation must be done because, on any soil map, map units are delineated but components are not.

For each of a map unit's components, a corresponding percent composition is recorded. A percent composition of 60 indicates that the corresponding component typically makes up approximately 60% of the map unit. Percent composition is a critical factor in some, but not all, aggregation methods.

The aggregation method "Most Limiting" is suitable only for attributes that correspond to a programmatically generated soil interpretation. Such an interpretation attempts to determine if a soil is suitable for a particular use. The results for such an interpretation can be ranked from least limiting (or most suitable) to most limiting (or least suitable). For this aggregation method, the most limiting result among all components of the map unit is returned.

The result returned by this aggregation method may or may not represent the dominant condition throughout the map unit. The result may well be based on the limitations of a map unit component of very minor extent. If one were making a decision based on this result, that decision would be based on the most conservative, or most pessimistic, result.

Component Percent Cutoff: None Specified

Components whose percent composition is below the cutoff value will not be considered. If no cutoff value is specified, all components in the database will be considered. The data for some contrasting soils of minor extent may not be in the database, and therefore are not considered.

Tie-break Rule: Higher

The tie-break rule indicates which value should be selected from a set of multiple candidate values, or which value should be selected in the event of a percent composition tie.

Disposal of Wastewater by Rapid Infiltration

Rapid infiltration of wastewater is a process in which wastewater applied in a level basin at a rate of 4 to 120 inches per week percolates through the soil. The wastewater may eventually reach the ground water. The application rate commonly exceeds the rate needed for irrigation of cropland. Vegetation is not a necessary part of the treatment; thus, the basins may or may not be vegetated. The thickness of the soil material needed for proper treatment of the wastewater is more than 72 inches. As a result, geologic and hydrologic investigation is needed to ensure proper design and performance and to determine the risk of ground-water pollution.

Soil properties are important considerations in areas where soils are used as sites for the treatment and disposal of organic waste and wastewater. Selection of soils with properties that favor waste management can help to prevent environmental damage.

Municipal wastewater is the waste stream from a municipality. It contains domestic waste and may contain industrial waste. It may have received primary or secondary treatment. It is rarely untreated sewage. Food-processing wastewater results from the preparation of fruits, vegetables, milk, cheese, and meats for public consumption. In places it is high in content of sodium and chloride. The effluent in lagoons and storage ponds is from facilities used to treat or store food-processing wastewater or domestic or animal waste. Domestic and food-processing wastewater is very dilute, and the effluent from the facilities that treat or store it commonly is very low in content of carbonaceous and nitrogenous material; the content of nitrogen commonly ranges from 10 to 30 milligrams per liter. The wastewater from animal waste treatment lagoons or storage ponds, however, has much higher concentrations of these materials, mainly because the manure has not been diluted as much as the domestic waste. The content of nitrogen in this wastewater generally ranges from 50 to 2,000 milligrams per liter. When wastewater is applied, checks should be made to ensure that nitrogen, heavy metals, and salts are not added in excessive amounts.

The ratings are based on the soil properties that affect the risk of pollution and the design, construction, and performance of the system. Depth to a water table, ponding, flooding, and depth to bedrock or a cemented pan affect the risk of pollution and the design and construction of the system. Slope, stones, and cobbles also affect design and construction. Saturated hydraulic conductivity (Ksat) and reaction affect performance. Permanently frozen soils are unsuitable for waste treatment.

The ratings are both verbal and numerical. Rating class terms indicate the extent to which the soils are limited by all of the soil features that affect agricultural waste management. "Not limited" indicates that the soil has features that are very favorable for the specified use. Good performance and very low maintenance can be expected. "Somewhat limited" indicates that the soil has features that are moderately favorable for the specified use. The limitations can be overcome or minimized by special planning, design, or installation. Fair performance and moderate maintenance can be expected. "Very limited" indicates that the soil has one or more features that are unfavorable for the specified use. The limitations generally cannot be overcome without major soil reclamation, special design, or expensive installation procedures. Poor performance and high maintenance can be expected.

Numerical ratings indicate the severity of individual limitations. The ratings are shown as decimal fractions ranging from 0.01 to 1.00. They indicate gradations between the point at which a soil feature has the greatest negative impact on the use (1.00) and the point at which the soil feature is not a limitation (0.00).

The map unit components listed for each map unit in the accompanying Summary by Map Unit table in Web Soil Survey or the Aggregation Report in Soil Data Viewer are determined by the aggregation method chosen. An aggregated rating class is shown for each map unit. The components listed for each map unit are only those that have the same rating class as listed for the map unit. The percent composition of each component in a particular map unit is presented to help the user better understand the percentage of each map unit that has the rating presented.

Other components with different ratings may be present in each map unit. The ratings for all components, regardless of the map unit aggregated rating, can be viewed by generating the equivalent report from the Soil Reports tab in Web Soil Survey or from the Soil Data Mart site. Onsite investigation may be needed to validate these interpretations and to confirm the identity of the soil on a given site.

Tables—Disposal of Wastewater by Rapid Infiltration

Disposal of Wastewater by Rapid Infiltration— Summary by Map Unit — Humboldt County, Nevada, East Part						
Map unit symbol	**Map unit name**	**Rating**	**Component name (percent)**	**Rating reasons (numeric values)**	**Acres in AOI**	**Percent of AOI**
831	Boton-Playas association	Very limited	Boton (50%)	Slow water movement (1.00)	592.4	94.9%
			Playas (35%)	Slow water movement (1.00)		
				Depth to saturated zone (1.00)		
				Ponding (1.00)		
990	Playas	Very limited	Playas (95%)	Slow water movement (1.00)	32.0	5.1%
				Depth to saturated zone (1.00)		
				Ponding (1.00)		
Totals for Area of Interest					**624.5**	**100.0%**

Disposal of Wastewater by Rapid Infiltration— Summary by Rating Value		
Rating	**Acres in AOI**	**Percent of AOI**
Very limited	624.4	100.0%
Totals for Area of Interest	**624.5**	**100.0%**

Rating Options—Disposal of Wastewater by Rapid Infiltration

Aggregation Method: Most Limiting

Aggregation is the process by which a set of component attribute values is reduced to a single value that represents the map unit as a whole.

A map unit is typically composed of one or more "components". A component is either some type of soil or some nonsoil entity, e.g., rock outcrop. For the attribute being aggregated, the first step of the aggregation process is to derive one attribute value for each of a map unit's components. From this set of component attributes, the next step of the aggregation process derives a single value that represents the map unit as a whole. Once a single value for each map unit is derived, a thematic map for soil map units can be rendered. Aggregation must be done because, on any soil map, map units are delineated but components are not.

For each of a map unit's components, a corresponding percent composition is recorded. A percent composition of 60 indicates that the corresponding component typically makes up approximately 60% of the map unit. Percent composition is a critical factor in some, but not all, aggregation methods.

The aggregation method "Most Limiting" is suitable only for attributes that correspond to a programmatically generated soil interpretation. Such an interpretation attempts to determine if a soil is suitable for a particular use. The results for such an interpretation can be ranked from least limiting (or most suitable) to most limiting (or least suitable). For this aggregation method, the most limiting result among all components of the map unit is returned.

The result returned by this aggregation method may or may not represent the dominant condition throughout the map unit. The result may well be based on the limitations of a map unit component of very minor extent. If one were making a decision based on this result, that decision would be based on the most conservative, or most pessimistic, result.

Component Percent Cutoff: None Specified

Components whose percent composition is below the cutoff value will not be considered. If no cutoff value is specified, all components in the database will be considered. The data for some contrasting soils of minor extent may not be in the database, and therefore are not considered.

Tie-break Rule: Higher

The tie-break rule indicates which value should be selected from a set of multiple candidate values, or which value should be selected in the event of a percent composition tie.

Land Application of Municipal Sewage Sludge

Application of sewage sludge not only disposes of waste material but also can improve crop production by increasing the supply of nutrients in the soils where the material is applied. Sewage sludge is the residual product of the treatment of municipal sewage. The solid component consists mainly of cell mass, primarily bacteria cells that developed during secondary treatment and have incorporated soluble organics into their own bodies. The sludge has small amounts of sand, silt, and other solid debris. The content of nitrogen varies. Some sludge has constituents that are toxic to plants or hazardous to the food chain, such as heavy metals and exotic organic compounds, and should be analyzed chemically prior to use.

The content of water in the sludge ranges from about 98 percent to less than 40 percent. The sludge is considered liquid if it is more than about 90 percent water, slurry if it is about 50 to 90 percent water, and solid if it is less than about 50 percent water.

The ratings are based on the soil properties that affect absorption, plant growth, microbial activity, erodibility, the rate at which the sludge is applied, and the method by which the sludge is applied. The properties that affect absorption, plant growth, and microbial activity include saturated hydraulic conductivity (Ksat), depth to a water table, ponding, the sodium adsorption ratio, depth to bedrock or a cemented pan, available water capacity, reaction, salinity, and bulk density. The wind erodibility group, soil erosion factor K, and slope are considered in estimating the likelihood that wind erosion or water erosion will transport the waste material from the application site. Stones, cobbles, a water table, ponding, and flooding can hinder the application of sludge. Permanently frozen soils are unsuitable for waste treatment.

The ratings are both verbal and numerical. Rating class terms indicate the extent to which the soils are limited by all of the soil features that affect agricultural waste management. "Not limited" indicates that the soil has features that are very favorable for the specified use. Good performance and very low maintenance can be expected. "Somewhat limited" indicates that the soil has features that are moderately favorable for the specified use. The limitations can be overcome or minimized by special planning, design, or installation. Fair performance and moderate maintenance can be expected. "Very limited" indicates that the soil has one or more features that are unfavorable for the specified use. The limitations generally cannot be overcome without major soil reclamation, special design, or expensive installation procedures. Poor performance and high maintenance can be expected.

Numerical ratings indicate the severity of individual limitations. The ratings are shown as decimal fractions ranging from 0.01 to 1.00. They indicate gradations between the point at which a soil feature has the greatest negative impact on the use (1.00) and the point at which the soil feature is not a limitation (0.00).

The map unit components listed for each map unit in the accompanying Summary by Map Unit table in Web Soil Survey or the Aggregation Report in Soil Data Viewer are determined by the aggregation method chosen. An aggregated rating class is shown for each map unit. The components listed for each map unit are only those that have the same rating class as listed for the map unit. The percent composition of each component in a particular map unit is presented to help the user better understand the percentage of each map unit that has the rating presented.

Other components with different ratings may be present in each map unit. The ratings for all components, regardless of the map unit aggregated rating, can be viewed by generating the equivalent report from the Soil Reports tab in Web Soil Survey or from the Soil Data Mart site. Onsite investigation may be needed to validate these interpretations and to confirm the identity of the soil on a given site.

Tables—Land Application of Municipal Sewage Sludge

Land Application of Municipal Sewage Sludge— Summary by Map Unit — Humboldt County, Nevada, East Part						
Map unit symbol	**Map unit name**	**Rating**	**Component name (percent)**	**Rating reasons (numeric values)**	**Acres in AOI**	**Percent of AOI**
831	Boton-Playas association	Very limited	Boton (50%)	Sodium content (1.00)	592.4	94.9%
				Slow water movement (0.37)		
			Playas (35%)	Droughty (1.00)		
				Slow water movement (1.00)		
				Depth to saturated zone (1.00)		
				Salinity (1.00)		
				Sodium content (1.00)		
990	Playas	Very limited	Playas (95%)	Droughty (1.00)	32.0	5.1%
				Slow water movement (1.00)		
				Depth to saturated zone (1.00)		
				Salinity (1.00)		
				Sodium content (1.00)		
Totals for Area of Interest					**624.5**	**100.0%**

Land Application of Municipal Sewage Sludge— Summary by Rating Value		
Rating	**Acres in AOI**	**Percent of AOI**
Very limited	624.4	100.0%
Totals for Area of Interest	**624.5**	**100.0%**

Rating Options—Land Application of Municipal Sewage Sludge

Aggregation Method: Most Limiting

Aggregation is the process by which a set of component attribute values is reduced to a single value that represents the map unit as a whole.

A map unit is typically composed of one or more "components". A component is either some type of soil or some nonsoil entity, e.g., rock outcrop. For the attribute being aggregated, the first step of the aggregation process is to derive one attribute value for each of a map unit's components. From this set of component attributes, the next step of the aggregation process derives a single value that represents the map unit as a whole. Once a single value for each map unit is derived, a thematic map for soil map units can be rendered. Aggregation must be done because, on any soil map, map units are delineated but components are not.

For each of a map unit's components, a corresponding percent composition is recorded. A percent composition of 60 indicates that the corresponding component typically makes up approximately 60% of the map unit. Percent composition is a critical factor in some, but not all, aggregation methods.

The aggregation method "Most Limiting" is suitable only for attributes that correspond to a programmatically generated soil interpretation. Such an interpretation attempts to determine if a soil is suitable for a particular use. The results for such an interpretation can be ranked from least limiting (or most suitable) to most limiting (or least suitable). For this aggregation method, the most limiting result among all components of the map unit is returned.

The result returned by this aggregation method may or may not represent the dominant condition throughout the map unit. The result may well be based on the limitations of a map unit component of very minor extent. If one were making a decision based on this result, that decision would be based on the most conservative, or most pessimistic, result.

Component Percent Cutoff: None Specified

Components whose percent composition is below the cutoff value will not be considered. If no cutoff value is specified, all components in the database will be considered. The data for some contrasting soils of minor extent may not be in the database, and therefore are not considered.

Tie-break Rule: Higher

The tie-break rule indicates which value should be selected from a set of multiple candidate values, or which value should be selected in the event of a percent composition tie.

Manure and Food-Processing Waste

The application of manure and food-processing waste not only disposes of waste material but also can improve crop production by increasing the supply of nutrients in the soils where the material is applied. Manure is the excrement of livestock and poultry, and food-processing waste is damaged fruit and vegetables and the peelings, stems, leaves, pits, and soil particles removed in food preparation. The manure and food-processing waste are solid, slurry, or liquid. Their nitrogen content varies. A high content of nitrogen limits the application rate. Toxic or otherwise dangerous wastes, such as those mixed with the lye used in food processing, are not considered in the ratings.

The ratings are based on the soil properties that affect absorption, plant growth, microbial activity, erodibility, the rate at which the waste is applied, and the method by which the waste is applied. The properties that affect absorption include saturated hydraulic conductivity (Ksat), depth to a water table, ponding, the sodium adsorption ratio, depth to bedrock or a cemented pan, and available water capacity. The properties that affect plant growth and microbial activity include reaction, the sodium adsorption ratio, salinity, and bulk density. The wind erodibility group, soil erosion factor K, and slope are considered in estimating the likelihood that wind erosion or water erosion will transport the waste material from the application site. Stones, cobbles, a water table, ponding, and flooding can hinder the application of waste. Permanently frozen soils are unsuitable for waste treatment.

The ratings are both verbal and numerical. Rating class terms indicate the extent to which the soils are limited by all of the soil features that affect agricultural waste management. "Not limited" indicates that the soil has features that are very favorable for the specified use. Good performance and very low maintenance can be expected. "Somewhat limited" indicates that the soil has features that are moderately favorable for the specified use. The limitations can be overcome or minimized by special planning, design, or installation. Fair performance and moderate maintenance can be expected. "Very limited" indicates that the soil has one or more features that are unfavorable for the specified use. The limitations generally cannot be overcome without major soil reclamation, special design, or expensive installation procedures. Poor performance and high maintenance can be expected.

Numerical ratings indicate the severity of individual limitations. The ratings are shown as decimal fractions ranging from 0.01 to 1.00. They indicate gradations between the point at which a soil feature has the greatest negative impact on the use (1.00) and the point at which the soil feature is not a limitation (0.00).

The map unit components listed for each map unit in the accompanying Summary by Map Unit table in Web Soil Survey or the Aggregation Report in Soil Data Viewer are determined by the aggregation method chosen. An aggregated rating class is shown for each map unit. The components listed for each map unit are only those that have the same rating class as listed for the map unit. The percent composition of each component in a particular map unit is presented to help the user better understand the percentage of each map unit that has the rating presented.

Other components with different ratings may be present in each map unit. The ratings for all components, regardless of the map unit aggregated rating, can be viewed by generating the equivalent report from the Soil Reports tab in Web Soil Survey or from the Soil Data Mart site. Onsite investigation may be needed to validate these interpretations and to confirm the identity of the soil on a given site.

Tables—Manure and Food-Processing Waste

Manure and Food-Processing Waste— Summary by Map Unit — Humboldt County, Nevada, East Part						
Map unit symbol	**Map unit name**	**Rating**	**Component name (percent)**	**Rating reasons (numeric values)**	**Acres in AOI**	**Percent of AOI**
831	Boton-Playas association	Very limited	Boton (50%)	Sodium content (1.00)	592.4	94.9%
				Salinity (0.78)		
				Slow water movement (0.50)		
			Playas (35%)	Slow water movement (1.00)		
				Depth to saturated zone (1.00)		
				Salinity (1.00)		
				Sodium content (1.00)		
				Droughty (1.00)		
990	Playas	Very limited	Playas (95%)	Slow water movement (1.00)	32.0	5.1%
				Depth to saturated zone (1.00)		
				Salinity (1.00)		
				Sodium content (1.00)		
				Droughty (1.00)		
Totals for Area of Interest					**624.5**	**100.0%**

Manure and Food-Processing Waste— Summary by Rating Value		
Rating	**Acres in AOI**	**Percent of AOI**
Very limited	624.4	100.0%
Totals for Area of Interest	**624.5**	**100.0%**

Rating Options—Manure and Food-Processing Waste

Aggregation Method: Most Limiting

Aggregation is the process by which a set of component attribute values is reduced to a single value that represents the map unit as a whole.

A map unit is typically composed of one or more "components". A component is either some type of soil or some nonsoil entity, e.g., rock outcrop. For the attribute being aggregated, the first step of the aggregation process is to derive one attribute value for each of a map unit's components. From this set of component attributes, the next step of the aggregation process derives a single value that represents the map unit as a whole. Once a single value for each map unit is derived, a thematic map for soil map units can be rendered. Aggregation must be done because, on any soil map, map units are delineated but components are not.

For each of a map unit's components, a corresponding percent composition is recorded. A percent composition of 60 indicates that the corresponding component typically makes up approximately 60% of the map unit. Percent composition is a critical factor in some, but not all, aggregation methods.

The aggregation method "Most Limiting" is suitable only for attributes that correspond to a programmatically generated soil interpretation. Such an interpretation attempts to determine if a soil is suitable for a particular use. The results for such an interpretation can be ranked from least limiting (or most suitable) to most limiting (or least suitable). For this aggregation method, the most limiting result among all components of the map unit is returned.

The result returned by this aggregation method may or may not represent the dominant condition throughout the map unit. The result may well be based on the limitations of a map unit component of very minor extent. If one were making a decision based on this result, that decision would be based on the most conservative, or most pessimistic, result.

Component Percent Cutoff: None Specified

Components whose percent composition is below the cutoff value will not be considered. If no cutoff value is specified, all components in the database will be considered. The data for some contrasting soils of minor extent may not be in the database, and therefore are not considered.

Tie-break Rule: Higher

The tie-break rule indicates which value should be selected from a set of multiple candidate values, or which value should be selected in the event of a percent composition tie.

Overland Flow Treatment of Wastewater

In this process wastewater is applied to the upper reaches of sloped land and allowed to flow across vegetated surfaces, sometimes called terraces, to runoff-collection ditches. The length of the run generally is 150 to 300 feet. The application rate ranges from 2.5 to 16.0 inches per week. It commonly exceeds the rate needed for irrigation of cropland. The wastewater leaves solids and nutrients on the vegetated surfaces as it flows downslope in a thin film. Most of the water reaches the collection ditch, some is lost through evapotranspiration, and a small amount may percolate to the ground water.

Wastewater includes municipal and food-processing wastewater and effluent from lagoons or storage ponds. Municipal wastewater is the waste stream from a municipality. It contains domestic waste and may contain industrial waste. It may have received primary or secondary treatment. It is rarely untreated sewage. Food-processing wastewater results from the preparation of fruits, vegetables, milk, cheese, and meats for public consumption. In places it is high in content of sodium and chloride. The effluent in lagoons and storage ponds is from facilities used to treat or store food-processing wastewater or domestic or animal waste. Domestic and food-processing wastewater is very dilute, and the effluent from the facilities that treat or store it commonly is very low in content of carbonaceous and nitrogenous material; the content of nitrogen commonly ranges from 10 to 30 milligrams per liter. The wastewater from animal waste treatment lagoons or storage ponds, however, has much higher concentrations of these materials, mainly because the manure has not been diluted as much as the domestic waste. The content of nitrogen in this wastewater generally ranges from 50 to 2,000 milligrams per liter. When wastewater is applied, checks should be made to ensure that nitrogen, heavy metals, and salts are not added in excessive amounts.

The ratings are for waste management systems that not only dispose of and treat wastewater but also are beneficial to crops. The ratings are both verbal and numerical. Rating class terms indicate the extent to which the soils are limited by all of the soil features that affect agricultural waste management. "Not limited" indicates that the soil has features that are very favorable for the specified use. Good performance and very low maintenance can be expected. "Somewhat limited" indicates that the soil has features that are moderately favorable for the specified use. The limitations can be overcome or minimized by special planning, design, or installation. Fair performance and moderate maintenance can be expected. "Very limited" indicates that the soil has one or more features that are unfavorable for the specified use. The limitations generally cannot be overcome without major soil reclamation, special design, or expensive installation procedures. Poor performance and high maintenance can be expected.

Numerical ratings indicate the severity of individual limitations. The ratings are shown as decimal fractions ranging from 0.01 to 1.00. They indicate gradations between the point at which a soil feature has the greatest negative impact on the use (1.00) and the point at which the soil feature is not a limitation (0.00).

The map unit components listed for each map unit in the accompanying Summary by Map Unit table in Web Soil Survey or the Aggregation Report in Soil Data Viewer are determined by the aggregation method chosen. An aggregated rating class is shown for each map unit. The components listed for each map unit are only those that have the same rating class as listed for the map unit. The percent composition of each component in a particular map unit is presented to help the user better understand the percentage of each map unit that has the rating presented.

Other components with different ratings may be present in each map unit. The ratings for all components, regardless of the map unit aggregated rating, can be viewed by generating the equivalent report from the Soil Reports tab in Web Soil Survey or from the Soil Data Mart site. Onsite investigation may be needed to validate these interpretations and to confirm the identity of the soil on a given site.

Tables—Overland Flow Treatment of Wastewater

Overland Flow Treatment of Wastewater— Summary by Map Unit — Humboldt County, Nevada, East Part						
Map unit symbol	**Map unit name**	**Rating**	**Component name (percent)**	**Rating reasons (numeric values)**	**Acres in AOI**	**Percent of AOI**
831	Boton-Playas association	Very limited	Boton (50%)	Sodium content (1.00)	592.4	94.9%
				Seepage (1.00)		
			Playas (35%)	Sodium content (1.00)		
				Depth to saturated zone (1.00)		
				Salinity (1.00)		
				Ponding (1.00)		
990	Playas	Very limited	Playas (95%)	Sodium content (1.00)	32.0	5.1%
				Depth to saturated zone (1.00)		
				Salinity (1.00)		
				Ponding (1.00)		
				Too level (0.50)		
Totals for Area of Interest					**624.5**	**100.0%**

Overland Flow Treatment of Wastewater— Summary by Rating Value		
Rating	**Acres in AOI**	**Percent of AOI**
Very limited	624.4	100.0%
Totals for Area of Interest	**624.5**	**100.0%**

Rating Options—Overland Flow Treatment of Wastewater

Aggregation Method: Most Limiting

Aggregation is the process by which a set of component attribute values is reduced to a single value that represents the map unit as a whole.

A map unit is typically composed of one or more "components". A component is either some type of soil or some nonsoil entity, e.g., rock outcrop. For the attribute being aggregated, the first step of the aggregation process is to derive one attribute value for each of a map unit's components. From this set of component attributes, the next step of the aggregation process derives a single value that represents the map unit as a whole. Once a single value for each map unit is derived, a thematic map for soil map units can be rendered. Aggregation must be done because, on any soil map, map units are delineated but components are not.

For each of a map unit's components, a corresponding percent composition is recorded. A percent composition of 60 indicates that the corresponding component

typically makes up approximately 60% of the map unit. Percent composition is a critical factor in some, but not all, aggregation methods.

The aggregation method "Most Limiting" is suitable only for attributes that correspond to a programmatically generated soil interpretation. Such an interpretation attempts to determine if a soil is suitable for a particular use. The results for such an interpretation can be ranked from least limiting (or most suitable) to most limiting (or least suitable). For this aggregation method, the most limiting result among all components of the map unit is returned.

The result returned by this aggregation method may or may not represent the dominant condition throughout the map unit. The result may well be based on the limitations of a map unit component of very minor extent. If one were making a decision based on this result, that decision would be based on the most conservative, or most pessimistic, result.

Component Percent Cutoff: None Specified

Components whose percent composition is below the cutoff value will not be considered. If no cutoff value is specified, all components in the database will be considered. The data for some contrasting soils of minor extent may not be in the database, and therefore are not considered.

Tie-break Rule: Higher

The tie-break rule indicates which value should be selected from a set of multiple candidate values, or which value should be selected in the event of a percent composition tie.

Slow Rate Treatment of Wastewater

Slow rate treatment of wastewater is a process in which wastewater is applied to land at a rate normally between 0.5 inch and 4.0 inches per week. The application rate commonly exceeds the rate needed for irrigation of cropland. The applied wastewater is treated as it moves through the soil. Much of the treated water may percolate to the ground water, and some enters the atmosphere through evapotranspiration. The applied water generally is not allowed to run off the surface. Waterlogging is prevented either through control of the application rate or through the use of tile drains, or both.

Soil properties are important considerations in areas where soils are used as sites for the treatment and disposal of organic waste and wastewater. Selection of soils with properties that favor waste management can help to prevent environmental damage.

Municipal wastewater is the waste stream from a municipality. It contains domestic waste and may contain industrial waste. It may have received primary or secondary treatment. It is rarely untreated sewage. Food-processing wastewater results from the preparation of fruits, vegetables, milk, cheese, and meats for public consumption. In places it is high in content of sodium and chloride. The effluent in lagoons and storage ponds is from facilities used to treat or store food-processing wastewater or domestic or animal waste. Domestic and food-processing wastewater is very dilute, and the effluent from the facilities that treat or store it commonly is very low in content of carbonaceous and nitrogenous material; the content of nitrogen commonly ranges from 10 to 30 milligrams per liter. The wastewater from animal waste treatment lagoons or storage ponds, however, has much higher concentrations of these materials, mainly because the manure has not been diluted as much as the domestic waste. The content of nitrogen in this wastewater generally ranges from 50 to 2,000 milligrams per liter. When wastewater is applied, checks should be made to ensure that nitrogen, heavy metals, and salts are not added in excessive amounts.

The ratings are based on the soil properties that affect absorption, plant growth, microbial activity, erodibility, and the application of waste. The properties that affect absorption include the sodium adsorption ratio, depth to a water table, ponding, available water capacity, saturated hydraulic conductivity (Ksat), depth to bedrock or a cemented pan, reaction, the cation-exchange capacity, and slope. Reaction, the sodium adsorption ratio, salinity, and bulk density affect plant growth and microbial activity. The wind erodibility group, soil erosion factor K, and slope are considered in estimating the likelihood of wind erosion or water erosion. Stones, cobbles, a water table, ponding, and flooding can hinder the application of waste. Permanently frozen soils are unsuitable for waste treatment.

The ratings are both verbal and numerical. Rating class terms indicate the extent to which the soils are limited by all of the soil features that affect agricultural waste management. "Not limited" indicates that the soil has features that are very favorable for the specified use. Good performance and very low maintenance can be expected. "Somewhat limited" indicates that the soil has features that are moderately favorable for the specified use. The limitations can be overcome or minimized by special planning, design, or installation. Fair performance and moderate maintenance can be expected. "Very limited" indicates that the soil has one or more features that are unfavorable for the specified use. The limitations generally cannot be overcome without major soil reclamation, special design, or expensive installation procedures. Poor performance and high maintenance can be expected.

Numerical ratings indicate the severity of individual limitations. The ratings are shown as decimal fractions ranging from 0.01 to 1.00. They indicate gradations between the point at which a soil feature has the greatest negative impact on the use (1.00) and the point at which the soil feature is not a limitation (0.00).

The map unit components listed for each map unit in the accompanying Summary by Map Unit table in Web Soil Survey or the Aggregation Report in Soil Data Viewer are determined by the aggregation method chosen. An aggregated rating class is shown for each map unit. The components listed for each map unit are only those that have the same rating class as listed for the map unit. The percent composition of each component in a particular map unit is presented to help the user better understand the percentage of each map unit that has the rating presented.

Other components with different ratings may be present in each map unit. The ratings for all components, regardless of the map unit aggregated rating, can be viewed by generating the equivalent report from the Soil Reports tab in Web Soil Survey or from the Soil Data Mart site. Onsite investigation may be needed to validate these interpretations and to confirm the identity of the soil on a given site.

Tables—Slow Rate Treatment of Wastewater

Slow Rate Treatment of Wastewater— Summary by Map Unit — Humboldt County, Nevada, East Part						
Map unit symbol	**Map unit name**	**Rating**	**Component name (percent)**	**Rating reasons (numeric values)**	**Acres in AOI**	**Percent of AOI**
831	Boton-Playas association	Very limited	Boton (50%)	Sodium content (1.00)	592.4	94.9%
				Slow water movement (0.26)		
			Playas (35%)	Sodium content (1.00)		
				Depth to saturated zone (1.00)		
				Salinity (1.00)		
				Slow water movement (1.00)		
				Ponding (1.00)		
990	Playas	Very limited	Playas (95%)	Sodium content (1.00)	32.0	5.1%
				Depth to saturated zone (1.00)		
				Salinity (1.00)		
				Slow water movement (1.00)		
				Ponding (1.00)		
Totals for Area of Interest					**624.5**	**100.0%**

Slow Rate Treatment of Wastewater— Summary by Rating Value		
Rating	**Acres in AOI**	**Percent of AOI**
Very limited	624.4	100.0%
Totals for Area of Interest	**624.5**	**100.0%**

Rating Options—Slow Rate Treatment of Wastewater

Aggregation Method: Most Limiting

Aggregation is the process by which a set of component attribute values is reduced to a single value that represents the map unit as a whole.

A map unit is typically composed of one or more "components". A component is either some type of soil or some nonsoil entity, e.g., rock outcrop. For the attribute being aggregated, the first step of the aggregation process is to derive one attribute value for each of a map unit's components. From this set of component attributes, the next step of the aggregation process derives a single value that represents the map unit as a whole. Once a single value for each map unit is derived, a thematic map for soil map units can be rendered. Aggregation must be done because, on any soil map, map units are delineated but components are not.

For each of a map unit's components, a corresponding percent composition is recorded. A percent composition of 60 indicates that the corresponding component typically makes up approximately 60% of the map unit. Percent composition is a critical factor in some, but not all, aggregation methods.

The aggregation method "Most Limiting" is suitable only for attributes that correspond to a programmatically generated soil interpretation. Such an interpretation attempts to determine if a soil is suitable for a particular use. The results for such an interpretation can be ranked from least limiting (or most suitable) to most limiting (or least suitable). For this aggregation method, the most limiting result among all components of the map unit is returned.

The result returned by this aggregation method may or may not represent the dominant condition throughout the map unit. The result may well be based on the limitations of a map unit component of very minor extent. If one were making a decision based on this result, that decision would be based on the most conservative, or most pessimistic, result.

Component Percent Cutoff: None Specified

Components whose percent composition is below the cutoff value will not be considered. If no cutoff value is specified, all components in the database will be considered. The data for some contrasting soils of minor extent may not be in the database, and therefore are not considered.

Tie-break Rule: Higher

The tie-break rule indicates which value should be selected from a set of multiple candidate values, or which value should be selected in the event of a percent composition tie.

Water Management

Water Management interpretations are tools for evaluating the potential of the soil in the application of various water management practices. Example interpretations include pond reservoir area, embankments, dikes, levees, and excavated ponds.

Embankments, Dikes, and Levees

Embankments, dikes, and levees are raised structures of soil material, generally less than 20 feet high, constructed to impound water or to protect land against overflow. Embankments that have zoned construction (core and shell) are not considered. The soils are rated as a source of material for embankment fill. The ratings apply to the soil material below the surface layer to a depth of about 5 feet. It is assumed that soil layers will be uniformly mixed and compacted during construction.

The ratings do not indicate the suitability of the undisturbed soil for supporting the embankment. Soil properties to a depth even greater than the height of the embankment can affect performance and safety of the embankment. Generally, deeper onsite investigation is needed to determine these properties.

Soil material in embankments must be resistant to seepage, piping, and erosion and have favorable compaction characteristics. Unfavorable features include less than 5 feet of suitable material and a high content of stones or boulders, organic matter, or salts or sodium. A high water table affects the amount of usable material. It also affects trafficability.

The ratings are both verbal and numerical. Rating class terms indicate the extent to which the soils are limited by all of the soil features that affect the specified use. "Not limited" indicates that the soil has features that are very favorable for the specified use. Good performance and very low maintenance can be expected. "Somewhat limited" indicates that the soil has features that are moderately favorable for the specified use. The limitations can be overcome or minimized by special planning, design, or installation. Fair performance and moderate maintenance can be expected. "Very limited" indicates that the soil has one or more features that are unfavorable for the specified use. The limitations generally cannot be overcome without major soil reclamation, special design, or expensive installation procedures. Poor performance and high maintenance can be expected.

Numerical ratings indicate the severity of individual limitations. The ratings are shown as decimal fractions ranging from 0.01 to 1.00. They indicate gradations between the point at which a soil feature has the greatest negative impact on the use (1.00) and the point at which the soil feature is not a limitation (0.00).

The map unit components listed for each map unit in the accompanying Summary by Map Unit table in Web Soil Survey or the Aggregation Report in Soil Data Viewer are determined by the aggregation method chosen. An aggregated rating class is shown for each map unit. The components listed for each map unit are only those that have the same rating class as listed for the map unit. The percent composition of each component in a particular map unit is presented to help the user better understand the percentage of each map unit that has the rating presented.

Other components with different ratings may be present in each map unit. The ratings for all components, regardless of the map unit aggregated rating, can be viewed by generating the equivalent report from the Soil Reports tab in Web Soil Survey or from the Soil Data Mart site. Onsite investigation may be needed to validate these interpretations and to confirm the identity of the soil on a given site.

Tables—Embankments, Dikes, and Levees

Embankments, Dikes, and Levees— Summary by Map Unit — Humboldt County, Nevada, East Part						
Map unit symbol	**Map unit name**	**Rating**	**Component name (percent)**	**Rating reasons (numeric values)**	**Acres in AOI**	**Percent of AOI**
831	Boton-Playas association	Very limited	Boton (50%)	Salinity (1.00)	592.4	94.9%
				Piping (1.00)		
			Playas (35%)	Depth to saturated zone (1.00)		
				Salinity (1.00)		
				Hard to pack (1.00)		
				Ponding (1.00)		
990	Playas	Very limited	Playas (95%)	Depth to saturated zone (1.00)	32.0	5.1%
				Salinity (1.00)		
				Hard to pack (1.00)		
				Ponding (1.00)		
Totals for Area of Interest					**624.5**	**100.0%**

Embankments, Dikes, and Levees— Summary by Rating Value		
Rating	**Acres in AOI**	**Percent of AOI**
Very limited	624.4	100.0%
Totals for Area of Interest	**624.5**	**100.0%**

Rating Options—Embankments, Dikes, and Levees

Aggregation Method: Most Limiting

Aggregation is the process by which a set of component attribute values is reduced to a single value that represents the map unit as a whole.

A map unit is typically composed of one or more "components". A component is either some type of soil or some nonsoil entity, e.g., rock outcrop. For the attribute being aggregated, the first step of the aggregation process is to derive one attribute value for each of a map unit's components. From this set of component attributes, the next step of the aggregation process derives a single value that represents the map unit as a whole. Once a single value for each map unit is derived, a thematic map for soil map units can be rendered. Aggregation must be done because, on any soil map, map units are delineated but components are not.

For each of a map unit's components, a corresponding percent composition is recorded. A percent composition of 60 indicates that the corresponding component typically makes up approximately 60% of the map unit. Percent composition is a critical factor in some, but not all, aggregation methods.

The aggregation method "Most Limiting" is suitable only for attributes that correspond to a programmatically generated soil interpretation. Such an interpretation attempts to determine if a soil is suitable for a particular use. The results for such an interpretation can be ranked from least limiting (or most suitable) to most limiting (or least suitable). For this aggregation method, the most limiting result among all components of the map unit is returned.

The result returned by this aggregation method may or may not represent the dominant condition throughout the map unit. The result may well be based on the limitations of a map unit component of very minor extent. If one were making a decision based on this result, that decision would be based on the most conservative, or most pessimistic, result.

Component Percent Cutoff: None Specified

Components whose percent composition is below the cutoff value will not be considered. If no cutoff value is specified, all components in the database will be considered. The data for some contrasting soils of minor extent may not be in the database, and therefore are not considered.

Tie-break Rule: Higher

The tie-break rule indicates which value should be selected from a set of multiple candidate values, or which value should be selected in the event of a percent composition tie.

Excavated Ponds (Aquifer-Fed)

Excavated ponds (aquifer-fed) are pits or dugouts that extend to a ground-water aquifer or to a depth below a permanent water table. Excluded are ponds that are fed only by surface runoff and embankment ponds that impound water 3 feet or more above the original surface. Excavated ponds are affected by depth to a permanent water table, saturated hydraulic conductivity (Ksat) of the aquifer, and quality of the water as inferred from the salinity of the soil. Depth to bedrock and the content of large stones affect the ease of excavation.

The ratings are both verbal and numerical. Rating class terms indicate the extent to which the soils are limited by all of the soil features that affect the specified use. "Not limited" indicates that the soil has features that are very favorable for the specified use. Good performance and very low maintenance can be expected. "Somewhat limited" indicates that the soil has features that are moderately favorable for the specified use. The limitations can be overcome or minimized by special planning, design, or installation. Fair performance and moderate maintenance can be expected. "Very limited" indicates that the soil has one or more features that are unfavorable for the specified use. The limitations generally cannot be overcome without major soil reclamation, special design, or expensive installation procedures. Poor performance and high maintenance can be expected.

Numerical ratings indicate the severity of individual limitations. The ratings are shown as decimal fractions ranging from 0.01 to 1.00. They indicate gradations between the point at which a soil feature has the greatest negative impact on the use (1.00) and the point at which the soil feature is not a limitation (0.00).

The map unit components listed for each map unit in the accompanying Summary by Map Unit table in Web Soil Survey or the Aggregation Report in Soil Data Viewer are determined by the aggregation method chosen. An aggregated rating class is shown for each map unit. The components listed for each map unit are only those that have the same rating class as listed for the map unit. The percent composition of each component in a particular map unit is presented to help the user better understand the percentage of each map unit that has the rating presented.

Other components with different ratings may be present in each map unit. The ratings for all components, regardless of the map unit aggregated rating, can be viewed by generating the equivalent report from the Soil Reports tab in Web Soil Survey or from the Soil Data Mart site. Onsite investigation may be needed to validate these interpretations and to confirm the identity of the soil on a given site.

Tables—Excavated Ponds (Aquifer-Fed)

Excavated Ponds (Aquifer-Fed)— Summary by Map Unit — Humboldt County, Nevada, East Part						
Map unit symbol	**Map unit name**	**Rating**	**Component name (percent)**	**Rating reasons (numeric values)**	**Acres in AOI**	**Percent of AOI**
831	Boton-Playas association	Very limited	Boton (50%)	Depth to water (1.00)	592.4	94.9%
			Playas (35%)	Slow refill (1.00)		
				Salinity and saturated zone (1.00)		
				Cutbanks cave (0.10)		
990	Playas	Very limited	Playas (95%)	Slow refill (1.00)	32.0	5.1%
				Salinity and saturated zone (1.00)		
				Cutbanks cave (0.10)		
Totals for Area of Interest					**624.5**	**100.0%**

Excavated Ponds (Aquifer-Fed)— Summary by Rating Value		
Rating	**Acres in AOI**	**Percent of AOI**
Very limited	624.4	100.0%
Totals for Area of Interest	**624.5**	**100.0%**

Rating Options—Excavated Ponds (Aquifer-Fed)

Aggregation Method: Most Limiting

Aggregation is the process by which a set of component attribute values is reduced to a single value that represents the map unit as a whole.

A map unit is typically composed of one or more "components". A component is either some type of soil or some nonsoil entity, e.g., rock outcrop. For the attribute being aggregated, the first step of the aggregation process is to derive one attribute value for each of a map unit's components. From this set of component attributes, the next step of the aggregation process derives a single value that represents the map unit as a whole. Once a single value for each map unit is derived, a thematic map for soil map units can be rendered. Aggregation must be done because, on any soil map, map units are delineated but components are not.

For each of a map unit's components, a corresponding percent composition is recorded. A percent composition of 60 indicates that the corresponding component typically makes up approximately 60% of the map unit. Percent composition is a critical factor in some, but not all, aggregation methods.

The aggregation method "Most Limiting" is suitable only for attributes that correspond to a programmatically generated soil interpretation. Such an interpretation attempts to determine if a soil is suitable for a particular use. The results for such an interpretation can be ranked from least limiting (or most suitable) to most limiting (or least suitable). For this aggregation method, the most limiting result among all components of the map unit is returned.

The result returned by this aggregation method may or may not represent the dominant condition throughout the map unit. The result may well be based on the limitations of a map unit component of very minor extent. If one were making a decision based on this result, that decision would be based on the most conservative, or most pessimistic, result.

Component Percent Cutoff: None Specified

Components whose percent composition is below the cutoff value will not be considered. If no cutoff value is specified, all components in the database will be considered. The data for some contrasting soils of minor extent may not be in the database, and therefore are not considered.

Tie-break Rule: Higher

The tie-break rule indicates which value should be selected from a set of multiple candidate values, or which value should be selected in the event of a percent composition tie.

Pond Reservoir Areas

Pond reservoir areas hold water behind a dam or embankment. Soils best suited to this use have low seepage potential in the upper 60 inches. The seepage potential is determined by the saturated hydraulic conductivity (Ksat) of the soil and the depth to fractured bedrock or other permeable material. Excessive slope can affect the storage capacity of the reservoir area.

The ratings are both verbal and numerical. Rating class terms indicate the extent to which the soils are limited by all of the soil features that affect the specified use. "Not limited" indicates that the soil has features that are very favorable for the specified use. Good performance and very low maintenance can be expected. "Somewhat limited" indicates that the soil has features that are moderately favorable for the specified use. The limitations can be overcome or minimized by special planning, design, or installation. Fair performance and moderate maintenance can be expected. "Very limited" indicates that the soil has one or more features that are unfavorable for the specified use. The limitations generally cannot be overcome without major soil reclamation, special design, or expensive installation procedures. Poor performance and high maintenance can be expected.

Numerical ratings indicate the severity of individual limitations. The ratings are shown as decimal fractions ranging from 0.01 to 1.00. They indicate gradations between the point at which a soil feature has the greatest negative impact on the use (1.00) and the point at which the soil feature is not a limitation (0.00).

The map unit components listed for each map unit in the accompanying Summary by Map Unit table in Web Soil Survey or the Aggregation Report in Soil Data Viewer are determined by the aggregation method chosen. An aggregated rating class is shown for each map unit. The components listed for each map unit are only those that have the same rating class as listed for the map unit. The percent composition of each component in a particular map unit is presented to help the user better understand the percentage of each map unit that has the rating presented.

Other components with different ratings may be present in each map unit. The ratings for all components, regardless of the map unit aggregated rating, can be viewed by generating the equivalent report from the Soil Reports tab in Web Soil Survey or from the Soil Data Mart site. Onsite investigation may be needed to validate these interpretations and to confirm the identity of the soil on a given site.

Tables—Pond Reservoir Areas

Pond Reservoir Areas— Summary by Map Unit — Humboldt County, Nevada, East Part						
Map unit symbol	**Map unit name**	**Rating**	**Component name (percent)**	**Rating reasons (numeric values)**	**Acres in AOI**	**Percent of AOI**
831	Boton-Playas association	Somewhat limited	Boton (50%)	Seepage (0.03)	592.4	94.9%
990	Playas	Not limited	Playas (95%)		32.0	5.1%
Totals for Area of Interest					**624.5**	**100.0%**

Pond Reservoir Areas— Summary by Rating Value		
Rating	**Acres in AOI**	**Percent of AOI**
Somewhat limited	592.4	94.9%
Not limited	32.0	5.1%
Totals for Area of Interest	**624.5**	**100.0%**

Rating Options—Pond Reservoir Areas

Aggregation Method: Most Limiting

Component Percent Cutoff: *None Specified*

Tie-break Rule: Higher

Soil Properties and Qualities

The Soil Properties and Qualities section includes various soil properties and qualities displayed as thematic maps with a summary table for the soil map units in the selected area of interest. A single value or rating for each map unit is generated by aggregating the interpretive ratings of individual map unit components. This aggregation process is defined for each property or quality.

Soil Erosion Factors

Soil Erosion Factors are soil properties and interpretations used in evaluating the soil for potential erosion. Example soil erosion factors can include K factor for the whole soil or on a rock free basis, T factor, wind erodibility group and wind erodibility index.

K Factor, Rock Free

Erosion factor K indicates the susceptibility of a soil to sheet and rill erosion by water. Factor K is one of six factors used in the Universal Soil Loss Equation (USLE) and the Revised Universal Soil Loss Equation (RUSLE) to predict the average annual rate of soil loss by sheet and rill erosion in tons per acre per year. The estimates are based primarily on percentage of silt, sand, and organic matter and on soil structure and saturated hydraulic conductivity (Ksat). Values of K range from 0.02 to 0.69. Other factors being equal, the higher the value, the more susceptible the soil is to sheet and rill erosion by water.

"Erosion factor Kf (rock free)" indicates the erodibility of the fine-earth fraction, or the material less than 2 millimeters in size.

Table—K Factor, Rock Free

K Factor, Rock Free— Summary by Map Unit — Humboldt County, Nevada, East Part				
Map unit symbol	**Map unit name**	**Rating**	**Acres in AOI**	**Percent of AOI**
831	Boton-Playas association	.55	592.4	94.9%
990	Playas	.37	32.0	5.1%
Totals for Area of Interest			**624.5**	**100.0%**

Rating Options—K Factor, Rock Free

Aggregation Method: All Components

Aggregation is the process by which a set of component attribute values is reduced to a single value that represents the map unit as a whole.

A map unit is typically composed of one or more "components". A component is either some type of soil or some nonsoil entity, e.g., rock outcrop. For the attribute being aggregated, the first step of the aggregation process is to derive one attribute value for each of a map unit's components. From this set of component attributes, the next step of the aggregation process derives a single value that represents the map unit as a whole. Once a single value for each map unit is derived, a thematic map for soil map units can be rendered. Aggregation must be done because, on any soil map, map units are delineated but components are not.

For each of a map unit's components, a corresponding percent composition is recorded. A percent composition of 60 indicates that the corresponding component typically makes up approximately 60% of the map unit. Percent composition is a critical factor in some, but not all, aggregation methods.

The aggregation method "All Components" returns the lowest or highest attribute value among all components of the map unit, depending on the corresponding "tie-break" rule. In this case, the "tie-break" rule indicates whether the lowest or highest value among all components should be returned. For this aggregation method, percent composition ties cannot occur.

The result returned by this aggregation method represents either the minimum or maximum value of the corresponding attribute throughout the map unit. The result may well be based on a map unit component of very minor extent.

Component Percent Cutoff: None Specified

Components whose percent composition is below the cutoff value will not be considered. If no cutoff value is specified, all components in the database will be considered. The data for some contrasting soils of minor extent may not be in the database, and therefore are not considered.

Tie-break Rule: Higher

The tie-break rule indicates which value should be selected from a set of multiple candidate values, or which value should be selected in the event of a percent composition tie.

Layer Options: All Layers

For an attribute of a soil horizon, a depth qualification must be specified. In most cases it is probably most appropriate to specify a fixed depth range, either in centimeters or inches. The Bottom Depth must be greater than the Top Depth, and the Top Depth can be greater than zero. The choice of "inches" or "centimeters" only applies to the depth of soil to be evaluated. It has no influence on the units of measure the data are presented in.

When "Surface Layer" is specified as the depth qualifier, only the surface layer or horizon is considered when deriving a value for a component, but keep in mind that the thickness of the surface layer varies from component to component.

When "All Layers" is specified as the depth qualifier, all layers recorded for a component are considered when deriving the value for that component.

Whenever more than one layer or horizon is considered when deriving a value for a component, and the attribute being aggregated is a numeric attribute, a weighted average value is returned, where the weighting factor is the layer or horizon thickness.

K Factor, Whole Soil

Erosion factor K indicates the susceptibility of a soil to sheet and rill erosion by water. Factor K is one of six factors used in the Universal Soil Loss Equation (USLE) and the Revised Universal Soil Loss Equation (RUSLE) to predict the average annual rate of soil loss by sheet and rill erosion in tons per acre per year. The estimates are based primarily on percentage of silt, sand, and organic matter and on soil structure and saturated hydraulic conductivity (Ksat). Values of K range from 0.02 to 0.69. Other factors being equal, the higher the value, the more susceptible the soil is to sheet and rill erosion by water.

"Erosion factor Kw (whole soil)" indicates the erodibility of the whole soil. The estimates are modified by the presence of rock fragments.

