1.0 INTRODUCTION

This annual report, prepared by Nye County Nuclear Waste Repository Project Office, summarizes the activities that were performed during the period from May 1, 1997 to April 30, 1998 under a grant (*DE-FG08-96NV12027*) from U.S. Department of Energy (DOE). These activities were conducted in support of the Independent Scientific Investigation Program (ISIP) of Nye County at the Yucca Mountain Site (YMS). The goal of the grant from the DOE is to provide opportunity for Nye County to conduct independent research and evaluate the potential impact of planned activities by DOE on the health and safety of the county residents and workers as well as on the environment and resources of the county.

The Nye County NWRPO is responsible for protecting the health and safety of the Nye County residents. NWRPO's on-site representative is responsible for designing and implementing the Independent Scientific Investigation Program (ISIP). Major objectives of the ISIP include:

- Investigating key issues related to conceptual design and performance of the repository that can have major impact on human health, safety, and the environment.
- Identifying areas not being addressed adequately by DOE

Nye County has identified several key scientific issues of concern that may affect repository design and performance, which initially were not being adequately addressed by DOE. Nye County has been conducting its own independent study to evaluate the significance of these issues. Many interactions with the Yucca Mountain Project scientists and engineers have proven beneficial in conveying Nye County's concern in these issues. DOE has been very responsive in addressing these issues and Nye County believes that such interactions and responses will lead to improved protection of the health and safety of the county

residents and workers as well as enhanced protection of the county's environment and resources.

The reader is referred to previous reports (NWRPO, 1995; Multimedia Environmental Technology, Inc., 1995 and 1997) for detailed explanation of these specific concerns.

1.1 SCOPE

This report summarizes the results of geologic and hydrologic research conducted in two boreholes, the Exploratory Studies Facility (ESF) tunnel, and the Enhanced Characterization of the Repository Block (ECRB) drift. UE-25 ONC#1 borehole was drilled in December of 1995. UE-25 ONC#1 and an existing borehole (USW NRG4) were instrumented by Nye County during March and April of 1996. Characterization of the cuttings from UE-25 ONC#1 and monitoring and pneumatic testing of both boreholes are ongoing and preliminary results are presented in this report. Petrographic and geochemical analyses of the cuttings from UE-25 ONC#1 are presented in Sections 2.0 and 5.1 respectively. Pneumatic testing, monitoring and sampling of the boreholes are discussed in Sections 4.0, 5.2 and 6.0. The Regional Hydrogeology of the area surrounding Yucca Mountain is presented in Section 3.0. A discussion of the ESF and ECRB tunnel monitoring activities can be found in Section 7.0. Section 8.0 contains a discussion concerning alternative repository design. Sections 9.0 and 10.0 summarize Nye County's ongoing activities concerning the development and management of a hydrogeologic database and associated GIS files. Finally, Section 11.0 is concerned with the re-establishment and maintenance of Nye County's documented Quality Assurance Program. The preliminary data and interpretations presented in this report do not constitute and should not be considered as the official position of Nye County.

1.2 NYE COUNTY'S BOREHOLE AND TUNNEL MONITORING STUDIES

The ISIP presently includes drilling new boreholes, instrumenting new and existing boreholes, analyzing the geology and geochemistry of drill cuttings, instrumenting tunnels and drifts, monitoring, data analysis, and numerical modeling activities to address the concerns of Nye County.

Figure 1-1 shows the regional setting of the Yucca Mountain. To investigate uncertainties in how water moves