Table—K Factor, Whole Soil

K Factor, Whole Soil— Summary by Map Unit — Humboldt County, Nevada, East Part				
Map unit symbol	**Map unit name**	**Rating**	**Acres in AOI**	**Percent of AOI**
831	Boton-Playas association	.55	592.4	94.9%
990	Playas	.37	32.0	5.1%
Totals for Area of Interest			**624.5**	**100.0%**

Rating Options—K Factor, Whole Soil

Aggregation Method: All Components

Aggregation is the process by which a set of component attribute values is reduced to a single value that represents the map unit as a whole.

A map unit is typically composed of one or more "components". A component is either some type of soil or some nonsoil entity, e.g., rock outcrop. For the attribute being aggregated, the first step of the aggregation process is to derive one attribute value for each of a map unit's components. From this set of component attributes, the next step of the aggregation process derives a single value that represents the map unit as a whole. Once a single value for each map unit is derived, a thematic map for soil map units can be rendered. Aggregation must be done because, on any soil map, map units are delineated but components are not.

For each of a map unit's components, a corresponding percent composition is recorded. A percent composition of 60 indicates that the corresponding component typically makes up approximately 60% of the map unit. Percent composition is a critical factor in some, but not all, aggregation methods.

The aggregation method "All Components" returns the lowest or highest attribute value among all components of the map unit, depending on the corresponding "tie-break" rule. In this case, the "tie-break" rule indicates whether the lowest or highest value among all components should be returned. For this aggregation method, percent composition ties cannot occur.

The result returned by this aggregation method represents either the minimum or maximum value of the corresponding attribute throughout the map unit. The result may well be based on a map unit component of very minor extent.

Component Percent Cutoff: None Specified

Components whose percent composition is below the cutoff value will not be considered. If no cutoff value is specified, all components in the database will be considered. The data for some contrasting soils of minor extent may not be in the database, and therefore are not considered.

Tie-break Rule: Higher

The tie-break rule indicates which value should be selected from a set of multiple candidate values, or which value should be selected in the event of a percent composition tie.

Layer Options: All Layers

For an attribute of a soil horizon, a depth qualification must be specified. In most cases it is probably most appropriate to specify a fixed depth range, either in centimeters or inches. The Bottom Depth must be greater than the Top Depth, and the Top Depth can be greater than zero. The choice of "inches" or "centimeters" only applies to the depth of soil to be evaluated. It has no influence on the units of measure the data are presented in.

When "Surface Layer" is specified as the depth qualifier, only the surface layer or horizon is considered when deriving a value for a component, but keep in mind that the thickness of the surface layer varies from component to component.

When "All Layers" is specified as the depth qualifier, all layers recorded for a component are considered when deriving the value for that component.

Whenever more than one layer or horizon is considered when deriving a value for a component, and the attribute being aggregated is a numeric attribute, a weighted average value is returned, where the weighting factor is the layer or horizon thickness.

T Factor

The T factor is an estimate of the maximum average annual rate of soil erosion by wind and/or water that can occur without affecting crop productivity over a sustained period. The rate is in tons per acre per year.

Table—T Factor

T Factor— Summary by Map Unit — Humboldt County, Nevada, East Part				
Map unit symbol	**Map unit name**	**Rating (tons per acre per year)**	**Acres in AOI**	**Percent of AOI**
831	Boton-Playas association	5	592.4	94.9%
990	Playas	5	32.0	5.1%
Totals for Area of Interest			**624.5**	**100.0%**

Rating Options—T Factor

Units of Measure: tons per acre per year

Aggregation Method: All Components

Aggregation is the process by which a set of component attribute values is reduced to a single value that represents the map unit as a whole.

A map unit is typically composed of one or more "components". A component is either some type of soil or some nonsoil entity, e.g., rock outcrop. For the attribute being aggregated, the first step of the aggregation process is to derive one attribute value for each of a map unit's components. From this set of component attributes, the next step of the aggregation process derives a single value that represents the map unit as a whole. Once a single value for each map unit is derived, a thematic map for soil map units can be rendered. Aggregation must be done because, on any soil map, map units are delineated but components are not.

For each of a map unit's components, a corresponding percent composition is recorded. A percent composition of 60 indicates that the corresponding component typically makes up approximately 60% of the map unit. Percent composition is a critical factor in some, but not all, aggregation methods.

The aggregation method "All Components" returns the lowest or highest attribute value among all components of the map unit, depending on the corresponding "tie-break" rule. In this case, the "tie-break" rule indicates whether the lowest or highest value among all components should be returned. For this aggregation method, percent composition ties cannot occur.

The result returned by this aggregation method represents either the minimum or maximum value of the corresponding attribute throughout the map unit. The result may well be based on a map unit component of very minor extent.

Component Percent Cutoff: None Specified

Components whose percent composition is below the cutoff value will not be considered. If no cutoff value is specified, all components in the database will be considered. The data for some contrasting soils of minor extent may not be in the database, and therefore are not considered.

Tie-break Rule: Lower

The tie-break rule indicates which value should be selected from a set of multiple candidate values, or which value should be selected in the event of a percent composition tie.

Interpret Nulls as Zero: No

This option indicates if a null value for a component should be converted to zero before aggregation occurs. This will be done only if a map unit has at least one component where this value is not null.

Wind Erodibility Group

A wind erodibility group (WEG) consists of soils that have similar properties affecting their susceptibility to wind erosion in cultivated areas. The soils assigned to group 1 are the most susceptible to wind erosion, and those assigned to group 8 are the least susceptible.

Table—Wind Erodibility Group

Wind Erodibility Group— Summary by Map Unit — Humboldt County, Nevada, East Part				
Map unit symbol	**Map unit name**	**Rating**	**Acres in AOI**	**Percent of AOI**
831	Boton-Playas association	4	592.4	94.9%
990	Playas	4L	32.0	5.1%
Totals for Area of Interest			**624.5**	**100.0%**

Rating Options—Wind Erodibility Group

Aggregation Method: All Components

Aggregation is the process by which a set of component attribute values is reduced to a single value that represents the map unit as a whole.

A map unit is typically composed of one or more "components". A component is either some type of soil or some nonsoil entity, e.g., rock outcrop. For the attribute being aggregated, the first step of the aggregation process is to derive one attribute value for each of a map unit's components. From this set of component attributes, the next step of the aggregation process derives a single value that represents the map unit as a whole. Once a single value for each map unit is derived, a thematic map for soil map units can be rendered. Aggregation must be done because, on any soil map, map units are delineated but components are not.

For each of a map unit's components, a corresponding percent composition is recorded. A percent composition of 60 indicates that the corresponding component typically makes up approximately 60% of the map unit. Percent composition is a critical factor in some, but not all, aggregation methods.

The aggregation method "All Components" returns the lowest or highest attribute value among all components of the map unit, depending on the corresponding "tie-break" rule. In this case, the "tie-break" rule indicates whether the lowest or highest value among all components should be returned. For this aggregation method, percent composition ties cannot occur.

The result returned by this aggregation method represents either the minimum or maximum value of the corresponding attribute throughout the map unit. The result may well be based on a map unit component of very minor extent.

Component Percent Cutoff: None Specified

Components whose percent composition is below the cutoff value will not be considered. If no cutoff value is specified, all components in the database will be considered. The data for some contrasting soils of minor extent may not be in the database, and therefore are not considered.

Tie-break Rule: Lower

The tie-break rule indicates which value should be selected from a set of multiple candidate values, or which value should be selected in the event of a percent composition tie.

Wind Erodibility Index

The wind erodibility index is a numerical value indicating the susceptibility of soil to wind erosion, or the tons per acre per year that can be expected to be lost to wind erosion. There is a close correlation between wind erosion and the texture of the surface layer, the size and durability of surface clods, rock fragments, organic matter, and a calcareous reaction. Soil moisture and frozen soil layers also influence wind erosion.

Table—Wind Erodibility Index

Wind Erodibility Index— Summary by Map Unit — Humboldt County, Nevada, East Part				
Map unit symbol	**Map unit name**	**Rating (tons per acre per year)**	**Acres in AOI**	**Percent of AOI**
831	Boton-Playas association	86	592.4	94.9%
990	Playas	86	32.0	5.1%
Totals for Area of Interest			**624.5**	**100.0%**

Rating Options—Wind Erodibility Index

Units of Measure: tons per acre per year

Aggregation Method: All Components

Aggregation is the process by which a set of component attribute values is reduced to a single value that represents the map unit as a whole.

A map unit is typically composed of one or more "components". A component is either some type of soil or some nonsoil entity, e.g., rock outcrop. For the attribute being aggregated, the first step of the aggregation process is to derive one attribute value for each of a map unit's components. From this set of component attributes, the next step of the aggregation process derives a single value that represents the map unit as a whole. Once a single value for each map unit is derived, a thematic map for soil map units can be rendered. Aggregation must be done because, on any soil map, map units are delineated but components are not.

For each of a map unit's components, a corresponding percent composition is recorded. A percent composition of 60 indicates that the corresponding component typically makes up approximately 60% of the map unit. Percent composition is a critical factor in some, but not all, aggregation methods.

The aggregation method "All Components" returns the lowest or highest attribute value among all components of the map unit, depending on the corresponding "tie-break" rule. In this case, the "tie-break" rule indicates whether the lowest or highest value among all components should be returned. For this aggregation method, percent composition ties cannot occur.

The result returned by this aggregation method represents either the minimum or maximum value of the corresponding attribute throughout the map unit. The result may well be based on a map unit component of very minor extent.

Component Percent Cutoff: None Specified

Components whose percent composition is below the cutoff value will not be considered. If no cutoff value is specified, all components in the database will be considered. The data for some contrasting soils of minor extent may not be in the database, and therefore are not considered.

Tie-break Rule: Higher

The tie-break rule indicates which value should be selected from a set of multiple candidate values, or which value should be selected in the event of a percent composition tie.

Soil Physical Properties

Soil Physical Properties are measured or inferred from direct observations in the field or laboratory. Examples of soil physical properties include percent clay, organic matter, saturated hydraulic conductivity, available water capacity, and bulk density.

Organic Matter

Organic matter is the plant and animal residue in the soil at various stages of decomposition. The estimated content of organic matter is expressed as a percentage, by weight, of the soil material that is less than 2 millimeters in diameter.

The content of organic matter in a soil can be maintained by returning crop residue to the soil. Organic matter has a positive effect on available water capacity, water infiltration, soil organism activity, and tilth. It is a source of nitrogen and other nutrients for crops and soil organisms. An irregular distribution of organic carbon with depth may indicate different episodes of soil deposition or soil formation. Soils that are very high in organic matter have poor engineering properties and subside upon drying.

For each soil layer, this attribute is actually recorded as three separate values in the database. A low value and a high value indicate the range of this attribute for the soil component. A "representative" value indicates the expected value of this attribute for the component. For this soil property, only the representative value is used.

Table—Organic Matter

Organic Matter— Summary by Map Unit — Humboldt County, Nevada, East Part				
Map unit symbol	**Map unit name**	**Rating (percent)**	**Acres in AOI**	**Percent of AOI**
831	Boton-Playas association	0.25	592.4	94.9%
990	Playas	0.05	32.0	5.1%
Totals for Area of Interest			**624.5**	**100.0%**

Rating Options—Organic Matter

Units of Measure: percent

Aggregation Method: All Components

Aggregation is the process by which a set of component attribute values is reduced to a single value that represents the map unit as a whole.

A map unit is typically composed of one or more "components". A component is either some type of soil or some nonsoil entity, e.g., rock outcrop. For the attribute being aggregated, the first step of the aggregation process is to derive one attribute value for each of a map unit's components. From this set of component attributes, the next step of the aggregation process derives a single value that represents the map unit as a whole. Once a single value for each map unit is derived, a thematic map for soil map units can be rendered. Aggregation must be done because, on any soil map, map units are delineated but components are not.

For each of a map unit's components, a corresponding percent composition is recorded. A percent composition of 60 indicates that the corresponding component typically makes up approximately 60% of the map unit. Percent composition is a critical factor in some, but not all, aggregation methods.

The aggregation method "All Components" returns the lowest or highest attribute value among all components of the map unit, depending on the corresponding "tie-break" rule. In this case, the "tie-break" rule indicates whether the lowest or highest value among all components should be returned. For this aggregation method, percent composition ties cannot occur.

The result returned by this aggregation method represents either the minimum or maximum value of the corresponding attribute throughout the map unit. The result may well be based on a map unit component of very minor extent.

Component Percent Cutoff: None Specified

Components whose percent composition is below the cutoff value will not be considered. If no cutoff value is specified, all components in the database will be considered. The data for some contrasting soils of minor extent may not be in the database, and therefore are not considered.

Tie-break Rule: Higher

The tie-break rule indicates which value should be selected from a set of multiple candidate values, or which value should be selected in the event of a percent composition tie.

Interpret Nulls as Zero: No

This option indicates if a null value for a component should be converted to zero before aggregation occurs. This will be done only if a map unit has at least one component where this value is not null.

Layer Options: All Layers

For an attribute of a soil horizon, a depth qualification must be specified. In most cases it is probably most appropriate to specify a fixed depth range, either in centimeters or inches. The Bottom Depth must be greater than the Top Depth, and the Top Depth can be greater than zero. The choice of "inches" or "centimeters" only applies to the depth of soil to be evaluated. It has no influence on the units of measure the data are presented in.

When "Surface Layer" is specified as the depth qualifier, only the surface layer or horizon is considered when deriving a value for a component, but keep in mind that the thickness of the surface layer varies from component to component.

When "All Layers" is specified as the depth qualifier, all layers recorded for a component are considered when deriving the value for that component.

Whenever more than one layer or horizon is considered when deriving a value for a component, and the attribute being aggregated is a numeric attribute, a weighted average value is returned, where the weighting factor is the layer or horizon thickness.

Percent Clay

Clay as a soil separate consists of mineral soil particles that are less than 0.002 millimeter in diameter. The estimated clay content of each soil layer is given as a percentage, by weight, of the soil material that is less than 2 millimeters in diameter. The amount and kind of clay affect the fertility and physical condition of the soil and the ability of the soil to adsorb cations and to retain moisture. They influence shrink-swell potential, saturated hydraulic conductivity (Ksat), plasticity, the ease of soil dispersion, and other soil properties. The amount and kind of clay in a soil also affect tillage and earth-moving operations.

Most of the material is in one of three groups of clay minerals or a mixture of these clay minerals. The groups are kaolinite, smectite, and hydrous mica, the best known member of which is illite.

For each soil layer, this attribute is actually recorded as three separate values in the database. A low value and a high value indicate the range of this attribute for the soil component. A "representative" value indicates the expected value of this attribute for the component. For this soil property, only the representative value is used.

Table—Percent Clay

Percent Clay— Summary by Map Unit — Humboldt County, Nevada, East Part				
Map unit symbol	**Map unit name**	**Rating (percent)**	**Acres in AOI**	**Percent of AOI**
831	Boton-Playas association	52.7	592.4	94.9%
990	Playas	51.0	32.0	5.1%
Totals for Area of Interest			**624.5**	**100.0%**

Rating Options—Percent Clay

Units of Measure: percent

Aggregation Method: All Components

Aggregation is the process by which a set of component attribute values is reduced to a single value that represents the map unit as a whole.

A map unit is typically composed of one or more "components". A component is either some type of soil or some nonsoil entity, e.g., rock outcrop. For the attribute being aggregated, the first step of the aggregation process is to derive one attribute value for each of a map unit's components. From this set of component attributes, the next step of the aggregation process derives a single value that represents the map unit as a whole. Once a single value for each map unit is derived, a thematic map for soil map units can be rendered. Aggregation must be done because, on any soil map, map units are delineated but components are not.

For each of a map unit's components, a corresponding percent composition is recorded. A percent composition of 60 indicates that the corresponding component typically makes up approximately 60% of the map unit. Percent composition is a critical factor in some, but not all, aggregation methods.

The aggregation method "All Components" returns the lowest or highest attribute value among all components of the map unit, depending on the corresponding "tie-break" rule. In this case, the "tie-break" rule indicates whether the lowest or highest value among all components should be returned. For this aggregation method, percent composition ties cannot occur.

The result returned by this aggregation method represents either the minimum or maximum value of the corresponding attribute throughout the map unit. The result may well be based on a map unit component of very minor extent.

Component Percent Cutoff: None Specified

Components whose percent composition is below the cutoff value will not be considered. If no cutoff value is specified, all components in the database will be considered. The data for some contrasting soils of minor extent may not be in the database, and therefore are not considered.

Tie-break Rule: Higher

The tie-break rule indicates which value should be selected from a set of multiple candidate values, or which value should be selected in the event of a percent composition tie.

Interpret Nulls as Zero: No

This option indicates if a null value for a component should be converted to zero before aggregation occurs. This will be done only if a map unit has at least one component where this value is not null.

Layer Options: All Layers

For an attribute of a soil horizon, a depth qualification must be specified. In most cases it is probably most appropriate to specify a fixed depth range, either in centimeters or inches. The Bottom Depth must be greater than the Top Depth, and the Top Depth can be greater than zero. The choice of "inches" or "centimeters" only applies to the depth of soil to be evaluated. It has no influence on the units of measure the data are presented in.

When "Surface Layer" is specified as the depth qualifier, only the surface layer or horizon is considered when deriving a value for a component, but keep in mind that the thickness of the surface layer varies from component to component.

When "All Layers" is specified as the depth qualifier, all layers recorded for a component are considered when deriving the value for that component.

Whenever more than one layer or horizon is considered when deriving a value for a component, and the attribute being aggregated is a numeric attribute, a weighted average value is returned, where the weighting factor is the layer or horizon thickness.

Liquid Limit

Liquid limit (LL) is one of the standard Atterberg limits used to indicate the plasticity characteristics of a soil. It is the water content, on a percent by weight basis, of the soil (passing #40 sieve) at which the soil changes from a plastic to a liquid state. Generally, the amount of clay- and silt-size particles, the organic matter content, and the type of minerals determine the liquid limit. Soils that have a high liquid limit have the capacity to hold a lot of water while maintaining a plastic or semisolid state.

Liquid limit is used in classifying soils in the Unified and AASHTO classification systems.

For each soil layer, this attribute is actually recorded as three separate values in the database. A low value and a high value indicate the range of this attribute for the soil component. A "representative" value indicates the expected value of this attribute for the component. For this soil property, only the representative value is used.

Table—Liquid Limit

Liquid Limit— Summary by Map Unit — Humboldt County, Nevada, East Part				
Map unit symbol	**Map unit name**	**Rating (percent)**	**Acres in AOI**	**Percent of AOI**
831	Boton-Playas association	60.5	592.4	94.9%
990	Playas	57.8	32.0	5.1%
Totals for Area of Interest			**624.5**	**100.0%**

Rating Options—Liquid Limit

Units of Measure: percent

Aggregation Method: All Components

Component Percent Cutoff: None Specified

Tie-break Rule: Higher

Interpret Nulls as Zero: No

Layer Options: All Layers

Percent Sand

Sand as a soil separate consists of mineral soil particles that are 0.05 millimeter to 2 millimeters in diameter. In the database, the estimated sand content of each soil layer is given as a percentage, by weight, of the soil material that is less than 2 millimeters in diameter. The content of sand, silt, and clay affects the physical behavior of a soil. Particle size is important for engineering and agronomic interpretations, for determination of soil hydrologic qualities, and for soil classification.

For each soil layer, this attribute is actually recorded as three separate values in the database. A low value and a high value indicate the range of this attribute for the soil component. A "representative" value indicates the expected value of this attribute for the component. For this soil property, only the representative value is used.

Table—Percent Sand

Percent Sand— Summary by Map Unit — Humboldt County, Nevada, East Part				
Map unit symbol	**Map unit name**	**Rating (percent)**	**Acres in AOI**	**Percent of AOI**
831	Boton-Playas association	8.9	592.4	94.9%
990	Playas	3.1	32.0	5.1%
Totals for Area of Interest			**624.5**	**100.0%**

Rating Options—Percent Sand

Units of Measure: percent

Aggregation Method: All Components

Aggregation is the process by which a set of component attribute values is reduced to a single value that represents the map unit as a whole.

A map unit is typically composed of one or more "components". A component is either some type of soil or some nonsoil entity, e.g., rock outcrop. For the attribute being aggregated, the first step of the aggregation process is to derive one attribute value for each of a map unit's components. From this set of component attributes, the next step of the aggregation process derives a single value that represents the map unit as a whole. Once a single value for each map unit is derived, a thematic map for soil map units can be rendered. Aggregation must be done because, on any soil map, map units are delineated but components are not.

For each of a map unit's components, a corresponding percent composition is recorded. A percent composition of 60 indicates that the corresponding component typically makes up approximately 60% of the map unit. Percent composition is a critical factor in some, but not all, aggregation methods.

The aggregation method "All Components" returns the lowest or highest attribute value among all components of the map unit, depending on the corresponding "tie-break" rule. In this case, the "tie-break" rule indicates whether the lowest or highest value among all components should be returned. For this aggregation method, percent composition ties cannot occur.

The result returned by this aggregation method represents either the minimum or maximum value of the corresponding attribute throughout the map unit. The result may well be based on a map unit component of very minor extent.

Component Percent Cutoff: None Specified

Components whose percent composition is below the cutoff value will not be considered. If no cutoff value is specified, all components in the database will be considered. The data for some contrasting soils of minor extent may not be in the database, and therefore are not considered.

Tie-break Rule: Higher

The tie-break rule indicates which value should be selected from a set of multiple candidate values, or which value should be selected in the event of a percent composition tie.

Interpret Nulls as Zero: No

This option indicates if a null value for a component should be converted to zero before aggregation occurs. This will be done only if a map unit has at least one component where this value is not null.

Layer Options: All Layers

For an attribute of a soil horizon, a depth qualification must be specified. In most cases it is probably most appropriate to specify a fixed depth range, either in centimeters or inches. The Bottom Depth must be greater than the Top Depth, and the Top Depth can be greater than zero. The choice of "inches" or "centimeters" only applies to the depth of soil to be evaluated. It has no influence on the units of measure the data are presented in.

When "Surface Layer" is specified as the depth qualifier, only the surface layer or horizon is considered when deriving a value for a component, but keep in mind that the thickness of the surface layer varies from component to component.

When "All Layers" is specified as the depth qualifier, all layers recorded for a component are considered when deriving the value for that component.

Whenever more than one layer or horizon is considered when deriving a value for a component, and the attribute being aggregated is a numeric attribute, a weighted average value is returned, where the weighting factor is the layer or horizon thickness.

Percent Silt

Silt as a soil separate consists of mineral soil particles that are 0.002 to 0.05 millimeter in diameter. In the database, the estimated silt content of each soil layer is given as a percentage, by weight, of the soil material that is less than 2 millimeters in diameter.

The content of sand, silt, and clay affects the physical behavior of a soil. Particle size is important for engineering and agronomic interpretations, for determination of soil hydrologic qualities, and for soil classification

For each soil layer, this attribute is actually recorded as three separate values in the database. A low value and a high value indicate the range of this attribute for the soil component. A "representative" value indicates the expected value of this attribute for the component. For this soil property, only the representative value is used.

Table—Percent Silt

Percent Silt— Summary by Map Unit — Humboldt County, Nevada, East Part				
Map unit symbol	**Map unit name**	**Rating (percent)**	**Acres in AOI**	**Percent of AOI**
831	Boton-Playas association	70.5	592.4	94.9%
990	Playas	45.9	32.0	5.1%
Totals for Area of Interest			**624.5**	**100.0%**

Rating Options—Percent Silt

Units of Measure: percent

Aggregation Method: All Components

Aggregation is the process by which a set of component attribute values is reduced to a single value that represents the map unit as a whole.

A map unit is typically composed of one or more "components". A component is either some type of soil or some nonsoil entity, e.g., rock outcrop. For the attribute being aggregated, the first step of the aggregation process is to derive one attribute value for each of a map unit's components. From this set of component attributes, the next step of the aggregation process derives a single value that represents the map unit as a whole. Once a single value for each map unit is derived, a thematic map for soil map units can be rendered. Aggregation must be done because, on any soil map, map units are delineated but components are not.

For each of a map unit's components, a corresponding percent composition is recorded. A percent composition of 60 indicates that the corresponding component typically makes up approximately 60% of the map unit. Percent composition is a critical factor in some, but not all, aggregation methods.

The aggregation method "All Components" returns the lowest or highest attribute value among all components of the map unit, depending on the corresponding "tie-break" rule. In this case, the "tie-break" rule indicates whether the lowest or highest value among all components should be returned. For this aggregation method, percent composition ties cannot occur.

The result returned by this aggregation method represents either the minimum or maximum value of the corresponding attribute throughout the map unit. The result may well be based on a map unit component of very minor extent.

Component Percent Cutoff: None Specified

Components whose percent composition is below the cutoff value will not be considered. If no cutoff value is specified, all components in the database will be considered. The data for some contrasting soils of minor extent may not be in the database, and therefore are not considered.

Tie-break Rule: Higher

The tie-break rule indicates which value should be selected from a set of multiple candidate values, or which value should be selected in the event of a percent composition tie.

Interpret Nulls as Zero: No

This option indicates if a null value for a component should be converted to zero before aggregation occurs. This will be done only if a map unit has at least one component where this value is not null.

Layer Options: All Layers

For an attribute of a soil horizon, a depth qualification must be specified. In most cases it is probably most appropriate to specify a fixed depth range, either in centimeters or inches. The Bottom Depth must be greater than the Top Depth, and the Top Depth can be greater than zero. The choice of "inches" or "centimeters" only applies to the depth of soil to be evaluated. It has no influence on the units of measure the data are presented in.

When "Surface Layer" is specified as the depth qualifier, only the surface layer or horizon is considered when deriving a value for a component, but keep in mind that the thickness of the surface layer varies from component to component.

When "All Layers" is specified as the depth qualifier, all layers recorded for a component are considered when deriving the value for that component.

Whenever more than one layer or horizon is considered when deriving a value for a component, and the attribute being aggregated is a numeric attribute, a weighted average value is returned, where the weighting factor is the layer or horizon thickness.

Plasticity Index

Plasticity index (PI) is one of the standard Atterberg limits used to indicate the plasticity characteristics of a soil. It is defined as the numerical difference between the liquid limit and plastic limit of the soil. It is the range of water content in which a soil exhibits the characteristics of a plastic solid.

The plastic limit is the water content that corresponds to an arbitrary limit between the plastic and semisolid states of a soil. The liquid limit is the water content, on a percent by weight basis, of the soil (passing #40 sieve) at which the soil changes from a plastic to a liquid state.

Soils that have a high plasticity index have a wide range of moisture content in which the soil performs as a plastic material. Highly and moderately plastic clays have large PI values. Plasticity index is used in classifying soils in the Unified and AASHTO classification systems.

For each soil layer, this attribute is actually recorded as three separate values in the database. A low value and a high value indicate the range of this attribute for the soil component. A "representative" value indicates the expected value of this attribute for the component. For this soil property, only the representative value is used.

Table—Plasticity Index

Plasticity Index— Summary by Map Unit — Humboldt County, Nevada, East Part				
Map unit symbol	**Map unit name**	**Rating (percent)**	**Acres in AOI**	**Percent of AOI**
831	Boton-Playas association	30.0	592.4	94.9%
990	Playas	30.0	32.0	5.1%
Totals for Area of Interest			**624.5**	**100.0%**

Rating Options—Plasticity Index

Units of Measure: percent

Aggregation Method: All Components

Aggregation is the process by which a set of component attribute values is reduced to a single value that represents the map unit as a whole.

A map unit is typically composed of one or more "components". A component is either some type of soil or some nonsoil entity, e.g., rock outcrop. For the attribute being aggregated, the first step of the aggregation process is to derive one attribute value for each of a map unit's components. From this set of component attributes, the next step of the aggregation process derives a single value that represents the map unit as a whole. Once a single value for each map unit is derived, a thematic map for soil map units can be rendered. Aggregation must be done because, on any soil map, map units are delineated but components are not.

For each of a map unit's components, a corresponding percent composition is recorded. A percent composition of 60 indicates that the corresponding component typically makes up approximately 60% of the map unit. Percent composition is a critical factor in some, but not all, aggregation methods.

The aggregation method "All Components" returns the lowest or highest attribute value among all components of the map unit, depending on the corresponding "tie-break" rule. In this case, the "tie-break" rule indicates whether the lowest or highest value among all components should be returned. For this aggregation method, percent composition ties cannot occur.

The result returned by this aggregation method represents either the minimum or maximum value of the corresponding attribute throughout the map unit. The result may well be based on a map unit component of very minor extent.

Component Percent Cutoff: None Specified

Components whose percent composition is below the cutoff value will not be considered. If no cutoff value is specified, all components in the database will be considered. The data for some contrasting soils of minor extent may not be in the database, and therefore are not considered.

Tie-break Rule: Higher

The tie-break rule indicates which value should be selected from a set of multiple candidate values, or which value should be selected in the event of a percent composition tie.

Interpret Nulls as Zero: No

This option indicates if a null value for a component should be converted to zero before aggregation occurs. This will be done only if a map unit has at least one component where this value is not null.

Layer Options: All Layers

For an attribute of a soil horizon, a depth qualification must be specified. In most cases it is probably most appropriate to specify a fixed depth range, either in centimeters or inches. The Bottom Depth must be greater than the Top Depth, and the Top Depth can be greater than zero. The choice of "inches" or "centimeters" only applies to the depth of soil to be evaluated. It has no influence on the units of measure the data are presented in.

When "Surface Layer" is specified as the depth qualifier, only the surface layer or horizon is considered when deriving a value for a component, but keep in mind that the thickness of the surface layer varies from component to component.

When "All Layers" is specified as the depth qualifier, all layers recorded for a component are considered when deriving the value for that component.

Whenever more than one layer or horizon is considered when deriving a value for a component, and the attribute being aggregated is a numeric attribute, a weighted average value is returned, where the weighting factor is the layer or horizon thickness.

Saturated Hydraulic Conductivity (Ksat)

Saturated hydraulic conductivity (Ksat) refers to the ease with which pores in a saturated soil transmit water. The estimates are expressed in terms of micrometers per second. They are based on soil characteristics observed in the field, particularly structure, porosity, and texture. Saturated hydraulic conductivity is considered in the design of soil drainage systems and septic tank absorption fields.

For each soil layer, this attribute is actually recorded as three separate values in the database. A low value and a high value indicate the range of this attribute for the soil component. A "representative" value indicates the expected value of this attribute for the component. For this soil property, only the representative value is used.

The numeric Ksat values have been grouped according to standard Ksat class limits.

Table—Saturated Hydraulic Conductivity (Ksat)

Saturated Hydraulic Conductivity (Ksat)— Summary by Map Unit — Humboldt County, Nevada, East Part				
Map unit symbol	**Map unit name**	**Rating (micrometers per second)**	**Acres in AOI**	**Percent of AOI**
831	Boton-Playas association	4.2750	592.4	94.9%
990	Playas	0.2150	32.0	5.1%
Totals for Area of Interest			**624.5**	**100.0%**

Rating Options—Saturated Hydraulic Conductivity (Ksat)

Units of Measure: micrometers per second

Aggregation Method: All Components

Aggregation is the process by which a set of component attribute values is reduced to a single value that represents the map unit as a whole.

A map unit is typically composed of one or more "components". A component is either some type of soil or some nonsoil entity, e.g., rock outcrop. For the attribute being aggregated, the first step of the aggregation process is to derive one attribute value for each of a map unit's components. From this set of component attributes, the next step of the aggregation process derives a single value that represents the map unit as a whole. Once a single value for each map unit is derived, a thematic map for soil map units can be rendered. Aggregation must be done because, on any soil map, map units are delineated but components are not.

For each of a map unit's components, a corresponding percent composition is recorded. A percent composition of 60 indicates that the corresponding component typically makes up approximately 60% of the map unit. Percent composition is a critical factor in some, but not all, aggregation methods.

The aggregation method "All Components" returns the lowest or highest attribute value among all components of the map unit, depending on the corresponding "tie-break" rule. In this case, the "tie-break" rule indicates whether the lowest or highest value among all components should be returned. For this aggregation method, percent composition ties cannot occur.

The result returned by this aggregation method represents either the minimum or maximum value of the corresponding attribute throughout the map unit. The result may well be based on a map unit component of very minor extent.

Component Percent Cutoff: None Specified

Components whose percent composition is below the cutoff value will not be considered. If no cutoff value is specified, all components in the database will be considered. The data for some contrasting soils of minor extent may not be in the database, and therefore are not considered.

Tie-break Rule: Fastest

The tie-break rule indicates which value should be selected from a set of multiple candidate values, or which value should be selected in the event of a percent composition tie.

Interpret Nulls as Zero: No

This option indicates if a null value for a component should be converted to zero before aggregation occurs. This will be done only if a map unit has at least one component where this value is not null.

Layer Options: All Layers

For an attribute of a soil horizon, a depth qualification must be specified. In most cases it is probably most appropriate to specify a fixed depth range, either in centimeters or inches. The Bottom Depth must be greater than the Top Depth, and the Top Depth can be greater than zero. The choice of "inches" or "centimeters" only applies to the depth of soil to be evaluated. It has no influence on the units of measure the data are presented in.

When "Surface Layer" is specified as the depth qualifier, only the surface layer or horizon is considered when deriving a value for a component, but keep in mind that the thickness of the surface layer varies from component to component.

When "All Layers" is specified as the depth qualifier, all layers recorded for a component are considered when deriving the value for that component.

Whenever more than one layer or horizon is considered when deriving a value for a component, and the attribute being aggregated is a numeric attribute, a weighted average value is returned, where the weighting factor is the layer or horizon thickness.

Saturated Hydraulic Conductivity (Ksat), Standard Classes

Saturated hydraulic conductivity (Ksat) refers to the ease with which pores in a saturated soil transmit water. The estimates are expressed in terms of micrometers per second. They are based on soil characteristics observed in the field, particularly structure, porosity, and texture. Saturated hydraulic conductivity is considered in the design of soil drainage systems and septic tank absorption fields.

For each soil layer, this attribute is actually recorded as three separate values in the database. A low value and a high value indicate the range of this attribute for the soil component. A "representative" value indicates the expected value of this attribute for the component. For this soil property, only the representative value is used.

The numeric Ksat values have been grouped according to standard Ksat class limits. The classes are:

Very low: 0.00 to 0.01

Low: 0.01 to 0.1

Moderately low: 0.1 to 1.0

Moderately high: 1 to 10

High: 10 to 100

Very high: 100 to 705

Table—Saturated Hydraulic Conductivity (Ksat), Standard Classes

Saturated Hydraulic Conductivity (Ksat), Standard Classes— Summary by Map Unit — Humboldt County, Nevada, East Part				
Map unit symbol	**Map unit name**	**Rating (micrometers per second)**	**Acres in AOI**	**Percent of AOI**
831	Boton-Playas association	4.2750	592.4	94.9%
990	Playas	0.2150	32.0	5.1%
Totals for Area of Interest			**624.5**	**100.0%**

Rating Options—Saturated Hydraulic Conductivity (Ksat), Standard Classes

Units of Measure: micrometers per second

Aggregation Method: All Components

Aggregation is the process by which a set of component attribute values is reduced to a single value that represents the map unit as a whole.

A map unit is typically composed of one or more "components". A component is either some type of soil or some nonsoil entity, e.g., rock outcrop. For the attribute being aggregated, the first step of the aggregation process is to derive one attribute value for each of a map unit's components. From this set of component attributes, the next step of the aggregation process derives a single value that represents the map unit as a whole. Once a single value for each map unit is derived, a thematic map for soil map units can be rendered. Aggregation must be done because, on any soil map, map units are delineated but components are not.

For each of a map unit's components, a corresponding percent composition is recorded. A percent composition of 60 indicates that the corresponding component typically makes up approximately 60% of the map unit. Percent composition is a critical factor in some, but not all, aggregation methods.

The aggregation method "All Components" returns the lowest or highest attribute value among all components of the map unit, depending on the corresponding "tie-break" rule. In this case, the "tie-break" rule indicates whether the lowest or highest value among all components should be returned. For this aggregation method, percent composition ties cannot occur.

The result returned by this aggregation method represents either the minimum or maximum value of the corresponding attribute throughout the map unit. The result may well be based on a map unit component of very minor extent.

Component Percent Cutoff: None Specified

Components whose percent composition is below the cutoff value will not be considered. If no cutoff value is specified, all components in the database will be considered. The data for some contrasting soils of minor extent may not be in the database, and therefore are not considered.

Tie-break Rule: Fastest

The tie-break rule indicates which value should be selected from a set of multiple candidate values, or which value should be selected in the event of a percent composition tie.

Interpret Nulls as Zero: No

This option indicates if a null value for a component should be converted to zero before aggregation occurs. This will be done only if a map unit has at least one component where this value is not null.

Layer Options: All Layers

For an attribute of a soil horizon, a depth qualification must be specified. In most cases it is probably most appropriate to specify a fixed depth range, either in centimeters or inches. The Bottom Depth must be greater than the Top Depth, and the Top Depth can be greater than zero. The choice of "inches" or "centimeters" only applies to the depth of soil to be evaluated. It has no influence on the units of measure the data are presented in.

When "Surface Layer" is specified as the depth qualifier, only the surface layer or horizon is considered when deriving a value for a component, but keep in mind that the thickness of the surface layer varies from component to component.

When "All Layers" is specified as the depth qualifier, all layers recorded for a component are considered when deriving the value for that component.

Whenever more than one layer or horizon is considered when deriving a value for a component, and the attribute being aggregated is a numeric attribute, a weighted average value is returned, where the weighting factor is the layer or horizon thickness.

Surface Texture

This displays the representative texture class and modifier of the surface horizon.

Texture is given in the standard terms used by the U.S. Department of Agriculture. These terms are defined according to percentages of sand, silt, and clay in the fraction of the soil that is less than 2 millimeters in diameter. "Loam," for example, is soil that is 7 to 27 percent clay, 28 to 50 percent silt, and less than 52 percent sand. If the content of particles coarser than sand is 15 percent or more, an appropriate modifier is added, for example, "gravelly."

Table—Surface Texture

Surface Texture— Summary by Map Unit — Humboldt County, Nevada, East Part				
Map unit symbol	**Map unit name**	**Rating**	**Acres in AOI**	**Percent of AOI**
831	Boton-Playas association	silt loam	592.4	94.9%
990	Playas	silty clay loam	32.0	5.1%
Totals for Area of Interest			**624.5**	**100.0%**

Rating Options—Surface Texture

Aggregation Method: All Components

Aggregation is the process by which a set of component attribute values is reduced to a single value that represents the map unit as a whole.

A map unit is typically composed of one or more "components". A component is either some type of soil or some nonsoil entity, e.g., rock outcrop. For the attribute being aggregated, the first step of the aggregation process is to derive one attribute value for each of a map unit's components. From this set of component attributes, the next step of the aggregation process derives a single value that represents the map unit as a whole. Once a single value for each map unit is derived, a thematic map for soil map units can be rendered. Aggregation must be done because, on any soil map, map units are delineated but components are not.

For each of a map unit's components, a corresponding percent composition is recorded. A percent composition of 60 indicates that the corresponding component typically makes up approximately 60% of the map unit. Percent composition is a critical factor in some, but not all, aggregation methods.

The aggregation method "All Components" returns the lowest or highest attribute value among all components of the map unit, depending on the corresponding "tie-break" rule. In this case, the "tie-break" rule indicates whether the lowest or highest value among all components should be returned. For this aggregation method, percent composition ties cannot occur.

The result returned by this aggregation method represents either the minimum or maximum value of the corresponding attribute throughout the map unit. The result may well be based on a map unit component of very minor extent.

Component Percent Cutoff: None Specified

Components whose percent composition is below the cutoff value will not be considered. If no cutoff value is specified, all components in the database will be considered. The data for some contrasting soils of minor extent may not be in the database, and therefore are not considered.

Tie-break Rule: Lower

The tie-break rule indicates which value should be selected from a set of multiple candidate values, or which value should be selected in the event of a percent composition tie.

Layer Options: Surface Layer

For an attribute of a soil horizon, a depth qualification must be specified. In most cases it is probably most appropriate to specify a fixed depth range, either in centimeters or inches. The Bottom Depth must be greater than the Top Depth, and the Top Depth can be greater than zero. The choice of "inches" or "centimeters" only applies to the depth of soil to be evaluated. It has no influence on the units of measure the data are presented in.

When "Surface Layer" is specified as the depth qualifier, only the surface layer or horizon is considered when deriving a value for a component, but keep in mind that the thickness of the surface layer varies from component to component.

When "All Layers" is specified as the depth qualifier, all layers recorded for a component are considered when deriving the value for that component.

Whenever more than one layer or horizon is considered when deriving a value for a component, and the attribute being aggregated is a numeric attribute, a weighted average value is returned, where the weighting factor is the layer or horizon thickness.

Water Content, 15 Bar

Water content, 15 bar, is the amount of soil water retained at a tension of 15 bars, expressed as a volumetric percentage of the whole soil material. Water retained at 15 bars is significant in the determination of soil water-retention difference, which is used as the initial estimation of available water capacity for some soils. Water retained at 15 bars is an estimation of the wilting point.

Water content varies between soil types, depending on soil properties that affect retention of water. The most important properties are the content of organic matter, soil texture, bulk density, and soil structure.

For each soil layer, water content is recorded as three separate values in the database. A low value and a high value indicate the range of this attribute for the soil component. A "representative" value indicates the expected value of this attribute for the component. For this soil property, only the representative value is used.

Table—Water Content, 15 Bar

Water Content, 15 Bar— Summary by Map Unit — Humboldt County, Nevada, East Part				
Map unit symbol	**Map unit name**	**Rating (percent)**	**Acres in AOI**	**Percent of AOI**
831	Boton-Playas association	26.8	592.4	94.9%
990	Playas	26.5	32.0	5.1%
Totals for Area of Interest			**624.5**	**100.0%**

Rating Options—Water Content, 15 Bar

Units of Measure: percent

Aggregation Method: All Components

Aggregation is the process by which a set of component attribute values is reduced to a single value that represents the map unit as a whole.

A map unit is typically composed of one or more "components". A component is either some type of soil or some nonsoil entity, e.g., rock outcrop. For the attribute being aggregated, the first step of the aggregation process is to derive one attribute value for each of a map unit's components. From this set of component attributes, the next step of the aggregation process derives a single value that represents the map unit as a whole. Once a single value for each map unit is derived, a thematic map for soil map units can be rendered. Aggregation must be done because, on any soil map, map units are delineated but components are not.

For each of a map unit's components, a corresponding percent composition is recorded. A percent composition of 60 indicates that the corresponding component typically makes up approximately 60% of the map unit. Percent composition is a critical factor in some, but not all, aggregation methods.

The aggregation method "All Components" returns the lowest or highest attribute value among all components of the map unit, depending on the corresponding "tie-break" rule. In this case, the "tie-break" rule indicates whether the lowest or highest value among all components should be returned. For this aggregation method, percent composition ties cannot occur.

The result returned by this aggregation method represents either the minimum or maximum value of the corresponding attribute throughout the map unit. The result may well be based on a map unit component of very minor extent.

Component Percent Cutoff: None Specified

Components whose percent composition is below the cutoff value will not be considered. If no cutoff value is specified, all components in the database will be considered. The data for some contrasting soils of minor extent may not be in the database, and therefore are not considered.

Tie-break Rule: Higher

The tie-break rule indicates which value should be selected from a set of multiple candidate values, or which value should be selected in the event of a percent composition tie.

Interpret Nulls as Zero: Yes

This option indicates if a null value for a component should be converted to zero before aggregation occurs. This will be done only if a map unit has at least one component where this value is not null.

Layer Options: All Layers

For an attribute of a soil horizon, a depth qualification must be specified. In most cases it is probably most appropriate to specify a fixed depth range, either in centimeters or inches. The Bottom Depth must be greater than the Top Depth, and the Top Depth can be greater than zero. The choice of "inches" or "centimeters" only applies to the depth of soil to be evaluated. It has no influence on the units of measure the data are presented in.

When "Surface Layer" is specified as the depth qualifier, only the surface layer or horizon is considered when deriving a value for a component, but keep in mind that the thickness of the surface layer varies from component to component.

When "All Layers" is specified as the depth qualifier, all layers recorded for a component are considered when deriving the value for that component.

Whenever more than one layer or horizon is considered when deriving a value for a component, and the attribute being aggregated is a numeric attribute, a weighted average value is returned, where the weighting factor is the layer or horizon thickness.

Water Content, One-Third Bar

Water content, one-third bar, is the amount of soil water retained at a tension of 1/3 bar, expressed as a volumetric percentage of the whole soil. Water retained at 1/3 bar is significant in the determination of soil water-retention difference, which is used as the initial estimation of available water capacity for some soils. Water retained at 1/3 bar is the value commonly used to estimate the content of water at field capacity for most soils.

Water content varies between soil types, depending on soil properties that affect retention of water. The most important properties are the content of organic matter, soil texture, bulk density, and soil structure.

For each soil layer, water content is recorded as three separate values in the database. A low value and a high value indicate the range of this attribute for the soil component. A "representative" value indicates the expected value of this attribute for the component. For this soil property, only the representative value is used.

Table—Water Content, One-Third Bar

Water Content, One-Third Bar— Summary by Map Unit — Humboldt County, Nevada, East Part				
Map unit symbol	**Map unit name**	**Rating (percent)**	**Acres in AOI**	**Percent of AOI**
831	Boton-Playas association	32.8	592.4	94.9%
990	Playas	33.4	32.0	5.1%
Totals for Area of Interest			**624.5**	**100.0%**

Rating Options—Water Content, One-Third Bar

Units of Measure: percent

Aggregation Method: All Components

Aggregation is the process by which a set of component attribute values is reduced to a single value that represents the map unit as a whole.

A map unit is typically composed of one or more "components". A component is either some type of soil or some nonsoil entity, e.g., rock outcrop. For the attribute being aggregated, the first step of the aggregation process is to derive one attribute value for each of a map unit's components. From this set of component attributes, the next step of the aggregation process derives a single value that represents the map unit as a whole. Once a single value for each map unit is derived, a thematic map for soil map units can be rendered. Aggregation must be done because, on any soil map, map units are delineated but components are not.

For each of a map unit's components, a corresponding percent composition is recorded. A percent composition of 60 indicates that the corresponding component typically makes up approximately 60% of the map unit. Percent composition is a critical factor in some, but not all, aggregation methods.

The aggregation method "All Components" returns the lowest or highest attribute value among all components of the map unit, depending on the corresponding "tie-break" rule. In this case, the "tie-break" rule indicates whether the lowest or highest value among all components should be returned. For this aggregation method, percent composition ties cannot occur.

The result returned by this aggregation method represents either the minimum or maximum value of the corresponding attribute throughout the map unit. The result may well be based on a map unit component of very minor extent.

Component Percent Cutoff: None Specified

Components whose percent composition is below the cutoff value will not be considered. If no cutoff value is specified, all components in the database will be considered. The data for some contrasting soils of minor extent may not be in the database, and therefore are not considered.

Tie-break Rule: Higher

The tie-break rule indicates which value should be selected from a set of multiple candidate values, or which value should be selected in the event of a percent composition tie.

Interpret Nulls as Zero: Yes

This option indicates if a null value for a component should be converted to zero before aggregation occurs. This will be done only if a map unit has at least one component where this value is not null.

Layer Options: All Layers

For an attribute of a soil horizon, a depth qualification must be specified. In most cases it is probably most appropriate to specify a fixed depth range, either in centimeters or inches. The Bottom Depth must be greater than the Top Depth, and the Top Depth can be greater than zero. The choice of "inches" or "centimeters" only applies to the depth of soil to be evaluated. It has no influence on the units of measure the data are presented in.

When "Surface Layer" is specified as the depth qualifier, only the surface layer or horizon is considered when deriving a value for a component, but keep in mind that the thickness of the surface layer varies from component to component.

When "All Layers" is specified as the depth qualifier, all layers recorded for a component are considered when deriving the value for that component.

Whenever more than one layer or horizon is considered when deriving a value for a component, and the attribute being aggregated is a numeric attribute, a weighted average value is returned, where the weighting factor is the layer or horizon thickness.

Soil Qualities and Features

Soil qualities are behavior and performance attributes that are not directly measured, but are inferred from observations of dynamic conditions and from soil properties. Example soil qualities include natural drainage, and frost action. Soil features are attributes that are not directly part of the soil. Example soil features include slope and depth to restrictive layer. These features can greatly impact the use and management of the soil.

AASHTO Group Classification (Surface)

AASHTO group classification is a system that classifies soils specifically for geotechnical engineering purposes that are related to highway and airfield construction. It is based on particle-size distribution and Atterberg limits, such as liquid limit and plasticity index. This classification system is covered in AASHTO Standard No. M 145-82. The classification is based on that portion of the soil that is smaller than 3 inches in diameter.

The AASHTO classification system has two general classifications: (i) granular materials having 35 percent or less, by weight, particles smaller than 0.074 mm in diameter and (ii) silt-clay materials having more than 35 percent, by weight, particles smaller than 0.074 mm in diameter. These two divisions are further subdivided into seven main group classifications, plus eight subgroups, for a total of fifteen for mineral soils. Another class for organic soils is used.

For each soil horizon in the database one or more AASHTO Group Classifications may be listed. One is marked as the representative or most commonly occurring. The representative classification is shown here for the surface layer of the soil.

Table—AASHTO Group Classification (Surface)

AASHTO Group Classification (Surface)— Summary by Map Unit — Humboldt County, Nevada, East Part				
Map unit symbol	**Map unit name**	**Rating**	**Acres in AOI**	**Percent of AOI**
831	Boton-Playas association	A-4	592.4	94.9%
990	Playas	A-6	32.0	5.1%
Totals for Area of Interest			**624.5**	**100.0%**

Rating Options—AASHTO Group Classification (Surface)

Aggregation Method: All Components

Aggregation is the process by which a set of component attribute values is reduced to a single value that represents the map unit as a whole.

A map unit is typically composed of one or more "components". A component is either some type of soil or some nonsoil entity, e.g., rock outcrop. For the attribute being aggregated, the first step of the aggregation process is to derive one attribute value for each of a map unit's components. From this set of component attributes, the next step of the aggregation process derives a single value that represents the map unit as a whole. Once a single value for each map unit is derived, a thematic map for soil map units can be rendered. Aggregation must be done because, on any soil map, map units are delineated but components are not.

For each of a map unit's components, a corresponding percent composition is recorded. A percent composition of 60 indicates that the corresponding component typically makes up approximately 60% of the map unit. Percent composition is a critical factor in some, but not all, aggregation methods.

The aggregation method "All Components" returns the lowest or highest attribute value among all components of the map unit, depending on the corresponding "tie-break" rule. In this case, the "tie-break" rule indicates whether the lowest or highest value among all components should be returned. For this aggregation method, percent composition ties cannot occur.

The result returned by this aggregation method represents either the minimum or maximum value of the corresponding attribute throughout the map unit. The result may well be based on a map unit component of very minor extent.

Component Percent Cutoff: None Specified

Components whose percent composition is below the cutoff value will not be considered. If no cutoff value is specified, all components in the database will be considered. The data for some contrasting soils of minor extent may not be in the database, and therefore are not considered.

Tie-break Rule: Lower

The tie-break rule indicates which value should be selected from a set of multiple candidate values, or which value should be selected in the event of a percent composition tie.

Layer Options: Surface Layer

For an attribute of a soil horizon, a depth qualification must be specified. In most cases it is probably most appropriate to specify a fixed depth range, either in centimeters or inches. The Bottom Depth must be greater than the Top Depth, and the Top Depth can be greater than zero. The choice of "inches" or "centimeters" only applies to the depth of soil to be evaluated. It has no influence on the units of measure the data are presented in.

When "Surface Layer" is specified as the depth qualifier, only the surface layer or horizon is considered when deriving a value for a component, but keep in mind that the thickness of the surface layer varies from component to component.

When "All Layers" is specified as the depth qualifier, all layers recorded for a component are considered when deriving the value for that component.

Whenever more than one layer or horizon is considered when deriving a value for a component, and the attribute being aggregated is a numeric attribute, a weighted average value is returned, where the weighting factor is the layer or horizon thickness.

Depth to Any Soil Restrictive Layer

A "restrictive layer" is a nearly continuous layer that has one or more physical, chemical, or thermal properties that significantly impede the movement of water and air through the soil or that restrict roots or otherwise provide an unfavorable root environment. Examples are bedrock, cemented layers, dense layers, and frozen layers.

This theme presents the depth to any type of restrictive layer that is described for each map unit. If more than one type of restrictive layer is described for an individual soil type, the depth to the shallowest one is presented. If no restrictive layer is described in a map unit, it is represented by the "> 200" depth class.

This attribute is actually recorded as three separate values in the database. A low value and a high value indicate the range of this attribute for the soil component. A "representative" value indicates the expected value of this attribute for the component. For this soil property, only the representative value is used.

Table—Depth to Any Soil Restrictive Layer

Depth to Any Soil Restrictive Layer— Summary by Map Unit — Humboldt County, Nevada, East Part				
Map unit symbol	**Map unit name**	**Rating (centimeters)**	**Acres in AOI**	**Percent of AOI**
831	Boton-Playas association	>200	592.4	94.9%
990	Playas	>200	32.0	5.1%
Totals for Area of Interest			**624.5**	**100.0%**

Rating Options—Depth to Any Soil Restrictive Layer

Units of Measure: centimeters

Aggregation Method: All Components

Aggregation is the process by which a set of component attribute values is reduced to a single value that represents the map unit as a whole.

A map unit is typically composed of one or more "components". A component is either some type of soil or some nonsoil entity, e.g., rock outcrop. For the attribute being aggregated, the first step of the aggregation process is to derive one attribute value for each of a map unit's components. From this set of component attributes, the next step of the aggregation process derives a single value that represents the map unit as a whole. Once a single value for each map unit is derived, a thematic map for soil map units can be rendered. Aggregation must be done because, on any soil map, map units are delineated but components are not.

For each of a map unit's components, a corresponding percent composition is recorded. A percent composition of 60 indicates that the corresponding component typically makes up approximately 60% of the map unit. Percent composition is a critical factor in some, but not all, aggregation methods.

The aggregation method "All Components" returns the lowest or highest attribute value among all components of the map unit, depending on the corresponding "tie-break" rule. In this case, the "tie-break" rule indicates whether the lowest or highest value among all components should be returned. For this aggregation method, percent composition ties cannot occur.

The result returned by this aggregation method represents either the minimum or maximum value of the corresponding attribute throughout the map unit. The result may well be based on a map unit component of very minor extent.

Component Percent Cutoff: None Specified

Components whose percent composition is below the cutoff value will not be considered. If no cutoff value is specified, all components in the database will be considered. The data for some contrasting soils of minor extent may not be in the database, and therefore are not considered.

Tie-break Rule: Lower

The tie-break rule indicates which value should be selected from a set of multiple candidate values, or which value should be selected in the event of a percent composition tie.

Interpret Nulls as Zero: No

This option indicates if a null value for a component should be converted to zero before aggregation occurs. This will be done only if a map unit has at least one component where this value is not null.

Drainage Class

"Drainage class (natural)" refers to the frequency and duration of wet periods under conditions similar to those under which the soil formed. Alterations of the water regime by human activities, either through drainage or irrigation, are not a consideration unless they have significantly changed the morphology of the soil. Seven classes of natural soil drainage are recognized-excessively drained, somewhat excessively drained, well drained, moderately well drained, somewhat poorly drained, poorly drained, and very poorly drained. These classes are defined in the "Soil Survey Manual."

Table—Drainage Class

Drainage Class— Summary by Map Unit — Humboldt County, Nevada, East Part				
Map unit symbol	**Map unit name**	**Rating**	**Acres in AOI**	**Percent of AOI**
831	Boton-Playas association	Well drained	592.4	94.9%
990	Playas	Very poorly drained	32.0	5.1%
Totals for Area of Interest			**624.5**	**100.0%**

Rating Options—Drainage Class

Aggregation Method: All Components

Aggregation is the process by which a set of component attribute values is reduced to a single value that represents the map unit as a whole.

A map unit is typically composed of one or more "components". A component is either some type of soil or some nonsoil entity, e.g., rock outcrop. For the attribute being aggregated, the first step of the aggregation process is to derive one attribute value for each of a map unit's components. From this set of component attributes, the next step of the aggregation process derives a single value that represents the map unit as a whole. Once a single value for each map unit is derived, a thematic map for soil map units can be rendered. Aggregation must be done because, on any soil map, map units are delineated but components are not.

For each of a map unit's components, a corresponding percent composition is recorded. A percent composition of 60 indicates that the corresponding component typically makes up approximately 60% of the map unit. Percent composition is a critical factor in some, but not all, aggregation methods.

The aggregation method "All Components" returns the lowest or highest attribute value among all components of the map unit, depending on the corresponding "tie-break" rule. In this case, the "tie-break" rule indicates whether the lowest or highest value among all components should be returned. For this aggregation method, percent composition ties cannot occur.

The result returned by this aggregation method represents either the minimum or maximum value of the corresponding attribute throughout the map unit. The result may well be based on a map unit component of very minor extent.

Component Percent Cutoff: None Specified

Components whose percent composition is below the cutoff value will not be considered. If no cutoff value is specified, all components in the database will be considered. The data for some contrasting soils of minor extent may not be in the database, and therefore are not considered.

Tie-break Rule: Lower

The tie-break rule indicates which value should be selected from a set of multiple candidate values, or which value should be selected in the event of a percent composition tie.

Frost Action

Potential for frost action is the likelihood of upward or lateral expansion of the soil caused by the formation of segregated ice lenses (frost heave) and the subsequent collapse of the soil and loss of strength on thawing. Frost action occurs when moisture moves into the freezing zone of the soil. Temperature, texture, density, saturated hydraulic conductivity (Ksat), content of organic matter, and depth to the water table are the most important factors considered in evaluating the potential for frost action. It is assumed that the soil is not insulated by vegetation or snow and is not artificially drained. Silty and highly structured, clayey soils that have a high water table in winter are the most susceptible to frost action. Well drained, very gravelly, or very sandy soils are the least susceptible. Frost heave and low soil strength during thawing cause damage to pavements and other rigid structures.

Table—Frost Action

Frost Action— Summary by Map Unit — Humboldt County, Nevada, East Part				
Map unit symbol	**Map unit name**	**Rating**	**Acres in AOI**	**Percent of AOI**
831	Boton-Playas association	Low	592.4	94.9%
990	Playas	None	32.0	5.1%
Totals for Area of Interest			**624.5**	**100.0%**

Rating Options—Frost Action

Aggregation Method: All Components

Aggregation is the process by which a set of component attribute values is reduced to a single value that represents the map unit as a whole.

A map unit is typically composed of one or more "components". A component is either some type of soil or some nonsoil entity, e.g., rock outcrop. For the attribute being aggregated, the first step of the aggregation process is to derive one attribute value for each of a map unit's components. From this set of component attributes, the next step of the aggregation process derives a single value that represents the map unit as a whole. Once a single value for each map unit is derived, a thematic map for soil map units can be rendered. Aggregation must be done because, on any soil map, map units are delineated but components are not.

For each of a map unit's components, a corresponding percent composition is recorded. A percent composition of 60 indicates that the corresponding component typically makes up approximately 60% of the map unit. Percent composition is a critical factor in some, but not all, aggregation methods.

The aggregation method "All Components" returns the lowest or highest attribute value among all components of the map unit, depending on the corresponding "tie-break" rule. In this case, the "tie-break" rule indicates whether the lowest or highest value among all components should be returned. For this aggregation method, percent composition ties cannot occur.

The result returned by this aggregation method represents either the minimum or maximum value of the corresponding attribute throughout the map unit. The result may well be based on a map unit component of very minor extent.

Component Percent Cutoff: None Specified

Components whose percent composition is below the cutoff value will not be considered. If no cutoff value is specified, all components in the database will be considered. The data for some contrasting soils of minor extent may not be in the database, and therefore are not considered.

Tie-break Rule: Higher

The tie-break rule indicates which value should be selected from a set of multiple candidate values, or which value should be selected in the event of a percent composition tie.

Frost-Free Days

The term "frost-free days" refers to the expected number of days between the last freezing temperature (0 degrees Celsius) in spring (January-July) and the first freezing temperature in fall (August-December). The number of days is based on the probability that the values for the standard "normal" period of 1961 to 1990 will be exceeded in 5 years out of 10.

This attribute is actually recorded as three separate values in the database. A low value and a high value indicate the range of this attribute for the soil component. A "representative" value indicates the expected value of this attribute for the component. For this attribute, only the representative value is used.

Table—Frost-Free Days

Frost-Free Days— Summary by Map Unit — Humboldt County, Nevada, East Part				
Map unit symbol	**Map unit name**	**Rating (days)**	**Acres in AOI**	**Percent of AOI**
831	Boton-Playas association	130	592.4	94.9%
990	Playas		32.0	5.1%
Totals for Area of Interest			**624.5**	**100.0%**

Rating Options—Frost-Free Days

Units of Measure: days

Aggregation Method: All Components

Aggregation is the process by which a set of component attribute values is reduced to a single value that represents the map unit as a whole.

A map unit is typically composed of one or more "components". A component is either some type of soil or some nonsoil entity, e.g., rock outcrop. For the attribute being aggregated, the first step of the aggregation process is to derive one attribute value for each of a map unit's components. From this set of component attributes, the next step of the aggregation process derives a single value that represents the map unit as a whole. Once a single value for each map unit is derived, a thematic map for soil map units can be rendered. Aggregation must be done because, on any soil map, map units are delineated but components are not.

For each of a map unit's components, a corresponding percent composition is recorded. A percent composition of 60 indicates that the corresponding component typically makes up approximately 60% of the map unit. Percent composition is a critical factor in some, but not all, aggregation methods.

The aggregation method "All Components" returns the lowest or highest attribute value among all components of the map unit, depending on the corresponding "tie-break" rule. In this case, the "tie-break" rule indicates whether the lowest or highest value among all components should be returned. For this aggregation method, percent composition ties cannot occur.

The result returned by this aggregation method represents either the minimum or maximum value of the corresponding attribute throughout the map unit. The result may well be based on a map unit component of very minor extent.

Component Percent Cutoff: None Specified

Components whose percent composition is below the cutoff value will not be considered. If no cutoff value is specified, all components in the database will be considered. The data for some contrasting soils of minor extent may not be in the database, and therefore are not considered.

Tie-break Rule: Higher

The tie-break rule indicates which value should be selected from a set of multiple candidate values, or which value should be selected in the event of a percent composition tie.

Interpret Nulls as Zero: No

This option indicates if a null value for a component should be converted to zero before aggregation occurs. This will be done only if a map unit has at least one component where this value is not null.

Hydrologic Soil Group

Hydrologic soil groups are based on estimates of runoff potential. Soils are assigned to one of four groups according to the rate of water infiltration when the soils are not protected by vegetation, are thoroughly wet, and receive precipitation from long-duration storms.

The soils in the United States are assigned to four groups (A, B, C, and D) and three dual classes (A/D, B/D, and C/D). The groups are defined as follows:

Group A. Soils having a high infiltration rate (low runoff potential) when thoroughly wet. These consist mainly of deep, well drained to excessively drained sands or gravelly sands. These soils have a high rate of water transmission.

Group B. Soils having a moderate infiltration rate when thoroughly wet. These consist chiefly of moderately deep or deep, moderately well drained or well drained soils that have moderately fine texture to moderately coarse texture. These soils have a moderate rate of water transmission.

Group C. Soils having a slow infiltration rate when thoroughly wet. These consist chiefly of soils having a layer that impedes the downward movement of water or soils of moderately fine texture or fine texture. These soils have a slow rate of water transmission.

Group D. Soils having a very slow infiltration rate (high runoff potential) when thoroughly wet. These consist chiefly of clays that have a high shrink-swell potential, soils that have a high water table, soils that have a claypan or clay layer at or near the surface, and soils that are shallow over nearly impervious material. These soils have a very slow rate of water transmission.

If a soil is assigned to a dual hydrologic group (A/D, B/D, or C/D), the first letter is for drained areas and the second is for undrained areas. Only the soils that in their natural condition are in group D are assigned to dual classes.

Table—Hydrologic Soil Group

Hydrologic Soil Group— Summary by Map Unit — Humboldt County, Nevada, East Part				
Map unit symbol	**Map unit name**	**Rating**	**Acres in AOI**	**Percent of AOI**
831	Boton-Playas association	B	592.4	94.9%
990	Playas	D	32.0	5.1%
Totals for Area of Interest			**624.5**	**100.0%**

Rating Options—Hydrologic Soil Group

Aggregation Method: All Components

Aggregation is the process by which a set of component attribute values is reduced to a single value that represents the map unit as a whole.

A map unit is typically composed of one or more "components". A component is either some type of soil or some nonsoil entity, e.g., rock outcrop. For the attribute being aggregated, the first step of the aggregation process is to derive one attribute value for each of a map unit's components. From this set of component attributes, the next step of the aggregation process derives a single value that represents the map unit as a whole. Once a single value for each map unit is derived, a thematic map for soil map units can be rendered. Aggregation must be done because, on any soil map, map units are delineated but components are not.

For each of a map unit's components, a corresponding percent composition is recorded. A percent composition of 60 indicates that the corresponding component typically makes up approximately 60% of the map unit. Percent composition is a critical factor in some, but not all, aggregation methods.

The aggregation method "All Components" returns the lowest or highest attribute value among all components of the map unit, depending on the corresponding "tie-break" rule. In this case, the "tie-break" rule indicates whether the lowest or highest value among all components should be returned. For this aggregation method, percent composition ties cannot occur.

The result returned by this aggregation method represents either the minimum or maximum value of the corresponding attribute throughout the map unit. The result may well be based on a map unit component of very minor extent.

Component Percent Cutoff: None Specified

Components whose percent composition is below the cutoff value will not be considered. If no cutoff value is specified, all components in the database will be considered. The data for some contrasting soils of minor extent may not be in the database, and therefore are not considered.

Tie-break Rule: Lower

The tie-break rule indicates which value should be selected from a set of multiple candidate values, or which value should be selected in the event of a percent composition tie.

Map Unit Name

A soil map unit is a collection of soil areas or nonsoil areas (miscellaneous areas) delineated in a soil survey. Each map unit is given a name that uniquely identifies the unit in a particular soil survey area.

Table—Map Unit Name

Map Unit Name— Summary by Map Unit — Humboldt County, Nevada, East Part				
Map unit symbol	**Map unit name**	**Rating**	**Acres in AOI**	**Percent of AOI**
831	Boton-Playas association	Boton-Playas association	592.4	94.9%
990	Playas	Playas	32.0	5.1%
Totals for Area of Interest			**624.5**	**100.0%**

Rating Options—Map Unit Name

Aggregation Method: No Aggregation Necessary

Aggregation is the process by which a set of component attribute values is reduced to a single value that represents the map unit as a whole.

A map unit is typically composed of one or more "components". A component is either some type of soil or some nonsoil entity, e.g., rock outcrop. For the attribute being aggregated, the first step of the aggregation process is to derive one attribute value for each of a map unit's components. From this set of component attributes, the next step of the aggregation process derives a single value that represents the map unit as a whole. Once a single value for each map unit is derived, a thematic map for soil map units can be rendered. Aggregation must be done because, on any soil map, map units are delineated but components are not.

For each of a map unit's components, a corresponding percent composition is recorded. A percent composition of 60 indicates that the corresponding component typically makes up approximately 60% of the map unit. Percent composition is a critical factor in some, but not all, aggregation methods.

The majority of soil attributes are associated with a component of a map unit, and such an attribute has to be aggregated to the map unit level before a thematic map can be rendered. Map units, however, also have their own attributes. An attribute of a map unit does not have to be aggregated in order to render a corresponding thematic map. Therefore, the "aggregation method" for any attribute of a map unit is referred to as "No Aggregation Necessary".

Tie-break Rule: Lower

The tie-break rule indicates which value should be selected from a set of multiple candidate values, or which value should be selected in the event of a percent composition tie.

Parent Material Name

Parent material name is a term for the general physical, chemical, and mineralogical composition of the unconsolidated material, mineral or organic, in which the soil forms. Mode of deposition and/or weathering may be implied by the name.

The soil surveyor uses parent material to develop a model used for soil mapping. Soil scientists and specialists in other disciplines use parent material to help interpret soil boundaries and project performance of the material below the soil. Many soil properties relate to parent material. Among these properties are proportions of sand, silt, and clay; chemical content; bulk density; structure; and the kinds and amounts of rock fragments. These properties affect interpretations and may be criteria used to separate soil series. Soil properties and landscape information may imply the kind of parent material.

For each soil in the database, one or more parent materials may be identified. One is marked as the representative or most commonly occurring. The representative parent material name is presented here.

Table—Parent Material Name

Parent Material Name— Summary by Map Unit — Humboldt County, Nevada, East Part				
Map unit symbol	**Map unit name**	**Rating**	**Acres in AOI**	**Percent of AOI**
831	Boton-Playas association	volcanic ash and loess over lacustrine deposits	592.4	94.9%
990	Playas		32.0	5.1%
Totals for Area of Interest			**624.5**	**100.0%**

Rating Options—Parent Material Name

Aggregation Method: All Components

Aggregation is the process by which a set of component attribute values is reduced to a single value that represents the map unit as a whole.

A map unit is typically composed of one or more "components". A component is either some type of soil or some nonsoil entity, e.g., rock outcrop. For the attribute being aggregated, the first step of the aggregation process is to derive one attribute value for each of a map unit's components. From this set of component attributes, the next step of the aggregation process derives a single value that represents the map unit as a whole. Once a single value for each map unit is derived, a thematic map for soil map units can be rendered. Aggregation must be done because, on any soil map, map units are delineated but components are not.

For each of a map unit's components, a corresponding percent composition is recorded. A percent composition of 60 indicates that the corresponding component typically makes up approximately 60% of the map unit. Percent composition is a critical factor in some, but not all, aggregation methods.

The aggregation method "All Components" returns the lowest or highest attribute value among all components of the map unit, depending on the corresponding "tie-break" rule. In this case, the "tie-break" rule indicates whether the lowest or highest value among all components should be returned. For this aggregation method, percent composition ties cannot occur.

The result returned by this aggregation method represents either the minimum or maximum value of the corresponding attribute throughout the map unit. The result may well be based on a map unit component of very minor extent.

Component Percent Cutoff: None Specified

Components whose percent composition is below the cutoff value will not be considered. If no cutoff value is specified, all components in the database will be considered. The data for some contrasting soils of minor extent may not be in the database, and therefore are not considered.

Tie-break Rule: Lower

The tie-break rule indicates which value should be selected from a set of multiple candidate values, or which value should be selected in the event of a percent composition tie.

Representative Slope

Slope gradient is the difference in elevation between two points, expressed as a percentage of the distance between those points.

The slope gradient is actually recorded as three separate values in the database. A low value and a high value indicate the range of this attribute for the soil component. A "representative" value indicates the expected value of this attribute for the component. For this soil property, only the representative value is used.

Table—Representative Slope

Representative Slope— Summary by Map Unit — Humboldt County, Nevada, East Part				
Map unit symbol	**Map unit name**	**Rating (percent)**	**Acres in AOI**	**Percent of AOI**
831	Boton-Playas association	1.0	592.4	94.9%
990	Playas	0.5	32.0	5.1%
Totals for Area of Interest			**624.5**	**100.0%**

Rating Options—Representative Slope

Units of Measure: percent

Aggregation Method: All Components

Aggregation is the process by which a set of component attribute values is reduced to a single value that represents the map unit as a whole.

A map unit is typically composed of one or more "components". A component is either some type of soil or some nonsoil entity, e.g., rock outcrop. For the attribute being aggregated, the first step of the aggregation process is to derive one attribute value for each of a map unit's components. From this set of component attributes, the next step of the aggregation process derives a single value that represents the map unit as a whole. Once a single value for each map unit is derived, a thematic map for soil map units can be rendered. Aggregation must be done because, on any soil map, map units are delineated but components are not.

For each of a map unit's components, a corresponding percent composition is recorded. A percent composition of 60 indicates that the corresponding component typically makes up approximately 60% of the map unit. Percent composition is a critical factor in some, but not all, aggregation methods.

The aggregation method "All Components" returns the lowest or highest attribute value among all components of the map unit, depending on the corresponding "tie-break" rule. In this case, the "tie-break" rule indicates whether the lowest or highest value among all components should be returned. For this aggregation method, percent composition ties cannot occur.

The result returned by this aggregation method represents either the minimum or maximum value of the corresponding attribute throughout the map unit. The result may well be based on a map unit component of very minor extent.

Component Percent Cutoff: None Specified

Components whose percent composition is below the cutoff value will not be considered. If no cutoff value is specified, all components in the database will be considered. The data for some contrasting soils of minor extent may not be in the database, and therefore are not considered.

Tie-break Rule: Higher

The tie-break rule indicates which value should be selected from a set of multiple candidate values, or which value should be selected in the event of a percent composition tie.

Interpret Nulls as Zero: No

This option indicates if a null value for a component should be converted to zero before aggregation occurs. This will be done only if a map unit has at least one component where this value is not null.

Unified Soil Classification (Surface)

The Unified soil classification system classifies mineral and organic mineral soils for engineering purposes on the basis of particle-size characteristics, liquid limit, and plasticity index. It identifies three major soil divisions: (i) coarse-grained soils having less than 50 percent, by weight, particles smaller than 0.074 mm in diameter; (ii) fine-grained soils having 50 percent or more, by weight, particles smaller than 0.074 mm in diameter; and (iii) highly organic soils that demonstrate certain organic characteristics. These divisions are further subdivided into a total of 15 basic soil groups. The major soil divisions and basic soil groups are determined on the basis of estimated or measured values for grain-size distribution and Atterberg limits. ASTM D 2487 shows the criteria chart used for classifying soil in the Unified system and the 15 basic soil groups of the system and the plasticity chart for the Unified system.

The various groupings of this classification correlate in a general way with the engineering behavior of soils. This correlation provides a useful first step in any field or laboratory investigation for engineering purposes. It can serve to make some general interpretations relating to probable performance of the soil for engineering uses.

For each soil horizon in the database one or more Unified soil classifications may be listed. One is marked as the representative or most commonly occurring. The representative classification is shown here for the surface layer of the soil.

Table—Unified Soil Classification (Surface)

Unified Soil Classification (Surface)— Summary by Map Unit — Humboldt County, Nevada, East Part				
Map unit symbol	**Map unit name**	**Rating**	**Acres in AOI**	**Percent of AOI**
831	Boton-Playas association	ML	592.4	94.9%
990	Playas	CL	32.0	5.1%
Totals for Area of Interest			**624.5**	**100.0%**

Rating Options—Unified Soil Classification (Surface)

Aggregation Method: All Components

Aggregation is the process by which a set of component attribute values is reduced to a single value that represents the map unit as a whole.

A map unit is typically composed of one or more "components". A component is either some type of soil or some nonsoil entity, e.g., rock outcrop. For the attribute being aggregated, the first step of the aggregation process is to derive one attribute value for each of a map unit's components. From this set of component attributes, the next step of the aggregation process derives a single value that represents the map unit as a whole. Once a single value for each map unit is derived, a thematic map for soil map units can be rendered. Aggregation must be done because, on any soil map, map units are delineated but components are not.

For each of a map unit's components, a corresponding percent composition is recorded. A percent composition of 60 indicates that the corresponding component typically makes up approximately 60% of the map unit. Percent composition is a critical factor in some, but not all, aggregation methods.

The aggregation method "All Components" returns the lowest or highest attribute value among all components of the map unit, depending on the corresponding "tie-break" rule. In this case, the "tie-break" rule indicates whether the lowest or highest value among all components should be returned. For this aggregation method, percent composition ties cannot occur.

The result returned by this aggregation method represents either the minimum or maximum value of the corresponding attribute throughout the map unit. The result may well be based on a map unit component of very minor extent.

Component Percent Cutoff: None Specified

Components whose percent composition is below the cutoff value will not be considered. If no cutoff value is specified, all components in the database will be considered. The data for some contrasting soils of minor extent may not be in the database, and therefore are not considered.

Tie-break Rule: Lower

The tie-break rule indicates which value should be selected from a set of multiple candidate values, or which value should be selected in the event of a percent composition tie.

Layer Options: Surface Layer

For an attribute of a soil horizon, a depth qualification must be specified. In most cases it is probably most appropriate to specify a fixed depth range, either in centimeters or inches. The Bottom Depth must be greater than the Top Depth, and the Top Depth can be greater than zero. The choice of "inches" or "centimeters" only applies to the depth of soil to be evaluated. It has no influence on the units of measure the data are presented in.

When "Surface Layer" is specified as the depth qualifier, only the surface layer or horizon is considered when deriving a value for a component, but keep in mind that the thickness of the surface layer varies from component to component.

When "All Layers" is specified as the depth qualifier, all layers recorded for a component are considered when deriving the value for that component.

Whenever more than one layer or horizon is considered when deriving a value for a component, and the attribute being aggregated is a numeric attribute, a weighted average value is returned, where the weighting factor is the layer or horizon thickness.

Water Features

Water Features include ponding frequency, flooding frequency, and depth to water table.

Depth to Water Table

"Water table" refers to a saturated zone in the soil. It occurs during specified months. Estimates of the upper limit are based mainly on observations of the water table at selected sites and on evidence of a saturated zone, namely grayish colors (redoximorphic features) in the soil. A saturated zone that lasts for less than a month is not considered a water table.

This attribute is actually recorded as three separate values in the database. A low value and a high value indicate the range of this attribute for the soil component. A "representative" value indicates the expected value of this attribute for the component. For this soil property, only the representative value is used.

Table—Depth to Water Table

Depth to Water Table— Summary by Map Unit — Humboldt County, Nevada, East Part				
Map unit symbol	**Map unit name**	**Rating (centimeters)**	**Acres in AOI**	**Percent of AOI**
831	Boton-Playas association	0	592.4	94.9%
990	Playas	0	32.0	5.1%
Totals for Area of Interest			**624.5**	**100.0%**

Rating Options—Depth to Water Table

Units of Measure: centimeters

Aggregation Method: All Components

Aggregation is the process by which a set of component attribute values is reduced to a single value that represents the map unit as a whole.

A map unit is typically composed of one or more "components". A component is either some type of soil or some nonsoil entity, e.g., rock outcrop. For the attribute being aggregated, the first step of the aggregation process is to derive one attribute value for each of a map unit's components. From this set of component attributes, the next step of the aggregation process derives a single value that represents the map unit as a whole. Once a single value for each map unit is derived, a thematic map for soil map units can be rendered. Aggregation must be done because, on any soil map, map units are delineated but components are not.

For each of a map unit's components, a corresponding percent composition is recorded. A percent composition of 60 indicates that the corresponding component typically makes up approximately 60% of the map unit. Percent composition is a critical factor in some, but not all, aggregation methods.

The aggregation method "All Components" returns the lowest or highest attribute value among all components of the map unit, depending on the corresponding "tie-break" rule. In this case, the "tie-break" rule indicates whether the lowest or highest value among all components should be returned. For this aggregation method, percent composition ties cannot occur.

The result returned by this aggregation method represents either the minimum or maximum value of the corresponding attribute throughout the map unit. The result may well be based on a map unit component of very minor extent.

Component Percent Cutoff: None Specified

Components whose percent composition is below the cutoff value will not be considered. If no cutoff value is specified, all components in the database will be considered. The data for some contrasting soils of minor extent may not be in the database, and therefore are not considered.

Tie-break Rule: Lower

The tie-break rule indicates which value should be selected from a set of multiple candidate values, or which value should be selected in the event of a percent composition tie.

Interpret Nulls as Zero: No

This option indicates if a null value for a component should be converted to zero before aggregation occurs. This will be done only if a map unit has at least one component where this value is not null.

Beginning Month: January

Ending Month: December

Flooding Frequency Class

Flooding is the temporary inundation of an area caused by overflowing streams, by runoff from adjacent slopes, or by tides. Water standing for short periods after rainfall or snowmelt is not considered flooding, and water standing in swamps and marshes is considered ponding rather than flooding.

Frequency is expressed as none, very rare, rare, occasional, frequent, and very frequent.

"None" means that flooding is not probable. The chance of flooding is nearly 0 percent in any year. Flooding occurs less than once in 500 years.

"Very rare" means that flooding is very unlikely but possible under extremely unusual weather conditions. The chance of flooding is less than 1 percent in any year.

"Rare" means that flooding is unlikely but possible under unusual weather conditions. The chance of flooding is 1 to 5 percent in any year.

"Occasional" means that flooding occurs infrequently under normal weather conditions. The chance of flooding is 5 to 50 percent in any year.

"Frequent" means that flooding is likely to occur often under normal weather conditions. The chance of flooding is more than 50 percent in any year but is less than 50 percent in all months in any year.

"Very frequent" means that flooding is likely to occur very often under normal weather conditions. The chance of flooding is more than 50 percent in all months of any year.

Table—Flooding Frequency Class

Flooding Frequency Class— Summary by Map Unit — Humboldt County, Nevada, East Part				
Map unit symbol	**Map unit name**	**Rating**	**Acres in AOI**	**Percent of AOI**
831	Boton-Playas association	None	592.4	94.9%
990	Playas	None	32.0	5.1%
Totals for Area of Interest			**624.5**	**100.0%**

Rating Options—Flooding Frequency Class

Aggregation Method: Dominant Condition

Component Percent Cutoff: None Specified

Tie-break Rule: More Frequent

Beginning Month: January

Ending Month: December

Ponding Frequency Class

Ponding is standing water in a closed depression. The water is removed only by deep percolation, transpiration, or evaporation or by a combination of these processes. Ponding frequency classes are based on the number of times that ponding occurs over a given period. Frequency is expressed as none, rare, occasional, and frequent.

"None" means that ponding is not probable. The chance of ponding is nearly 0 percent in any year.

"Rare" means that ponding is unlikely but possible under unusual weather conditions. The chance of ponding is nearly 0 percent to 5 percent in any year.

"Occasional" means that ponding occurs, on the average, once or less in 2 years. The chance of ponding is 5 to 50 percent in any year.

"Frequent" means that ponding occurs, on the average, more than once in 2 years. The chance of ponding is more than 50 percent in any year.

Table—Ponding Frequency Class

Ponding Frequency Class— Summary by Map Unit — Humboldt County, Nevada, East Part				
Map unit symbol	**Map unit name**	**Rating**	**Acres in AOI**	**Percent of AOI**
831	Boton-Playas association	Frequent	592.4	94.9%
990	Playas	Frequent	32.0	5.1%
Totals for Area of Interest			**624.5**	**100.0%**

Rating Options—Ponding Frequency Class

Aggregation Method: All Components

Aggregation is the process by which a set of component attribute values is reduced to a single value that represents the map unit as a whole.

A map unit is typically composed of one or more "components". A component is either some type of soil or some nonsoil entity, e.g., rock outcrop. For the attribute being aggregated, the first step of the aggregation process is to derive one attribute value for each of a map unit's components. From this set of component attributes, the next step of the aggregation process derives a single value that represents the map unit as a whole. Once a single value for each map unit is derived, a thematic map for soil map units can be rendered. Aggregation must be done because, on any soil map, map units are delineated but components are not.

For each of a map unit's components, a corresponding percent composition is recorded. A percent composition of 60 indicates that the corresponding component typically makes up approximately 60% of the map unit. Percent composition is a critical factor in some, but not all, aggregation methods.

The aggregation method "All Components" returns the lowest or highest attribute value among all components of the map unit, depending on the corresponding "tie-break" rule. In this case, the "tie-break" rule indicates whether the lowest or highest value among all components should be returned. For this aggregation method, percent composition ties cannot occur.

The result returned by this aggregation method represents either the minimum or maximum value of the corresponding attribute throughout the map unit. The result may well be based on a map unit component of very minor extent.

Component Percent Cutoff: None Specified

Components whose percent composition is below the cutoff value will not be considered. If no cutoff value is specified, all components in the database will be considered. The data for some contrasting soils of minor extent may not be in the database, and therefore are not considered.

Tie-break Rule: More Frequent

The tie-break rule indicates which value should be selected from a set of multiple candidate values, or which value should be selected in the event of a percent composition tie.

Beginning Month: January

Ending Month: December

Ecological Site Assessment

Individual soil map unit components can be correlated to a particular ecological site. The Ecological Site Assessment section includes ecological site descriptions, plant growth curves, state and transition models, and selected National Plants database information.

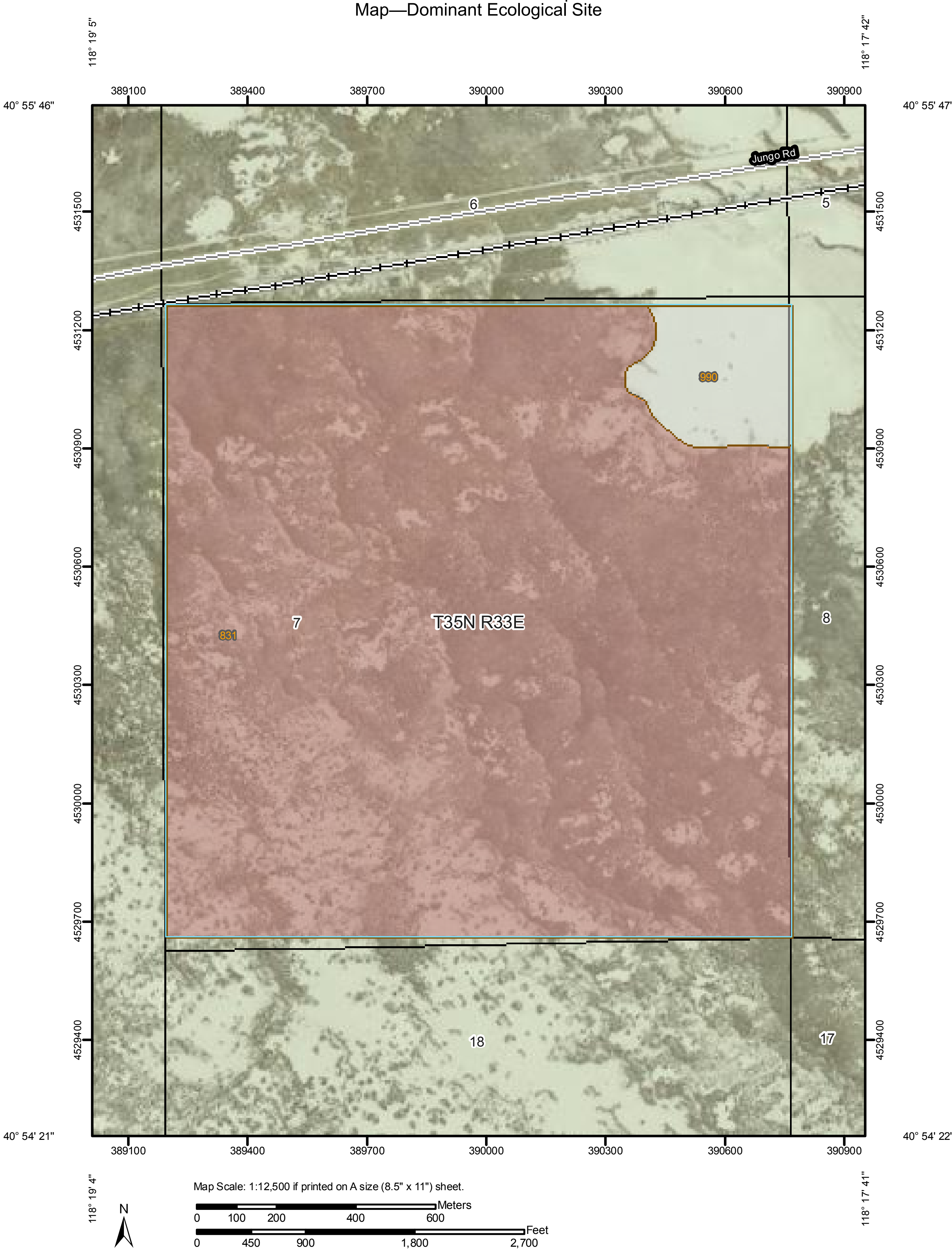
All Ecological Sites — Rangeland

An "ecological site" is the product of all the environmental factors responsible for its development. It has characteristic soils that have developed over time; a characteristic hydrology, particularly infiltration and runoff, that has developed over time; and a characteristic plant community (kind and amount of vegetation). The vegetation, soils, and hydrology are all interrelated. Each is influenced by the others and influences the development of the others. For example, the hydrology of the site is influenced by development of the soil and plant community. The plant community on an ecological site is typified by an association of species that differs from that of other ecological sites in the kind and/or proportion of species or in total production.

An ecological site name provides a general description of a particular ecological site. For example, "Loamy Upland" is the name of a rangeland ecological site. An "ecological site ID" is the symbol assigned to a particular ecological site.

The map identifies the dominant ecological site for each map unit, aggregated by dominant condition. Other ecological sites may occur within each map unit. Each map unit typically consists of one or more components (soils and/or miscellaneous areas). Each soil component is associated with an ecological site. Miscellaneous areas, such as rock outcrop, sand dunes, and badlands, have little or no soil material and support little or no vegetation and therefore are not linked to an ecological site. The table below the map lists all of the ecological sites for each map unit component in your area of interest.

Map—Dominant Ecological Site



Map Scale: 1:12,500 if printed on A size (8.5" x 11") sheet.

Meters: 0, 100, 200, 400, 600

Feet: 0, 450, 900, 1,800, 2,700

MAP LEGEND

Area of Interest (AOI)

Area of Interest (AOI)

Soils

Soil Map Units

Soil Ratings

R024XY003NV — SODIC TERRACE 6-8 P.Z.

Not rated or not available

Political Features

Cities

PLSS Township and Range

PLSS Section

Water Features

Oceans

Streams and Canals

Transportation

Rails

Interstate Highways

US Routes

Major Roads

Local Roads

MAP INFORMATION

Map Scale: 1:12,500 if printed on A size (8.5" × 11") sheet.

The soil surveys that comprise your AOI were mapped at 1:24,000.

Please rely on the bar scale on each map sheet for accurate map measurements.

Source of Map: Natural Resources Conservation Service
Web Soil Survey URL: http://websoilsurvey.nrcs.usda.gov
Coordinate System: UTM Zone 11N NAD83

This product is generated from the USDA-NRCS certified data as of the version date(s) listed below.

Soil Survey Area: Humboldt County, Nevada, East Part
Survey Area Data: Version 4, Dec 12, 2006

Date(s) aerial images were photographed: 7/14/2006

The orthophoto or other base map on which the soil lines were compiled and digitized probably differs from the background imagery displayed on these maps. As a result, some minor shifting of map unit boundaries may be evident.

Table—Ecological Sites by Map Unit Component

Humboldt County, Nevada, East Part				
Map unit symbol	**Component name (percent)**	**Ecological site**	**Acres in AOI**	**Percent of AOI**
831	Boton (50%)	R024XY003NV — SODIC TERRACE 6-8 P.Z.	592.4	94.9%
	Playas (35%)			
990	Playas (95%)		32.0	5.1%
Totals for Area of Interest			**624.5**	**100.0%**

References

American Association of State Highway and Transportation Officials (AASHTO). 2004. Standard specifications for transportation materials and methods of sampling and testing. 24th edition.

American Society for Testing and Materials (ASTM). 2005. Standard classification of soils for engineering purposes. ASTM Standard D2487-00.

Cowardin, L.M., V. Carter, F.C. Golet, and E.T. LaRoe. 1979. Classification of wetlands and deep-water habitats of the United States. U.S. Fish and Wildlife Service FWS/OBS-79/31.

Federal Register. July 13, 1994. Changes in hydric soils of the United States.

Federal Register. September 18, 2002. Hydric soils of the United States.

Hurt, G.W., and L.M. Vasilas, editors. Version 6.0, 2006. Field indicators of hydric soils in the United States.

National Research Council. 1995. Wetlands: Characteristics and boundaries.

Soil Survey Division Staff. 1993. Soil survey manual. Soil Conservation Service. U.S. Department of Agriculture Handbook 18. http://soils.usda.gov/

Soil Survey Staff. 1999. Soil taxonomy: A basic system of soil classification for making and interpreting soil surveys. 2nd edition. Natural Resources Conservation Service, U.S. Department of Agriculture Handbook 436. http://soils.usda.gov/

Soil Survey Staff. 2006. Keys to soil taxonomy. 10th edition. U.S. Department of Agriculture, Natural Resources Conservation Service. http://soils.usda.gov/

Tiner, R.W., Jr. 1985. Wetlands of Delaware. U.S. Fish and Wildlife Service and Delaware Department of Natural Resources and Environmental Control, Wetlands Section.

United States Army Corps of Engineers, Environmental Laboratory. 1987. Corps of Engineers wetlands delineation manual. Waterways Experiment Station Technical Report Y-87-1.

United States Department of Agriculture, Natural Resources Conservation Service. National forestry manual. http://soils.usda.gov/

United States Department of Agriculture, Natural Resources Conservation Service. National range and pasture handbook. http://www.glti.nrcs.usda.gov/

United States Department of Agriculture, Natural Resources Conservation Service. National soil survey handbook, title 430-VI. http://soils.usda.gov/

United States Department of Agriculture, Natural Resources Conservation Service. 2006. Land resource regions and major land resource areas of the United States, the Caribbean, and the Pacific Basin. U.S. Department of Agriculture Handbook 296. http://soils.usda.gov/

United States Department of Agriculture, Soil Conservation Service. 1961. Land capability classification. U.S. Department of Agriculture Handbook 210.

EXHIBIT 11

EXHIBIT 11

U.S. Department of Commerce
National Oceanic & Atmospheric Administration

Precipitation; Daily Extreme Maximum; By Month

Date Range Selected: 1968 to 1986

National Climatic Data Center
Federal Building
151 Patton Avenue
Asheville, North Carolina 28801

264108/99999, Jungo Meyer Rch
null

Station POR For Element **EMXP: 1968 to 1986**

Lat. 40.883°33'N, Lon. 118.433°33'W
Elev. 4203 ft. above sea level

Month	Precipitation (inches)	Date(s)
1	0.64	01/24/1969
2	0.50	02/15/1986
3	0.50	03/15/1979
4	0.53	04/14/1973
5	0.50	05/10/1986
6	0.97	06/09/1972
7	1.67	07/17/1976
8	0.96	08/19/1975
9	1.35	09/27/1983
10	0.95	10/01/1984
11	1.26	11/23/1983
12	1.11	12/24/1969
All	1.67	See Above

Notes

+ Occurred on one or more previous dates during the month. The date in the Date field is the last day of occurrence. Used through December 1983 only.

B Adjusted Total. Monthly value totals based on proportional available data across the entire month.

E An estimated monthly or annual total.

Some suspect values remain in the database (to be corrected in the future), although they only comprise a very small % of the data.

I Monthly means or totals based on incomplete time series. 1 to 9 days are missing. Annual means or totals include one or more months which had 1 to 9 days that were missing.

M Used to indicate data element missing.

T Trace of precipitation, snow fall, or snow depth. The precipitation data value will = zero. Includes ice on the ground from hail, reported as snow/ice depth.

Element Element Types are included to provide cross-reference for users of the NCDC CDO System.

Station Station is identified by: Coop ID/WBAN, Station Name, State/Country.

U.S. Department of Commerce
National Oceanic & Atmospheric Administration

Precipitation; Most; By Month

Date Range Selected: 1968 to 1986

National Climatic Data Center
Federal Building
151 Patton Avenue
Asheville, North Carolina 28801

264108/99999, Jungo Meyer Rch null

Station POR For Element **TPCP: 1968 to 1986**

Lat. 40.883°33'N, Lon. 118.433°33'W
Elev. 4203 ft. above sea level

Month	Precipitation (inches)	Date(s)
1	3.05	1969
2	1.63	1969
3	1.83	1975 (E)
4	2.08	1978
5	1.61	1980
6	1.97	1972
7	2.80	1976
8	1.56	1983
9	2.03	1983
10	1.80	1984 (I)
11	4.12	1981
12	3.48	1983
All	4.12	See Above

Notes

+ Occurred on one or more previous dates during the month. The date in the Date field is the last day of occurrence. Used through December 1983 only.

B Adjusted Total. Monthly value totals based on proportional available data across the entire month.

E An estimated monthly or annual total.

Some suspect values remain in the database (to be corrected in the future), although they only comprise a very small % of the data.

I Monthly means or totals based on incomplete time series. 1 to 9 days are missing. Annual means or totals include one or more months which had 1 to 9 days that were missing.

M Used to indicate data element missing.

T Trace of precipitation, snow fall, or snow depth. The precipitation data value will = zero. Includes ice on the ground from hail, reported as snow/ice depth.

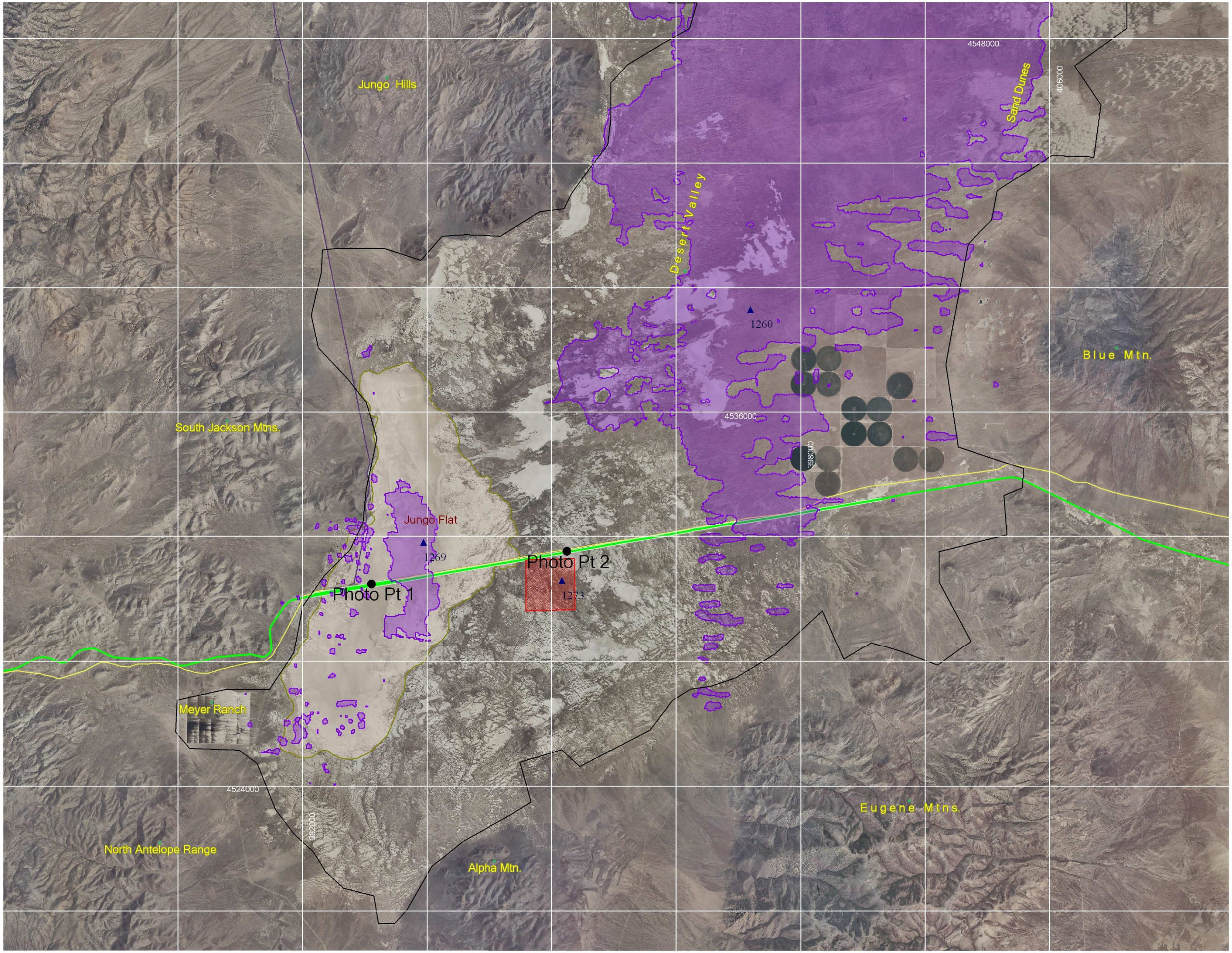
Element Element Types are included to provide cross-reference for users of the NCDC CDO System.

Station Station is identified by: CoopID/WBAN, Station Name, State/Country.

EXHIBIT 12

EXHIBIT 12

Jungo Area Flood Elevation 1269 Meters Above Mean Sea Level



Calculated from USGS digital elevation model, 30 meter, NAVD 1984

The shaded polygon(s) delineate the areas calculated to be inundated by a flood that reaches a maximum elevation of 1269 meters.

Base layer - 2010 National Agricultural Imagery Program aerial photography.

N
W E
S

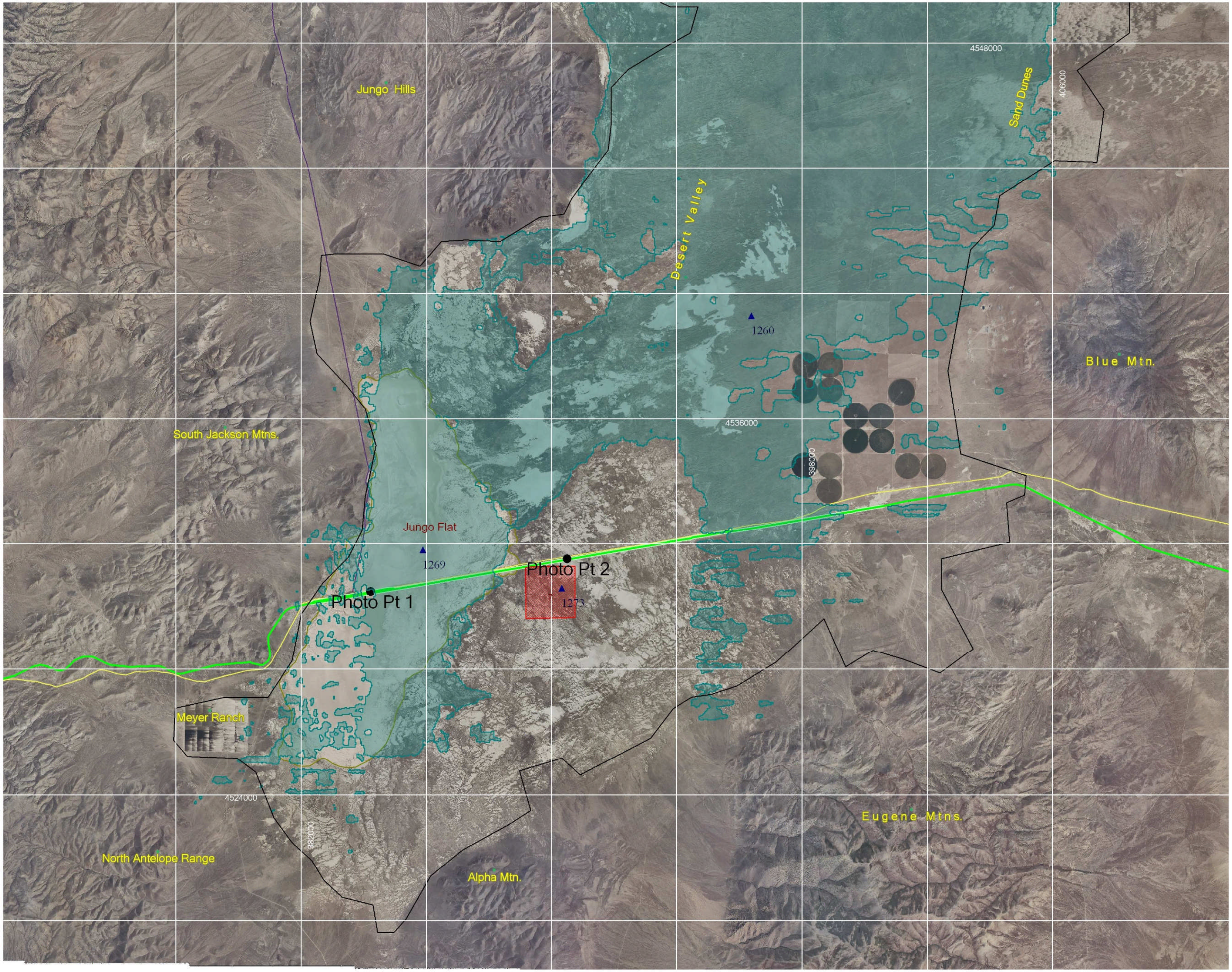
0 1 2 3 4 km

0 1 2 3 mi

1 : 115,000

The map depicted here is based upon the projected cartesian coordinate system Universal Transverse Mercator, North American Datum 1983, zone 11.

- spot elevations
- Sub-Basin - Flood Prone Area
- Flood-Elev-1269
- UPRR
- Bottle Crk Rd
- Jungo Rd



Jungo Area Flood Elevation 1271 Meters Above Mean Sea Level

Calculated from USGS digital elevation model, 30 meter, NAVD 1984

The shaded polygon(s) delineate the areas calculated to be inundated by a flood that reaches a maximum elevation of 1271 meters.

Base layer - 2010 National Agricultural Imagery Program aerial photography.

N
W E
S

0 1 2 3 4 km

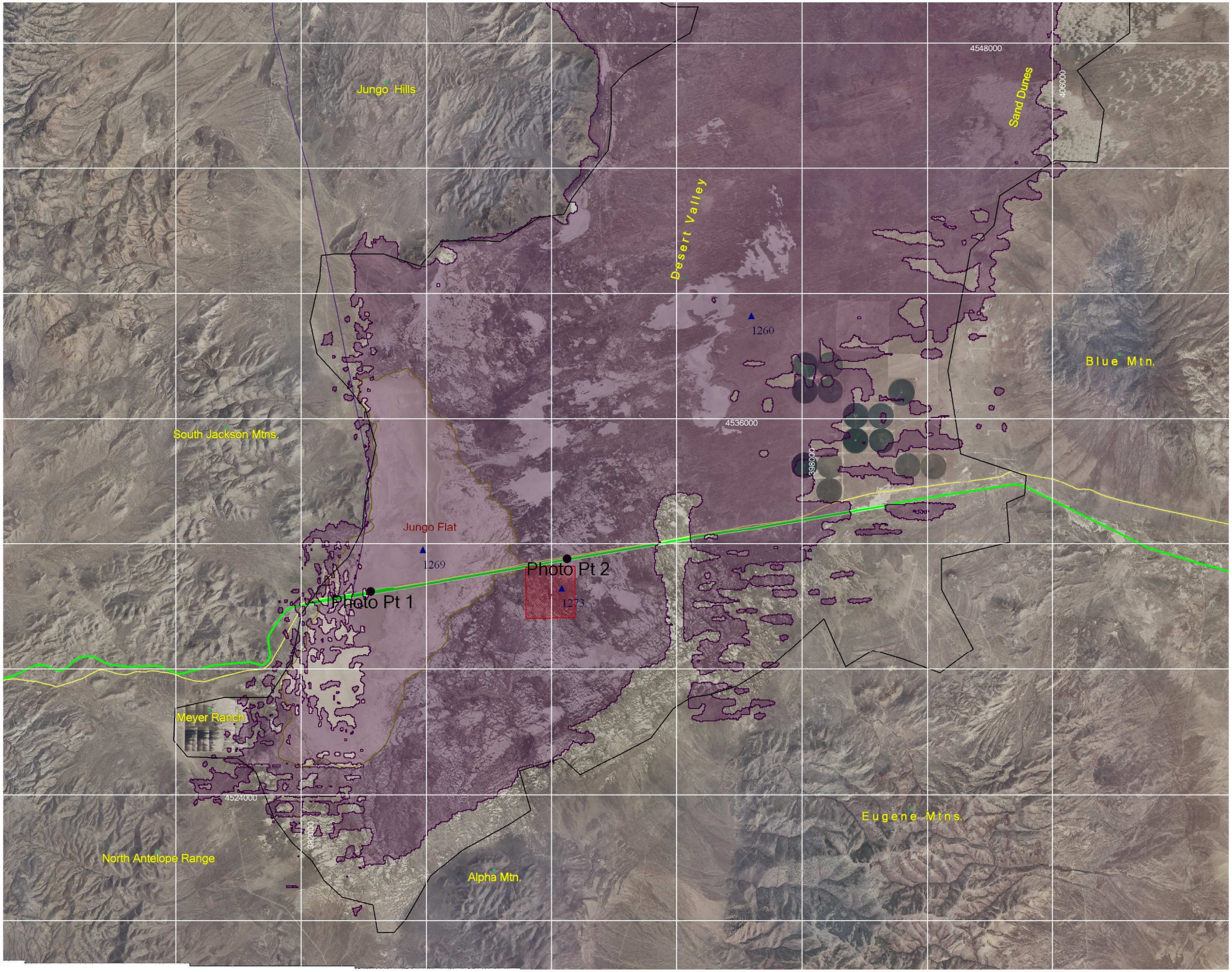
0 1 2 3 mi

1 : 115,000

The map depicted here is based upon the projected cartesian coordinate system Universal Transverse Mercator, North American Datum 1983, zone 11.

- spot elevations
- Sub-Basin - Flood Prone Area
- Flood-Elev-1271
- UPRR
- Bottle Crk Rd
- Jungo Rd

Hoenikker Associates



Jungo Area Flood Elevation 1273 Meters Above Mean Sea Level

Calculated from USGS digital elevation model, 30 meter, NAVD 1984

The shaded polygon(s) delineate the areas calculated to be inundated by a flood that reaches a maximum elevation of 1273 meters.

Base layer - 2010 National Agricultural Imagery Program aerial photography.

N
W E
S

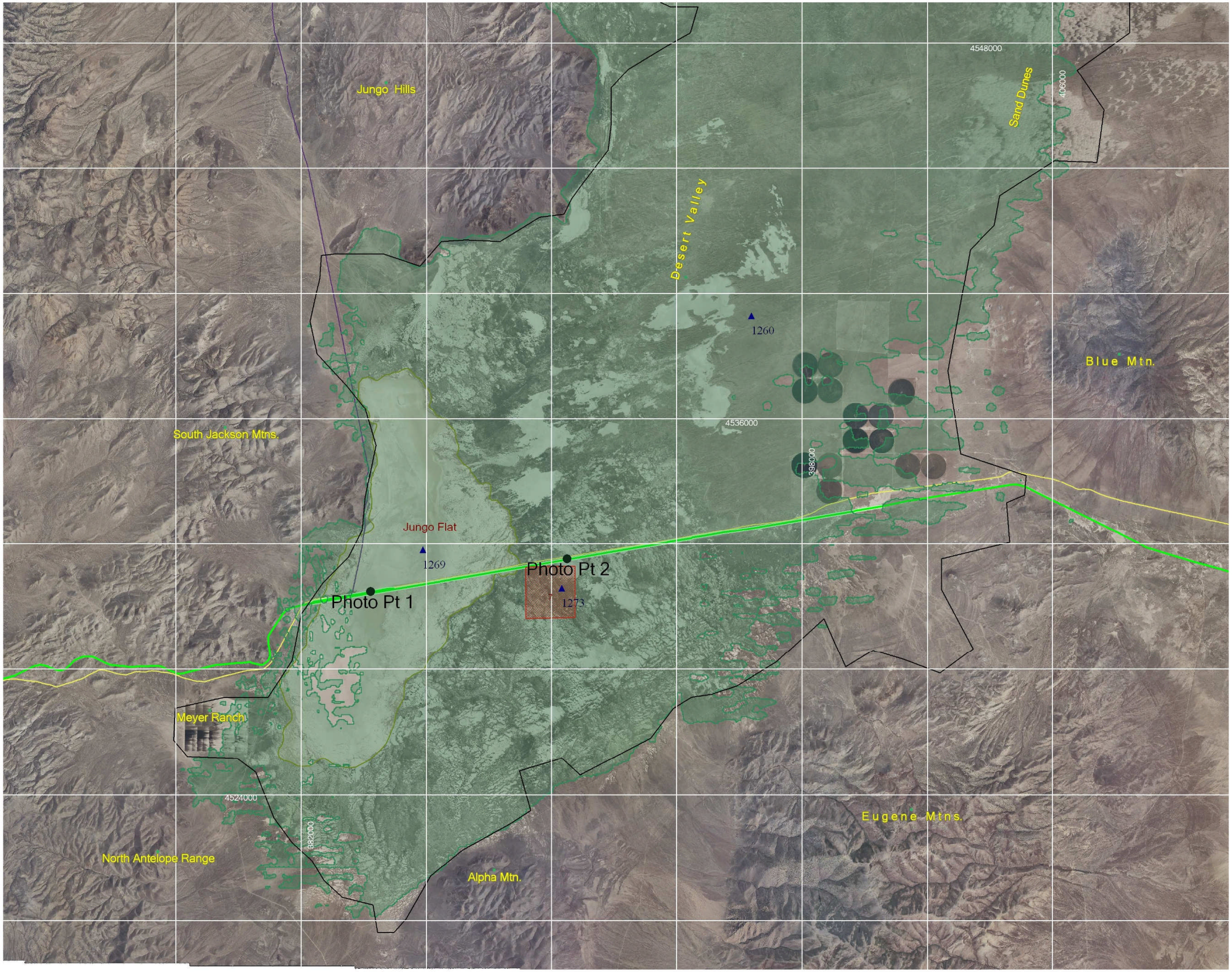
0 1 2 3 4 km

0 1 2 3 mi

1 : 115,000

The map depicted here is based upon the projected cartesian coordinate system Universal Transverse Mercator, North American Datum 1983, zone 11.

- spot elevations
- Sub-Basin - Flood Prone Area
- Flood-Elev-1273
- UPRR
- Bottle Crk Rd
- Jungo Rd



Jungo Area Flood Elevation 1275 Meters Above Mean Sea Level

Calculated from USGS digital elevation model, 30 meter, NAVD 1984

The shaded polygon(s) delineate the areas calculated to be inundated by a flood that reaches a maximum elevation of 1275 meters.

Base layer - 2010 National Agricultural Imagery Program aerial photography.

N
W E
S

0 1 2 3 4 km

0 1 2 3 mi

1 : 115,000

The map depicted here is based upon the projected cartesian coordinate system Universal Transverse Mercator, North American Datum 1983, zone 11.

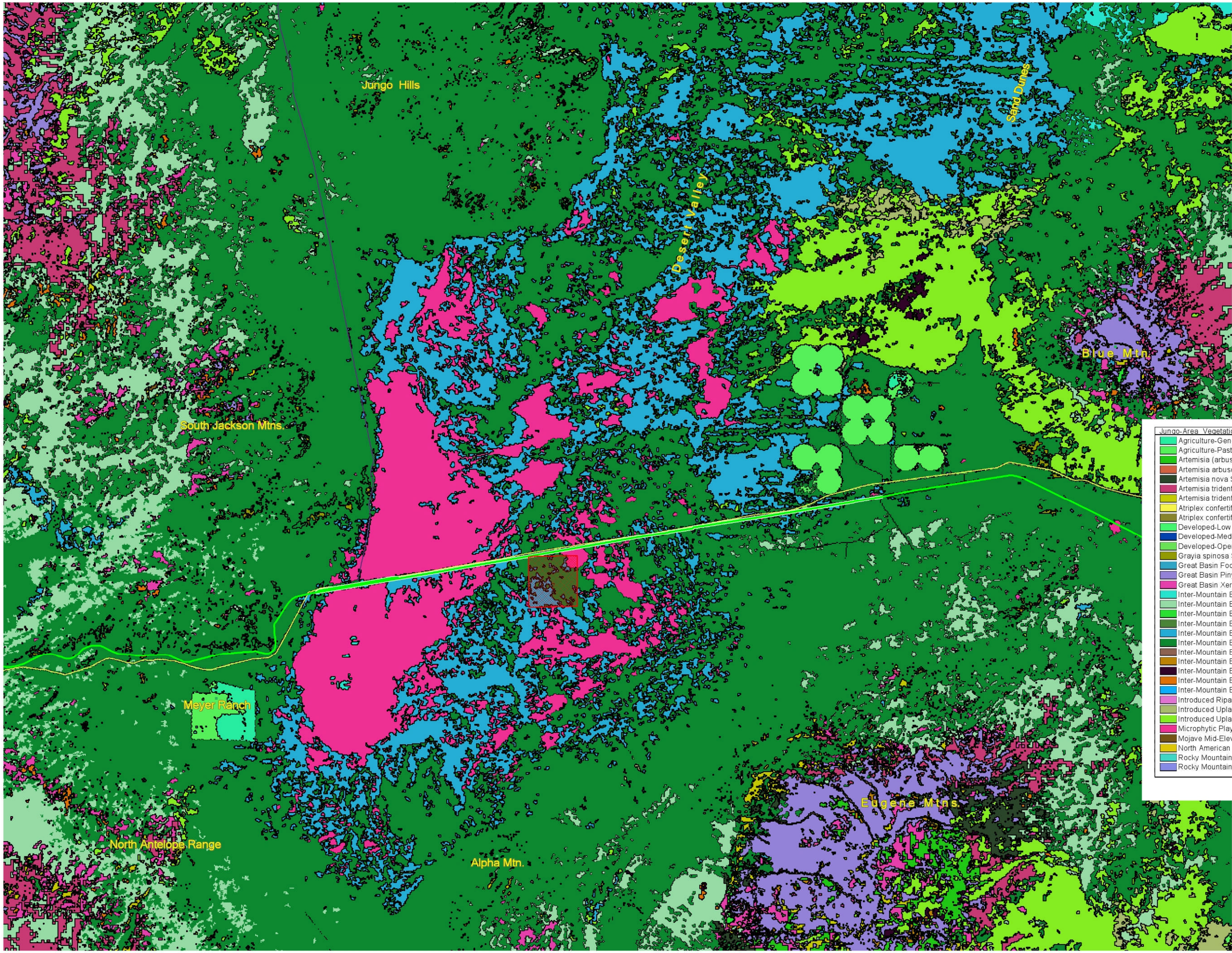
spot elevations
Sub-Basin - Flood Prone Area
Flood-Elev-1275
UPRR
Bottle Crk Rd
Jungo Rd

EXHIBIT 13

EXHIBIT 13

Jungo Area Vegetation Synthesis Classifications

Derived from data provided by the Nevada Natural Heritage Program, Peterson, E. B. 2008. A Synthesis of Vegetation Maps for Nevada (Initiating a 'Living' Vegetation Map).



N
W E
S

0 1 2 3 4 km

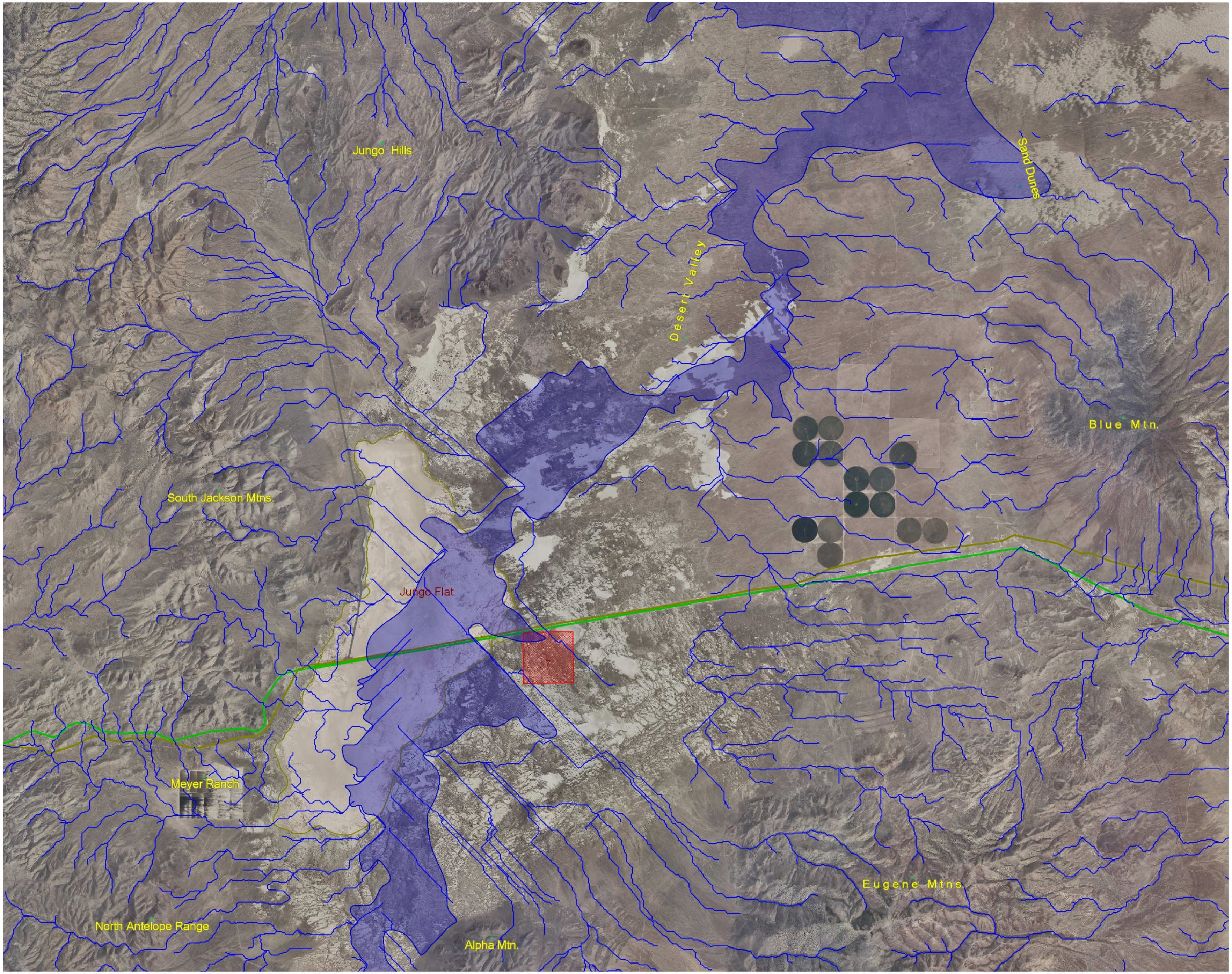
0 1 2 3 mi

1 : 115,000

The map depicted here is based upon the projected cartesian coordinate system Universal Transverse Mercator, North American Datum 1983, zone 11.

EXHIBIT 14

EXHIBIT 14



Jungo Area

Stream Reach - Overland Flow
Natural Ponding / Catchment Area

A terrain / watershed analysis to determine the direction and location of storm run-off and natural catchment areas. The ponding areas indicated are the calculated initial points of collection and would expand omnidirectionally based upon elevation. No man made obstructions of flow were considered in the building of the model.

N
W E
S

0 1 2 3 4 km

0 1 2 3 mi

1 : 115,000

- Natural-Ponding / Catchment-Area
- Jungo Rd
- Bottle Crk Rd
- Union Pacific Railroad
- jungo_flat

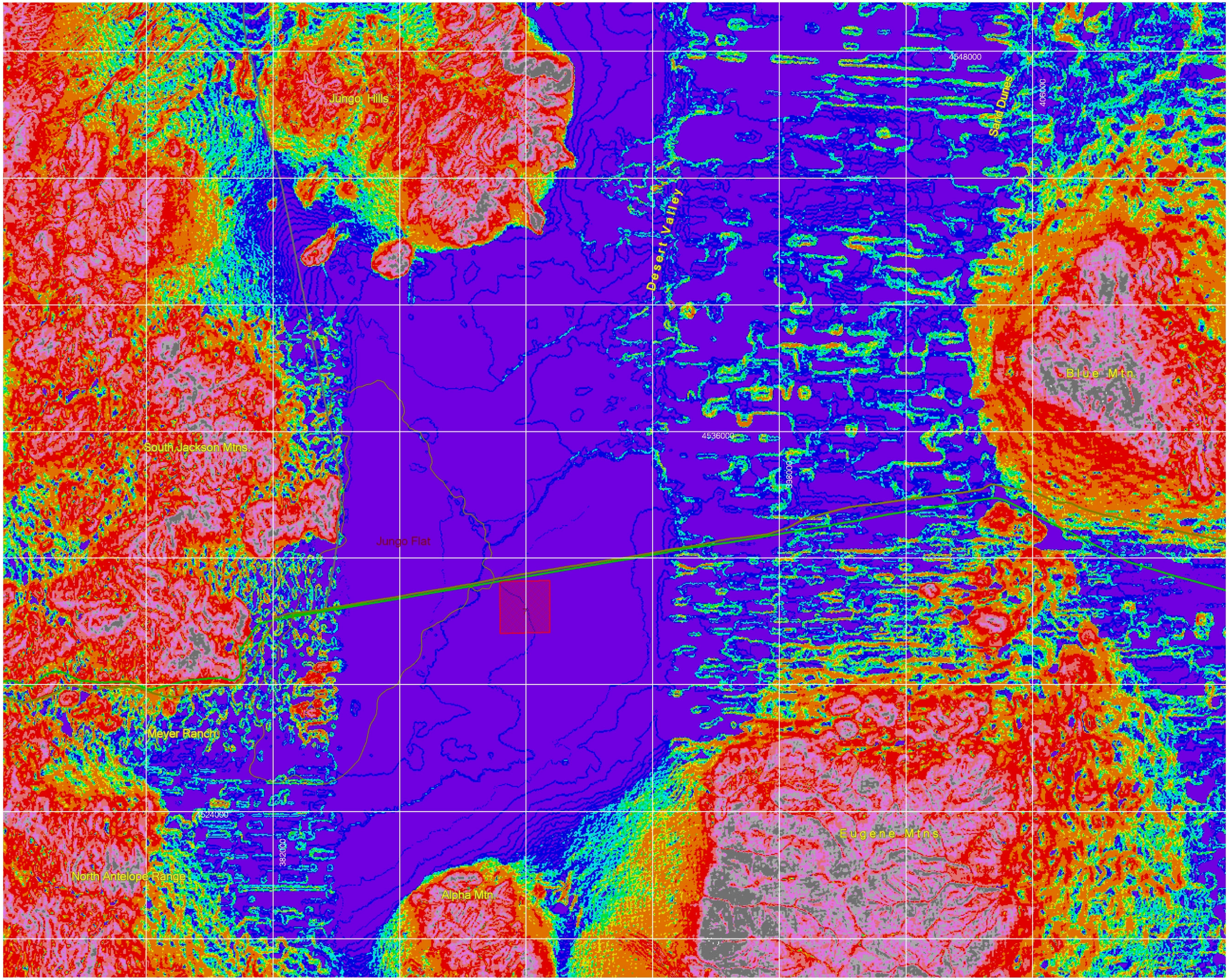
The map depicted here is based upon the projected cartesian coordinate system Universal Transverse Mercator, North American Datum 1983

USGS Digital Elevation Model - Vertical Datum 1983

EXHIBIT 15

EXHIBIT 15

Jungo Area Slope Analysis



Landform slope was determined from USGS digital elevation model 30 meter grid, NAVD 1983

N
W E
S

0 1 2 3 4 km

0 1 2 3 mi

1 : 115,000

The map depicted here is based upon the projected cartesian coordinate system Universal Transverse Mercator, North American Datum 1983, zone 11.

jungo-s7-survey-boundary
7

- Jungo Rd
- Bottle Crk Rd
- Union Pacific Railroad

slope%
50% & Above
40 - 50%
30 - 40%
20 - 30%
10 - 20%
5 - 10%
4 - 5%
3 - 4%
2 - 3%
1 - 2%
0 - 1%

EXHIBIT 16

EXHIBIT 16

EXHIBIT 17

EXHIBIT 17

EXHIBIT 18

EXHIBIT 18

EXHIBIT 19

EXHIBIT 19

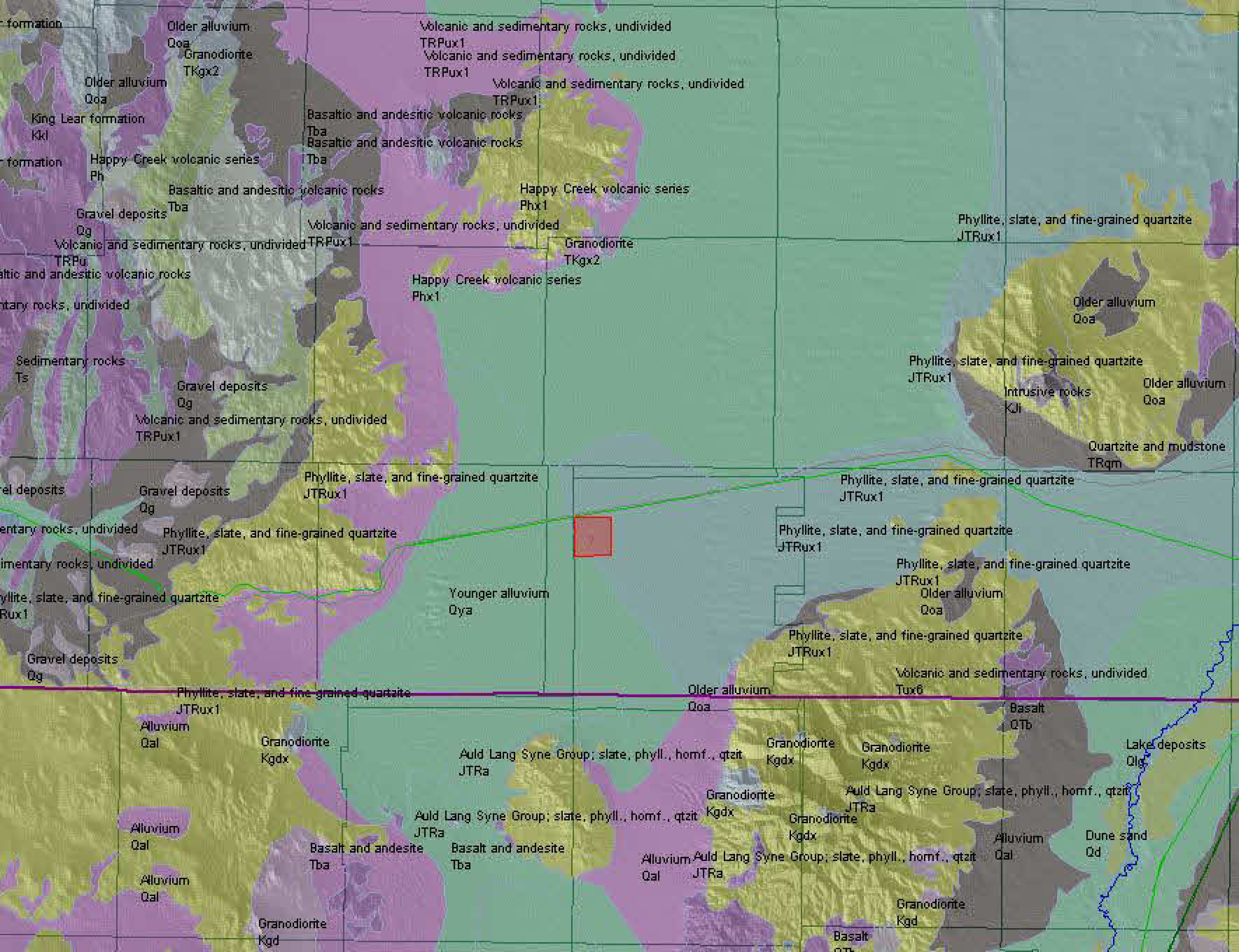
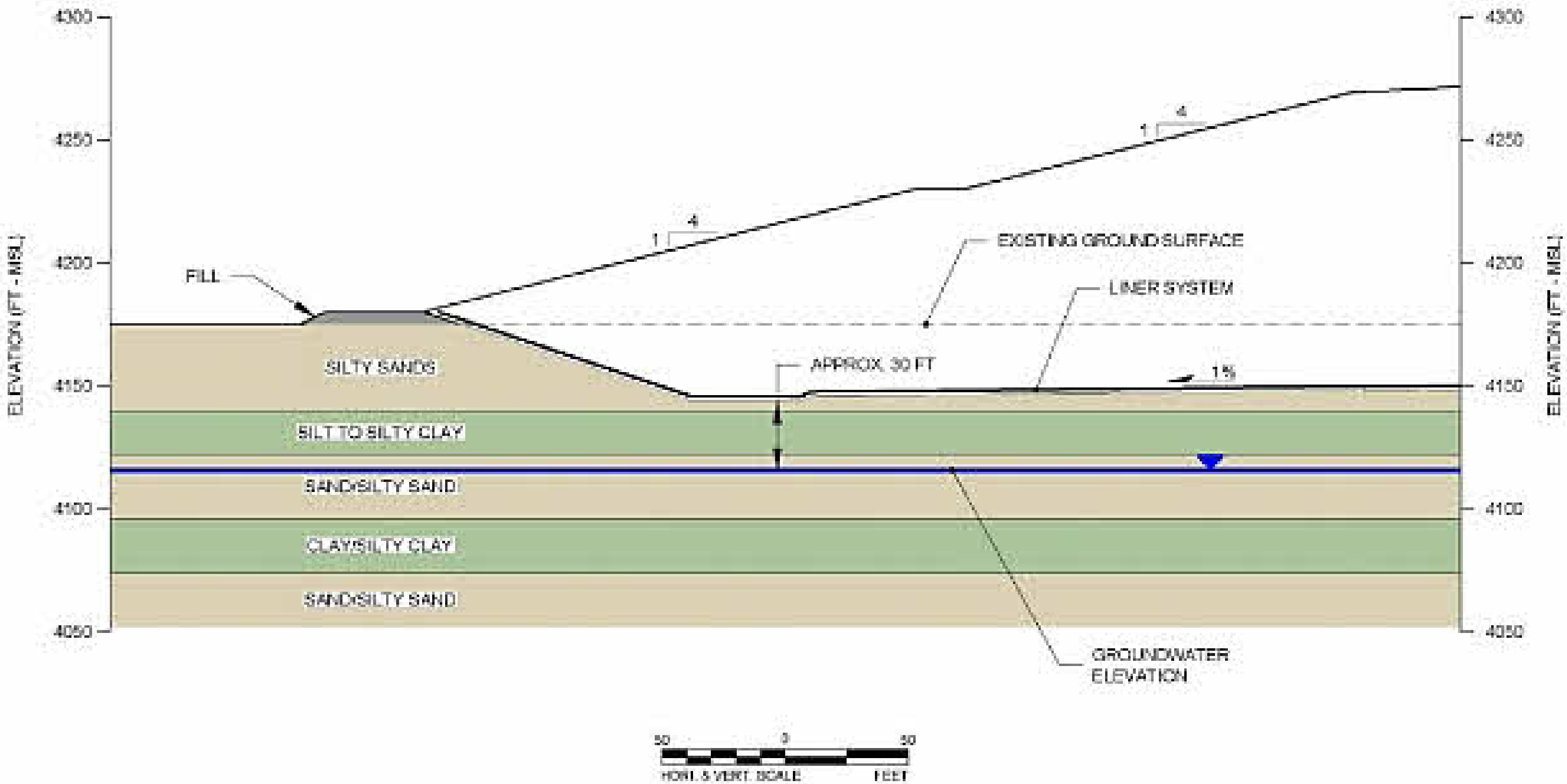

formation
Older alluvium
Qoa
Granodiorite
TKgx2
Older alluvium
Qoa
King Lear formation
Kkl
formation
Happy Creek volcanic series
Ph
Basaltic and andesitic volcanic rocks
Tba
Gravel deposits
Qg
Volcanic and sedimentary rocks, undivided
TRPu
Volcanic and sedimentary rocks, undivided
TRPux1
Volcanic and sedimentary rocks, undivided
TRPux1
Volcanic and sedimentary rocks, undivided
TRPux1
Basaltic and andesitic volcanic rocks
Tba
Basaltic and andesitic volcanic rocks
Tba
Happy Creek volcanic series
Phx1
Volcanic and sedimentary rocks, undivided
TRPux1
Granodiorite
TKgx2
Happy Creek volcanic series
Phx1
Sedimentary rocks
Ts
Gravel deposits
Qg
Volcanic and sedimentary rocks, undivided
TRPux1
Phyllite, slate, and fine-grained quartzite
JTRux1
Older alluvium
Qoa
Phyllite, slate, and fine-grained quartzite
JTRux1
Intrusive rocks
KJi
Older alluvium
Qoa
Quartzite and mudstone
TRqm
Gravel deposits
Qg
Phyllite, slate, and fine-grained quartzite
JTRux1
Phyllite, slate, and fine-grained quartzite
JTRux1
Phyllite, slate, and fine-grained quartzite
JTRux1
Phyllite, slate, and fine-grained quartzite
JTRux1
Phyllite, slate, and fine-grained quartzite
JTRux1
Older alluvium
Qoa
Younger alluvium
Qya
Phyllite, slate, and fine-grained quartzite
JTRux1
Gravel deposits
Qg
Volcanic and sedimentary rocks, undivided
Tux6
Phyllite, slate, and fine-grained quartzite
JTRux1
Older alluvium
Qoa
Basalt
QTb
Alluvium
Qal
Granodiorite
Kgdx
Auld Lang Syne Group; slate, phyll., hornf., qtzit
JTRa
Granodiorite
Kgdx
Granodiorite
Kgdx
Lake deposits
Qlg
Granodiorite
Kgdx
Auld Lang Syne Group; slate, phyll., hornf., qtzit
JTRa
Granodiorite
Kgdx
Alluvium
Qal
Auld Lang Syne Group; slate, phyll., hornf., qtzit
JTRa
Basalt and andesite
Tba
Basalt and andesite
Tba
Alluvium
Qal
Auld Lang Syne Group; slate, phyll., hornf., qtzit
JTRa
Alluvium
Qal
Dune sand
Qd
Alluvium
Qal
Granodiorite
Kgd
Granodiorite
Kgd
Basalt

EXHIBIT 20

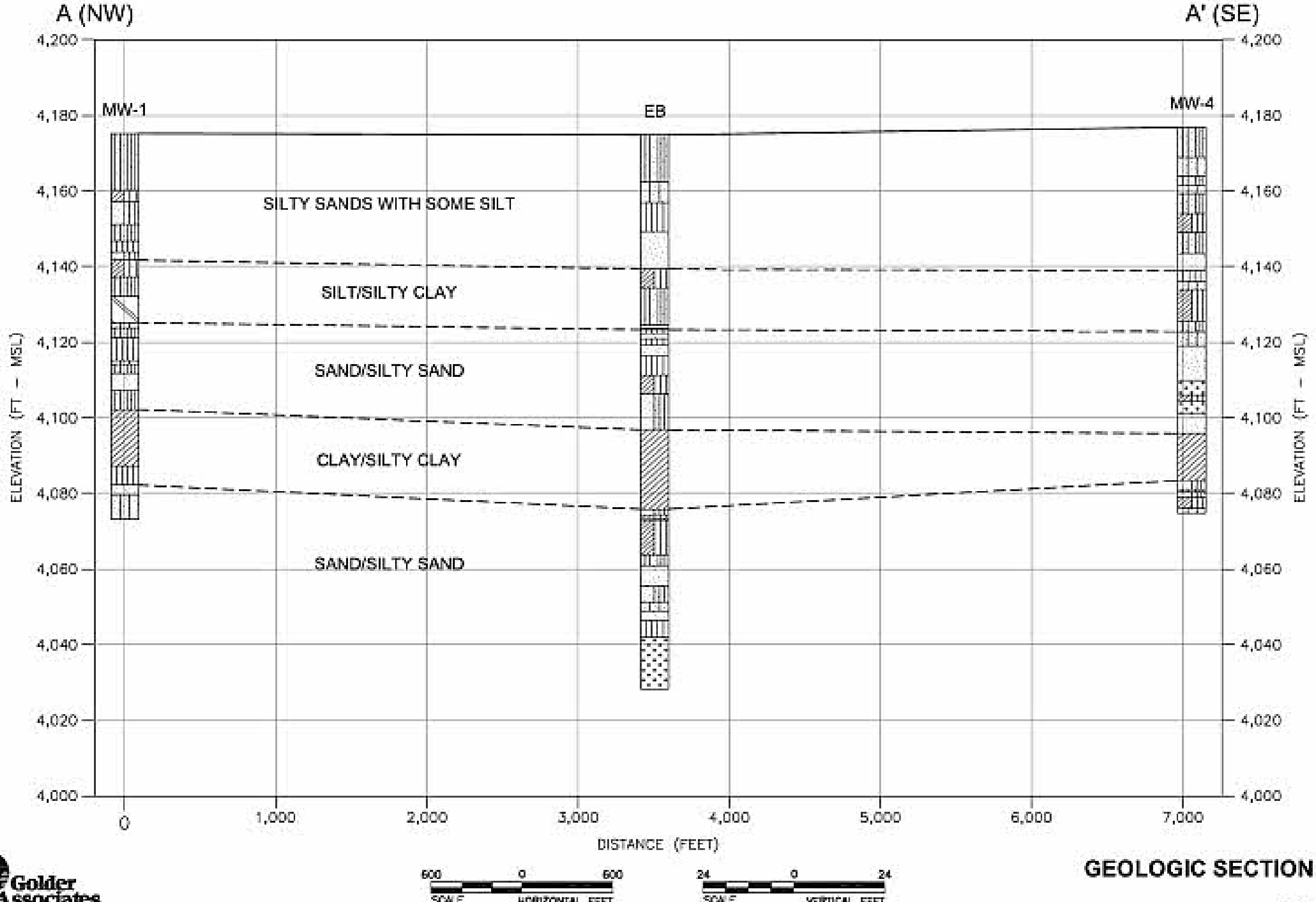
EXHIBIT 20



4300
4250
4200
4150
4100
4050
ELEVATION (FT - MSL)
FILL
1
4
EXISTING GROUND SURFACE
LINER SYSTEM
SILTY SANDS
APPROX. 30 FT
1%
SILT TO SILTY CLAY
SAND/SILTY SAND
CLAY/SILTY CLAY
SAND/SILTY SAND
GROUNDWATER
ELEVATION
50
0
50
HORI. & VERT. SCALE
FEET

EXHIBIT 21

EXHIBIT 21



Golder Associates
Sacramento, CA

GEOLOGIC SECTION A-A'

FIGURE 5

EXHIBIT 22

EXHIBIT 22

NGP

OTCBB: NGLPF
TSX V: NGP

HIGHLIGHTS

Blue Mountain Faulkner 1

- Tests indicate capacity can be increased
- Resource potential of 100 MW
- 21 miles of electric transmission line owned by NGP; 125 MW capacity line will accomodate future build-out
- First of geothermal developers to receive an ITC grant (US$57.9 M)

* Last updated July 2011

BLUE MOUNTAIN

THE POWER IS ON AT FAULKNER 1!

Nevada Geothermal Power Inc. (NGP) owns a 100% interest in the Blue Mountain geothermal project located in Humboldt County, Northern Nevada. The property covers 11,120 acres, located 21 mi (33 km) from the state electrical transmission grid.

NGP's nameplate capacity 49.5 MW (gross) Blue Mountain Faulkner 1 geothermal power plant declared commercial operation November 20, 2009.

NGP has a 20-year Power Purchase Agreement (PPA) with NV Energy for all of the electricity at 'Faulkner 1' and the 21 mile transmission line is owned by NGP.

In 2009, NGP was awarded a US $57.9 M ITC grant from the U.S. Department of Treasury for the Faulkner 1 geothermal power plant as well as an additional US$7.9 M for well field expenditures completed post application in July 2011. In addition, NGP closed a US$98.5 M loan at 4.14% in September 2010, with John Hancock Financial Services back by the US Department of Energy with a loan guarantee for 80% of the loan amount.

www.nevadageothermal.com
info@nevadageothermal.com

TSX V: NGP
OTCBB: NGLPF

toll free: 866.688.0808 x118
telephone: 604.688.1553

EXHIBIT 23

EXHIBIT 23

A Natural Source of Clean Power

Blue Mountain, Nevada

Click to view Fact Sheet (PDF)

Maps
Photos

Nevada Geothermal Power Inc. (NGP) owns a 100% interest in the 49.5 MW Blue Mountain 'Faulkner 1' geothermal power project located in Humboldt County, Northern Nevada. The property covers 11,126.46 acres (17.4 square miles), located 21 miles (34 km) from the state electrical transmission grid.

NGP's 'Faulkner 1' geothermal power plant was placed in service October 12, 2009, four months ahead of schedule.

NGP also has a 20-year Power Purchase Agreement for up to 49.5 MW gross of geothermal power at Blue Mountain with NV Energy (formerly Nevada Power Company).

"The Power is on!"

Blue Mountain Highlights

- NGP's nameplate capacity 49.5 MW Blue Mountain 'Faulkner 1' geothermal power plant was placed in service on October 12, 2009, four months ahead of schedule
- Tests indicate capacity can be increased
- 20-year power purchase agreement (PPA) with NV Energy for all of the electricity at 'Faulkner 1'
- Resource potential of 100 MW
- 21 miles of electric transmission line owned by NGP, 120kV transmission line will accommodate future build-out
- First of geothermal developers to receive an ITC grant ($57.9M)

EXHIBIT 24

EXHIBIT 24

MEMORANDUM

Date: April 1, 2011

Project No.: 063-7079-200

To: Rick Kiel, P.E.

Company: Golder Associates Inc.

From: Ken Haskell, P.E. (California)
Nagesh Koragappa, P.E., G.E. (California)

RE: UPDATED DESIGN SEISMIC GROUND MOTIONS AND SEISMIC IMPACT EVALUATION FOR THE PROPOSED JUNGO DISPOSAL SITE, HUMBOLDT COUNTY, NEVADA

This memorandum summarizes the updated design seismic ground motions and seismic impact evaluations for the proposed Jungo Disposal Site (JDS). An updated seismic hazards assessment was completed to reflect the latest predicted seismic ground motions that were developed after Golder Associates Inc. (Golder) completed the initial seismic characterization for the JDS.

In addition, this memorandum summarizes the results of updated permanent seismic displacement calculations and the results of our initial liquefaction evaluation. These analyses were completed to address the Nevada Division of Environmental Protection's (NDEP's) comments dated February 2, 2011.

1.0 UPDATED SEISMIC HAZARD CHARACTERIZATION

The Jungo Disposal Site is located within a seismic impact zone, which is defined as a location that has a 10 percent or greater probability of experiencing a seismically induced peak ground acceleration (PGA) in bedrock of 0.1g or greater in a 250-year period.

Using the 2002 United States Geological Survey (USGS) database for an earthquake event with a 10 percent probability of exceedance in a 250-year period, Golder initially estimated that the design bedrock PGA was 0.28g at the JDS. This design event, which is specified by Federal Subtitle D regulations and the Nevada Administrative Code, has an associated return period of 2,475 years.

In 2008, the USGS seismic ground motion database was updated to include the latest, state-of-the-art relationships between earthquake magnitude, distance from the epicenter, and peak bedrock accelerations. Using the 2008 USGS seismic hazard mapping, the revised estimated design bedrock PGA for this site is 0.25g, which is approximately 10 percent lower than that originally estimated by Golder and previously used to assess the seismic impacts on the liner system.

2.0 UPDATED PERMANENT SEISMIC DISPLACEMENT ESTIMATES

2.1 Review of Previous Analyses

The previous versions of the Report of Design included estimated permanent seismic displacements along the base liner using a PGA of 0.28g. Potential attenuation of ground motions within the thick soil profile below the JDS were conservatively ignored. Using the simplified approach by Bray et. al. (1998), Golder estimated that the permanent seismically induced displacements would be less than 1 inch (0.8

EXHIBIT 25

EXHIBIT 25

GeothermEx, Inc.
5221 CENTRAL AVENUE, SUITE 201
RICHMOND, CALIFORNIA 94804-5829

TELEPHONE: (510) 527-9876
FAX: (510) 527-8164
E-MAIL: mw@geothermex.com

STATUS OF RESOURCE DEVELOPMENT AT THE BLUE MOUNTAIN GEOTHERMAL PROJECT, HUMBOLDT COUNTY, NEVADA

for

NEVADA GEOTHERMAL POWER, INC.
Vancouver, British Columbia

by

GeothermEx, Inc.
Richmond, California

21 APRIL 2008

GeothermEx, Inc. 5221 CENTRAL AVENUE, SUITE 201
RICHMOND, CALIFORNIA 94804-5829

TELEPHONE: (510) 527-9876
FAX: (510) 527-8164
E-MAIL: mw@geothermex.com

CONTENTS

GeothermEx, Inc. 5221 CENTRAL AVENUE, SUITE 201
RICHMOND, CALIFORNIA 94804-5829

TELEPHONE: (510) 527-9876
FAX: (510) 527-8164
E-MAIL: mw@geothermex.com

ILLUSTRATIONS

GeothermEx, Inc. 5221 CENTRAL AVENUE, SUITE 201
RICHMOND, CALIFORNIA 94804-5829

TELEPHONE: (510) 527-9876
FAX: (510) 527-8164
E-MAIL: mw@geothermex.com

EXECUTIVE SUMMARY

On behalf of Nevada Geothermal Power, Inc. (NGP), GeothermEx has reviewed the status of resource development at NGP's Blue Mountain geothermal project. NGP plans to build and operate a binary geothermal power plant at Blue Mountain with a megawatt (MW) capacity of 49.5 MWgross (38.8 MW net). The purpose of this report is to provide documentation about the geothermal resource for lenders who are considering construction financing for the project. This report focuses on three aspects of the Blue Mountain resource:

- The estimated MW capacity of the resource,
- The results of production well testing through March 2008, and
- The proposed injection strategy for the project.

As of the end of March 2008, NGP's drilling at Blue Mountain has included fourteen temperature-gradient wells, two deep slim holes, and five full-diameter wells. Three of the full-diameter wells have demonstrated high productivity in well tests. Two of the full-diameter wells did not yield fluids in commercial quantities, though they confirmed favorable reservoir temperatures. A sixth full-diameter well is currently being drilled for injection.

To estimate the MW capacity of the Blue Mountain resource, GeothermEx has applied a probabilistic technique (Monte Carlo simulation) to the assessment of heat in place. Based on information gathered through deeper drilling and updated geochemical analysis, GeothermEx has revised its 2004 estimate of the MW capacity. The MW capacity of the Blue Mountain resource is now estimated to have a minimum value of 40 MW net (at 90% probability) and a most-likely value of 57 MW net (the modal value of the probability distribution).

The three successful production wells at Blue Mountain have each been flow tested for periods of 2 to 3 days. The tests, although short, have been sufficient to demonstrate the

TELEPHONE: (510) 527-9876
FAX: (510) 527-8164
E-MAIL: mw@geothermex.com

prolific nature of these wells. The three successful production wells are expected to yield net power output in excess of 7 MW net apiece, with a combined initial output of 22.2 MW net. This MW estimate takes into account the power usage of a production pump in each well, as well as an additional 20% parasitic load for each well's proportionate share of the power to operate the binary power plant (including injection pumps, if needed).

NGP has identified several potential locations for injection to the west and north of the production wells. The identified injection locations are all at least one half mile from the nearest production well. This should provide adequate separation between injection and production, while still allowing for the possibility of pressure support from injection. The injection well locations are also planned to be slightly downhill from the power plant, to minimize the need for injection booster pumps.

NGP has budgeted for four injection wells to handle the output of the proposed binary plant, and they have included contingent funds of US$11 million for three more full-sized wells. In GeothermEx's opinion, it is likely that 5 to 6 injectors will be required. NGP has planned a total of six production wells to be available at plant start-up. Since their most recent production well appears to have been unsuccessful, they will likely need to drill three more successful production wells to achieve the target plant capacity. Funds for two of these are included in the budget, and the cost of the third production well could be covered by the contingent funds. Considering the five full-diameter wells drilled for production through the end of March, NGP has achieved an effective average output of 4.4 MW net per well, including dry holes. NGP's planned targets for the three remaining production wells are modest step-outs to the west and north of the three successful production wells, at locations considered to have good prospects for success. It is likely that these three production wells will average at least 5.6 MW net apiece, which would achieve the equivalent of 39 MW net. The US$11 million in contingency funds for three full-diameter wells appears to be sufficient for 1-2 injectors and 1 producer. Thus,

TELEPHONE: (510) 527-9876
FAX: (510) 527-8164
E-MAIL: mw@geothermex.com

NGP's drilling budget (including contingency funds) appears adequate for the target output of 38.8 net MW.

GeothermEx, Inc. 5221 CENTRAL AVENUE, SUITE 201
RICHMOND, CALIFORNIA 94804-5829

TELEPHONE: (510) 527-9876
FAX: (510) 527-8164
E-MAIL: mw@geothermex.com

1. PURPOSE AND SCOPE

On behalf of Nevada Geothermal Power, Inc. (NGP), GeothermEx has reviewed the status of resource development at NGP's Blue Mountain geothermal project. NGP plans to build and operate a binary geothermal power plant at Blue Mountain with a MW capacity of 49.5 MWgross (38.8 MW net). The purpose of this report is to provide documentation about the geothermal resource for lenders who are considering construction financing for the project. This report focuses on three aspects of the Blue Mountain resource:

- The estimated MW capacity of the resource based on a probabilistic assessment of the heat in place.
- The results of production well testing through March 2008.
- The proposed injection strategy for the project.

GeothermEx has been providing technical assistance to NGP in the development of the Blue Mountain resource. In December 2004, we prepared a resource assessment based on the exploration drilling that had been accomplished at that time. That report included a summary of the early project development history, which is not repeated here. GeothermEx has provided drilling engineering and well test engineering services to NGP for wells drilled at Blue Mountain since 2006. The information in this report derives primarily from well tests that GeothermEx has designed and supervised, as well as additional data supplied by NGP (such as well locations and temperatures measured in temperature-gradient wells). GeothermEx has not independently verified the data supplied by NGP, but we believe it to be accurate, based on our familiarity with the project.

GeothermEx, Inc. 5221 CENTRAL AVENUE, SUITE 201
RICHMOND, CALIFORNIA 94804-5829

TELEPHONE: (510) 527-9876
FAX: (510) 527-8164
E-MAIL: mw@geothermex.com

As of the end of March 2008, NGP's drilling at Blue Mountain has included fourteen temperature-gradient wells (to depths generally less than 1,000 feet), two deep slim holes (to depths greater than 2,000 feet), and five full-diameter wells (with measured depths ranging from 2,370 feet to 5,426 feet). Figure 1 shows the well locations in the field. The full-diameter wells are typically completed with 13-3/8-inch casing from the surface to approximately 2,000 feet, with un-lined 12-1/4-inch hole extending below the 13-3/8-inch casing to total depth. Table 1 summarizes the results of the full-diameter wells. Three of the full-diameter wells (23-14, 25-14, and 26A-14) have demonstrated high productivity in well tests. Two of the full-diameter wells (38-14 and 44-14) did not yield fluids in commercial quantities, though they confirmed favorable reservoir temperatures. Maximum measured temperatures have been 370 to 374°F in the three successful producers and 357 to 359°F in the two unsuccessful producers. All of the full-diameter wells have encountered artesian pressures, with static wellhead pressures in the range of 90 to 140 pounds per square inch (gauge) (psig). NGP has maintained a spacing of approximately 1,000 feet between the wells drilled for production. A sixth full-diameter well (58-15) is currently being drilled for injection about half a mile southwest of the cluster of the successful production wells.

Chapter 2 presents GeothermEx's current estimate of the MW capacity of the resource based on heat in place. Chapter 3 summarizes well test results, with detailed test data and associated temperature-pressure surveys included in appendices to this report. Chapter 4 describes NGP's injection strategy, including a discussion of proposed locations and the number of wells that are anticipated to be required (both producers and injectors) to support the proposed plant.

GeothermEx, Inc. 5221 CENTRAL AVENUE, SUITE 201
RICHMOND, CALIFORNIA 94804-5829

TELEPHONE: (510) 527-9876
FAX: (510) 527-8164
E-MAIL: mw@geothermex.com

2. MEGAWATT CAPACITY ESTIMATE

To estimate the MW capacity of the Blue Mountain resource, GeothermEx has applied a probabilistic technique (Monte Carlo simulation) to the assessment of heat in place. Our report of December 2004 included a detailed description of the methodology, which we have used successfully in numerous geothermal projects for over two decades. Briefly, the methodology estimates reasonable ranges of the parameters needed for a volumetric heat calculation (area, thickness, and average temperature), based on the best available field data and analogies to other projects in similar geologic environments. Ranges of heat recovery factors and plant performance parameters are also estimated, based on industry experience and current technology. The ranges of input parameters are then sampled statistically, and the calculation of an equivalent MW capacity is repeated thousands of times by computer, yielding an overall probability distribution. It is important to note that the presence of a certain amount of heat in place does not guarantee that this heat can be commercially extracted. Commercial operation depends on having wells with adequate permeability, which can only be demonstrated by drilling.

Since the December 2004 report, new information has become available that justifies revising the input parameters for the MW capacity estimate at Blue Mountain in two respects:

1. Drilling since 2004 has confirmed a greater thickness of formation at potentially commercial temperatures. Appendix A presents temperature and pressure surveys from all the NGP wells and several of the mineral exploration wells that preceded them. Two deep wells (DB-2 and 38-14) have shown temperature reversals, but the lower portion of DB-2 re-establishes a positive thermal gradient, and 38-14 appears to approach an isothermal gradient on bottom. Bottom-hole temperatures in both these wells (268°F in DB-2 and 311°F in 38-14) are within a range that is potentially exploitable with current plant technology. Other deep wells (including

TELEPHONE: (510) 527-9876
FAX: (510) 527-8164
E-MAIL: mw@geothermex.com

23-14, 26A-14 and 44-14) show isothermal conditions or increasing temperatures on bottom. As of 2004, the minimum thickness for purposes of the MW capacity estimate was assumed to be 350 meters (1,150 feet). Given subsequent drilling results, a minimum thickness of 500 meters (1,640 feet) now appears warranted. The maximum thickness assumed in 2004 (1,500 meters, or 4,920 feet) is left unchanged; this assumption was based on comparisons with eleven other geothermal fields in similar geologic settings in the Basin and Range, and it is still considered valid as a maximum.

2. Geochemical data obtained from well tests since 2004 has suggested higher temperatures for source fluids. A report by Thermochem in December 2006 estimated source-fluid temperatures of up to 240°C (464°F) based on cation geothermometry. GeothermEx has reviewed chemical analyses of several wells drilled since 2006, and our estimates of source-fluid temperatures are similar to those of Thermochem. Given the geochemical evidence, it appears appropriate for purposes of Monte Carlo simulation to increase the estimate of the maximum average temperature to 235° (versus our 2004 estimate of 220°C). Our estimate of the minimum average temperature (145°C, or 293°F) remains unchanged, considering the temperature reversals in the two deepest wells (DB-2 and 38-14), as well as the likelihood of lower temperatures on the margins of the system.

The other input parameters for the calculation of heat in place remain the same as in the 2004 GeothermEx report. Notably, our estimate of the area of the documented thermal anomaly (outlined with a thick, pink line in Figure 1) remains in the range of 2 to 3 square miles. Drilling since 2004 has occurred almost exclusively within this anomaly and has provided little justification for extending its boundaries. However, it should be noted that the limits of the thermal anomaly at Blue Mountain have not been clearly defined by peripheral wells, except to the northeast, where TG-2 shows a relatively low thermal gradient (3.5 °F per 100 feet). The proposed program of injection well-drilling

TELEPHONE: (510) 527-9876
FAX: (510) 527-8164
E-MAIL: mw@geothermex.com

(blue dots on Figure 1, plus the currently drilling 58-15) will provide significant new information along the western and northern sides of the system.

With the two modifications discussed above for the heat-in-place calculation (the increase in the minimum thickness and the maximum average reservoir temperature), GeothermEx has revised the MW capacity estimate for Blue Mountain. Figure 2 illustrates the result. Based on currently available data, the MW capacity of the reservoir is estimated to have a minimum value of 40 MW net (90% probability) and a most-likely value of 57 MW net (the modal value of the probability distribution).

TELEPHONE: (510) 527-9876
FAX: (510) 527-8164
E-MAIL: mw@geothermex.com

3. PRODUCTION WELL RESULTS

3.1 Testing Method

The successful production wells at Blue Mountain have each been flow tested for periods of 2 to 3 days using an 8-inch James tube, an atmospheric flash vessel, and a weir box to measure the rate of water discharge at atmospheric pressure. The relatively short test durations have been dictated by several factors, including limitations of sump capacity and potential for formation of calcium carbonate scale downhole under self-flowing conditions. (It is anticipated that, in actual operations, the wells will be pumped and produced fluids will be prevented from flashing down-hole, so calcium carbonate scaling will not be a problem). The tests, although short, have been sufficient to demonstrate the prolific nature of the successful producers. For each test, flowing temperature-pressure-spinner (TPS) surveys have been conducted to determine the downhole temperature at the flash point and to provide a cross-check on the enthalpy determination from the James tube technique. At the end of each well's flow test, the pressure build-up has been recorded downhole, to allow calculation of formation properties, such as the permeability-thickness product (kh) and the skin factor. A Productivity Index (PI) has been calculated from a comparison of the flowing pressure below the flash point with the pressure recorded at the same elevation in a static temperature-pressure survey.

For two of the flow tests (26A-14 and 25-14), interference data have been measured by monitoring pressures with capillary tubing in four offsetting wells (23-14, 38-14, DB-1, and DB-2). This interference testing information has allowed an estimation of kh-values for the bulk formation (for comparison with kh-values from pressure build-ups after flow in individual producers). Further interference testing (planned for mid-summer 2008) will involve flowing two or more wells at once and injecting into one or more injection wells. This testing is expected to last several weeks and will include downhole scale inhibition in the producers to avoid build-up of calcium carbonate scale. The testing is

TELEPHONE: (510) 527-9876
FAX: (510) 527-8164
E-MAIL: mw@geothermex.com

also expected to include the use of tracers to investigate the degree of communication between injectors and producers. The longer-term interference testing is expected to help define how the reservoir will respond with multiple wells flowing and injecting, and it may affect the choice of well locations for the latter part of the development drilling program.

3.2 Production Testing Results

Test results for the three successful production wells (23-14, 25-14, and 26A-14) are summarized in Table 2. All three wells have shown high PI values (greater than 5 gallons per minute (gpm) per psi of pressure drawdown). The PI values and reservoir pressure data have been used to estimate the performance of the wells under pumped conditions, assuming conventional line-shaft pumps. The pump-flow calculations indicate that output of the wells under initial conditions will be governed by the capacity of the pumps, which have been assumed to be limited to 2,500 gpm. At this flow rate, the three successful production wells at Blue Mountain are expected to yield net power output in excess of 7 MW net apiece, with a combined initial output of 22.2 MW net. This MW estimate takes into account the power usage of the production pump itself, as well as an additional 20% parasitic load for each well's proportionate share of the power to operate the binary power plant (including injection pumps, if needed). Detailed well testing data for wells 23-14, 25-14, and 26A-14 are included in Appendices B, C, and D, respectively, including:

- Field readings during flow tests
- Calculated flow rates and enthalpy values
- TPS logs showing fluid entry zones and flash points under flowing conditions
- Pressure build-up data and estimation of formation parameters (kh and skin) from Horner analysis
- Assumptions regarding estimates of productivity with downhole pumps
- Plots of estimated power output (gross and net) as a function of pump setting depth

TELEPHONE: (510) 527-9876
FAX: (510) 527-8164
E-MAIL: mw@geothermex.com

As a general comment on the flow test data, the flow rates and enthalpy values derived from downhole flowing temperatures (measured by TPS logs) appear more reliable for these wells than the James tube results. For instance, the James tube results for both 23-14 and 26A-14 yielded enthalpy values that were 40-50 BTU/lbm too high relative to values indicated by the downhole flowing temperatures. This may reflect some systemic bias in the James tube data; certainly the James-tube lip pressures were strongly affected by freezing conditions on certain tests (especially 26A-14 on 15-17 January 2008 and 25-14 on 27-29 January 2008).

Flow testing was also performed on the 44-14 well that completed drilling on 1 March 2008 (see Appendix E). In this case, the well flowed intermittently during the month of March, with periodic cycles of surging flow ("geysering"). A TPS log run on 27 March showed that flashing in the wellbore was occurring down to about 2,540 feet below ground level (GL) at a flow rate of about 200 gpm (in contrast to flash points in the range of 400 to 600 feet below GL for the other wells at much higher rates). The calculated PI was less than 0.5 gpm per psi of drawdown. At the low flow rates indicated by this test, even installation of a pump in 44-14 would not be expected to result in any net power output, due to heat losses in the upper part of the well. There is a possibility that near-wellbore formation damage from the drilling operation is contributing to poor performance of 44-14. Further testing is planned to assess whether the well would benefit from an acid stimulation.

No flow test data is available for well 38-14, the southern-most and the deepest of the full-diameter wells. This well was directionally drilled to the east. Although it shows artesian pressures and potentially commercial temperatures (maximum 359°F), the well flows no more than a few tens of gallons per minute. NGP is considering this well as a potential re-drill candidate.

TELEPHONE: (510) 527-9876
FAX: (510) 527-8164
E-MAIL: mw@geothermex.com

3.3 Interference Testing

The four wells in which downhole pressure were monitored from mid-December 2007 to mid-February 2008 all show clear pressure responses to changing flow rates at the two wells tested during this period (26A-14 and 25-14). Appendix F shows plots of these responses: one set of plots is labeled with letters corresponding to changes in flow rates; a second set shows a preliminary attempt to match the data using pressure-transient equations for radial flow in porous media. The matches for monitoring wells 23-14 and DB-2 are reasonably close to the measured data for the first period of flow of from 26A-14 and the subsequent build-up. However, later flow events are not very well matched by this analytical model: the measured data seem to take longer to rebound in pressure, and do not return to initial pressures even three weeks after the end of the last flow period. The matches for monitoring wells 38-14 and DB-1 are even less satisfying: the measured responses at 38-14 seem much more attenuated than the analytical model would predict, and the responses at DB-1 are actually the inverse of what one would expect (that is, when other wells were trending down in pressure, DB-1 was going up, and vice versa). The measured responses indicate that there is heterogeneity in the actual reservoir that is not captured by the simple analytical model. At a qualitative level, the immediacy of responses at the monitoring wells to changes in flow rates suggest locally high permeability, while the relatively slow speed of recovery of measured pressures to initial levels suggests some sort of boundary effect that slows recharge into the system.

The match to the first flow period of 26A-14 suggests bulk kh-values of the formation on the order of 40,000 millidarcy-feet for wells 23-14 and 38-14, and 25,000 millidarcy-feet for well DB-2 (Table 3). The data for DB-1 are not interpretable by this analytical model, so no kh-value is estimated for this well from the interference data. The interference matches to the other three wells appear to be consistent with the kh-value from the build-up analysis of 26A-14 (32,500 millidarcy-feet, see Table 2). At the same time, the very high kh-values from the build-up analyses of 23-14 and 25-15 (120,000

TELEPHONE: (510) 527-9876
FAX: (510) 527-8164
E-MAIL: mw@geothermex.com

millidarcy-feet and 140,800 millidarcy-feet, respectively) are consistent with the qualitative interpretation discussed above, that is, a local high-permeability region within a larger system of lower permeability. The multi-well test program planned for the summer of 2008 is intended to better define how this system will respond to several wells flowing simultaneously for longer periods of time, including the potentially pressure-supporting effects of injection.

GeothermEx, Inc. 5221 CENTRAL AVENUE, SUITE 201
RICHMOND, CALIFORNIA 94804-5829

TELEPHONE: (510) 527-9876
FAX: (510) 527-8164
E-MAIL: mw@geothermex.com

4. INJECTION STRATEGY

NGP has identified several potential locations for injection to the west and north of the production wells drilled to date (Figure 1). The first of these injection wells (58-15) is currently drilling. The identified injection locations are all at least one half mile from the nearest production well (existing or planned). This should allow adequate separation between injection and production, while still allowing for the possibility of pressure support from injection. The injection well locations are also planned to be slightly downhill from the power plant, to minimize the need for injection booster pumps.

NGP has budgeted for four injection wells to handle the output of the proposed binary plant, and they have included contingent funds that would allow for drilling more injection wells if needed. They have planned a total of six production wells at plant start-up. The ratio of injectors to producers at binary geothermal plants in the Basin and Range has historically averaged about 0.9, though the range of this ratio can be quite variable (anywhere from 0.6 at Steamboat Hot Springs to 1.3 at Brady's). Based on this comparative information, and given NGP's assumption of 6 active production wells, it is likely that 5 to 6 injectors will be required at Blue Mountain.

NGP had planned to drill 6 to 8 more wells after 44-14 (2 producers, 4 injectors, and 2 contingent wells). Given that well 44-14 appears to be non-productive, NGP has increased its drilling contingency to US$11 million, to cover the need for a third producer and the possibility of 1 to 2 more injectors. Considering the five full-diameter wells drilled for production through the end of March, NGP has achieved an effective average output of 4.4 MW net per well, including dry holes. Recent temperature-gradient drilling (TG-16, -17, and -18) has confirmed the presence of encouraging thermal gradients in the northwestern portion of the thermal anomaly (see Appendix A), and NGP's planned targets for the next two production wells (14-14 and 21-14, see Figure 1) are modest step-outs to the west and north of the three successful production wells, at locations

TELEPHONE: (510) 527-9876
FAX: (510) 527-8164
E-MAIL: mw@geothermex.com

considered to have good prospects for success. The location of the third production well has not been finalized, but NGP anticipates it will also be to the west or north of existing producers, maintaining the spacing of approximately 1,000 feet for producers and an offset of about one-half mile between producers and injectors. It is likely that the three remaining production wells to be drilled will average at least 5.6 MW net apiece, which would take the project from the currently tested capacity of 22.2 MW net to a total of 39 MW net. The US$11 million in contingency funds for three full-diameter wells appears to be sufficient for 1-2 injectors and 1 producer, which would bring the project to a total of 6 producers and 5-6 injectors. Thus, NGP's drilling budget (including contingency funds) appears adequate for the target output of 38.8 net MW.

GeothermEx, Inc.
5221 CENTRAL AVENUE, SUITE 201
RICHMOND, CALIFORNIA 94804-5829
TELEPHONE: (510) 527-9876
FAX: (510) 527-8164
E-MAIL: mw@geothermex.com

TABLES

Table 1: Full-Diameter Wells, Blue Mountain Geothermal Project

Well	Drilled For	Result	Measured Depth (feet)	Completion Date	Maximum Temperature (°F)	Comment
23-14	Production	Successful	3,415	16 Sep 2007	370.5	
25-14	Production	Successful	2,370	14 Jan 2008	374.0	
26A-14	Production	Successful	2,815	13 Sep 2006	371.0	
38-14	Production	Unsuccessful	5,426	6 Jul 2007	359.0	Negligible flow. Possible candidate for re-drill.
44-14	Production	Unsuccessful	3,600	1 Mar 2008	357.8	Geysering flow, about 200 gpm. Possible candiate for acid job.
58-15	Injection	Drilling	NA	NA	NA	Drilling at >2,850 feet as of 13 April 2008

Table 2: Production Well Testing Results, Blue Mountain Geothermal Project

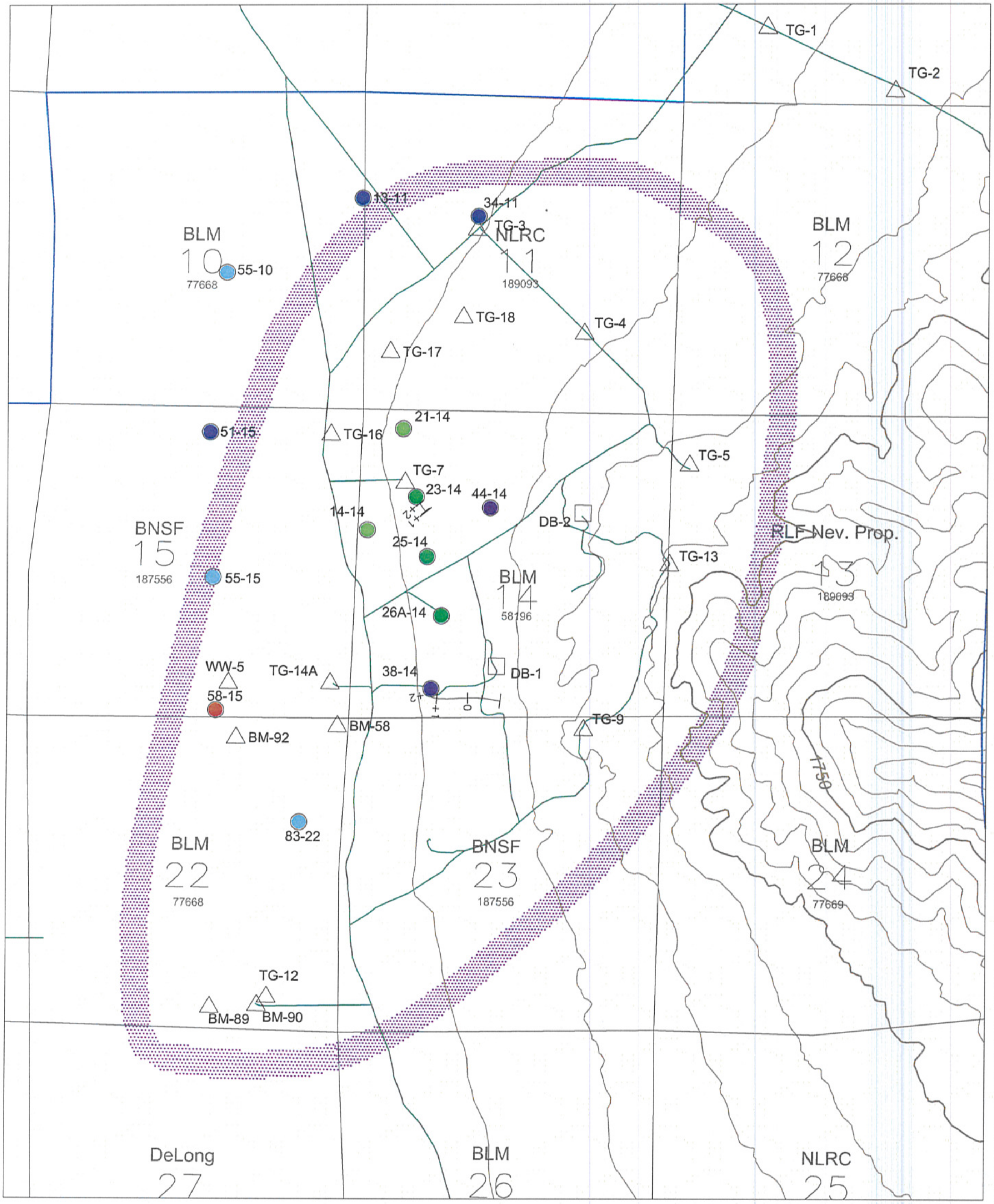
Well	Measured Depth (feet)	Testing Date(s)	Productivity Index (PI) (gpm/psi)	Permeability-Thickness Product (kh) (millidarcy-feet)	Skin Factor	Anticipated Initial Pumped Rate (gpm)	Equivalent Net MW
23-14	3,415	26-28 Sep 2007	7.1	120,000	+ 16	2,500	7.5
25-14	2,370	27-29 Jan 2008	7.3	140,800	+ 3.9	2,500	7.5
26A-14	2,815	29 Sep - 2 Oct 2006 19-20 Dec 2007 15-17 Jan 2008	5.8	32,500	- 8	2,500	7.2
Total							22.2

Table 3: Interference Testing Results, Blue Mountain Geothermal Project

Well	Measured Depth (feet)	Depth of Pressure-Monitoring Chamber (feet below ground level)	Approximate Elevation of Pressure-Monitoring Chamber (feet above sea level)	Approximate Permeability-Thickness Product (kh) (millidarcy-feet)
23-14	3,415	1,914	2,400	40,000
38-14	2,370	2,204	1,900	40,000
DB-1	2,815	1,150	3,200	?
DB-2	5,000	1,665	2,900	25,000

GeothermEx, Inc.
5221 CENTRAL AVENUE, SUITE 201
RICHMOND, CALIFORNIA 94804-5829
TELEPHONE: (510) 527-9876
FAX: (510) 527-8164
E-MAIL: mw@geothermex.com

FIGURES



LEGEND

- Thermal anomaly area
- 23-14 Existing producer
- 58-15 Currently drilling injector
- DB-2 Deep slim hole (> 2000 ft)
- TG-7 Temperature-gradient well / Water well
- 21-14 Proposed producer
- 51-15 Proposed injector
- 38-14 Unsuccessful producer
- 55-15 Potential injector

Figure 1: Well location map, Blue Mountain field

DATE: 02 APR 2008	GeothermEx
DRAWN: JWM APP.: JWL	GEOTHERMAL EXPLORATION DEVELOPMENT AND OPERATIONS 5221 Central Ave Suite 201, Richmond CA 94804 T:510.527.9876 F:510.527.9876

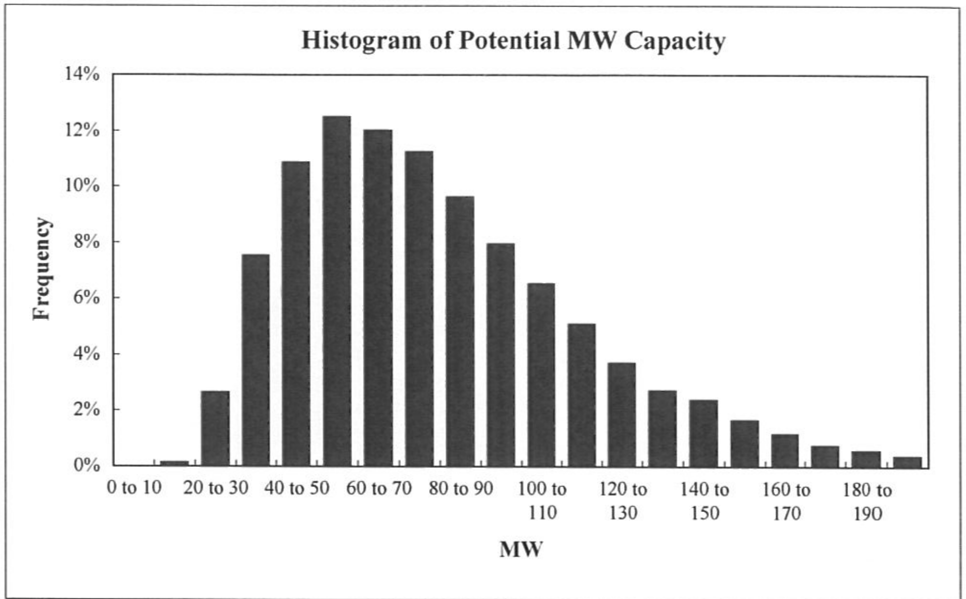
SUMMARY OF INPUT PARAMETERS

Variable Parameters	Minimum	Most Likely	Maximum
Reservoir Area (sq. mi.)	2.0		3.0
Reservoir Thickness (m)	500		1,500
Rock Porosity	0.03		0.07
Reservoir Temperature (°C)	145		235
Recovery Factor	0.10		0.20

Fixed Parameters		
Rock Volumetric Heat Capacity	2,680	kJ/cu. m°C
Rejection Temperature	12	°C
Utilization Factor	0.45	
Plant Capacity Facto:	0.95	
Power Plant Life	20	years

RESULTS

	Statistics		
	Net MW	MW/sq. mi.	Recovery Efficiency
Mean	80	32.2	1.50%
Std. Deviation	36	14.0	0.33%
Minimum (90% prob.)	**40**	16.4	1.08%
Most-likely (Modal)	**57**	26.3	1.47%



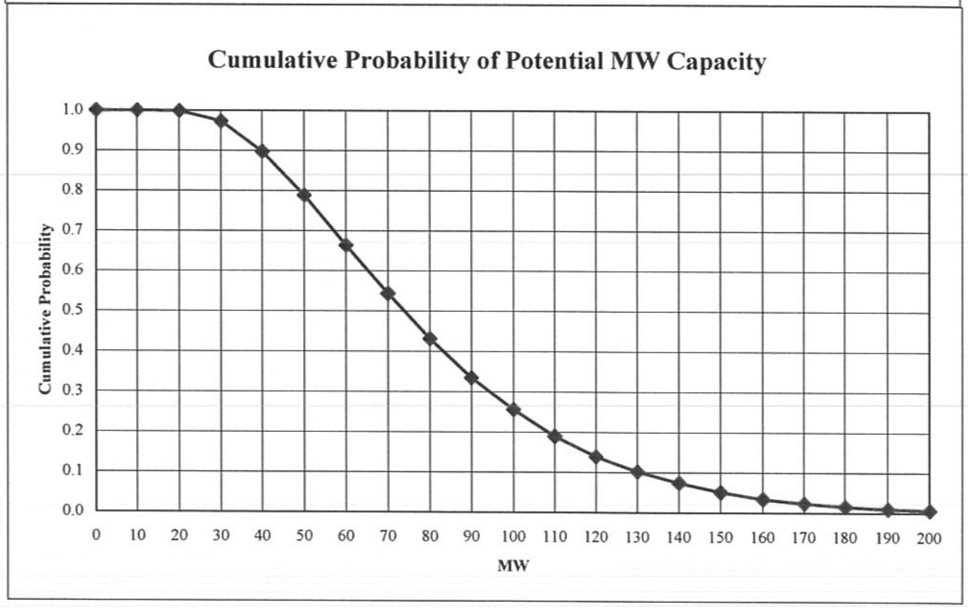


Figure 2:
Probabilistic Calculation of Potential MW Capacity
Blue Mountain, Nevada

EXHIBIT 26

EXHIBIT 26

March 4, 2012

HUFF POST GREEN

THE INTERNET NEWSPAPER: NEWS BLOGS VIDEO COMMUNITY

Ohio Earthquakes Caused By Drilling Wastewater Well, Expert Says

By THOMAS J. SHEERAN 01/ 2/12 09:33 PM ET AP

CLEVELAND -- A northeast Ohio well used to dispose of wastewater from oil and gas drilling almost certainly caused a series of 11 minor quakes in the Youngstown area since last spring, a seismologist investigating the quakes said Monday.

Research is continuing on the now-shuttered injection well at Youngstown and seismic activity, but it might take a year for the wastewater-related rumblings in the earth to dissipate, said John Armbruster of Columbia University's Lamont-Doherty Earth Observatory in Palisades, N.Y.

Brine wastewater dumped in wells comes from drilling operations, including the so-called fracking process to extract gas from underground shale that has been a source of concern among environmental groups and some property owners. Injection wells have also been suspected in quakes in Ashtabula in far northeast Ohio, and in Arkansas, Colorado, and Oklahoma, Armbruster said.

Thousands of gallons of brine were injected daily into the Youngstown well that opened in 2010 until its owner, Northstar Disposal Services LLC, agreed Friday to stop injecting the waste into the earth as a precaution while authorities assessed any potential links to the quakes.

After the latest and largest quake Saturday at 4.0 magnitude, state officials announced their beliefs that injecting wastewater near a fault line had created enough pressure to cause seismic activity. They said four inactive wells within a five-mile radius of the Youngstown well would remain closed. But they also stressed that injection wells are different from drilling wells that employ fracking.

Armbruster said Monday he expects more quakes will occur despite the shutdown of the Youngstown well.

"The earthquakes will trickle on as a kind of a cascading process once you've caused them to occur," he said. "This one year of pumping is a pulse that has been pushed into the ground, and it's going to be spreading out for at least a year."

The quakes began last March with the most recent on Christmas Eve and New Year's Eve each occurring within 100 meters of the injection well. The Saturday quake in McDonald, outside of Youngstown, caused no serious injuries or property damage.

Youngstown Democrat Rep. Robert Hagan on Monday renewed his call for a moratorium on fracking and well injection disposal to allow a review of safety issues.

"If it's safe, I want to do it," he said in a telephone interview. "If it's not, I don't want to be part and parcel to destruction of the environment and the fake promise of jobs."

He said a moratorium "really is what we should be doing, mostly toward the injection wells, but we should be asking questions on drilling itself."

A spokesman for Gov. John Kasich, an outspoken supporter of the growing oil and natural gas industry in Ohio, said the shale industry shouldn't be punished for a fracking byproduct.

"That would be the equivalent of shutting down the auto industry because a scrap tire dump caught fire somewhere," said Kasich spokesman Rob Nichols.

He said 177 deep injection wells have operated without incident in Ohio for decades and the Youngstown well was closed within 24 hours of a study detailing how close a Christmas Eve quake was to the well.

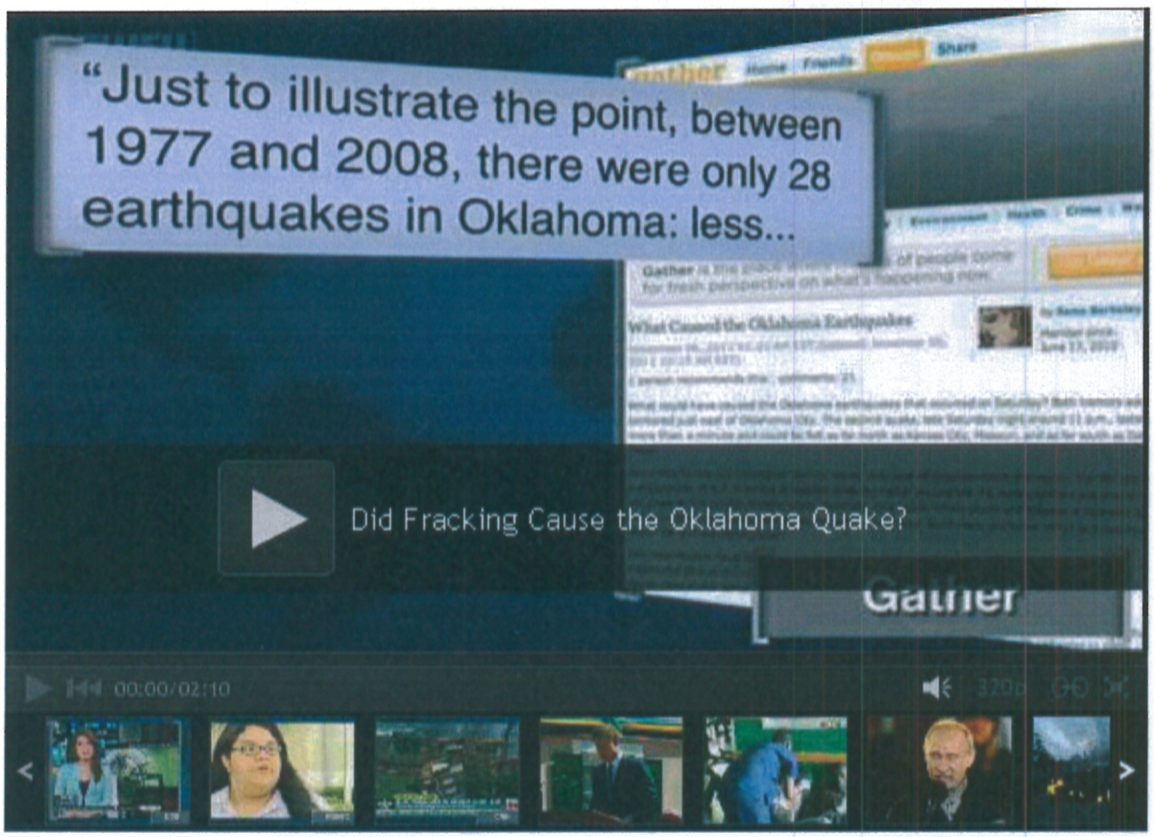
The industry-supported Ohio Oil and Gas Association said the rash of quakes was "a rare and isolated event that should not cast doubt about the effectiveness" of injection wells.

Such wells "have been used safely and reliably as a disposal method for wastewater from oil and gas operations in the U.S. since the 1930s," the association's executive vice president, Thomas E. Stewart, said in a statement Monday.

Environmentalists are critical of the hydraulic fracturing process, called fracking, which utilizes chemical-laced water and sand to blast deep into the ground and free the shale gas. Critics fear the process itself or the drilling liquid, which can contain carcinogens, could contaminate water supplies, either below ground, by spills, or in disposed wastewater.

Permits allowing hydraulic fracturing in Ohio's portion of the Marcellus and the deeper Utica Shale formations rose from one in 2006 to at least 32 in 2011.

RELATED ON HUFFPOST:



Twitter:
Enter Email Address Get Alerts

CONTRIBUTE
TO THIS STORY

- Send Corrections
- Send us a Link
- Contact us

- Send a Tip
- Send Photos/Videos
- Comment

Filed by Benjamin Hart | Report Corrections

More in Green...

- Comments
- 1,626
- Pending Comments
- 0
- View FAQ

View All
Favorites
Recency |
Popularity
Page: **1** 2 3 4 5 Next › Last » (28 total)
Page: **1** 2 3 4 5 Next › Last » (28 total)

EXHIBIT 27

EXHIBIT 27

A Guide to Geothermal Energy and the Environment

Geothermal facilities located in a Philippine cornfield (top left); at Mammoth Lakes, California (top right); in the Mojave Desert, California (bottom left); and in a tropical forest, Mt. Apo, Philippines (bottom right). Source: Geothermal Education Office.

By Alyssa Kagel, Diana Bates, & Karl Gawell

Geothermal Energy Association
209 Pennsylvania Avenue SE, Washington, D.C. 20003
Phone: (202) 454-5261 Fax: (202) 454-5265
www.geo-energy.org

Updated April 2007

Executive Summary

INTRODUCTION AND OVERVIEW

Geothermal energy, defined as heat from the Earth, is a statute-recognized renewable resource. The first U.S. geothermal power plant, opened at The Geysers in California in 1960, continues to operate successfully. The United States, as the world's largest producer of geothermal electricity, generates an average of 15 billion kilowatt hours of power per year, comparable to burning close to 25 million barrels of oil or 6 million short tons of coal per year.[1]

Geothermal has a higher capacity factor (a measure of the amount of real time during which a facility is used) than many other power sources. Unlike wind and solar resources, which are more dependent upon weather fluctuations and climate changes, geothermal resources are available 24 hours a day, 7 days a week. While the carrier medium for geothermal electricity (water) must be properly managed, the source of geothermal energy, the Earth's heat, will be available indefinitely.

A geothermal resource assessment shows that nine western states together have the potential to provide over 20 percent of national electricity needs. Although geothermal power plants, concentrated in the West, provide the third largest domestic source of renewable electricity after hydropower and biomass, they currently produce less than one percent of total U.S. electricity.

EMISSIONS

The visible plumes seen rising from some geothermal power plants are actually water vapor emissions (steam), not smoke. Because geothermal power plants do not burn fuel like fossil fuel plants, they release virtually no air emissions. A case study of a coal plant updated with scrubbers and other emissions control technologies emits 24 times more carbon dioxide, 10,837 times more sulfur dioxide, and 3,865 times more nitrous oxides per megawatt hour than a geothermal steam plant. Averages of four significant pollutants, as emitted from geothermal and coal facilities, are listed in the table below. Following the table is a brief discussion of other emissions that have sometimes been associated with geothermal development.

[1] Using Energy Information Administration (EIA) average geothermal energy production, 1990 – 2003, and EIA conversion information

Water Quality: Geothermal fluids used for electricity are injected back into geothermal reservoirs using wells with thick casing to prevent cross-contamination of brines with groundwater systems. They are not released into surface waterways. At The Geysers facility, 11 million gallons of treated wastewater from Santa Rosa are pumped daily for injection into the geothermal reservoir. Injection reduces surface water pollution and increases geothermal reservoir resilience.

Land Use: Geothermal power plants can be designed to "blend-in" to their surrounding more so than fossil fired plants, and can be located on multiple-use lands that incorporate farming, skiing, and hunting. Over 30 years, the period of time commonly used to compare the life cycle impacts from different power sources, a geothermal facility uses 404 square meters of land per gigawatt hour, while a coal facility uses 3632 square meters per gigawatt hour.

--*Subsidence*: Subsidence, or the slow, downward sinking of land, may be linked to geothermal reservoir pressure decline. Injection technology, employed at all geothermal sites in the United States, is an effective mitigating technique.

* --*Induced Seismicity*: While earthquake activity, or seismicity, is a natural phenomenon, geothermal production and injection operations have at times resulted in low-magnitude events known as "microearthquakes." These events typically cannot be detected by humans, and are often monitored voluntarily by geothermal companies.

Geysers, Fumaroles, and Geothermal Resources: While almost all geothermal resources currently developed for electricity production are located in the vicinity of natural geothermal surface features, much of the undeveloped geothermal resource base may be found deep under the Earth without any corresponding surface thermal manifestations. Geothermal surface features, while useful in identifying resource locations, are not used during geothermal development. U.S. laws and regulations protect and preserve national parks and their significant thermal features.

Impact on Wildlife and Vegetation: Before geothermal construction can begin, an environmental review may be required to categorize potential effects upon plants and animals. Power plants are designed to minimize the potential effect upon wildlife and vegetation, and they are constructed in accordance with a host of state and federal regulations that protect areas set for development.

EXHIBIT 28

EXHIBIT 28

To:

Jon Taylor PE CEM
Nevada Division of Environmental Protection
Bureau of Waste Management
Solid Waste Facilities Branch
901 S. Stewart St., Suite 4001
Carson City, NV 89701-5249
Phone: (775) 687-9477 Fax:775.687.5856

Dear Mr. Taylor,

This is another response to the Nevada Division of Environmental Protection's (NDEP) intent to issue an operating permit for the Jungo Rd. landfill.
In regards to the issue of soil liquefaction in the event of a large earthquake, it is my understanding that the evaluations, testing and sampling regimes carried out by Golder & Assoc. are inadequate as a basis for accurately defining the risk factor at the proposed site.

Liquefaction risk can be modeled by determining the geologic deposits most inclined toward this activity as defined by *Youd, T.L., and Perkins, D.M., 1978. "Mapping Liquefaction –Induced Ground Failure Potential" in American Society of Civil Engineers, Journal of the Geotechnical Engineering Division: v. 104, no. GT4,* and detailed in their chart. See Table 1 below.

Table 1. Estimated susceptibility of sedimentary deposits to liquefaction during strong seismic shaking (from Youd and Perkins, 1978).

Type of deposit (1)	General distribution of cohesionless sediments in deposits (2)	Likelihood that Cohesionless Sediments, When Saturated, Would Be Susceptible to Liquefaction (by age of Deposit)			
		<500 yr (3)	Holocene (4)	Pleistocene (5)	Pre-Pleistocene (6)
(a) Continental Deposits					
River channel	Locally variable	Very high	High	Low	Very low
Flood plain	Locally variable	High	Moderate	Low	Very low
Alluvial fan and plain	Widespread	Moderate	Low	Low	Very low
Marine terraces and plains	Widespread	—	Low	Very low	Very low
Delta and fan-delta	Widespread	High	Moderate	Low	Very low
Lacustrine and playa	Variable High	Moderate	Low	Very low	
Colluvium	Variable High	Moderate	Low	Very low	
Talus	Widespread	Low	Low	Very low	Very low
Dunes	Widespread	High	Moderate	Low	Very low
Loess	Variable High	High	High	Unknown	
Glacial till	Variable Low	Low	Very low	Very low	
Tuff	Rare	Low	Low	Very low	Very low
Tephra	Widespread	High	High	?	?
Residual soils	Rare	Low	Low	Very low	Very low
Sebka	Locally variable	High	Moderate	Low	Very low
(b) Coastal Zone					
Delta	Widespread	Very high	High	Low	Very low
Esturine	Locally variable	High	Moderate	Low	Very low
Beach					
High wave energy	Widespread	Moderate	Low	Very low	Very low
Low wave energy	Widespread	High	Moderate	Low	Very low
Lagoonal	Locally variable	High	Moderate	Low	Very low
Fore shore	Locally variable	High	Moderate	Low	Very low
(c) Artificial					
Uncompacted fill	Variable	Very high	—	—	—
Compacted fill	Variable	Low	—	—	—

By assigning risk values based upon known geologic formations, a map can be produced that illustrates this data. No such document was provided by Golder, so, I am including this for your information. This document does not purport to be a final analysis but should have been an initial step of an investigation, for a state government environmental inquiry, to determine the suitability of native foundational materials of any large structure. The proposed Jungo dump will be almost a mile square and would rest upon lacustrine and aeolian Quaternary deposits less than 100 feet above an active aquifer. Some investigation would seem prudent. I have attached a map interpolating the areas of risk as outlined by Youd & Perkins above.

As defined by the map, the landfill site would be in the "moderate" risk category. Golder assigns a "low" risk in their appendices. This discrepancy is unsurprising, given their tendency toward misinterpretation of Berger's study of the area, which I and others have repeatedly pointed out to NDEP in past comments and at the "informational" meeting in Winnemucca. This pattern of misinterpretation and / or incorrect citation gave me the impetus to take a closer look at the soils data provided by Golder. Golder incorrectly describes the lithography of the area as stratified in neat layers which is false, WRIR – 95-4119 disputes this unequivocally. The importance of this cannot be stated enough. There aren't nice alternating layers of clays and silts, it is a heterogeneous mass acting as a single unconfined aquifer. A new well could be drilled 100 meters from any already in place and a different sequence of "layering" would present itself. If one were to accept Golder's depiction, which I don't...but even if you did (which you shouldn't), a low liquefaction assessment is still wrong.

I have attached the well logs for "EB" with an overlay of the soil testing points which were the basis for Golder's assignation of a "low" risk factor for liquefaction. That being, soil types, plasticity, liquid limits, etc. It could be argued that the points tested were "cherry picked" in an effort to reach a predefined outcome. Additionally, pages 2, 4 & 6 were missing from the borehole logs, perhaps an oversight on Golder's and NDEP's part. Regardless, I am uncertain that a true risk factor can be derived from these datasets even if they were collected in an unambiguous fashion. It is my contention that only in situ testing by cone penetration method could adequately describe the risks involved. "*Simplified model for evaluating soil liquefaction potential using CPTU* " *- C.H. Juang Clemson University, SC, USA - C.S. Ku I-Shou University, Kaohsiung, Taiwan - C.C. Chen Clemson University, SC, USA – 2nd International Symposium on Cone Penetration Testing, Huntington Beach, CA, USA, May 2010*
I have also attached this paper for your perusal.

In an effort to better understand the seriousness and implications of earthquake related liquefaction, a friend introduced me to a couple of geophysicists, who know something about the geology of northern Nevada. In our brief conversations they related something in passing that would seem obvious to some. All the predictive analysis doesn't really mean anything if the soils are already saturated. If the normal water level in southern Desert Valley is 60 feet below ground surface, then the soils at and below that level are already liquified. In the event of a quake liquefaction wouldn't have to take place because of the severity of the geologic force, it has already happened. If consideration is given to the importance of seasonal flooding, which was outlined in a comment I sent previously (01/09/12), the upper layers of soil are also at risk.

In summation, the determination of a "low" risk value for liquefaction is not supportable and an increased risk because of seasonal flooding is demonstrable. For these reasons, this permit should be denied. The high desert valleys and playas are no place for a dump.

Chuck Schlarb - Winnemucca, NV

What's wrong with this picture?

Well - EB Geotechnical Analysis.

Boring Log sheets 2, 4 & 6 are missing from Appendix A.

Moisture Content & Unit Weight
Lab Results from:
51'
75'
100'

Particle Size Distribution
20'
60'
80'
110'
130'
145'

Liquid & Plastic Limits
80'
130'

Were the samples cherry picked for desired results?

See below

Golder Associates
1009 Enterprise Way, Suite 350
Roseville, CA 95678
Telephone: 916-786-2424
Fax: 916-786-2434

BORING NUMBER EB

PROJECT NUMBER 063-7079-100
PROJECT NAME Subsurface Investigation
LOCATION Jungo Road, Winnemucca, NV
DRILLING METHOD Hollow Stem Auger
SAMPLING METHOD Cal Modified, SPT, Shelby
GROUND ELEVATION 4174.80
TOP OF CASING —
LOGGED BY AAH
REMARKS Approximately 7 feet of heave in the bottom of the borehole at 145 feet bgs.

DATE STARTED 1/12/07
DATE COMPLETED 1/13/07
CASING TYPE/DIAMETER —
SCREEN TYPE/SLOT —
GRAVEL PACK TYPE —
GROUT TYPE/QUANTITY —
DEPTH TO WATER 57.1
GROUND WATER ELEVATION 4117.7

DEPTH TO WATER	BLOW COUNTS	RECOVERY (inches)	SAMPLE ID.	EXTENT	DEPTH (ft. BGL)	U.S.C.S.	GRAPHIC LOG	LITHOLOGIC DESCRIPTION	CONTACT DEPTH
								SILTY SAND/SANDY SILT with trace to little CLAY. Light Yellowish Brown (2.5Y 1/3). ~50-60% fine sand, ~40-50% low plasticity fines. Dry. Loose.	
	6 7 9	16	SPT		5	SM-ML			
	6 7 9	16	SPT		10				12.5
								SILTY SAND with trace CLAY. Light Yellowish Brown (2.5Y 1/3). ~70-80% fine sand, ~20-30% low plasticity fines. Dry. Loose.	
	5 7 8	15	SPT		15	SM			18.0
								CLAYEY SILT with some SAND. Light Yellowish Brown (2.5Y 1/3). Dry. Loose. Compact.	
								Particle Size Distribution	
	8 14 15	12	SPT		20	ML		Sample submitted for lab analyses. 15.7% fine sand, 84.3% low to medium plasticity fines.	

Golder Associates
Golder Associates
1009 Enterprise Way, Suite 350
Roseville, CA 95678
Telephone: 916-786-2424
Fax: 916-786-2434

BORING NUMBER EB

PROJECT NUMBER 063-7079-100 **DATE STARTED** 1/12/07

PROJECT NAME Subsurface Investigation **DATE COMPLETED** 1/13/07

Continued from Previous Page

DEPTH TO WATER	BLOW COUNTS	RECOVERY (inches)	SAMPLE ID.	EXTENT	DEPTH (ft. BGL)	U.S.C.S.	GRAPHIC LOG	LITHOLOGIC DESCRIPTION	CONTACT DEPTH
						SP		SAND with trace to little fines. Light Olive Brown (2.5Y 5/4). ~90-95% fine to medium sand, ~5-10% low plasticity fines. Moist. Compact. *(continued)*	54.0
	5 19 29	14	SPT		55	ML		CLAYEY SILT with little to some fine SAND. Olive Brown (2.5Y 4/4). ~10-20% fine sand, ~80-90% low plasticity fines. Moist. Compact.	55.8
▼						SP		SAND with trace to little fines.	58.5
	5 6 6	18	SPT		60	ML		CLAYEY SILT with some SAND. Light Olive Brown (2.5Y 5/4). Moist. Loose. Particle Size - Distribution Sample submitted for lab analyses. 0.7% medium grained sand, 16.8% fine grained sand, 82.5% low to medium plasticity fines.	63.5
	5 6 7	16	SPT		65	ML-CL		CLAYEY SILT/SILTY CLAY with little to some fine SAND. Light Olive Brown (2.5Y 5/4). ~10-20% fine sand, ~80-90% low to medium plasticity fines. Moist. Loose. Greenish Grey (Gley1 5/10Y). ~5% fine sand, ~95% low plasticity fines.	68.5
∇	22 19 50	18	MC		70 75	SP-SM		SAND with little to some fines. Very Dark Grey (2.5Y 4/1). Wet to saturated. Moisture Content - Unit Weight SAND with trace fines. Very Dark Grey (2.5Y 4/1). ~5% coarse sand, ~45% medium sand, ~45% fine sand, ~5% fines. Saturated. Submitted sample for lab analyses. Unit Weight: Wet 154.1, Dry 126.9. MC = 21.4%.	78.0
	4 5 22		SPT		80	CH		CLAY with some SAND and trace GRAVEL. Greenish Grey (Gley1 5/10 Y). Moist. Firm to stiff. Liquid & Plastic Limits FAT CLAY and some SAND. Sample submitted for lab analyses. 1.5% fine gravel, 0.7% coarse grained sand, 2.2% medium sand, 13.3% fine sand, 82.3% low to high plasticity fines. Liquid limit 60. Plasticity index 34. 95.6% <#40. 82.3% <#200.	

Golder Associates
1009 Enterprise Way, Suite 350
Roseville, CA 95678
Telephone: 916-786-2424
Fax: 916-786-2434

BORING NUMBER EB

PROJECT NUMBER 063-7079-100 **DATE STARTED** 1/12/07

PROJECT NAME Subsurface Investigation **DATE COMPLETED** 1/13/07

Continued from Previous Page

DEPTH TO WATER	BLOW COUNTS	RECOVERY (Inches)	SAMPLE ID.	EXTENT	DEPTH (ft. BGL)	U.S.C.S.	GRAPHIC LOG	LITHOLOGIC DESCRIPTION	CONTACT DEPTH
	15 19							sand, 98.6% low to medium plasticity fines.	111.0
						SM-ML		SILTY SAND/SANDY SILT with little to some CLAY. Very Dark Grey (2.5Y 4/1). ~50-60% fine sand, ~40-50% low plasticity fines. Compact. Moist to wet.	114.0
					115	SP		SAND with trace to little fines. Very Dark Grey (2.5Y 4/1). ~90-95% fine to medium sand, ~5-10% low plasticity fines. Wet to saturated.	119.5
	14 20 25	18	SPT		120	SP-SM		SAND with trace to little CLAY. Very Dark Grey (2.5Y 4/1). ~70-80% fine to medium sand, ~20-30% low plasticity fines. Compact. Wet to saturated. SILTY CLAY/CLAYEY SILT with little to some fine sand. Very Dark Grey (2.5Y 4/1). ~5% fine sand, ~95% low plasticity fines. Moist. Very stiff.	123.5
	0 6 8	18	MC		125	SM		SILTY SAND with trace to little CLAY. Very Dark Grey (2.5Y 4/1). ~60-70% fine sand, ~30-40% low plasticity fines. Saturated, flowing sand.	126.0
						SP		SAND with trace to little fines. Dark Grey to Dark Greyish Brown (2.5Y 4.2). ~90-95% fine to medium sand, ~5-10% low plasticity fines. Wet to saturated. Loose.	128.5
	7 13 23	18	SPT		130	ML		CLAYEY SILT and SAND. Dark Greyish Brown (2.5Y 7/2). Trace of white mineral. Moist. Firm to very stiff. Liquid & Plastic Limits Submitted sample for lab analyses. 3.7% coarse sand, 9.1% medium sand, 21.3% fine sand, 50.8% silt, 15.1% low plasticity clay. Liquid limit 48. Plasticity index 15. 87.2% <#40. 65.9% <#200.	133.0
					135	SW		SAND with trace to little fines. Dark Greyish Brown (2.5Y 4/2). ~90-95% fine to medium sand, ~5-10% low plasticity fines. Wet to saturated.	

EXHIBIT 29

EXHIBIT 29

Review of Potential Public Health & Groundwater Quality Impacts of the Proposed Jungo Landfill

G. Fred Lee, PhD, PE(TX), BCEE, F.ASCE & Anne Jones-Lee, PhD
G. Fred Lee & Associates
El Macero, California
phone: 530-753-9630
gfredlee@aol.com www.gfredlee.com
December 9, 2011

Nevada Land and Resource, Inc. of Carson City, NV (owner) and Recology of San Francisco, CA (operator) have proposed to construct and operate a Class I municipal solid waste (MSW) landfill facility, referred to as the Jungo Landfill, approximately 25 miles west of the city of Winnemucca, NV. The Nevada Division of Environmental Protection (NDEP) Bureau of Waste Management provides information concerning that proposed landfill and its permitting process for that landfill at various locations on the Internet including:

- NDEP "Proposed Jungo Landfill" Webpage, dated October 27, 2011 [http://ndep.nv.gov/bwm/jungo.htm]
- NDEP "Fact Sheet" http://ndep.nv.gov/docs_11/jungo_fact_sheet-2011.pdf
- Report of Design of Landfill http://ndep.nv.gov/bwm/docs/report_of_design.pdf
- Draft Permit http://ndep.nv.gov/docs_11/jungo_permit_draft-2011.pdf
- Plan of Operation http://ndep.nv.gov/bwm/docs/jungo_plan_operations.pdf

Presented below are excerpts from the above-named documents to highlight key characteristics and other aspects of the proposed landfill that are of concern relative to ensuring protection of public health and environmental quality for as long as the wastes are a threat; specific comments are offered on some of those issues. In these comments reference is made to more in-depth discussion of some of the issues in our "Flawed Technology" review of MSW landfilling practices and their ability to provide protection of public health and environmental quality for as long as the wastes represent a threat. That review is available as:

Lee, G. F., and Jones-Lee, A., "Flawed Technology of Subtitle D Landfilling of Municipal Solid Waste," Report of G. Fred Lee & Associates, El Macero, CA, December (2004). Updated July (2011). http://www.gfredlee.com/Landfills/SubtitleDFlawedTechnPap.pdf

NDEP Fact Sheet

According to the Nevada Department of Environmental Protection (NDEP) "Fact Sheet" about the site [http://ndep.nv.gov/docs_11/jungo_fact_sheet-2011.pdf]:

"Description of Proposed Permit Issuance
Nevada Land and Resource Inc. has requested to construct and operate a Class I Landfill in Humboldt County Nevada. The Landfill will be constructed with a double liner with leachate collection and groundwater monitoring for the life of the landfill. Post closure care and monitoring will continue for 30 years upon final closure of the site. The Jungo Disposal Site serves as a regional disposal site for portions of Northern California generally including the nine counties which make up the San Francisco Bay Area, and tributary communities along the rail route. Refuse will be delivered to the site by rail at an estimated average annual rate of up to 4,000 tons/day. The Jungo Disposal Site is located approximately 25 miles west of Winnemucca,

Nevada. The landfill is located on a 634-acre parcel that consists of Section 7 of Township 35N, Range 33E. The landfill disposal footprint encompasses approximately 562-acres.

Proposed Action
The Nevada Division of Environmental Protection (NDEP) is proposing to approve and issue a Permit to Nevada Land and Resource Inc. for the Construction and Operation of a Class I Landfill in Humboldt County Nevada."

Sections of the October 2011 Nevada Department of Environmental Protection (NDEP) draft permit for the Jungo Landfill [http://ndep.nv.gov/docs_11/jungo_permit_draft-2011.pdf] are quoted and commented upon below:

"1 FACILITY SUMMARY
The Jungo Disposal Site serves as a regional disposal site for portions of Northern California generally including the nine counties which make up the San Francisco Bay Area, and tributary communities along the rail route. Refuse will be delivered to the site by rail at an estimated average annual rate of up to 4,000 tons/day. The Jungo Disposal Site is located approximately 25 miles west of Winnemucca, Nevada. The landfill is located on a 634-acre parcel that consists of Section 7 of Township 35N, Range 33E. The landfill disposal footprint encompasses approximately 562-acres.

1.1 GENERAL DESCRIPTION
The Landfill is on land designated as Agricultural use, approximately 25 miles to the west of the City of Winnemucca. The 562 acre Class I landfill unit is required to conduct Groundwater Monitoring, Methane Monitoring and will conduct Closure and Post Closure activities concurrent with landfill development. ***The Landfill will perform 30 years of Post-Closure care and monitoring.****"* [emphasis added]

"1.4 FACILITY DESIGN

Permitted Design Summary
Table 1

Class I	*Rev 00*
Disposal Area (acres)	*562*
Maximum Elevation (amsl)	*4375*
Minimum Elevation (amsl)	*4150*
Disposal Capacity (yds^3)	*$97(10^6)$*
Total Volume (yds^3)	*$111(10^6)$*

As discussed in these comments the proposed Jungo Landfill will be a very large MSW landfill that will if permitted be a significant threat to pollute groundwater in the area of the landfill.

"2.2 PERMIT ACTIONS (NAC 444.643)
This Permit is based upon the information submitted in the Permit application, and as approved by the Nevada Division of Environmental Protection (Division)."

NDEP's webpage devoted to the "Proposed Jungo Landfill," dated October 27, 2011, [http://ndep.nv.gov/bwm/jungo.htm] provides general information about surficial physical characteristics and climate of the proposed site, and links to resource documents and landfill application documents. It states:
"About This Webpage – This webpage provides information about the Division of Environmental Protection's (NDEP) permitting process to construct and operate a Class I municipal solid waste landfill facility at the Jungo disposal site located in Humboldt County, Nevada. The Jungo Disposal Site is located approximately 30 miles west of Winnemucca, Nevada along Jungo Road."

In the website's section on the "Climate and Hydrology" of the proposed landfill area, it is reported:
"Mean annual precipitation is estimated to be approximately 8 inches."
"Based on data from Rye Patch Reservoir located 14 miles to the south, evaporation from free water sources is approximately 48-inches per year (Cohen, 1965). The prevailing wind direction in Desert Valley is toward the west-southwest. The 25-year, 24-hour storm event is estimated to be 1.62 inches (NOAA, 2006)."

The NDEP stated in the "Topography and Drainage" section:
"*Precipitation or snow melt on the valley floor accumulates in localized depressions until it infiltrates or evaporates. At the Jungo Disposal Site, these shallow depressions are on the order of several inches deep. During normal precipitation events, water accumulates in the depressions until it evaporates or infiltrates into the subsurface soils.*

In the event of intense storms, it is possible that localized depressions may fill and then sheet flow to the next depressions located to the north or west. This is consistent with the United States Department of Agriculture (USDA), Natural Resources Conservation Service (NRCS) (2007), which estimates that ponding may occur locally to depths of 6 to 12 inches."

Jungo Draft Permit
The NDEP draft permit for the Jungo Landfill states in Section 2.4:
"*2.4 COMPLIANCE WITH STATUTES AND REGULATIONS*
The Permittee shall comply with NRS 444.440 through 444.620, and NAC 444.570 through 444.7499, as applicable."
A subsequent section of these comments discusses the NDEP regulations for this landfill relative to their providing protection of public health and groundwater quality, and from other potential impacts of this proposed landfill. As discussed in these comments the proposed landfill will fall far short of the regulatory requirement to provide protection of groundwater quality.

Approach to Jungo Landfill Impact Review
For the past five decades I (G. Fred Lee) have been involved in reviewing and researching the impacts of MSW landfills and the ability of various waste management systems to protect public

health and environmental quality from adverse impacts of the wastes. I have examined the nature, impacts, and reasonably expected impacts of more than 85 existing and proposed solid waste landfill systems in the US, Canada, and several other countries. Based on my university research on landfill liners and the investigation of landfill impacts I have developed more than 100 professional papers and reports on these issues. This experience has led to a systematic approach to evaluating potential impact of a proposed landfill focusing on the following issues:

- Suitability of the site for the proposed landfill
- Type of landfilling approach, e.g., "dry tomb" or "wet cell"
- Adequacy of the design of the landfill waste containment system, including the liner, leachate collection and removal system, landfill cover, groundwater monitoring system, landfill gas management and monitoring system, for protecting public health and environmental/groundwater quality
- Reliability and adequacy of closure plans
- Reliability and adequacy of the postclosure funding for landfill monitoring and maintenance for as long as the waste in the landfill will be a threat
- Adequacy of minimum regulatory requirements for providing for protection of public health, groundwater and surface water quality, and the interests of those within the sphere of influence of the landfill for as long as the wastes in the landfill will be a threat.

This review of the potential impacts of the proposed Jungo Landfill addresses each of these issues. It is based and focused on landfill siting and design information for the proposed landfill that is provided on the NDEP website for the Jungo Landfill [http://ndep.nv.gov/bwm/jungo.htm].

Out of our academic background and professional expertise and experience in researching and investigating impacts and potential impacts of individual landfills, we have developed our "Flawed Technology" review report. In that report, we synthesize and discuss the key elements of landfilling as it is practiced, and strengths and weaknesses of those practices for ensuring the protection of public health, groundwater and surface water quality, and the interests of those within the sphere of influence of the landfill for as long as the wastes in the landfill will be a threat. About 150 references to the professional literature on anticipated potential impacts of US EPA Subtitle D landfills are included in our approximately 100-page discussion of these issues. The "Flawed Technology" review is available as:

> Lee, G. F., and Jones-Lee, A., "Flawed Technology of Subtitle D Landfilling of Municipal Solid Waste," Report of G. Fred Lee & Associates, El Macero, CA, December (2004). Updated July (2011). http://www.gfredlee.com/Landfills/SubtitleDFlawedTechnPap.pdf

In our comments presented herein we make reference to sections of this "Flawed Technology" review for further technical information and references to the professional literature on the topics being discussed.

Qualifications to Provide Comments

Information on Drs. G. Fred Lee and Anne Jones-Lee's qualifications to provide these comments is summarized below. Dr. Lee earned his bachelor's degree in environmental health sciences from San Jose State College in San Jose, CA in 1955. His undergraduate education included work on public health aspects of landfilling of municipal solid wastes. He earned his Master of Science in Public Health degree from the University of North Carolina, Chapel Hill, NC in 1957, and his PhD degree in Environmental Engineering from Harvard University in 1960 where he minored in public health protection and aquatic chemistry. Both his master's and PhD degree work included studies on water quality, public health protection, and waste management.

For 30 years Dr. Lee held teaching and research positions in graduate-level environmental engineering/environmental science programs at several major US universities. During that time he conducted more than $5 million in research and published more than 500 papers and reports on various aspects of water quality and impacts of chemical contaminants on public health and environmental quality. His work included investigating numerous municipal solid waste landfills and conducting research for the US EPA and others on landfill liner properties. In 1989 Dr. Lee retired from university teaching and research, and expanded his part-time, private consulting activities into a full-time business. He was joined in that work by his wife, Dr. Anne Jones-Lee, who at that time held an associate professorship in environmental engineering/ science.

In the 1970s while a university professor, Dr. G. Fred Lee was asked by the US EPA to undertake research on landfill liner integrity and the ability of such liners to prevent penetration of waste-derived chemicals. Over the past 40 years he has been active in investigating and reviewing the literature developed by others on the ability of plastic sheeting liners/covers to be effective in "dry tomb" type landfills to prevent the release of leachate through the liner over the time that the wastes in the landfill will be a threat. They have been active in investigating more than 85 municipal solid waste landfills located in various parts of the US and other countries. Drs. Lee and Jones-Lee have been active in developing publications on issues affecting the ability of "dry tomb" type landfills to protect public health, groundwater resources, environmental quality, and the interests of those in the sphere of influence of the landfill; they have developed more than 120 papers and reports on these issues. Many of those papers and reports are available on their website, www.gfredlee.com, in the Landfill Groundwater section at http://www.gfredlee.com/plandfil2.htm. An area of particular concern in my investigation of MSW landfills are the processes that occur in a landfill that impact the potential impact of the wastes to pollute the environment. Of particular concern are the processes that lead to landfill gas formation and the leaching of the wastes to be present in water (leachate) that penetrates through the wastes. Additional information on their qualification to provide these comments is provided in the appendix to these comments.

Dr, G. Fred Lee was provided a guided tour of the proposed landfill area by Mike MacDonald Humboldt District Attorney on the afternoon of December 1, 2011.

Ownership of the Jungo Landfill

The "Application for a Permit to Construct and Operate a Class I Landfill Facility Jungo Disposal Site, Humboldt County, Nevada" that is dated July 2011 states that the Jungo Landfill will be developed by Nevada Land and Resource LLC of Carson City, Nevada/Recology of San Francisco, California. However, the "Application for a Permit to Construct and Operate a Class I Landfill Facility, Jungo Disposal Site, Humboldt County, Nevada , Volume Ill, Plan Of Operations," Revision 4, Prepared for Jungo Land & Investments, Inc. by Golder Associates Inc. (July 2011) [http://ndep.nv.gov/bwm/docs/jungo_plan_operations.pdf] states:

"Jungo Land & Investments, Inc. (JLII), the landfill owner and operator, is submitting the following Plan of Operations for a Class I municipal solid waste disposal site as required by the general provisions for solid waste disposal defined in the Nevada Administrative Code (NAC 444.684)."
On page 1 of that document, Section 1.1 Site Description states:
"The facility will be operated by JLII in accordance with applicable State of Nevada solid waste regulations. The land is currently owned by Nevada Land and Resources, Inc. but will be acquired by JLII prior to development. JLII currently has a leasehold interest with an option to purchase the property, which JLII plans to exercise once the necessary State permits have been obtained."
It is unclear which organization (Nevada Land and Resource LLC of Carson City, Nevada/Recology and/or Jungo Land & Investments, Inc. (JLII)) will be responsible for care of the landfill to provide protection of public health and groundwater quality for as long as the landfill will be a threat to pollute groundwater or cause other adverse environmental impacts of the landfill.

Design of the Proposed Jungo Landfill
The design proposed for the Jungo Landfill is presented on the NDEP website as, "Application for a Permit to Construct and Operate a Class I Landfill Facility, Jungo Disposal Site, Humboldt County, Nevada, Report of Design Revision 5, Prepared for Jungo Land and Investments, Inc. Prepared by Golder Associates Inc. Roseville, CA dated April/July 2011." [http://ndep.nv.gov/bwm/docs/report_of_design.pdf]
Comments on that application are provided below.

The first phase of the review of the potential impact of a proposed landfill is an evaluation of the type of landfill containment system, i.e., "dry tomb" or "wet cell" design. A key difference between those two types of landfills is the length of time during which the landfill containment system, liner, cover, gas management system, monitoring, closure and postclosure systems and approaches must function as intended and prevent the release of hazardous and otherwise deleterious chemicals in the MSW to the environment. A "dry tomb" type landfill relies on the concept that as long as the MSW in the landfill are kept dry there will be no landfill gas or leachate generation. Both gas generation and leachate production processes require that liquid interact with the waste; water in contact with fermentable organics will result in the production of landfill gas, and liquid in contact with wastes will leach leachable components to generate leachate. While in principle such a "dry tomb" landfilling approach can offer protection of public health, groundwater resources and the environment from pollution by waste-derived chemicals, the approach relies on the ability of the containment systems to keep the wastes dry essentially forever. This is because without fermentation and leaching processes acting on the buried MSW, the hazardous and otherwise deleterious components simply remain entombed; those components do not become non-hazardous or non-deleterious just by the passage of time. Thus, as long as the buried wastes are kept dry, they are a threat to generate leachate and landfill gas effectively forever for hundreds to a thousand years or more.

In current practice the landfill liner and cover are composed of plastic sheeting and clay layers, which are relied upon to keep the wastes in the "dry tomb" dry. The plastic sheeting layer, typically LDPE in the landfill cover, deteriorates over time and allows water to penetrate through the cover and enter the wastes where it generates leachate. The landfill liner typically consists of a layer of plastic sheeting (HDPE) and a compacted clay layer under the plastic sheeting. At best, those systems can be effective in keeping the wastes dry for a comparatively short period of time compared to the time that the wastes in a dry tomb type landfill will be a threat to generate landfill gas and leachate. Thus, even if those systems were well-designed and well-constructed, over time their ability to keep the wastes dry will deteriorate; they will not be amenable to ready and thorough inspection, maintenance, and repair as they will be buried beneath the wastes or cover layers.

Similarly, the systems designed to contain/collect leachate and manage landfill gas will function for a short period of time compared to the duration of time that the wastes in a "dry tomb" type landfill will be a threat to generate leachate and landfill gas. It has been well-established that plastic sheeting HDPE layers deteriorate over time and their "low permeability" properties diminish, decreasing the ability of the liner systems to collect all leachate that can be generated in the landfill when water enters the landfill through a landfill cover.

It was recognized by some in the technical community in the early 1980s when the regulations requiring "dry-tomb"-type landfills were promulgated by the US EPA, and is now widely recognized, that in practice the "dry tomb" landfilling approach is seriously flawed for the protection of groundwater quality; it only serves to postpone release of waste-derived constituents to the environment.

The proposed Jungo Landfill is a "dry tomb" type landfill, with plastic sheeting and compacted clay liner and cover; many of the deficiencies discussed on our "Flawed Technology" review characterize are applicable to the ability of this landfill to provide public health and groundwater resources protection in the vicinity of the proposed landfill for as long as the wastes in the landfill will be a threat.

The NDEP "Fact Sheet" on the proposed Jungo Landfill,
[http://ndep.nv.gov/docs_11/jungo_fact_sheet-2011.pdf] states:
"Proposed Action
The Nevada Division of Environmental Protection (NDEP) is proposing to approve and issue a Permit to Nevada Land and Resource Inc. for the Construction and Operation of a Class I Landfill in Humboldt County Nevada."

The Fact Sheet *"Description of Proposed Permit Issuance"* section states:
"Post closure care and monitoring will continue for 30 years upon final closure of the site."

Section 1.1 of NDEP's October 2011 draft permit for Jungo Landfill
[http://ndep.nv.gov/docs_11/jungo_permit_draft-2011.pdf] states in the "General Description":
"The Landfill will perform 30 years of Post-Closure care and monitoring." emphasis added

The postclosure care and monitoring period begins once the landfill or parts thereof is closed and no longer accepts wastes. Thus for the 30 years following closure of the Jungo Landfill, Recology-Nevada Land and Resource LLC, and/or Jungo Land & Investments, Inc. would be required to provide postclosure monitoring, maintenance and groundwater remediation when the landfill liners fail to collect the leachate that is generated in the landfill when the landfill cover no longer prevents water from entering the wastes that generates leachate and landfill gas that has the potential to pollute the area of the landfill with hazardous and otherwise deleterious chemicals derived from the MSW. However, it could be reasonably anticipated that with careful design and construction, the generation of landfill leachate, or at least the evidence of leakage of leachate from the landfill, could be delayed for several decades. It could turn out that the leakage and pollution problems that will inevitably arise from the dry tomb Jungo Landfill are delayed until the after the 30-yr postclosure period has passed.

While this situation is allowed in the NDEP landfilling regulations it can be strongly adverse to the people in Humboldt County, NV where the Jungo Landfill is proposed to be located. The consequences of the development of the proposed Jungo Landfill, with the very limited period of responsibility for protection of public health of current and future residents, groundwater resources, and other issues of importance to Humboldt County and the state of Nevada, should be understood as part of permitting this landfill. As presently proposed with this draft permit, Recology-Nevada Land and Resource LLC, Jungo Land & Investments, Inc. will be able to dump large amounts of San Francisco, CA area garbage in Humboldt, NV, make a large amount of money in doing so, and leave the County and the State with a massive liability of impaired public health and destroyed water resources. Since Recology-Nevada Land and Resource LLC will not be required to provide the Superfund-like remediation of the proposed landfill area as this landfill pollutes the area, the County/State and its residents will be left to suffer the impacts and pay for remediation. The costs of those efforts can readily be several tens of millions of dollars. In permitting of this landfill as proposed NDEP will be enabling Recology-Nevada Land and Resource LLC, Jungo Land & Investments, Inc. to reap the benefits of the operation, and enabling the people in the San Francisco Bay area to enjoy garbage disposal for costs less than would be incurred if they were disposed of in CA with its stricter landfilling requirements, while burdening the current and future people of Humboldt County and the state of Nevada with the health, welfare, groundwater resource, and financial consequences.

A subsequent section of these comments discusses the significant deficiencies in the NDEP landfilling regulations that allow Nevada to become a dumping ground for other states' solid wastes. The Jungo Landfill, as proposed, could not be permitted in several other states. In the 1970s California adopted landfilling regulations that require that landfill developers bear the responsibility for developing landfills that will protect groundwater quality for as long as the wastes in the landfill will be a threat. California has recently defined the minimum post closure funding period as 100 years, a period that can be extended if needed.

Following are comments on inadequacies in the proposed landfill location, design, operation, closure, and especially the postclosure funding for monitoring and maintenance for as long as the wastes in this proposed landfill will be a threat.

Comments on "Application for a Permit to Construct and Operate a Class I Landfill Facility, Jungo Disposal Site, Humboldt County, Nevada, Report of Design Revision 5, Volume I" Prepared for Jungo Land and Investments, Inc. by Golder Associates April 2011 [http://ndep.nv.gov/bwm/docs/report_of_design.pdf] (Referred to as "Report of Design")

Pages 2 and 3 of the Report of Design lists how the Jungo Disposal site satisfies a number of NV restrictions for location of Class I landfills, including the following:

- *"NAC 444.678 (2) and (3) The landfill design includes containment systems, controls, and monitoring systems that will prevent uncontrolled migration of landfill gas, control leachate, and prevent degradation of groundwater."*

That statement concerning the alleged protective nature of the proposed Jungo Landfill design is misleading at best. It gives the erroneous impression that the landfill as proposed will be able to contain the MSW waste components within the landfill for as long as the wastes, when contacted by water, will be a threat. This issue was discussed above and is reviewed at length in the "Flawed Technology" review.

- *"NAC 444.678 (9) The nearest surface water body is more than 14 miles from the site. The landfill is located within 100 feet of the uppermost groundwater aquifer. However, to prevent degradation of the groundwater aquifer, the landfill design incorporates extensive protective measures consisting of low-permeability containment systems, conservatively designed leachate control system, and landfill gas control systems. These protective measures are described in Section 2.3."*

That statement regarding the ability of the proposed landfill to prevent degradation of groundwater quality is an unreliable representation of the true protective nature of the proposed Jungo Landfill to prevent groundwater pollution for as long as the wastes in the landfill will be able to generate leachate that will penetrate through the liner and migrate through the unsaturated zone to the groundwater table rendering it unusable for domestic and some other purposes. The technical aspects of this issue were discussed above and is reviewed at length in the "Flawed Technology" review. Details of this assessment are also presented in the discussion of the unreliable information provided by Golder in Section 2.3.

- *"NAC 444.6785- Floodplain: The site is not located within a floodplain. The site is located within a desert basin where precipitation temporarily collects in shallow depressions until it evaporates or infiltrates into the underlying soils."*

That statement is an inadequate and unreliable assessment of the characteristics of the proposed landfill site. As discussed in section 2.1.3 (p. 4) of the Report of Design and in the NDEP discussion of "Topography and Drainage," in times of intense rainfall the area of the landfill can have accumulations of water to a depth of a foot or more. This characteristic causes the site to be similar to one within a floodplain.

A discussion of the site geology begins on page 5 of the Report of Design. The geology in the area of the proposed landfill is complex with multi-layered strata of clays, silts, and sands. The geology of a proposed landfill site is key to providing natural protection of the groundwater quality from pollution by landfill leachate. Based on the information provided by Golder, the geology of this site does not provide natural protection of groundwater quality from pollution of groundwater by landfill leachate when the liner system ultimately fails to prevent leachate penetration.

Page 10 of the Report of Design states in the Ground Water Velocity section:

“*Rising head slug tests were conducted in each well on February 2, 2007 to determine the hydraulic conductivity of the middle sand and silty sand. With these data, hydraulic conductivities were calculated for each well. To determine a hydraulic conductivity for the site, the geometric mean of the four individual well conductivities was calculated. As such, the hydraulic conductivity at the site is estimated to be* 1.2×10^{-4} *cm/s. The slug test data is presented in Appendix D.*

Using the calculated gradient (i), the hydraulic conductivity (K), and the estimated effective porosity of the water-bearing zone (n_e)*, the approximate groundwater seepage velocity can be calculated using Darcy's Law (* $v = Ki/n_e$*). An effective porosity value of 0.15 for the sandy zones is assumed, based on information from Cohen (1963). Groundwater seepage velocity beneath the site is estimated to be* 2.4×10^{-7} *cm/s (0.25 feet per year [ft/yr]).”*

The information on the groundwater horizontal velocity shows that the geology of the area does not provide for protection of offsite groundwater from pollution by leachate-polluted groundwater that will occur under the landfill as the landfill liner systems fail. The information provided is misleading because the hydraulic conductivity was reported as the geometric mean. It is not the mean velocity that defines how fast offsite groundwater stands to be polluted by landfill leachate; it is the fastest velocity that will define the incipient, or first, pollution of offsite groundwater once the groundwater under the landfill is polluted by leachate. The farmer who has a well near the landfill wants to know the earliest estimated time at which his well could be polluted.

Pages 10 and 11 of the Report of Design present information on the vertical gradient of groundwater at the proposed site. This characteristic is important for understanding the ability of geology of the area under the landfill to prevent the transport of leachate to the underlying groundwater at the landfill site. From the information presented in the Report of Design, it is clear that leachate that will eventually penetrate the liner will eventually reach the saturated groundwater under the landfill, i.e., there is effectively no natural protection of the groundwater from pollution by landfill leachate. Under those conditions, the protection of groundwater quality is completely dependent on the integrity of the landfill liner system. As noted previously, and discussed further below, the liner proposed for the Jungo Landfill will not prevent leachate penetration for as long as the wastes in the landfill will be a threat to generate leachate when contacted by water. Further, if this landfill were to be permitted as proposed, postclosure funding would only be assured for 30 years of the hundreds or more years that the wastes in this landfill would be threat to cause groundwater pollution.

Lopes, T. J., “Hydrologic Evaluation of the Jungo Area, Southern Desert Valley, Nevada” Open-File Report 2010–1009 U.S. Department of the Interior U.S. Geological Survey (2010) http://pubs.usgs.gov/of/2010/1009/pdf/ofr20101009.pdf.

The abstract of that USGS (Lopes) report states:
“*On September 22, 2009, the Interior Appropriation (S.A. 2494) was amended to require the U.S. Geological Survey to evaluate the proposed Jungo landfill site for:*
(1) potential water-quality impacts on nearby surface-water resources, including Rye Patch Reservoir and the Humboldt River;

(2) potential impacts on municipal water resources of Winnemucca, Nevada;
*(3) locations and altitudes of aquifers; *
(4) how long it will take waste seepage from the site to contaminate local aquifers; and
(5) the direction and distance that contaminated groundwater would travel at 95 and 190 years. This evaluation was based on review of existing data and information.
Estimates indicate that contaminants would travel about 0.02 mile and a maximum of 2.5 miles in 95 years and about 0.04 mile and a maximum of 5.0 miles in 190 years. The closest supply wells that could be impacted by contaminants are 5 to 6 miles downgradient and are used for industry, irrigation, and stock watering."

That USGS (Lopez) report states on page 7:
"*Slug tests done on four monitoring wells at the proposed Jungo landfill site had K values that ranged from 0.26 to 0.45 ft/d and averaged 0.34 ft/d (Golder Associates, Inc., 2008, appendix D). Near the proposed Jungo landfill site, the maximum hydraulic conductivity is 50 ft/d (Berger, 1995)."* That statement illustrates the substantial difference between the "average" and the "maximum" hydraulic conductivity at this site; the maximum rate of movement is nearly 150 times faster than the average.

Further, the large range in hydraulic conductivities indicates that only four slug tests for an area with complex geology of the Jungo Landfill site are not adequate to define the hydrological characteristics of the groundwater under the proposed landfill, especially given that the landfill would, if permitted as proposed, be one of the largest landfills in Nevada, and for that matter elsewhere. It has been our experience that a much more comprehensive geotechnical/ hydrological investigation needs to be conducted to adequately characterize the geology/ hydrogeology under and near the landfill.

The 2010 USGS (Lopez) report was not included in the List of References on page 26 of the Report of Design that is dated April 2011.

Another important issue that needs to be considered is that the future generations (forever) that will own land near the proposed landfill will want to be able to use their groundwater resources without adverse impacts of the landfill. No landfill should be allowed to be developed without protecting to a very high degree the future uses of properties near the landfill.

An important issue that needs to be understood is the current distance to the nearest water supply well may not exist in the future. A land owner of adjacent and nearby properties should be able to use his/her land for agricultural and other purposes including developing a water supply well on their property near the property line with the landfill without adverse impacts of the landfill. However the proposed landfill will only have a few hundred feet of buffer land this owned by the landfill developer. This means that wells developed on private property near the landfill can be polluted in a much shorter time than that projected for the existing well. As landfill developer should not be able to control how a adjacent/nearby property uses their land as a result of the landfill developer failing to develop a landfill that will protect the groundwater quality from pollution by landfill leachate for as long as the wastes in the landfill can generate leachate when contacted by water.

While Lopez mentions that some pollutants in MSW leachate can be adsorbed on the aquifer particles and not travel at the same rate as the water, there are some constituents in MSW landfill leachate that are attenuated very little if at all and will move at the rate of water movement.

The conclusion that must be drawn from the limited groundwater flow data available is that when the landfill liners system eventually fails to prevent leachate from entering the underlying aquifer system the groundwater under the landfill will be polluted by hazardous and otherwise deleterious chemicals derived from the MSW. The lateral movement of groundwater under and near the proposed landfill will transport pollutant from the landfill offsite and pollute the groundwaters near the landfill. As discussed in the review of Nevada landfilling regulations presented below, that pollution will violate Nevada landfilling regulations.

In describing "Refuse Quantities and Landfill Capacity" on Page 12, the Report of Design states: "*The site will accept only municipal solid waste (MSW). Typically, MSW from Northern California is processed to remove recyclable or compostable materials including selected metals, plastics, and greenwaste. In addition, a screening program exists to remove hazardous waste before it is loaded into waste containers. The screening program is described in the Operating Plan (Volume Ill).*

The waste will be comprised of residential, commercial and selected special wastes, which will include construction and demolition (C&D) wastes, and waste tires. Wastes will be containerized for rail delivery to the disposal site. At the point of loading, most wastes will be commingled. Exceptions to commingling can include tires and inerts. No hazardous wastes will be accepted."

That manner of describing the wastes that would be disposed of at the Jungo Landfill is highly misleading. It misrepresents the MSW as benign, devoid of "hazardous" components, and not posing a significant threat to pollute the groundwaters with hazardous and otherwise deleterious chemicals or being capable of adversely affecting the health and welfare of people and animals that use that water as a water supply. The fact is that wastes of the types described as being acceptable for disposal at the proposed landfill do contain hazardous and otherwise deleterious chemicals – even if they are not categorized by regulations as "hazardous wastes" – that will produce leachates that can render leachate-containing groundwaters unusable for water supply purposes. Those components include chemicals that are known to cause adverse health effects, chemicals that cause adverse impacts at levels below drinking water MCLs, chemicals for which there are not presently regulatory standards, chemicals whose hazards are not yet recognized, as well as salts and other chemicals that impart tastes, odors, or other qualities to the water that, whether or not they pose a hazard to public health, destroy its utility for water supply.

A detailed discussion of these issues is provided in the "Flawed Technology" review. For example, in the section, "Hazardous versus Non Hazardous Waste Classification," the following passage (page 53) describes "non-conventional" contaminants expected in MSW:
"Non-conventional contaminants are largely organic chemicals that have not been defined, and whose potential hazards to public health and groundwater quality are not known. Typically the organic Priority Pollutants – those organics that are identified and quantified – represent a very small fraction of the total organic matter present in leachate as measured by chemical oxygen demand and total organic carbon. It is estimated that from 90 to 95 percent of the organic

materials in municipal landfill leachate are of unknown composition. Those chemicals have not been identified, and obviously their potential impacts on public health and groundwater quality are unknown."

The following passage on page 55of the "Flawed Technology" review describes the findings of C. Daughton, a US EPA senior scientist, with regard to classifying and describing pollutants:
"According to Daughton (2004a),
'Since the 1970s, the impact of chemical pollution has focused almost exclusively on conventional "priority pollutants," especially on those collectively referred to as "persistent, bioaccumulative, toxic" (PBT) pollutants, "persistent organic pollutants" (POPs), or "bioaccumulative chemicals of concern (BCCs). The "dirty dozen" is a ubiquitous, notorious subset of these, comprising highly halogenated organics (e.g., DDT, PCBs). The conventional priority pollutants, however, are only one piece of the larger risk puzzle.'

Daughton has indicated that there are over 22 million organic and inorganic substances, with nearly 6 million commercially available. The current water quality regulatory approach addresses less than 200 of these chemicals, where in general PPCPs and many other chemicals are not regulated. According to Daughton, 'Regulated pollutants compose but a very small piece of the universe of chemical stressors to which organisms can be exposed on a continual basis.'"

Despite the Jungo Report of Design's reassuring description of the acceptable waste stream, the MSW that will be accepted at the proposed Jungo Landfill will contain hazardous and otherwise deleterious chemicals that will be a significant threat to human health and the usability of the area groundwater for water supply.

With respect to the acceptance of C&D (construction and demolition) wastes at the proposed Jungo Landfill, it has been well-established that C&D wastes contain hazards chemicals that are a threat to public health and groundwater quality. Issues associated with C&D wastes in landfills are discussed in the "Flawed Technology" review section, "Construction and Demolition Waste Landfilling," on pages 58-63. That discussion includes the passage (page 60):
"Additional information on the potential presence of PCBs in C & D wastes is presented by Lee, and Jones-Lee (2010 d,e). Studies in the San Francisco Bay area have been found that urban stormwater runoff contains sufficient PCBs to contribute to excessive PCBs concentrations in receiving water fish. One of the sources of the PCBs in urban stormwater runoff has been found to be runoff from residential/commercial/industrial demolition areas where there is release of PCBs from caulking compounds used as sealant at wood and concrete joints."

Section 4.2 of the Draft Permit for the proposed Jungo Landfill [http://ndep.nv.gov/docs_11/jungo_permit_draft-2011.pdf] lists the following as "Prohibited Solid Wastes":
"The Permittee is prohibited from placing in the Class I landfill the following wastes:
1. *Liquid waste as defined by NAC 444.692(4)*
2. *Hazardous waste, as defined NAC 444.580 (NRS 459.430)*
3. *PCB waste, as defined by NAC 444.6665*
4. *BioSolids*
5. *Asbestos*

6. Reserved"
That provision is also misleading with regard to materials that will be allowed, or could be placed, in the Jungo Landfill if approved. For example, even though NDEP "prohibits" the disposal of "PCB waste," the acceptance of C&D wastes in the proposed Jungo Landfill will result in the deposition of PCBs in the landfill since, as discussed earlier, PCBs are known to be present in some C&D wastes. As discussed elsewhere in these comments as well as in the "Flawed Technology" review, the fact that materials classified as "hazardous waste" are prohibited does not mean that no chemicals or materials that are hazardous or otherwise deleterious to public health/welfare or groundwater quality will be allowed in the landfill, or that all materials that are accepted cannot adversely affect public health/welfare or groundwater quality.

Page 12 of the Report of Design states:
"The maximum refuse thickness is 200 feet at the center of the landfill. The maximum refuse height extends approximately 200 feet above the surrounding grades at the center of the landfill.

The disposal volume is approximately 104 million cubic yards. Based on an estimated in place effective density of 1,100 pounds/cubic yard (pcy), the landfill has a refuse capacity of approximately 57.1 million tons. Effective density is defined as the weight of disposed refuse divided by the total volume occupied by refuse and soil cover. For initial planning, it assumed that approximately 600,000 tons of refuse will be disposed annually. Accordingly, this disposal rate would result in a projected life of 95 years. The projected life will decrease as the disposal tonnages increase."

The disposal of 600,000 tons/year of San Francisco area garbage for 95 years will result in a massive landfill that, as discussed herein, will be a significant source of pollutants for the area groundwater.

The Report of Design also states on Page 12:
"*The base grades have been designed to maximize the separation between the bottom of the liner system and groundwater. The minimum separation distance is approximately 24 to 26 feet at the sumps after settlement of the base grades due to the weight of the overlying refuse. The average separation distance will be approximately 37 to 38 feet following base settlement induced by refuse loading (Section 2.3 .4.1). Section 2.3 describes the containment systems and controls used to protect the underlying groundwater from potential impacts of leachate and landfill gas."*

The statement in the last sentence "*Section 2.3 describes the containment systems and controls used to protect the underlying groundwater from potential impacts of leachate and landfill gas."* is significantly misleading with respect to what is known to be the ability of the proposed Jungo Landfill liner system to prevent groundwater pollution. As discussed in these comments, at best – with high-quality design and construction – the proposed landfill liner will only delay groundwater pollution; evidence of groundwater pollution from this landfill could potentially be delayed to a time beyond the 30-year period during which Nevada Land and Resource LLC/Recology-Jungo Land & Investments, Inc. are required to provide postclosure monitoring, maintenance, and remediation for groundwater polluted by landfill leachate. There is no question that over the very long time that the wastes in the proposed landfill will be a threat to generate leachate when contacted by water, the liner system will fail to prevent leachate from penetrating the liner system and polluting the underlying groundwater.

The first paragraph of Page 13 in the Report of Design states:
"*2.2.2 Site Development*
The site development is illustrated in the landfill design drawings provided in Volume II. The landfill disposal boundary is located 100 feet from the west, south, and east property boundaries. The disposal boundary is located 200 to 300 feet from the north property boundary to allow the development of a rail yard for unloading waste containers."

Providing only 100 to 300 feet buffer between the disposal boundary and adjacent properties is grossly inadequate for dissipation of nuisance and hazardous airborne releases from the landfill before they trespass onto adjacent/nearby properties during the nearly 100-year active life of the landfill. Typically a mile or more buffer lands is required to allow on-site dissipation of odors and volatile hazardous chemicals that will be released from a MSW landfill. As discussed below, the presence of MSW landfill odors indicates the presence of volatile organic compounds (VOCs) that are a threat to human and animal health. It is clear that the operation of the proposed landfill would cause trespass of hazardous and otherwise deleterious chemicals onto adjacent/nearby properties. Nevada Land and Resource LLC/Recology-Jungo Land & Investments, Inc. should not be allowed to use adjacent properties to augment the landfill property needed to dissipate odors and other chemical releases.

Page 14 of the Report of Design, Section 2.3.1, lists the components of the liner design as follows:

- *"1-foot-thick operations soil layer;*
- *1-foot thick gravel blanket for the primary LCRS with a permeability of 1 cm/s or greater;*
- *central leachate collection piping within each module to provide redundant leachate capacity;*
- *16-oz geotextile cushion;*
- *60-mil high-density polyethylene (HDPE) primary geomembrane;*
- *2-foot thick compacted low-permeability soil liner with a permeability (k) less than or equal to* $1x10^{-7}$ *cm/s;*
- *A secondary geocomposite drainage layer for the secondary LCRS; and*
- *A 60-mil high-density polyethylene (HDPE) secondary geomembrane*

On the side-slopes, the base liner system is comprised of the following components from top to bottom:

- *2-foot-thick operations soil layer;*
- *Geocomposite drainage layer (geonet with geotextile heat-bonded to both sides) for the LCRS;*
- *60-mil HDPE primary geomembrane;*
- *2-foot thick compacted low-permeability soil liner (k* $1x10^{-7}$ *cm/s).*
- *A secondary geocomposite drainage layer for the secondary LCRS; and*
- *A 60-mil high-density polyethylene (HDPE) secondary geomembrane"*

The bottom liner and the side slopes liner proposed for the landfill would consist of a single composite liner (plastic sheet and compacted clay) underlain by a drainage layer that is underlain by a plastic sheeting layer. This proposed design is a step toward a double-composite liner but will not provide the additional protection afforded by a true double-composite liner. The difference is that the lower plastic sheeting layer (secondary geomembrane) of the proposed system is not backed, and necessarily in intimate contact, with a compacted clay layer of the type specified in US EPA Subtitle D requirements for a composite liner.

Dr. David Daniel, a speaker in the US EPA seminar series on "Design and Construction of RCRA/CERCLA Final Covers," (conducted by the US EPA Office of Research and Development CERI 90-50 Washington DC, 1990), discussed the relative rates of leakage of various types of landfill liner designs. As discussed in our "Flawed Technology" review, he pointed that an HDPE liner without a low permeability clay layer in intimate contact with it, can leak at a very high rate compared to a true composite liner or even just a compacted soil layer. As also discussed in greater detail in our "Flawed Technology" review, a single-composite liner will eventually lose its ability to prevent passage of leachate through it; leachate will pass through the areas of deterioration that will inevitably and unpreventably develop over time, while the wastes in the "dry tomb"-type landfill continue to be a threat. The inability of a composite liner to contain leachate that will be generated as the integrity of the cover also inevitably deteriorates, will result in the entrance of leachate into the drainage layer just below the composite liner. Leachate can be collected and removed from the landfill drainage system as long as the lower plastic sheeting layer maintains its intended integrity. However, that plastic sheeting layer will also deteriorate over time, increasingly lose its low permeability properties; one would not expect that that liner would resist deterioration significantly longer than the low permeability cover or the composite liner. Furthermore, like the composite liner, the bottom plastic sheeting liner would not be available for regular and thorough inspection, maintenance, and repair as it will be located beneath the landfilled wastes and containment systems. The result will be that the leachate that will inevitably develop within the landfill will be able to pass through the holes in the plastic sheeting into the groundwater system underlying the landfill.

A fundamental issue that was not addressed by Golder in its design report in the Report of Design is who will remove leachate from the leachate collection system and the secondary geocomposite drainage layer once Nevada Land and Resource LLC /Recology-Jungo Land & Investments, Inc. is no longer responsible for the postclosure monitoring, maintenance, and other care issues, i.e., in year 31 and for the subsequent hundreds of years or more after closure when the buried wastes will still be a threat to generate leachate that can pollute groundwater. Current Nevada landfilling regulations and as outlined in the plan of the landfill developer, Nevada Land and Resource LLC/Recology Jungo Land & Investments, Inc. will be able to walk away from the site 30 years after closure and leave a massive pile of San Francisco Bay area garbage. The state of Nevada and Humboldt County will be left to deal with the abandoned site, which will ultimately and predictably need a "superfund"-like cleanup to address the polluted groundwater that this landfill will cause.

A key to reducing the rate of leachate penetration through holes and areas of deterioration in the plastic sheeting and compacted clay layers is minimizing the head (depth) of leachate on the plastic sheeting liner. During the active life and 30-yr monitored postclosure care period the landfill owner/operator will be required to remove leachate from the leachate collection system and secondary leak detection layer. As cover inspection, maintenance, and repair becomes less rigorous as could be expected to occur after the 30-yr postclosure period, leachate generation will be accelerated. If leachate removal is not adequately attended to, leachate will build up on the liner and penetrate the liners more rapidly. However as discussed further below, the issue of who will be responsible for maintaining the landfill cover in year 31 and beyond after closure, has not been addressed by the applicant or regulators. It is essential that rigorous inspection, maintenance, and repair be continued after the 30-yr postclosure period to maintain the system's ability to retard the infiltration of water into the landfill that will generate leachate that will build up in the landfill and cause the landfill liner system to leak at a much higher rate than if the leachate were collected in the leachate collection system and secondary leak detection layers. The proposed design for the Jungo Landfill will virtually ensure that the County will inherit a significant environmental, public health, and financial liability when Nevada Land and Resource LLC /Recology-Jungo Land & Investments, Inc. walks away after the 30-yr postclosure period.

Page 16 of the Report of Design describes the proposed leachate collection and removal system as follows:

"2.3.2 Leachate Collection and Removal System (LCRS)
The landfill liner system design includes a blanket LCRS (Drawing 4, Volume II) that has a high hydraulic capacity that is designed to collect leachate while minimizing leachate head build-up on the liner. The maximum leachate head on the liner is estimated to be only a fraction of one-inch, which is considerably less than the 12-inch (30 centimeter) maximum depth allowed by NAC 444.681. The leakage potential of a liner system is reduced by decreasing the potential head build-up on the liner system."

The statement regarding the expected depth (head) of leachate on the liner only applies as long as the leachate is actively and effectively removed from the sump. While Nevada Land and Resource LLC /Recology-Jungo Land & Investments, Inc. would be responsible for removing leachate from the leachate collection system during the active life and for 30 years after landfill closure, neither the Report of Design, nor other documents we have reviewed concerning this proposed landfill defines ho will conduct diligent leachate removal beginning in year 31 of postclosure, or before year 31 if these companies are no longer in business.

Page 16 of the Report of Design states
"*Extracted leachate will be used for dust control over constructed, lined modules. In the event that the collected leachate exceeds the dust control needs, the excess leachate will be re-circulated within the landfill. However, such recirculation volumes are expected to be very small with a negligent impact on the moisture content of the waste or depth of leachate head on the liner."*

The use of leachate for dust control is not allowed in several other states because it contributes pollutants to the stormwater runoff from the landfill area. That practice should not be allowed at the Jungo Landfill should it be permitted.

Section 2.3.3 on Page 16 of the Report of Design addresses "Landfill Gas Control." That section, however, provides little information on the approach that will be used to control landfill gas releases. It also fails to discuss the fact that even with highly effective control of landfill gas releases there will still be releases of landfill gas to the landfill area. With only a few hundred feet of buffer land between waste deposition areas and adjacent property lines, trespass of landfill gas and the associated hazardous and obnoxious chemicals can be reasonably anticipated onto adjacent properties. As noted above, the landfill gas will contain VOCs that pose a cancer risk to humans, domestic animals and wildlife that are exposed to the odors released from the MSW landfill. Issues and problems of landfill gas and airborne emissions from landfills are also discussed in our "Flawed Technology" review beginning on page 39.

As discussed in our "Flawed Technology" review it is important to understand that the proposed Jungo Landfill will likely generate landfill gas for a very long time much beyond the 30 year postclosure period. An issue that should be defined is who will operate and maintain the gas collection and treatment system for as long as the Jungo Landfill will generate landfill gas?

Page 19 of the Report of Design begins a description of report leachate generation at the proposed landfill and the hydraulic capacity of the proposed leachate collection and removal system (LCRS):
"2.3.4.3 Leachate Generation and LCRS Capacity
A very conservative leachate generation model was developed to conservatively size the hydraulic capacity of the LCRS. A conservative approach was used to provide an additional level of environmental protection relative to leachate management.

The model was developed using the computer program Hydrologic Evaluation of Landfill Performance (HELP). Appendix G includes details on the HELP modeling for the Jungo Disposal Site. The conservatively developed HELP model estimates a peak leachate generation rate of75 gallons/acre/day (gpad) for the Jungo Disposal Site. This estimated leachate generation rate is very high for an arid site with only 8-inches of average annual precipitation."

The repeated characterization of the leachate generation model and its output is misleading at best. The HELP model upon which the report indicated the assessments were made is not reliable for predicting the rate at which water can enter a landfill through the landfill cover over the period during which the wastes in the landfill will be a threat to generate leachate when contacted by water. While the nature, rate, pattern, and other details of the deterioration that will occur in the plastic sheeting layer in the cover cannot be predicted and depend to large extent on the nature, rigor, and effectiveness of cover inspection, maintenance, and repair, it is clear that deterioration will occur over time; that deterioration, and the inability to reliably model it, render the HELP model unreliable for long-term prediction of leachate generation.

Page 21 of the Report of Design addresses drainage control:
"2.3.4.5 Drainage Controls During Operations
Drainage controls will be implemented during site development to control surface water run-on and runoff. Surface water run-on will be prevented by the following measures:

- *A 4-foot high perimeter berm will be constructed to prevent run-on from shallow (6-inch to 12-inch) ponding that may occur locally following intense thunderstorms."*

The effectiveness of this approach for preventing run-on onto the landfill surface area will depend in large part on the adequacy of design and construction, and most importantly on the rigor and reliability of dike inspection, maintenance, and repair for as long as the wastes in the landfill will be a threat to generate leachate, likely hundreds or more years after closure. Another important consideration is whether the soils of the area are adequate for construction of a dike capable of preventing flood water in the area outside the dike from penetrating the dike and flooding the area of the landfill during the period over which the wastes in the landfill will be a threat to generate leachate when contacted by water. The dike will need to be properly designed, constructed, and maintained to prevent seepage of water through it during the times that the area around the landfill property is flooded with a foot or more of water. Even with such design and construction, dikes of that type that are subject to a variety of failure mechanisms including settlement cracking, wind erosion, burrowing animals, and plant roots. Again, no mention was made as to who will maintain the dike for the hundreds of years that will be necessary after the postclosure period; that issue should be addressed before the landfill is permitted.

Section 2.3.5 "Closure Design" on Page 21 of the Report of Design describes the design of the landfill closure, and states:
"*A final cover system will be constructed over the waste at the Jungo Disposal Site as part of the closure activities. The final cover system is a prescriptive cover, in accordance with NAC 444.6891) consisting of the following components (Drawing 8, Volume II):*

- *A minimum 2-foot thick vegetative soil layer;*
- *A geocomposite drainage layer;*
- *A 60-mil HDPE geomembrane layer (textured on both sides); and*
- *A one-foot thick foundation layer."*

That design for the landfill cover is the design that is specified in US EPA Subtitle D and NDEP regulations.

That section also states:
"The above cover system provides a low-permeability barrier that has permeability less than or equal to the base liner system. HELP modeling of the cover system indicates that a negligible amount of water will infiltrate through the cover."

Beginning on page 20, our "Flawed Technology" review discusses long-term problems and deficiencies with a landfill cover design of the type proposed for the Jungo Landfill for keeping the buried wastes dry. Those deficiencies include the eventual deterioration of the plastic sheeting layer (geomembrane) in the cover, a component that is the key to preventing entrance of water into the wastes through the cover. Since the plastic sheeting layer is buried under a 2-ft vegetative soil layer, it is not possible to maintain a pro-active, preventive approach to maintaining cover integrity; it is not possible to thoroughly inspect the plastic sheeting layer for areas of weakness and make needed repairs before the reliable functioning of the cover to prevent water from penetrating the cover and entering the wastes is compromised. Instead, cover failure is typically not known until the cover has been sufficiently breached that leachate has been generated and has migrated to the leachate collection system sump. By the time leachate is detected, substantial breach of the cover is likely to have already occurred.

The presence of leachate in the leachate collection system of a closed cell is typically the first indication that there is need to repair the landfill cover. Repair of the plastic sheeting layer in the cover necessitates searching the landfill cover's plastic sheeting layer that is buried under the top soil layer to find the areas of the buried plastic sheeting layer that have deteriorated and repair them. This requires that funds remain available for such searches and repairs whenever needed over the 100s of years or more during which the cover must function to keep the wastes dry. Once again it was not specified who would provide the needed inspection, maintenance, and repair of the cover when Nevada Land and Resource LLC /Recology-Jungo Land & Investments, Inc.'s 30 years of postclosure funding expires. What is clear is that a large amount of funds will be needed to maintain the landfill cover on the Jungo Landfill for as long as a reliable low-permeability cover is needed to control leachate generation in the landfill.

The description of the closure design in the Report of Design also states (page 22):
"The Jungo Disposal Site will pursue an alternative Evapotranspirative (ET) final cover design once the landfill is in operation."
Issues of importance in incorporating an evapotranspirative cover into the design of a landfill cover are discussed in our "Flawed Technology" review beginning on page 24. The potential for saturated and unsaturated flow of water through such a cover during periods of extended precipitation must be considered in evaluating whether this type of cover will keep the wastes dry. In making such an assessment, it is important that maximum precipitation values, rather than commonly used average values, be used in the estimation of the penetration of water through the alternative cover.

"Application for Permit to Construct and Operate a Class I Landfill Facility, Jungo Disposal Site, Humboldt County, Nevada, Volume III, Plan of Operations," Revision 4, Prepared for Jungo Land & Investments, Inc. by: Golder Associates Inc., dated April (2011) [http://ndep.nv.gov/bwm/docs/jungo_plan_operations.pdf]
The "Plan of Operations" document discusses characteristics of the proposed Jungo Landfill. Presented below is our review of a number of the issues raised by that Plan of Operations that can have an adverse impact on public health and welfare, and groundwater quality. Many of these issues have been discussed in other sections of these comments as well as in our "Flawed Technology" review.

Section 1.0 – Introduction in the Plan of Operations states:
"Jungo Land & Investments, Inc. (JLII), the landfill owner and operator, is submitting the following Plan of Operations for a Class I municipal solid waste disposal site as required by the general provisions for solid waste disposal defined in the Nevada Administrative Code (NAC 444.684)."

Page 1, Section 1.1 Site Description states:
"The facility will be operated by JLII in accordance with applicable State of Nevada solid waste regulations. The land is currently owned by Nevada Land and Resources, Inc. but will be acquired by JLII prior to development. JLII currently has a leasehold interest with an option to purchase the property, which JLII plans to exercise once the necessary State permits have been obtained. Property ownership documents will be maintained in the landfill operating record."

This transfer of ownership raises questions about which firm or firms will be responsible for providing postclosure care (monitoring, maintenance, and eventual groundwater remediation when the landfill liners fail to prevent leachate generated in the landfill from polluting groundwater under and downgradient of the landfill) when the landfill is no longer generating revenue. What will be the role of Recology a principal developer of the landfill and the firm that apparently will gain significant financial benefit from the operation of the landfill? It will be important that this transfer of ownership is transparent and not a shell game to relieve the developers of the landfill from the significant long-term responsibility and liability for controlling the adverse impacts of the landfill on public health and the groundwater resources of the area of the landfill.

The site description section continues on Page 2 of the Plan of Operations and states:
"*The Jungo Disposal Site will be capable of operating 7 days per week, 24 hours per day. However, peak hours of activity will be associated with the arrival of a unit waste train. Generally a full train can be unloaded and the waste placed in the landfill within a 10-hour period. At other times, personnel may be onsite for maintenance, monitoring and construction purposes."*

It has been our experience that permitting agencies for landfills typically restrict the hours of operation of a landfill so that certain adverse impacts of the landfill, such as noise, are limited to daylight hours. While at this time such adverse impacts will apparently not impact nearby human populations, in the future the owners of adjacent and nearby lands should not have the development and use of their lands limited by the operations of the landfill at night. This is especially important at the proposed Jungo Landfill because those operations would, as proposed, involve the deposition to wastes almost to the edge of the property.

Section 5.0 beginning on page 10 of the Plan of Operations presents a characterization of the nature and types of wastes that would, and would not be accepted at the proposed landfill. As was found in, and discussed in these comments concerning the Report of Design, the manner in which the Plan describes the wastes that would and would not be disposed of at the Jungo Landfill is highly misleading. As discussed above, and in our "Flawed Technology" review, wastes of the types described as being acceptable for disposal at the proposed landfill do contain hazardous and otherwise deleterious chemicals – even if they are not categorized by regulations as "hazardous wastes" – that will produce leachates that can render leachate-containing groundwaters unusable for water supply purposes.

Page 11 of the Plan of Operations discusses the characteristics of the rail haul of the garbage. An issue that was not mentioned, but needs to be specifically addressed, is that the garbage transport containers should be water-tight to prevent the discharge of garbage juice" along the rail route. The regulatory program should include periodic inspection of the containers to ensure that they maintain their water-tight characteristics for as long as they are used. The liquid ("garbage juice") that will be formed in the railcars during transit will be a threat to the health of wildlife along the rail line. Those waste residues that leak onto the ground along the rail line would also be expected to contaminate stormwater runoff from the rail line area; the polluted runoff would pose a threat to human health, water quality and wildlife and in waters receiving stormwater runoff from the rail track areas.

Page 11 Section 5.2, Page 13 section 5.8, and Page 14 section 5.8.5 of the Plan of Operations address C&D waste. As discussed previously with regard to the Report of Design document, No mention was made about the fact that C&D wastes often contain PCBs that were used as caulking in older buildings.

Page 14 Section 5.8.5 Handling Procedures for Hazardous or PCB Wastes, states:
"The General Manager and/or operators at the landfill will be responsible for the management of any hazardous and PCB wastes, which may be discovered in the waste stream."
That statement implies that no "hazardous waste" will be allowed to be deposited in this landfill and that the site manager is to take action to control the deposition of such wastes if they are discovered. The US EPA and the NDEP allow household hazardous wastes to be legally deposited in a MSW landfill. Further, it is common practice for some small industries to comingle hazardous wastes and the industrial solid wastes that are allowed in MSW landfills. It is also inconsistent with the allowance of C&D wastes, some of which, as discussed previously, are known to contain PCBs, in the landfill.

Page 16 of the Plan of Operations presents a description of landfill gas control and states:
"6.0 Control of Explosive Gas (NAC 444.667)
Operators of solid waste disposal facilities must ensure that the concentration of methane gas generated by the landfill does not exceed 25 percent of the lower explosive limit (LEL) for methane in landfill structures (excluding gas control or recovery system components), and 100 percent of the LEL for methane at the landfill property boundary."

Since the VOC components of MSW landfill gas can penetrate an intact (without holes) landfill liner by diffusion there is a great likelihood that landfill gas from the Jungo Landfill would trespass onto adjacent properties in violation of this regulation. The Preliminary Landfill Gas Collection Plan (Jungo Drawing 06) shows that the landfill soil gas probes are to be spaced at about 1000 feet apart. The penetration of landfill gas through the liner will be in specific areas which could follow preferential pathways in the heterogeneous soils of the area. The proposed landfill gas probe monitoring locations are spaced too far apart to reliably detect landfill gas released through the liner into subsurface soils before the gas trespasses onto adjacent property.

Page 18 of the Plan of Operation, Section 8.0 Operation & Maintenance (NAC 444.686) states:
"The Jungo Disposal Site will be operated in a manner, which does not create odors, unsightliness, or other nuisances. The working face will be kept as narrow as possible while maintaining safe and efficient equipment operation. Bulky waste material which may provide for the harborage of rodents will not be used for the final surface of side slopes. Waste will be spread into layers not exceeding two feet in thickness prior to compaction, and compacted using dozers and/or compactors. The equipment will make a minimum of two passes over each waste layer. The perimeter boundary of the extent of waste placement will be at least 100 feet from the property boundary of the site.

Odors from landfill operations will be controlled through the placement of daily, intermediate and final cover. In addition, the narrow working face will act to minimize any odors. In the event that a highly odorous load is received, the odorous material may receive cover more frequently."

Such claims that the site "*will be operated in a manner, which does not create odors, unsightliness, or other nuisances"* and *"odors from landfill operations will be controlled"* are hollow. In the past 50 years that he has been reviewing existing impacts of MSW landfills, Dr. Lee routinely hears landfill developers making assurance that it will "control" offsite releases from the wastes that cause adverse impacts, including odors, fugitive papers, etc., to adjacent and nearby property owners. Such assurances notwithstanding, Lee has yet to observe an MSW landfill that did not create nuisance conditions within 100 feet or so of where the wastes are deposited.

Page 24 of the Plan of Operations states in Section 12.7 Leachate Release:
"The Ground Water Monitoring Plan provides the means for determining the presence of leachate below the liner system and to initiate corrective action in the event that leachate reaches ground water. The presence of leachate in the collection structures is a design function of a leachate collection and removal system (LCRS) and a lined waste management unit. The presence of leachate in a containment structure is expected and is the result of a system that is functioning as originally planned and designed."

Contrary to the claims articulated in that section, the groundwater monitoring plan does not provide "*the means for determining the presence of leachate below the liner system and to initiate corrective action in the event that leachate reaches ground water."* There is no doubt that over the hundreds of years or longer that the wastes in that landfill would be a threat to generate leachate when contacted by water there likely will be leachate in the leachate collection system that will not be removed and that will penetrate the liner system and enter the underlying groundwater system. The proposed monitoring program has little chance of detecting incipient leakage of leachate from the landfill before widespread pollution of the groundwater occurs. These issues are discussed in the other sections of these comment, and in detail in the "Flawed Technology" review.

Page 27 of the Plan of Operations, Section 14.0 Closure and Postclosure and Financial Assurance (NAC 444.6891 through NAC 444.6897 and NAC 444.685 through NAC 444.6859) states, "*Closure and postclosure plans have been prepared for the Jungo Disposal Site and specify activities required for compliance with NAC 444.6891 through NAC 444.6897. These plans are included in Appendix C as required by NAC 444.6897.*"

"*The Jungo Disposal Site will utilize a trust fund to demonstrate financial assurance for the Class I operation. NDEP will be notified upon placement and funding of the standby trust fund. Financial assurance estimates for closure and postclosure monitoring and maintenance are included in Appendix C."*

The NDEP website [http://ndep.nv.gov/bwm/jungo.htm] that presents characteristics of the proposed Jungo Landfill provides a link to Jungo Landfill Application Volume I "Table –

Closure Cost Post Closure Estimates." That link leads to "Table 5. Post-Closure Monitoring and Maintenance Cost Estimates" which shows a total annual cost for 30 year of post closure care of $12,502,500. That cost estimate includes "*vegetation maintenance, leachate sampling and testing, landfill gas monitoring/maintenance, groundwater monitoring, maintenance, surface water monitoring/maintenance, drainage/cover maintenance, security maintenance and inspection.*" No cost estimates are included for replacement of the landfill cover when it will no longer adequately prevents entrance of water into the landfill, or for the superfund-like remediation that will eventually have to be conducted at the site. The agency (County and State) will have to fund these costs ($416,750 year plus cover replacement and groundwater remediation) from year 31 and beyond.

As discussed in these comments, the Jungo Landfill developer/owner Nevada Land and Resource LLC /Recology-Jungo Land & Investments, Inc. has repeatedly state that it will provide postclosure care (landfill monitoring, maintenance of the landfill cover and other components of the monitoring and containment system including leachate removal) for 30 years. Since the landfill will be a significant threat to public health and groundwater quality well-beyond that 30-year period, and since the NDEP landfilling regulations state that the postclosure period can be extended, the NDEP permit for this landfill should specify that the postclosure period for this landfill will extend as long as the wastes in the landfill can generate leachate and/or landfill gas. It should be understood that that period can be expected to last for over hundreds of years. Nevada Land and Resource LLC /Recology-Jungo Land & Investments, Inc. would thus be required to fund postclosure monitoring, maintenance, and remediation, including replacement of the deteriorated landfill cover as needed to stop leachate generation and the remediation of the pollution of groundwater that will occur at this landfill at any time in the future.

One of the items mentioned on the NDEP Jungo Landfill webpage is an "Agreement of Trust" in which funds payable to NDEP are to be kept by the Union Bank of California to provide assurance for "closure and/or post-closure care of the facility." It appears, however, that the trust funds will not be available to address postclosure funding needs for year 31 and beyond. Also, apparently none of the trust funds can be used by Humboldt County should it become responsible for providing postclosure care. A dedicated trust fund of sufficient magnitude should be established from disposal fees to address all plausible worst-case failure scenarios for the landfill containment system for as long as the wastes in the landfill will be a threat to generate leachate when contacted by water. The payment should be to the NDEP and Humboldt County as appropriate to meet true costs of long-term postclosure care and remediation.

End of Post-Closure Care

Neither the NDEP nor US EPA provides guidance on when postclosure care can be terminated without risk to public health/welfare or environmental quality. Landfills will continue to pose a threat to public health/welfare and environmental quality until such time that the wastes in the landfill can no longer generate leachate that could cause groundwater pollution and/or release landfill gas. We suggested in our "Flawed Technology" review that post-closure care may be able to be reasonably discontinued once representative samples of wastes taken from the landfill, when properly contacted with water, do not produce leachate that could impair the use of groundwater or surface water for domestic or other purposes, including animal water supply. Since there is no protocol for conducting this type of evaluation, the NDEP/US EPA needs to develop a protocol to make a reliable, objective evaluation of when postclosure care can be terminated without compromising long-term protection of public health/welfare and environmental quality.

Page 28 of the Plan of Operations, Section 15.0 Monitoring Plan (NAC 444.683) states: *"Environmental monitoring will be completed during landfill development and following closure and will include groundwater monitoring, leachate monitoring, and landfill gas monitoring. Surface water monitoring will not be completed because there is no nearby surface water body. However, storm water monitoring will be completed in accordance with NPDES requirements. Appendix D includes a monitoring plan that address groundwater, leachate, and landfill gas monitoring."*

The NDEP website [http://ndep.nv.gov/bwm/jungo.htm] that presents characteristics of the proposed Jungo Landfill provides a link to Jungo Landfill Application Volume III Appendix D: Monitoring Plan, "Figure 2 – groundwater monitoring map." According to that figure, the proposed landfill will have a set of groundwater monitoring wells at the downgradient edge of the landfill that are spaced about 900 feet apart. As discussed in our "Flawed Technology" review beginning on page 27, that approach to groundwater monitoring for landfill-derived pollution has a very low ability of detecting the initial failure of the landfill liner that leads to groundwater pollution by landfill leachate. The placement of the monitoring wells immediately adjacent to the edge of the landfill is even more problematic at the Jungo Landfill because waste deposition areas are so near the edge of the landfill property. The zone of capture about the conventional monitoring well is about a 1 ft radius about the well. Leachate-polluted groundwater will emanate from the Jungo site as a narrow plume from areas of breach. With monitoring wells space about 900 feet apart, narrow leachate plumes can readily pass the line of groundwater monitoring wells at the edge of landfill around the around the perimeter of the landfill without being detected. There is no doubt that offsite groundwaters will eventually be polluted by landfill leachate without its being detected by the proposed monitoring approach for the Jungo Landfill.

The discussion of monitoring in the Plan of Operations focuses on detecting potential releases from the landfill. However, the Plan states that there are no nearby offsite groundwater wells that would be impacted by a release from the site. Also it is stated that there are no municipal water wells within 10 miles of the site. The nearest groundwater well is used for agricultural purposes and is located more than one mile northeast of, and upgradient from, the landfill site. The Plan of Operations' discussion about the nearest existing well that could be polluted when the landfill liner system fails has no relevance to the NDEP regulations governing the protection of groundwater from pollution by landfill leachate. As discussed in another section of these comments, NDEP regulations for protection of groundwater quality are explicit in requiring that the landfill shall not pollute groundwater at any location. There is no provision that allows for offsite pollution of groundwater as long as there are no existing wells in the adjacent and nearby areas that could be polluted.

The proposed Jungo Landfill is planned to rise about 200 ft above the ground surface. Such above-gradient landfills are prone to developing seeps of leachate through their above-ground sides that will pollute stormwater runoff. Therefore, it will be important to continue the stormwater runoff monitoring for as long as the wastes in the landfill can generate leachate when contacted by water.

The NDEP website [http://ndep.nv.gov/bwm/jungo.htm] that presents characteristics of the proposed Jungo Landfill provides a link to Jungo Landfill Application Volume III Appendix D: Monitoring Plan, which contains "Table 2–Monitoring Parameters and Methods" that lists the chemicals that will be monitored at the proposed Jungo Landfill. Our "Flawed Technology" review beginning on page 35 discusses inadequacies of the approaches typically used in monitoring pollution sources including landfills. One of the inadequacies is that they only monitor for the presence of a very small number of the chemicals in MSW that can be a threat to human and animal health and groundwater quality. This issue is discussed in another section of these comments.

Compliance with Nevada Landfilling Regulations
A review of the State of Nevada solid waste regulations is presented on the Internet as:
NDEP Solid Waste Disposal Regulations
[http://www.leg.state.nv.us/NAC/NAC-444.html#NAC444Sec570]
Sections of those regulations that are pertinent to the evaluation of the compliance with the Nevada landfilling regulations are presented below.

NAC 444.605 "Pollutant" defined. (NRS 444.560**)** "Pollutant" has the meaning ascribed to it in NRS 445A.400.

NRS 445A.405 "Pollution" defined. "Pollution" means the human-caused or human-induced alteration of the chemical, physical, biological and radiological integrity of water.
(Added to NRS by 1973, 1709)—(Substituted in revision for NRS 445.181)

NAC 444.644 Systems for solid waste. (*NRS 444.560*****)***
1. All solid wastes must be:

(a) Stored, collected, utilized, treated, processed and disposed of by means that do not create a health hazard, public nuisance or impairment of the environment.

(b) Handled in such a manner which does not contribute to breeding of insects and rodents or to support any disease vector.

2. All solid waste systems must be operated in a manner that will not cause or contribute to pollution of:

(a) The atmosphere; or

(b) Surface or groundwaters of the State.

NAC 444.678 Location restrictions: Generally. (*NRS 444.560*****)*** *The location of a Class I site must:*

1. Be easily accessible in all kinds of weather to all vehicles expected to use it.

2. Prevent pollutants and contaminants from the municipal solid waste landfill units at the site from degrading the waters of the State.

3. Prevent uncontrolled migration of gas at the site.

The above regulations are explicit in requiring that landfills must be developed so as to prevent the pollution of the state's groundwaters. There is no time limitation on that requirement.

NAC 444.683 Plan for monitoring water; suspension of monitoring requirements. (NRS 444.560)

1. The plan for monitoring water for a Class I site must provide a complete description of a system capable of monitoring the performance of the design of the site, including monitoring of the groundwater to detect the release of pollutants or contaminants from the municipal solid waste landfill unit into the waters of the State."

"3. The solid waste management authority may suspend monitoring requirements if the owner or operator of a Class I site demonstrates that there is no potential for migration of pollutants or contaminants from the site to waters of the State during the active life of the site, including the period for closure and postclosure. The demonstration must be:

(b) Based on:

(2) Predictions of the fate and transportation of the pollutants or contaminants that consider the maximum rate of the migration of contaminants and the impact of the pollutants or contaminants on public health and safety and the environment.

The information on movement of groundwater in the vicinity of the landfill is such that the pollution the groundwater under the landfill will lead to offsite groundwater pollution that will be a violation of this regulation. There will likely also be fugitive papers from the landfill that will trespass onto adjacent properties.

NAC 444.686 Operation and maintenance. (NRS 444.560)

1. The operation and maintenance of a Class I site must be in a manner which will not create odors, unsightliness or other nuisances.

Because of the extremely limited amount of buffer land owned by the landfill between the deposition footprint and adjacent property line, offsite emanation of odors from this landfill will, without question, result in violations of this regulation.

NAC 444.6894 Program for postclosure for each municipal solid waste landfill unit within Class I site. (NRS 444.560)

1. After the closure of each municipal solid waste landfill unit of a Class I site, the owner or operator of the site shall conduct a program for postclosure for that unit. Except as otherwise provided in subsection 2, the program must be conducted for 30 years and consist of at least the following:

(a) The integrity and effectiveness of any final cover must be maintained, including making repairs to the cover as necessary to correct the effects of settlement, subsidence, erosion or other events, and preventing runon and runoff from eroding or otherwise damaging the final cover.

(b) The system to collect leachate must be maintained and operated in accordance with the requirements in NAC 444.681, if applicable. The solid waste management authority may allow the owner or operator to stop managing leachate if the owner or operator demonstrates that leachate no longer poses a threat to public health and safety and the environment.

(c) The groundwater must be monitored in accordance with [NAC 444.7481] to [444.7499], inclusive, and the system for monitoring the groundwater must be maintained, if applicable.
(d) The system for monitoring gas must be maintained and operated in accordance with [NAC 444.667].
2. The length of the program for postclosure may be:
(a) Decreased by the solid waste management authority if the owner or operator demonstrates that the reduced period is sufficient to protect public health and safety and the environment and this demonstration is approved by the solid waste management authority; or
(b) Increased by the solid waste management authority if it determines that the lengthened period is necessary to protect public health and safety and the environment.

The postclosure period for the proposed Jungo Landfill should be extended until the wastes in the landfill are no longer a threat to generate leachate and landfill gas when contacted by water. If the proposed landfill is permitted NDEP should make this requirement a part of the permit that is issued to Nevada Land and Resource /Recology-Jungo Land & Investments, Inc.

Overall

A San Francisco based firm proposes to develop a large landfill near Winnemucca, Nevada that will receive 4000 tons/day of San Francisco, CA area municipal solid wastes. The proposed landfill location is subject to period flooding during periods of intense rainfall. There are important groundwaters underlying the landfill that can be polluted by the ultimate failure of the landfill liner. The proposed landfill liner and waste containment system is essentially the minimum allowed under the US EPA Subtitle D and Nevada DEP landfills development regulations. These regulations in some instances are deficient in providing the protection of public health, water resources quality and several other impacts of MSW. Some states will not allow this design of an MSW landfill to be developed in the state. In no event should the citizens of the state of Nevada and Humboldt County be required in any way to bear any costs for postclosure care.

~~~~~~

Comments on
NDEP December 1, 2011Jungo Landfill Hearing Presentation by
J. Taylor, NDEP Staff Member Responsible for Jungo Landfill Technical Review

G. Fred Lee, PhD, PE(TX), BCEE, F.ASCE & Anne Jones-Lee, PhD
G. Fred Lee & Associates
El Macero, California
phone: 530-753-9630
gfredlee@aol.com www.gfredlee.com

At the December 1, 2011 NDEP hearing for the Jungo Landfill, Jon Taylor, PE, CEM–NDEP Permitting, made a technical-review presentation on the characteristics of the proposed Jungo Landfill that NDEP has recommended for permitting. Dr. G. Fred Lee made a tape-recording of his presentation. Presented below are quotations and paraphrases of some of the statements that
~~~~~~

J. Taylor made concerning the so-called protective nature of the proposed Jungo Landfill along with our comments on their technical accuracy. In these comments we have only provided summary overview discussion of issues that we covered in detail in our comments on the Golder Design and Operations reports, and for which the technical basis is covered in our "Flawed Technology" review. Those reports should be consulted for more detailed discussion of the issues discussed herein.

Mr. Taylor indicated that he was the NDEP staff member responsible for technical review of the proposed Jungo Landfill. He also indicated that he had incorporated into the current design of this proposed landfill several features that *"provided for greater protection from the landfill impacts."*

The times indicated at the beginning of the comments are approximate times into the hearing. The reference to time will be replaced with specific citations to the location of the comment issues from the transcription of the hearing that NDEP made when it becomes available.

7:14 Taylor discussed the sizes of current large landfills in Nevada, and indicated that Apex, Rawhide, Crestline are the three largest landfills in the state. If Jungo is permitted, it will be the fourth largest landfill. In his response to comments Taylor should provide information on the current and anticipated future daily MSW loads to each and the percentage of the wastes currently received by each landfill from sources outside of the state of Nevada. Such information will provide a much better comparison between those landfills and the proposed Jungo Landfill.

9:26 Taylor said that because of the proximity of the landfill bottom to groundwater, the landfill would require *"more protective design and monitoring"* to mitigate for there being less than 100 ft. between the bottom of the landfill and underlying groundwater table as required by NDEP regulations. He indicated that that condition could be mitigated by requiring an improved landfill liner design beyond the minimum allowed (single-composite liner). The mitigation improvements would include an additional HDPE liner and secondary leachate collection under the composite liner and improved monitoring. Taylor's approach for so-called mitigation for the lack of at least 100 feet of separation between the bottom of the landfill and groundwater table is fundamentally flawed for providing protection from groundwater pollution by leachate that will eventually penetrate the "improved" landfill liner design without detection by the proposed monitoring approach before it passes onto adjacent property. Additional discussion of those so-called improvements is presented below.

15:37 Taylor indicated that the minimum design for landfill cover is 6 in of soil and that the design for the proposed Jungo Landfill cover would be 3 ft of soil and an HDPE liner. As discussed in our comments on the Golder Report of Design, the design of the Jungo Landfill cover will not prevent the entrance of water into the closed landfill cells over the time that the wastes in the landfill will be a threat to generate leachate when contacted by water.

15:39 Taylor indicated that there would be improved gas control for the Jungo Landfill; improvements include gas collection pipes in the leachate collection system. As discussed in our comments on the Golder Report of Design, the gas probes for monitoring landfill gas releases to the soils adjacent to the perimeter of the landfill are spaced too far apart to reliably detect initial landfill gas releases through the liner below the ground surface. Taylor did not mention that the gas collection pipes in the leachate collection system will need vigilant maintenance to prevent them from becoming plugged with deposits. He also did not mention who will operate the gas collection system in the postclosure period beyond year 31 when Recology et al. will walk away from the landfill and leave the financial burden for the landfill to the State and County. This issue is discussed further below.

16:41 Taylor stated that one of the additional criteria for the Jungo Landfill is a 24-hour detection evaluation program that focuses on groundwater monitoring at 10 and 25 years to evaluate the performance of the liner at 10 and 25 years of operation. The 25-year review will be for about 25% of the projected active life of the landfill. As discussed in another section of these comments, that approach is not reliable for evaluating liner performance over the period during which the wastes at the landfill will be a threat.

18:42 In response to a comment made by a member of the public, Taylor stated that *"the playa standing water is not sheet flow."* The fact is that the proposed landfill area periodically is flooded is similar to the siting of a landfill in a floodplain, a practice that is prohibited by US EPA and Nevada landfilling regulations. As discussed in our comments on the Golder Report, using a dike to try to keep the flood water out of the landfill area, as is being planned for the Jungo Landfill, is subject to significant problems and is unreliable for keeping standing water away from the landfill.

20:40 A member of the public questioned the suitability of the soils of the area for use in the landfill. Taylor stated in response, *"Settlement monitoring part of the performance review is to address soil settlement properties."* The suitability of the soils (lack thereof) of the area of the landfill is discussed in a separate section of these comments.

22:09 Taylor stated, *"the prescriptive design of the liner is a single-composite liner with a primary geomembrane and a compacted soil liner."* and that the Jungo Landfill will contain another geomembrane beneath the single composite liner.

22:36 Taylor stated, *"gas collection includes a pipe in the leachate collection system to collect gas."* As discussed in another section of these comments, that system requires postclosure operation of the gas collection system for as long as the wastes in the landfill can produce landfill gas when contacted by water. That period can extend well-beyond the monitored 30-year postclosure period provided by Recology et al.

26:20 Taylor stated that two angle borings under the sump and two vertical wells at the boundary on each side of the 25 year waste footprint would be used for the interim groundwater monitoring for 25% of the landfill projected active life. He stated that the proposed landfill will have *"a lot of groundwater monitoring."* That characterization notwithstanding, as discussed in our comments on the Golder Design report the perimeter groundwater monitoring wells are spaced too-far apart to detect the failure of the landfill leachate collection system before polluted leachate-polluted groundwater trespasses onto adjacent property. Leachate that initially penetrates the liner system near the down-groundwater-gradient part of the landfill will produce narrow, finger-like plumes of leachate that can pass between the perimeter monitoring wells and not be detected by them.

Taylor's so-called "performance monitoring" that he designed and proposed for about 25% of the proposed landfill active life of about 100 years, cannot be expected to properly assess the long-term ability of the proposed landfill liner system to collect all leachate generated in the landfill over the hundreds of years that the proposed dry tomb landfill will be a threat to generate leachate when contacted by water. The basic problem is that Taylor has failed to properly assess the rate of leachate passage through the compacted clay layer underlying holes that will inevitably be present in the HDPE plastic sheeting layer in the composite liner at the time of construction, that can develop upon waste deposition, and that develop as the plastic sheeting layer deteriorates. A far more reliable approach for detecting inadequacies in landfill liner construction that results in early landfill liner failure is the detection of leachate in the secondary leachate detection layer under the composite liner. If, at 25 years, leachate is found in that leak detection layer then it is clear that the composite liner was not properly constructed or protected. Trying to detect early liner failure by monitoring four perimeter monitoring wells, two on each side of the first 25-year cells, and by two horizontal monitoring wells under the sumps is expensive and highly unreliable.

29:28 Asked by a member of audience what he was looking for in the groundwater monitoring. Taylor responded, *"Once the landfill starts generating leachate, we're going to be testing leachate for everything under the sun"* and then see if any of those leachate parameters are in the monitoring wells tested at 25 years. Contrary to Taylor's figurative claim of *"testing for everything under the sun,"* it is well-known that MSW leachate contains innumerable chemicals that are not included in typical monitoring regimens, as well as unregulated chemicals, that can be a threat to public health and the environment. Those issues are discussed in our comments on the monitoring section of the Golder report.

38:32 A member of the audience stated that 21 out of 27 issues reviewed in the USDA NRCS Soils report were of poor to very poor quality for use in developing a landfill. A discussion of the USDA NRCA report is presented later in these comments.

Taylor again stated that he *"try to take requirements and push them as far as I can."* As discussed in these comments, Taylor in response to comments should provide the specific Nevada landfilling regulations that are the basis for his so-called constraints in imposing requirements on the proposed landfill to provide long-term protection of public health and the environment from that landfill.

43:21 Taylor stated that there will be *"ongoing closure certification by NDEP personnel* as parts of the landfill reach capacity and close. This could mean that parts of the landfill will begin the 30-year postclosure period while other parts of the landfill are still receiving wastes.

40:36 Members of the audience pointed out that NDEP's statements about the prevailing wind direction in the area of the proposed landfill is wrong.

44:30 Taylor stated that the 30-yr postclosure care can be extended – *"something going on can extend that timeframe."* He did not define what he meant by *"something going on."* Taylor should discuss in his response to comments what he meant by extending the postclosure period and what may trigger that, for the period of time during which the wastes in the landfill, when contacted by water, can generate leachate that can pollute groundwater if the liner system fails to collect all leachate generated in the landfill. He should also discuss specific failure scenarios and what would be done by him/NDEP and his successors to reliably shepherd the operations/monitoring and maintenance of the Jungo Landfill over the hundreds of years that this landfill will require close inspection by NDEP.

45:26 A member of audience asked, *"Why is it only 30-yrs of postclosure; why can't it be 100 years?"* Taylor's response was, *"30 years is in regulations." "I am constrained by the regulations."* His claim of being constrained by the NDEP regulations from improving the design of this landfill to match that used by some other states, including California (from which the wastes for Jungo Landfill would originate) is questioned. California adopted landfilling regulations in the 1980s that require that an MSW landfill be located, designed, monitored, and maintained in a manner so as to prevent groundwater impairment by landfill leachate. There is no time limitation on that requirement. More recently, the CA Integrated Waste Management Board (now called CalRecycle) adopted regulations that require that the assured postclosure funding for a landfill be provided for at least 100 years, not the 30 years minimum specified in the US EPA Subtitle D regulations. NDEP should cite specific NDEP regulations that prevent Nevada from adopting the California approach for postclosure funding for monitoring, maintenance, and, as needed, remediation of groundwater pollution.

47:29 A member of audience asked, *"Where do you get the soil for the cover?"* Taylor's response was, *"It will come out of the excavation as the cells are being installed."* A member of the audience retorted, *"It's going to be covered with bug dust."* The 153-page US Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS) report, "Custom Soil Resource, Report for Humboldt County, Nevada, East Part" US Department of Agriculture October 13, (2009), discusses the characteristics and suitability of the soils in the area of the proposed Jungo Landfill for use in various components of the proposed landfill as well as for other uses. Neither the Golder Design Report for the Jungo Landfill nor the NDEP report that provided information on the proposed Jungo Landfill make reference to that USDA NRCS report or its conclusions regarding the suitability of area soils for use in the landfill development and maintenance. While both the Golder Design Report and the NDEP report make reference to other, earlier USDA NRCS reports on other issues such as flooding of the area, neither Golder nor NDEP was evidently aware of the USDA NRCS 2009 report that specifically discusses the use of area soils in the development of the proposed landfill. This is a serious deficiency in the review of the literature pertinent to the evaluation of the landfill area for its suitability for siting the proposed Jungo Landfill.

Table 1 was prepared by us to summarize USDA NRCS (2009) findings concerning the unsuitability of the soils of the area for use in landfill development. The US Department of Agriculture and Natural Resources Conservation Service develop "soil survey interpretations," that integrate measured characteristics of soils into assessments and rankings of a soil's predicted behavior and suitability for specified soil uses (Source: Natural Resources Conservation Service [http://soils.usda.gov/technical/handbook/contents/part617.html]).

According to USDA NRCS (2009):
"Rating class terms indicate the extent to which the soils are limited by all of the soil features that affect the specified use.
"Not limited" indicates that the soil has features that are very favorable for the specified use. Good performance and very low maintenance can be expected.
"Somewhat limited" indicates that the soil has features that are moderately favorable for the specified use. The limitations can be overcome or minimized by special planning, design, or installation. Fair performance and moderate maintenance can be expected.
"Very limited" indicates that the soil has one or more features that are unfavorable for the specified use. The limitations generally cannot be overcome without major soil reclamation, special design, or expensive installation procedures. Poor performance and high maintenance can be expected."

Table 1 provides a summary of information (extracted from the USDA NRCS 2009 report) concerning soil interpretations for those uses of soils in the eastern portion of Humboldt County, NV that could be pertinent to the development and maintenance of the Jungo Landfill. Those uses include: Local Roads & Streets, Shallow Excavations, Gravel Source / Sand Source, Roadfill Source, Source of Reclamation Material, Topsoil Source, Catastrophic Mortality, Large Animal Disposal, Pit/Trench, Clay Liner Material Source, Composting Facility - Subsurface, Composting Medium & Final Cover, Rubble & Debris Disposal, Large-Scale Event, Sanitary Facilities (e.g., sanitary landfills) Daily Cover, Sanitary Landfill (Area), Sanitary Landfill (Trench), Waste Management (Disposal of Wastewater by Irrigation), Water Management (Embankments, Dikes, and Levees) , Pond Reservoir Areas. Also provided in Table 1 is a brief, quoted description of the basis for the interpretation ranking assigned by the USDA/NRCS, the ranking itself, as well as reasons given for the ranking. (The "Humboldt County, Nevada, East Part" region covered by the report was defined by two "map unit" areas, "Boton-Playas Association" and "Playas." Information on only the "Boton-Playas Association" area was included in Table 1 as that was the area in which the landfill would be sited. The "rankings" of quality of the Playas area was basically the same as those for the "Boton-Playas Association.")

Overall, as can be seen in Table 1, for essentially all 19 purposes for which area soils could be used in some way in the development and maintenance of the Jungo Landfill, the area soils have been characterized by the USDA as being "poor," "severely limited," or "very limited." The best ranking area soils received for 3 of the 19 uses that may be associated in some way with landfill development was "somewhat limited."

Table 1. Summary of Key USDA/NRCS Soil Survey Interpretations and Ratings of Suitabilities & Limitations for Use
Humboldt County, NV East Part Boton-Playas Association Soils*

Uses	Description	Rating	Reason	page*
Local Roads & Streets	The ratings are based on the soil properties that affect the ease of excavation and grading and the traffic-supporting capacity	very limited	low strength, shrink-swell, depth to sat. zone, ponding	17
Shallow Excavations	The ratings are based on the soil properties that influence the ease of digging and the resistance to sloughing.	some-what limited	cutbanks cave	19
Gravel Source / Sand Source	Gravel Source / Sand Source	poor	bottom layer; thickest layer	24, 28
Roadfill Source	The ratings are based on the amount of suitable material and on soil properties that affect the ease of excavation and the performance of the material after it is in place.	poor	low strength, shrink-swell, wetness depth	26
Source of Reclamation Material	The ratings are based on the amount of suitable material and on soil properties that affect the ease of excavation and the performance of the material after it is in place.	poor	salinity, sodium, alk, low org. matter, water erosion, croughty, too clayey	30
Topsoil Source	The ratings are based on the soil properties that affect plant growth; the ease of excavating, loading, and spreading the material; and reclamation of the borrow area.	poor	sodium, salinity, wetness depth, too clayey	32
Catastrophic Mortality, Large Animal Disposal, Pit/Trench	Catastrophic Mortality, Large Animal Disposal, Pit/Trench	very limited	salt, water gathering, cutbanks cave, wetness, ponding, sodium, too clayey	35, 38
Clay Liner Material Source	This interpretation shows the degree and kinds of properties that make soil material suitable for use as a clay liner. The ratings are based on the soil properties that affect ease of excavation, compactability of the material, the thickness of the soil layer, reclamation of the area, and erosion from the site.	poor	area reclaim difficult; hard to pack	40
Composting Facility - Subsurface	The ratings are based on the soil properties that affect attenuation of suspended, soil solution, and gaseous decomposition products and microorganisms, construction and maintenance of the site, and public health. Improper site selection, design, or installation may cause contamination of ground water, seepage, and contamination of stream systems from surface drainage or floodwater.	some-what limited	low precip, water gathering, cutbanks cave	44

Composting Medium & Final Cover	This interpretation shows the degree and kinds of properties that make soil material suitable for use as composting medium and final cover material. The ratings are based on the soil properties that affect ease of excavation, workability of the material, the thickness of the soil layer, reclamation of the area, and erosion from the site.	poor	sodium	47
Rubble & Debris Disposal, Large-Scale Event	Such a landfill involves excavating a large pit or trench, placing the rubble and debris in the trench, and covering each layer with a blanket of soil material. A final blanket of cover material is placed over the whole facility when completed. The ratings are based on the soil properties that affect attenuation of suspended, soil solution, and gaseous decomposition products and microorganisms; construction and maintenance of the site; and public health. Improper site selection, design, or installation may cause contamination of ground water, seepage, and contamination of stream systems from surface drainage or floodwater.	severely limited	salt, water gathering, cutbanks cave, wetness, poinding, sodium, too clayey	51
Sanitary Facilities (e.g., sanitary landfills) Daily Cover	The ratings also apply to the final cover for a landfill. They are based on the soil properties that affect workability, the ease of digging, and the ease of moving and spreading the material over the refuse daily during wet and dry periods. These properties include soil texture, depth to a water table, ponding, rock fragments, slope, depth to bedrock or a cemented pan, reaction, and content of salts, sodium, or lime.	very limited	depth to sat. zone, sodium, hard to compact, salinity, ponding	54
Sanitary Landfill (Area)	In an "area sanitary landfill," solid waste is placed in successive layers on the surface of the soil. The waste is spread, compacted, and covered daily with a thin layer of soil from a source away from the site. A final cover of soil material at least 2 feet thick is placed over the completed landfill. A landfill must be able to bear heavy vehicular traffic. It can result in the pollution of ground water. Ease of excavation and revegetation should be considered. The ratings are based on the soil properties that affect trafficability and the risk of pollution. These properties include flooding, saturated hydraulic conductivity (Ksat), depth to a water table, ponding, slope, and depth to bedrock or a cemented pan.	very limited	depth to sat zone; ponding	56
Sanitary Landfill (Trench)	The ratings are based on the soil properties that affect the risk of pollution, the ease of excavation, trafficability, and revegetation. These properties include saturated hydraulic conductivity (Ksat), depth to bedrock or a cemented pan, depth to a water table, ponding, slope, flooding, texture, stones and boulders, highly organic layers, soil reaction, and content of salts and sodium.	very limited	salt, depth to sat zone, sodium, ponding, too clayey	60

Waste Management (Disposal of Wastewater by Irrigation)	The ratings are based on the soil properties that affect the design, construction, management, and performance of the irrigation system.	very limited	sodium, slow water movement, droughty, depth to sat zone, salinity	63
Water Management (Embankments, Dikes, and Levees)	The soils are rated as a source of material for embankment fill.Soil material in embankments must be resistant to seepage, piping, and erosion and have favorable compaction characteristics. Unfavorable features include less than 5 feet of suitable material and a high content of stones or boulders, organic matter, or salts or sodium. A high water table affects the amount of usable material. It also affects trafficability.	very limited	salinity, piping, depth to sat zone, hard to pack, ponding	81
Pond Reservoir Areas	Pond reservoir areas hold water behind a dam or embankment. Soils best suited to this use have low seepage potential in the upper 60 inches. The seepage potential is determined by the saturated hydraulic conductivity (Ksat) of the soil and the depth to fractured bedrock or other permeable material	some-what limited	seepage	87

*Source: USDA and NRCS, "Custom Soil Resource Report for Humboldt County, Nevada, East Part," US Department of Agriculture (USDA) and Natural Resources Conservation Service (NRCS), October 13 (2009). Page numbers given in Table refer to page numbers in USDA/NRCS report on which tables of rankings for the given use appear.

~~~~~~~~~~~~~~~

The information in the USDA NRCS soils report raises serious questions about the reliability of the statements made in the Golder Design Report and by Taylor at the hearing concerning the use of local excavation soils for landfill development. It also contributes to the significant questions of the technical credibility of evaluation of the proposed Jungo Landfill.

48:08 Taylor stated, *"At the end of the day, this land becomes deed restricted. There must be a restriction on the deed to be sure this property…"* A deed restriction that limits the use of the closed landfill area, even if thorough and well-crafted, is in the end only as reliable as the agency and its personnel are in implementing the deed restriction over the hundreds of years that the wastes in the landfill will be a threat to pollute the environment to prevent future land-use activities from damaging or diminishing the integrity of the landfill containment and monitoring systems. NDEP should address who will be responsible for reliable implementation of the deed restriction over the hundreds of years that they will be needed to be enforced.

49:09 Taylor stated the financial assurance, trust fund was *"for NDEP to hire a third-party contractor to perform activities in the application and required by the permit"* for 30 yrs. and described it as being *"cash in the bank."* This statement fails to address the true long-term need for financial assurance that will extend well-beyond the 30-year period covered by the implement he described in order to protect the groundwater and the health/welfare of the people of the County.
~~~~~~~~~~~~~~~

59:48 Taylor stated, *"What I have on my desk is a well-engineered, well-designed landfill."* As discussed in these comments, the proposed landfill will, at best, only delay groundwater pollution by landfill leachate and will cause the state of Nevada and Humboldt County to inherit a massive liability of San Francisco Bay area garbage to the detriment of the current and future County residents. While the proposed Jungo Landfill may be a well-design and well-engineered landfill by Nevada standards, a landfill of that design and provision could not be permitted in several other states because of inadequacies in its siting and design, as well as foreseeable problems in its ability to control releases from the landfill, and the lack of assured postclosure funding for care for as long as the wastes in the landfill will be a threat.

60:00 Taylor commented on the Nevada Department of Wildlife's (NDOW) concern about standing water in industrial area ponds that would be threat to wildlife that could drink from the ponds. Taylor indicated that there would be no wildlife mortality due to a fence to keep wildlife out of the landfill property. While Recology would be responsible for maintaining the fence and ensuring its adequacy during the active life and monitored postclosure period, Taylor did not indicate who would be responsible for such monitoring and maintenance after Recology walks away from responsibility for postclosure maintenance of the landfill area. This should be defined.

61:40 Taylor stated, *"For us, designed this landfill out about as far as I think I can while still being within my regulatory constraints. In other words, I'm trying hard not to exceed my regulatory requirements."* If the degree of protection afforded by landfills is, in fact, restricted by Nevada regulations, NDEP should cite the statutory limitations and make those limitations very clear to the people who stand to be adversely affected by this landfill, now and in the future. However, we have reviewed the NDEP landfilling regulations and do not find any statement of constraints that prohibit NDEP from requiring landfill developers to provide design proposals that will be fully protective of public health and the environment for as long as the wastes are a threat. In fact the NDEP landfilling regulations at several locations specify that an MSW landfill shall not be adverse to groundwater quality, cause offsite nuisance, or result in other adverse impacts to adjacent and nearby property owners/users. NDEP should provide specific citations to the so-called constraints that prevent NDEP from making this landfill fully protective.

Taylor mentioned that leachate could be used for dust control at the landfill. As discussed in our report, that practice can lead to pollution of stormwater runoff by hazardous and otherwise deleterious chemicals in the leachate.

64:48 Taylor: *"I will evaluate and respond to **all** comments."* (emphasis his). It will be important that NDEP address the specific literature that we have provided that discusses the technical basis upon which we have challenged the reliability of the information in the Golder Jungo Landfill design report concerning the long-term protection afforded by the proposed landfill.

65:26 Taylor stated, *"If there are off-site complaints about nuisance, NDEP would inspect and change operation practices to control the nuisance conditions."* Given that landfill buffer lands are virtually nonexistent, there being only few hundred feet between the proposed edge of waste deposition and adjacent property lines, there is no doubt that nuisance offsite odor conditions will exist at this landfill and that they would, at times, extend for several miles from the landfill property.

Biographical Information for G. Fred Lee and Anne Jones-Lee

Expertise and Experience in Hazardous Chemical Site and Municipal/Industrial Landfill Impact Assessment/Management

Dr. G. Fred Lee's work on hazardous chemical site and municipal/industrial landfill impact assessment began in the mid-1950s while he was an undergraduate student in environmental health sciences at San Jose State College in San Jose, California. His course and field work involved review of municipal and industrial solid waste landfill impacts on public health and the environment.

He obtained a Master of Science in Public Health degree from the University of North Carolina, Chapel Hill, in 1957. The focus of his masters degree work was on water quality evaluation and management with respect to public health and environmental protection from chemical constituents and pathogenic organisms.

Dr. Lee obtained a PhD degree specializing in environmental engineering from Harvard University in 1960. As part of this degree work he obtained further formal education in the fate, effects and significance and the development of control programs for chemical constituents in surface and ground water systems. An area of specialization during his PhD work was aquatic chemistry, which focused on the transport, fate and transformations of chemical constituents in aquatic (surface and ground water) and terrestrial systems as well as in waste management facilities.

For a 30-year period, he held university graduate-level teaching and research positions in departments of civil and environmental engineering at several major United States universities, including the University of Wisconsin-Madison, University of Texas at Dallas, and Colorado State University. During this period he taught graduate-level environmental engineering courses in water and wastewater analysis, water and wastewater treatment plant design, surface and ground water quality evaluation and management, and solid and hazardous waste management. He has published over 1,100 professional papers and reports on his research results and professional experience. His research included, beginning in the 1970s, the first work done on the impacts of organics on clay liners for landfills and waste piles/lagoons.

His work on the impacts of hazardous chemical site and municipal/industrial solid waste landfills began in the 1960s when, while directing the Water Chemistry Program in the Department of Civil and Environmental Engineering at the University of Wisconsin-Madison, he became involved in the review of the impacts of municipal solid waste landfills on groundwater quality.

In the 1970s, while he was Director of the Center for Environmental Studies at the University of Texas at Dallas, he was involved in the review of a number of municipal solid and industrial (hazardous) waste landfill situations, focusing on the impacts of releases from the landfill on public health and the environment.

In the early 1980s while holding a professorship in Civil and Environmental Engineering at Colorado State University, he served as an advisor to the town of Brush, Colorado, on the potential impacts of a proposed hazardous waste landfill on the groundwater resources of interest to the community. Based on this work, he published a paper in the Journal of the American Water Works Association discussing the ultimate failure of the liner systems proposed for that landfill in preventing groundwater pollution by landfill leachate. In 1984 this paper was judged by the Water Resources Division of the American Water Works Association as the best paper published in the journal for that year.

In the 1980s, he conducted a comprehensive review of the properties of HDPE liners of the type being used today for lining municipal solid waste and hazardous waste landfills with respect to their compatibility with landfill leachate and their expected performance in containing waste-derived constituents for as long as the waste will be a threat.

In the 1980s while he held the positions of Director of the Site Assessment and Remediation Division of a multi-university consortium hazardous waste research center and Distinguished Professor of Civil and Environmental Engineering at the New Jersey Institute of Technology, he was involved in numerous situations concerning the impact of landfilling of municipal solid waste on public health and the environment. He has served as an advisor to the states of California, Michigan, New Jersey and Texas on solid waste regulations and management. He was involved in evaluating the potential threat of uranium waste solids from radium watch dial painting on groundwater quality when disposed of by burial in a gravel pit. The public in the area of this state of New Jersey proposed disposal site objected to the State's proposed approach. Dr. Lee provided testimony in litigation, which caused the judge reviewing this matter to prohibit the State from proceeding with the disposal of uranium/radium waste at the proposed location.

Dr. Lee's expertise includes surface and ground water quality evaluation and management. This expertise is based on academic course work, research conducted by Dr. Lee and others and consulting activities. He has served as an advisor to numerous governmental agencies in the US and other countries on water quality issues. Further, he has served on several editorial boards for professional journals, including Ground Water, Environmental Science and Technology, Environmental Toxicology and Chemistry, J. Stormwater, J. Remediation etc. Throughout his over-50-year professional career, he has been a member of several professional organization committees, including chairing the American Water Works Association national Quality Control in Reservoirs Committee and the US Public Health Service PCBs in Drinking Water Committee.

Beginning in the 1960s, while a full-time university professor, Dr. Lee was a part-time private consultant to governmental agencies, industry and environmental groups on water quality and solid and hazardous waste and mining waste management issues. His work included evaluating the impacts of a number of municipal and industrial solid waste landfills. Much of this work was done on behalf of water utilities, governmental agencies and public interest groups who were concerned about the impacts of a proposed landfill on their groundwater resources, public health and the environment.

In 1989, he retired after 30 years of graduate-level university teaching and research and expanded the part-time consulting that he had been doing with governmental agencies, industry and community and environmental groups into a full-time activity. A principal area of his work since then has been assisting water utilities, municipalities, industry, community and environmental groups, agricultural interests and others in evaluating the potential public health and environmental impacts of proposed or existing hazardous, as well as municipal solid waste landfills. He has been involved in the review of approximately 85 different landfills and waste piles (tailings) in various parts of the United States and in other countries, including 12 hazardous waste landfills, eight Superfund site landfills and five construction and demolition waste landfills. He has also served as an advisor to a hazardous waste landfill developer and to IBM corporate headquarters and other companies on managing hazardous wastes.

Dr. Anne Jones-Lee is vice president of G. Fred Lee & Associates. She earned her BS degree in biology from Southern Methodist University in 1973 and her PhD degree in environmental science from the University of Texas Dallas in 1978. For 11 years she held teaching and research positions in graduate degree programs of several US universities, where she specialized in evaluating the impact of chemicals and pathogens on public health and water quality. Dr. Jones-Lee is editor of Drs. Lee and Jones-Lee's "Stormwater Runoff Water Quality Newsletter." She has worked with Dr. G. Fred Lee since 1975 in research and consulting, and has co-authored many papers and reports.

Dr. Anne Jones-Lee (his wife) and he have published extensively on the issues that should be considered in developing new or expanded municipal solid waste and hazardous waste landfills in order to protect the health, groundwater resources, environment and interests of those within the sphere of influence of the landfill. Their over 150 professional papers and reports on landfilling issues provide guidance not only on the problems of today's minimum US EPA Subtitle D landfills, but also on how landfilling of non-recyclable wastes can and should take place to protect public health, groundwater resources, the environment, and the interests of those within the sphere of influence of a landfill/waste management unit. They make many of their publications available as downloadable files from their web site, www.gfredlee.com.

Their work on landfill issues has particular relevance to "Superfund" and hazardous waste site remediation, since regulatory agencies often propose to perform site remediation by developing an onsite landfill or capping waste materials that are present at the Superfund site. The proposed approach frequently falls short of providing true long-term health and environmental protection from the landfilled/ capped waste.

In the early 1990s, Dr. Lee was appointed to a California Environmental Protection Agency's Comparative Risk Project Human Health Subcommittee that reviewed the public health hazards of chemicals in California's air and water. In connection with this activity, Dr. Jones-Lee and he developed a report, "Impact of Municipal and Industrial Non-Hazardous Waste Landfills on Public Health and the Environment: An Overview," that served as a basis for the human health advisory committee to assess public health impacts of municipal landfills.

In 2004 Dr Lee was selected as one of two independent peer reviewers by the Pottstown (PA) Landfill Closure Committee to review the adequacy of the proposed closure of the Pottstown Landfill to protect public health, groundwater resources and the environment for as long as the wastes in the closed landfill will be a threat.

In addition to teaching and serving as a consultant in environmental engineering for over 50 years, Dr. Lee is a registered professional engineer in the state of Texas and an American Academy of Environmental Engineers (AAEE) board certified Environmental Engineer. The latter recognizes his leadership roles in the environmental engineering field. He served as the chief examiner for the AAEE in north-central California during 1990-2010 and in the 1980s in New Jersey, where he has been responsible for administering examinations for professional engineers with extensive experience and expertise in various aspects of environmental engineering, including solid and hazardous waste management.

In November 2009 elected Dr. Lee as a fellow of the American Society of Civil Engineers. This election recognizes Dr. Lee five decade career as a national/international leader university graduate level educator and environmental consultant recognizing his leadership role in the environmental quality management field. In September 2010 the Sacramento Section of the American Society of Civil Engineers awarded Dr. Lee as the Outstanding ASCE Life Member.

His work on landfill impacts has included developing and presenting several two-day short-courses devoted to landfills and groundwater quality protection issues. These courses have been presented through the American Society of Civil Engineers, the American Water Resources Association, and the National Ground Water Association in several United States cities, including New York, Atlanta, Seattle and Chicago, and the University of California Extension Programs at several of the UC campuses, as well as through other groups. He has also participated in a mine waste management short-course organized by the University of Wisconsin-Madison and the University of Nevada. He has been an American Chemical Society tour speaker, where he is invited to lecture on landfills and groundwater quality protection issues, as well as domestic water supply water quality issues throughout the United States.

Throughout Dr. Lee's 30-year university graduate-level teaching and research career and his subsequent 22-year private consulting career, he has been active in developing professional papers and reports that are designed to help regulatory agencies and the public gain technical information on environmental quality management issues. Drs. Lee and Jones-Lee have provided a number of reviews on issues pertinent to the appropriate landfilling of solid wastes. Their most comprehensive review of municipal solid waste landfilling issues is what they call the "Flawed Technology of Subtitle D Landfilling of Municipal Solid Waste," which was originally developed in 1992, and redeveloped and updated in the fall of 2004. Between the two versions they have published numerous invited and contributed papers that provide information on various aspects of municipal solid waste landfilling, with emphasis on protecting public health and the environment from waste components for as long as they will be a threat. The "Flawed Technology" review has been periodically updated, including the most recent update in June 2010, which can be found on their website at http://www.gfredlee.com/Landfills/SubtitleDFlawedTechnPap.pdf

This review provides a comprehensive, integrated discussion of the problems that can occur with minimum-design Subtitle D landfills and landfills developed in accord with state regulations that conform to minimum Subtitle D requirements. The "Flawed Technology" review contains a listing of the various reviews that Drs. Lee and Jones-Lee have developed, as well as peer-reviewed literature. Over 40 peer-reviewed papers are cited in "Flawed Technology" supporting issues discussed in this review.

Drs. Lee and Jones-Lee have developed guidance on the evaluation of the potential impacts of landfills. This guidance is available as,

Lee, G. F., and Jones-Lee, A., "Guidance on the Evaluation of the Potential Impacts of a Proposed Landfill," Report of G. Fred Lee & Associates, El Macero, CA January (2007). http://www.gfredlee.com/Landfills/EvaluationImpactLF.pdf.

SUMMARY BIOGRAPHICAL INFORMATION

NAME: G. Fred Lee

ADDRESS: 27298 E. El Macero Dr.
El Macero, CA 95618-1005

DATE & PLACE OF BIRTH:
July 27, 1933
Delano, California, USA

TELEPHONE:
530/753-9630
(home/office)

E-MAIL: gfredlee@aol.com

WEBPAGE: http://www.gfredlee.com

EDUCATION

Ph.D.	Environmental Engineering & Environmental Science, Harvard University, Cambridge, Mass. 1960
M.S.P.H.	Environmental Science-Environmental Chemistry, School of Public Health, University of North Carolina, Chapel Hill, NC 1957
B.A.	Environmental Health Science, San Jose State College, San Jose, CA 1955

ACADEMIC AND PROFESSIONAL EXPERIENCE

Current Position:
Consultant, President, G. Fred Lee and Associates
Previous Positions:
Distinguished Professor, Civil and Environmental Engineering, New Jersey Institute of Technology, Newark, NJ, 1984-89
Senior Consulting Engineer, EBASCO-Envirosphere, Lyndhurst, NJ (part-time), 1988-89
Coordinator, Estuarine and Marine Water Quality Management Program, NJ Marine Sciences Consortium Sea Grant Program, 1986

Director, Site Assessment and Remedial Action Division, Industry, Cooperative Center for Research in Hazardous and Toxic Substances, New Jersey Institute of Technology et al., Newark, NJ, 1984-1987

Professor, Department of Civil and Environmental Engineering, Texas Tech University, 1982-1984

Professor, Environmental Engineering, Colorado State University, 1978-1982

Professor, Environmental Engineering & Sciences; Director, Center of Environmental Studies, University of Texas at Dallas, 1973-1978

Professor of Water Chemistry, Department of Civil & Environmental Engineering, University of Wisconsin-Madison, 1961-1973

Registered Professional Engineer, State of Texas, Registration No. 39906

American Academy of Environmental Engineers Board Certified Environmental Engineer, Certificate No. 0701 Chief Examiner Northern California for AAEE Board Certification including in the solid and hazardous waste management

PUBLICATIONS AND AREAS OF ACTIVITY

Published over 1,100 professional papers, chapters in books, professional reports, and similar materials. The topics covered include:

$ Studies on sources, significance, fate and the development of control programs for chemicals in aquatic and terrestrial systems.
$ Analytical methods for chemical contaminants in fresh and marine waters.
$ Landfills and groundwater quality protection issues.
$ Impact of landfills on public health and environment.
$ Environmental impact and management of various types of wastewater discharges including municipal, mining, electric generating stations, domestic and industrial wastes, paper and steel mill, refinery wastewaters, etc.
Stormwater runoff water quality evaluation and BMP development for urban areas and highways.
$ Eutrophication causes and control, groundwater quality impact of land disposal of municipal and industrial wastes, environmental impact of dredging and dredged material disposal, water quality modeling, hazard assessment for new and existing chemicals, water quality and sediment criteria and standards, water supply water quality, assessment of actual environmental impact of chemical contaminants on water quality.

LECTURES

Presented over 760 lectures at professional society meetings, universities, and to professional and public groups.

GRANTS AND AWARDS

Principal investigator for over six million dollars of contract and grant research in the water quality and solid and hazardous waste management field.

GRADUATE WORK CONDUCTED UNDER SUPERVISION OF G. FRED LEE
Over 90 M.S. theses and Ph.D. dissertations have been completed under the supervision of Dr. Lee.
Municipal Solid Waste Landfills and
Groundwater Quality Protection Issues Publications

Drs. G. Fred Lee and Anne Jones-Lee have prepared several papers and reports on various aspects of municipal solid waste (MSW) management and hazardous waste management by landfilling, groundwater quality protection issues, as well as other issues of concern to those within a sphere of influence of a landfill. These materials provide an overview of the key problems associated with landfilling of MSW and hazardous waste utilizing lined "dry tomb" landfills and suggest alternative approaches for MSW management that will not lead to groundwater pollution by landfill leachate and protect the health and interests of those within the sphere of influence of a landfill. Copies of many of these papers and reports are available as downloadable files from Drs. G. Fred Lee's and Anne Jones-Lee's web page (http://www.gfredlee.com). Recent papers and reports on landfilling issues are listed below. Copies of the papers and reports listed below as well as a complete list of publications on this and related topics are available upon request.
Publications are available in the following topics at http://www.gfredlee.com/plandfil2.htm

- Overall Problems with “Dry Tomb” Landfills
- Liner Failure Issues
- Groundwater Pollution by Leachate
- Groundwater Monitoring
- Post-Closure Care
- Permitting of Landfills
- Fermentation/Leaching “Wet Cell” Landfills
- Landfill Mining
- Landfills and the 3R’s
- NIMBY Issues
- Review of Specific Landfills
- Hazardous Waste Landfills
- Groundwater Protection Issues

Landfills that have been examined by G, Fred Lee

Arizona *(State Landfilling Regulations)*	Verde Valley - Copper Tailings Pile Closure Mobile – Southpoint Landfill
California *(State Landfilling Regulations)*	Colusa County – CERRS Landfill San Gabriel Valley – Azusa Landfill (Superfund Site) City of Industry – Puente Hills Landfill North San Diego County, 3 landfills San Diego County – Gregory Canyon Landfill El Dorado County Landfill

	Yolo County Landfill Half Moon Bay – Apanolio Landfill Pittsburg – Keller Canyon Landfill Chuckwalla Valley – Eagle Mountain Landfill Mountain View – Mountain View Landfill Barstow – Hidden Valley (Hazardous Waste) Mojave Desert – Broadwell Landfill (Hazardous Waste) Cadiz – Bolo Station-Rail Cycle Landfill University of California-Davis Landfills (4) (3 Superfund Site) San Marcos – San Marcos Landfill Placer County - Western Regional Sanitary Landfill Placer County – Turkey Carcass Disposal Pits Imperial County – Mesquite Landfill Los Angeles County – Calabasas Landfill and Palos Verdes Landfill Contra Costa County – Concord Naval Weapons Station Tidal LF (Superfund) Nevada County – Lava Cap Mine Area Landfill (Superfund Site) Sylmar – Sunshine Canyon Landfill Roseville – Roseville Landfill San Diego County – Campo Landfill Colusa County – Cortina Landfill Imperial – Allied Imperial Landfill Brisbane – Brisbane Landfill
Colorado (*State Landfilling Regulations)*	Last Chance/Brush – (Hazardous Waste Landfill) Denver - Lowry (Hazardous Waste Landfill) Telluride/Idarado Mine Tailings
Delaware	Various MSW landfills – Evaluate past disposal of industrial wastes
Florida	Alachua County Landfill
Georgia	Meriwether County – Turkey Run Landfill Hancock County – Culverton Plantation Landfill
Illinois (*State Landfilling Regulations*)	Crystal Lake – McHenry County Landfill Wayne County Landfill Kankakee County – Kankakee Landfill Peoria County – Peoria Waste Disposal (Hazardous Waste) DeWitt County – Chemical Waste Unit at Clinton Landfill
Indiana (*State Landfilling Regulations*)	Posey County Landfill New Haven-Adams Center Landfill (Hazardous Waste)
Louisiana	New Orleans vicinity - Gentilly Landfill and Chef Menteur Debris Waste Disposal Area
Michigan (*State Landfilling Regulations*)	Menominee Township – Landfill Ypsilanti- Waste Disposal Inc. (Hazardous Waste - PCB's)
Minnesota	Reserve Mining Co., Silver Bay - taconite tailings Wright County - Superior FCR Landfill Four landfills in Sherburne County
Missouri	Jefferson County - Bob's Home Service (Hazardous Waste)

Nevada	Jungo Disposal Site Humboldt County,
New Jersey	Fort Dix Landfill (Superfund Site) Cherry Hill – GEMS (Superfund Site) Lyndhurst - Meadowlands Landfill Scotch Plains Leaf Dump
New York	Staten Island - Fresh Kills Landfill, Niagara Falls Landfill – (Hazardous Waste), New York City – Ferry Point Landfill
North Dakota	Turtle River Township - Grand Forks Balefill Facility Landfill
Ohio	Clermont County - BFI/CECOS Landfill (Hazardous Waste) Huber Heights - Taylorville Road Hardfill Landfill (C&DD) Morrow County – Washington and Harmony Townships C&DD Landfills
Pennsylvania	Pottstown – Pottstown Landfill
Rhode Island	Richmond – Landfill (C&D)
South Carolina	Spartanburg - Palmetto Landfill
Texas	Dallas/Sachse – Landfill Fort Worth - Acme Brick Landfill (Hazardous Waste) City of Dallas - Jim Miller Road Landfill Pasadena – Mobil Mining and Minerals industrial waste pile
Vermont	Coventry, Vermont - Coventry Landfill
Washington	Tacoma - 304th and Meridian Landfill
Wisconsin	Madison and Wausau Landfills
INTERNATIONAL LANDFILLS	
Belize	Mile 27 Landfill
Alberta, Canada	Waste Management proposed Thorhild Landfill
Ontario, Canada (*Prov. Landfilling Regulations*)	Greater Toronto Area - Landfill Siting Issues Kirkland Lake - Adams Mine Site Landfill Pembroke - Cott Solid Waste Disposal Areas
Manitoba, Canada	Winnipeg Area - Rosser Landfill
New Brunswick, Canada	St. John's - Crane Mountain Landfill
Nova Scotia, Canada	Sydney Tar Ponds and Coke Ovens Site
England	Mercyside Waste Disposal Bootle Landfill
Hong Kong	Three New MSW Landfills

Ireland	County Cork - Bottlehill Landfill County Clare - Central Waste Management Facility, Ballyduff
Korea	Yukong Gas Co. - Hazardous Waste Landfill
Mexico (*Haz. Waste Landfilling Reg.*)	San Luis Pontosi Landfill- (Hazardous Waste)
New Zealand	Hampton Downs Landfill North Waikato Regional Landfill
Puerto Rico	Salinas - Campo Sur Landfill

Surface and Groundwater Quality Evaluation and Management
and
Municipal Solid & Industrial Hazardous Waste Landfills

http://www.gfredlee.com

Dr. G. Fred Lee and Dr. Anne Jones-Lee have prepared professional papers and reports on the various areas in which they are active in research and consulting including domestic water supply water quality, water and wastewater treatment, water pollution control, and the evaluation and management of the impacts of solid and hazardous wastes. Publications are available in the following areas:

Landfills and Groundwater Quality Protection
Water Quality Evaluation and Management for Wastewater Discharges
Stormwater Runoff, Ambient Waters and Pesticide Water Quality Management Issues, TMDL Development, Water Quality Criteria/Standards Development and Implementation
Impact of Hazardous Chemicals -- Superfund
LEHR Superfund Site Reports to DSCSOC
Lava Cap Mine Superfund Site reports to SYRCL
Smith Canal
Contaminated Sediment -- Aquafund, BPTCP, Sediment Quality Criteria
Domestic Water Supply Water Quality
Excessive Fertilization/Eutrophication, Nutrient Criteria
Reuse of Reclaimed Wastewaters
Watershed Based Water Quality Management Programs:
    Sacramento River Watershed Program
    Delta -- CALFED Program
    Upper Newport Bay Watershed Program
    San Joaquin River Watershed DO and OP Pesticide TMDL Programs
Stormwater Runoff Water Quality Newsletter

G. Fred Lee Advisory Services

G. Fred Lee & Associates was organized in the late 1960s to cover the part-time consulting activities that Dr. Lee undertook while a full-time university professor. In 1989, when Dr. Lee retired from 30 years of graduate-level teaching and research, he and Dr. Anne Jones-Lee, who was also a university professor, expanded G. Fred Lee & Associates into a full-time business activity. Examples of governmental agencies, consulting firms, citizens groups, industries and others for whom G. Fred Lee has served as an advisor include the following:

U.S. Environmental Protection Agency - Various Locations
Vison, Elkins, Searls, Connally & Smith, Attorneys - Houston, TX
International Joint Commission for the Great Lakes
U.S. Public Health Service - Washington, DC
Attorney General, State of Texas - Austin, TX
Madison Metropolitan Sewerage District - Madison, WI
Great Lakes Basin Commission - Windsor, Ontario
U.S. Army Environmental Hygiene Agency - Edgewood Arsenal, MD
City of Madison - Madison, WI
Council on Environmental Quality - Washington, DC
National Academies of Sciences and Engineering - Washington, DC
Water Quality Board State of Texas - Austin, TX
U.S. General Accounting Office - Washington, DC
U.S. Army Corps of Engineers - Vicksburg, MS
Tennessee Valley Authority - Various locations in Tennessee Valley
National Oceanic & Atmospheric Administration - Various locations
Organization for Economic Cooperation & Development - Paris
Attorney General, State of Illinois - Chicago, IL
State of Texas Hazardous Waste Legislative Committee - Austin
State of New Mexico Environmental Improvement Agency - Santa Fe
New York District Corps of Engineers - New York, NY
San Francisco District Corps of Engineers - San Francisco, CA
Wisconsin Electric Power Company - Milwaukee, WI
WAPORA - Washington, DC
Reserve Mining Company - Silver Bay, MN
United Engineers - Philadelphia, PA
Automated Environmental Systems - Long Island, NY
Procter & Gamble Company - Cincinnati, OH
Inland Steel Development Company - Chicago, IL
Kennecott Copper Corporation - Salt Lake City, UT
U.S. Steel Corporation - Pittsburgh, PA
Nekoosa Edwards, Inc. - WI
Zimpro, Inc. - Rothschild, WI
FMC Corporation - Philadelphia, PA
Acme Brick Company - Forth Worth, TX
Monsanto Chemical Company - St. Louis, MO
Gould, Inc. - Cleveland, OH

Illinois Petroleum Council - Chicago, IL
Inland Steel Corporation - Chicago, IL
Industrial Biotest Laboratories - Northbrook, IL
Wisconsin Pulp & Paper Industries - Upper Fox Valley, WI
Thilmany Pulp & Paper Company - Green Bay, WI
Chicago Park District - Chicago, IL
Nalco Chemical Company - Chicago, IL
Boise Cascade Development Company - Chicago, IL
Foley & Lardner, Attorneys - Milwaukee, WI
Timken & Lonsdorf, Attorneys - Wausau, WI
Strasburger, Price, Kelton, Martin & Unis, Attorneys - Dallas, TX
Rooks, Pitts, Fullagar & Poust, Attorneys - Chicago, IL
Jones, Day, Cockley & Reaves, Attorneys - Cleveland, OH
Sullivan, Hanft, Hastings, Fride & O'Brien, Attorneys - Duluth, MN
Hinshaw, Culbertson, Molemann, Hoban & Fuller, Attnys - Chicago, IL
Colorado Springs - Colorado Springs, CO
Mayer, Brown & Platt, Attorneys - Chicago, IL
Pueblo Area Council of Governments - Pueblo, CO
Platte River Power Authority - Fort Collins, CO
Linquist & Vennum, Attorneys - Minneapolis, MN
Norfolk District Corps of Engineers - Norfolk, VA
Spanish Ministry of Public Works - Madrid, Spain
The Netherlands - Rijkswaterstaat - Amsterdam, The Netherlands
U.S. Department of Energy - Various locations in US
King Industries - Norwalk, CT
Attorney General, State of Florida - Tallahassee, FL
State of Colorado Governor's Office - Denver, CO
Cities of Fort Collins, Longmont, and Loveland - CO
E.I. DuPont - Wilmington, DE
Allied Chemical Company - Morristown, NJ
Outboard Marine - Waukegan, IL
Amoco Oil Company - Denver, CO
Appalachian Timber Services - Charleston, WV
Mission Viejo Development - Denver, CO
Fisher, Brown, Huddleston & Gun, Attorneys - Fort Collins, CO
Tom Florczak, Attorney - Colorado Springs, CO
Wastewater Authority - Burlington, VT
Tad Foster, Attorney - Pueblo, CO
Holmes, Roberts & Owen, Attorneys - Denver, CO
Center for Energy and Environment Research - Puerto Rico
City of Brush - Brush, CO
Rock Island District Corps of Engineers - Rock Island, IL
Santo Domingo Water Authority - Dominican Republic
Ministry of Public Works and Environment - Buenos Aires, Argentina
Neville Chemical - Pittsburgh, PA
Fike Chemical Company - Huntington, WV

Stauffer Chemical Company - Richmond, CA
Adolph Coors Company - Golden, CO
Water Research Commission - South Africa
Grinnell Fire Protection Systems - Lubbock, TX
City of Lubbock Parks Department - Lubbock, TX
National Planning Council - Amman, Jordan
City of Olathe - Olathe, KS
City of Lubbock - Lubbock, TX
US AID - Amman, Jordan
Buffalo Springs Lake Improvement Association - Buffalo Springs, TX
Union Carbide Company - Charleston, WV
Canadian River Municipal Water Authority - Lake Meredith, TX
Mobil Chemical Company - Pasadena, TX
Unilever Ltd. - Rotterdam, The Netherlands
Brazos River Authority - Waco, TX
U.S. Army Construction Engineering Research Laboratory - Champaign, IL
James Yoho, Attorney - Danville, IL
Zukowsky, Rogers & Flood, Attorneys - Crystal Lake, IL
State of California Water Resources Control Board - Sacramento
Public Service Electric & Gas - Newark, NJ
Health Officer - Boonton Township, NJ
Scotland & Robeson Counties - Lumberton, NC
International Business Machines Corporation - White Plains, NY
Newark Watershed Conservation & Development Authority - NJ
State of Vermont Planning Agency - Montpelier, VT
CDM, Inc. - Edison, NJ
Attorney General, State of North Carolina - Raleigh, NC
City of Vernon - Vernon, NJ
Ebasco Services - Lyndhurst, NJ
Kraft, Inc. - Northbrook IL, with work in Canada, FL and MN
USSR Academy of Sciences - Moscow, USSR
Tillinghast, Collins & Graham, Attorneys - Providence, RI
City of Richmond, RI
Idarado Mining Company - Telluride, CO
Levy, Angstreich, Attorneys - Cherry Hill, NJ
Newport City Development - Jersey City, NJ
Orbe, Nugent & Collins, Attorneys - Ridgewood, NJ
Schmeltzer, Aptaker & Shepard, Attorneys - Washington, DC
CP Chemical - Sewaren, NJ
Dan Walsh, Attorney - Carson City, NJ
William Cody Kelly - Lake Tahoe, NV
NJ Department of Environmental Protection - Trenton, NJ
Hufstedler, Miller, Kaus & Beardsley, Attorneys - Los Angeles, CA
Main San Gabriel Basin Watermaster - CA
Metropolitan Water District of Southern California - Los Angeles, CA
San Diego Unified Port District - San Diego, CA

Delta Wetlands - CA
Simpson Paper Company - Humboldt County, CA
City of Sacramento - CA
Northern California Legal Services - Sacramento, CA
Rocketdyne - Canoga Park, CA
RR&C Development Co. - City of Industry, CA
American Dental Association - Chicago, IL
Emerald Environmental - Phoenix, AZ
Clayton Chemical Company - Sauget, IL
Stanford Ranch - Rocklin, CA
Public Liaison Committee - Kirkland Lake, Ontario
Miller Brewing Company, Los Angeles, CA
ASARCO Inc., Tacoma, WA
CALAMCO, Stockton, CA
Yunkong Gas Company, South Korea
Sutherlands, Pembroke, Ontario
Silverado Constructors, Irvine, CA
Agricultural Interests in Puerto Rico
City of Winnipeg, Manitoba
Strain Orchards, Colusa, CA
Davis South Campus Superfund Oversight Committee, Davis, CA
Monterrey County, California Housing Authority, Salinas, CA
CROWD, Tacoma, WA
Newport Beach, CA
SOLVE, Phoenix, AZ
Sports Fishing Alliance, San Francisco, CA
Caltrans (California Department of Transportation)
Citizens Group near St. John's, New Brunswick
Colonna Shipyards, Norfolk, VA
Clermont County, OH
Wright County, MN
Waikato River Protection Society, New Zealand
Drobac & Drobac, Attorneys, Santa Cruz, CA
Phelps Dunbar, L.L.P., Houston, TX
Walters Williams & Co, New Zealand
Environmental Protection Department, Hong Kong
NYPRIG New York City, NY
DeltaKeeper, Stockton
City of Stockton, CA
Central Valley Regional Water Quality Board, Sacramento, CA
Carson Harbor Village, Carson, CA
Sanitary District of Hammond, IN
South Bay CARES, Los Angeles, CA
Memphremagog Regional Council, Quebec, CANADA
Mobile, AZ
Pottstown Landfill Closure Committee, Pottstown, PA

Grand Forks County Citizens Coalition, Grand Forks, ND
Sunshine Canyon Landfill, Sylmar, CA
Meriwether County, GA
Hancock County, GA
Louisiana Environmental and Action Network, Baton Rouge, LA
OUTRAGE and POWER, Kankakee, IL
John Cobey et al., Morrow County, OH
Heart of Illinois Sierra Club and Peoria Families Against Toxic Waste, Peoria, IL
Sierra Club of Canada, Cape Breton Group, Nova Scotia
Tulane Environmental Law Center, New Orleans, LA
Backcountry Against Dumps, Boulevard, CA
The Roth Law Firm, Marshall, TX
Citizens group Meriwether, County, GA
North Sacramento Land Company, Sacramento, California
Macuga, Liddle & Durbin Detroit, Michigan
Lozeau & Drury, Alameda, CA
DeWitt County, IL
Concerned Citizens of Thorhild County Alberta, Canada
Wisconsin Fox River Consortium
Minnesota Agricultural Water Resources Coalition
Brisbane Baylands Community Advisory Group

Announcement of American Society of Civil Engineers (ASCE) Election of Dr. G. Fred Lee as ASCE Fellow

In December 2009 Dr. G. Fred Lee was elected as an ASCE Fellow. This election recognizes Dr. Lee five decade career as a national/international leader university graduate level educator and environmental consultant. The ASCE announcement of this election is presented below.

G. FRED LEE, Ph.D., P.E., BCEE, F.ASCE, earned his Master of Science in Public Health from the University of North Carolina in 1957 and his PhD degree in environmental engineering from Harvard University in 1960. For 30 years he served on the graduate civil and environmental engineering/science faculty of several major US universities where he taught, conducted research, mentored the Masters and PhD work of 90 students, published extensively in professional journals, and actively undertook public service for the regulatory, professional, and lay communities.

In 1989 Dr. Lee retired from his academic career to focus on private consulting and public service; he is president of G. Fred Lee & Associates. Areas of emphasis include domestic water supply water quality focusing on how land use in a water supply watershed impacts water supply water quality; investigation and management of surface and groundwater quality, stormwater runoff, contaminated sediments, land surface activities that impact groundwater quality, and use of reclaimed wastewater; and investigation and management of impacts of solid and hazardous chemicals including MSW and hazardous waste landfills, Superfund, and other hazardous chemical sites.

Dr. Lee has served on the editorial boards for several professional publications, and currently serves on the editorial board for the Journals *Stormwater* and *Remediation*. Dr. Lee has long served on the American Academy of Environmental Engineers' (AAEE) examination board for AAEE professional engineer certification; until 2009 he served as Chief Examiner for Northern California in Water Supply and Wastewater and in the Hazardous Waste areas for 20 years.

Dr. Lee has published more than 1100 professional papers and reports many of which are posted on his website [www.gfredlee.com]. In addition, out of the need for greater influence of science and engineering in water quality regulation and management, he created and authors an email-based Stormwater Runoff Water Quality Newsletter which he has distributed about monthly for the past 12 years, at no-cost, to about 8,000 subscribers.

Outstanding ASCE Life Member

Dr. G. Fred Lee — G. Fred Lee & Associates

Dr. Lee has been a full-time consultant through the firm of G. Fred Lee & Associates since 1989 when he moved to El Macero, CA (near Sacramento). This firm specializes in evaluating and managing the impacts of chemicals on water quality, advanced level water supply water quality, water and waste water treatment, water pollution control, and solid and hazardous waste investigation and management. Dr. Lee has established a website, www.gfredlee.com, where he has make available over 600 papers and reports developed from his research and consulting activities. In December 2009, Dr. G. Fred Lee was elected as an ASCE Fellow. This election recognizes Dr. Lee's five-decade career as a national/international leader, university graduate-level educator, and environmental consultant.

From: *The Engineerogram*, ASCE Sacramento Section Newsletter, Volume 72 No. 09, September 2010

SUMMARY RESUME

Anne Jones-Lee, PhD

CONTACT INFORMATION:

27298 East El Macero Drive
El Macero, CA 95618-1005
phone: 530-753-9630
annejlee23@sbcglobal.net

EDUCATION

Ph.D. Environmental Sciences, University of Texas at Dallas, Richardson, TX, 1978. Areas of Specialization: Aquatic Toxicology/Chemistry, Aquatic Biology, Water Quality Evaluation and Management

M.S. Environmental Sciences, University of Texas at Dallas, Richardson, TX, 1975

B.S. Biology, Southern Methodist University, Dallas, TX, 1973

ACADEMIC AND PROFESSIONAL EXPERIENCE

1989 – Present Vice President, G. Fred Lee & Associates
[A list of major project areas in which Dr. Jones-Lee (R. A. Jones) had a leading role is provided at the close of this resume]

2000-2004 Adjunct Research Scientist, California State University, Fresno, CA

1984 - 1989 Associate Professor of Civil and Environmental Engineering (tenured), New Jersey Institute of Technology, Newark, NJ

1988 - 1989 Consulting Engineer, Ebasco-Envirosphere, Lyndhurst, NJ (part-time)

1984 - 1988 Director of Environmental Engineering Laboratories, Department of Civil and Environmental Engineering, NJIT, Newark, NJ

1982 - 1984 Research Associate and Lecturer, Department of Civil Engineering, Texas Tech University, Lubbock, TX

1982 Coordinator for Aquatic Biology, Fluor Engineers Advanced Technology Division, Irvine, CA

1978 - 1981 Research Assistant Professor, Department of Civil Engineering, Colorado State University, Fort Collins, CO

1973 - 1974 Research Technician, Frito-Lay Research and Development Laboratory, Irving, TX

SUMMARY OF PROFESSIONAL REPORTS AND PUBLICATIONS

Published more than 250 professional papers, and co-authored more than 450 reports and occasional papers. Topic areas addressed include:

- Sources, significance, fate, and control of chemical contaminants in fresh water, marine, and estuarine systems
- Environmental impact of various types of wastewater discharges including mining, electric generating station, domestic, and industrial
- Causes and control of eutrophication; groundwater quality; impact of land disposal of municipal and industrial wastes; environmental impact of dredging and dredged sediment disposal; water quality modeling; hazard assessment of new and existing chemicals; water quality criteria and standards; water supply water quality; assessment of actual environmental impact of chemical contaminants on water quality; toxicity of sediments; impact of landfills on environmental quality.

Served as collaborator in essentially all research and consulting projects and publications of Dr. G. Fred Lee since the mid-1970s; many of their publications are available on their website at www.gfredlee.com. A bibliographic listing of papers and reports on which Dr. Jones-Lee (R. A. Jones) was senior author is provided at the close of this resume.

SUMMARY OF PROFESSIONAL PRESENTATIONS

Presented 55 lectures and professional papers at professional society meetings, short courses, universities, public service groups, and national and international conferences.

1983–With Dr. G. F. Lee, presented workshop to South African Water Research Commission on application of OECD eutrophication modeling approach to South African impoundments

1987–With Dr. G. F. Lee, presented one-week workshop for the USSR Academy of Sciences on water quality management programs for Volga River system

AWARDS

Charles B. Dudley Award - American Society for Testing and Materials award for contribution to Hazardous Solid Waste Testing, "Application of Site-Specific Hazard Assessment Testing to Solid Wastes," published (1984).

1986 Best Paper of the Year - American Water Works Association Resources Division award for paper published in the Journal, "Is Hazardous Waste Disposal in Clay Vaults Safe?" (1986)

TEACHING EXPERTISE AND EXPERIENCE

Taught Graduate Courses in

- Microbiological Aspects of Environmental Engineering
- Introductory Chemical Aspects of Environmental Engineering
- Aquatic Toxicology
- Water and Wastewater Analysis
- Introduction to Water and Wastewater Treatment
- Introduction to Environmental Engineering

Faculty Director of Women in Science and Engineering Program (1988)

OTHER PROFESSIONAL ACTIVITIES

Editor of the "Stormwater Runoff Water Quality Newsletter." Past issues available at http://www.gfredlee.com/newsindex.htm

Webmaster for G. Fred Lee and Anne Jones-Lee's website, www.gfredlee.com

EXHIBIT 30

EXHIBIT 30

AFFIDAVIT

STATE OF NEVADA)

) ss

COUNTY OF HUMBOLDT)

Comes now, James F. Reed, your affiant, after having been duly sworn, under pains of penalty of perjury, under the laws of the State of Nevada, truthfully states the following:

1) That your affiant gives and makes this affidavit in connection with establishing standing to appeal by the Clean Desert Foundation, Inc. (CDF) to appeal the issuance of an operating permit to operate the Jungo Landfill by Recology which is pending before the Nevada State Environmental Commission (SEC) under permit No. SW495REV00.
2) Your affiant is a member in good standing and an officer of CDF.
3) CDF is a Nevada non-profit corporation organized to educate the public and governmental entities about the beauty of the high desert and how policies and programs threaten said beauty. CDF also may bring legal action to further the goals and purposes of the organization.
4) Affiant knows where the proposed landfill site is and has used the public and private land in, near and on the actual landfill site for recreation for over almost twenty years, on more occasions that can be remembered but in excess of fifty times.
5) Affiant truly believes that the issuance of the permit will directly injure CDF, and also result in imminent harm to its present and future members, including your affiant as a current member by, among other things, the constant noise from the delivery of waste via train, and the noise from the heavy equipment on site, and the offensive odors, and increase in number of rodents to the site.
6) Said past and future recreational activities include and/or will include, hiking, rock collecting, photography, animal watching, flower and plant inspection/observation, camping, star gazing and the general use and enjoyment of Desert Valley proper and in and around the landfill site.
7) This affidavit is made freely, voluntarily and without coercion or for compensation.

James F Reed

James F. Reed

Sworn to before me this 17th day of April, 2012.

Eva J-Sanchez

Notary Public

EVA J. SANCHEZ
Notary Public - State of Nevada
Appointment Recorded in Humboldt County
No: 07-4531-9 - Expires August 1, 2015

EXHIBIT 31

EXHIBIT 31

AFFIDAVIT

STATE OF NEVADA)
) ss
COUNTY OF HUMBOLDT)

Comes now, Massey K. Mayo, your affiant, after having been duly sworn, under pains of penalty of perjury, under the laws of the State of Nevada, truthfully states the following:

1) That your affiant gives and makes this affidavit in connection with establishing standing to appeal by the Clean Desert Foundation, Inc. (CDF) to appeal the issuance of an operating permit to operate the Jungo Landfill by Recology which is pending before the Nevada State Environmental Commission (SEC) under permit No. SW495REV00.
2) Your affiant is a member in good standing of CDF.
3) CDF is a Nevada non-profit corporation organized to educate the public and governmental entities about the beauty of the high desert and how policies and programs threaten said beauty. CDF also may bring legal action to further the goals and purposes of the organization.
4) Affiant was raised in Winnemucca, Nevada and knows where the proposed landfill site is and has used the public and private land in, near, and on the actual landfill site for recreation for over twenty years, on more occasions that can be remembered but in the last few years in excess of fifteen times.
5) Affiant truly believes that the issuance of the permit will directly injure CDF, and cause imminent harm to its present and future members, including your affiant by, among other things, the constant noise from the delivery of waste via train, and the noise from the heavy equipment on site, and the offensive odors, and increase in number of rodents to the site, and the overall degradation to the Nevada desert and beauty of said area.
6) Said past and future recreational activities include and/or will include, hiking, rock collecting, camping, star gazing and the general use and enjoyment of Desert Valley proper and in and around the landfill site.
7) This affidavit is made freely, voluntarily and without coercion or for compensation.

Massey K. Mayo
____
Massey K. Mayo

Sworn to before me this 17th day of April, 2012.

Eva J. Sanchez
____
Notary Public

EVA J. SANCHEZ
Notary Public - State of Nevada
Appointment Recorded in Humboldt County
No: 07-4531-9 - Expires August 1, 2015

CERTIFICATE OF SERVICE

I hereby certify that on this 17th day of April, 2012, I have deposited in the U.S. Mail in a properly addressed and stamped envelope a true and correct copy of the CDF opening brief on appeal, addressed to the following:

John Frankovich, Esq.
Debbie Leonard, Esq.
McDonald Carano Wilson
100 W. Liberty St., 10th Floor
Reno, Nevada 89501

Office of Attorney General
Attn: Cassandra Joseph
100 N. Carson St.
Carson City, NV 89701

Richard Cook
4320 Paradise Ranchos Drive
Winnemucca, NV 89445

Tammy Bendell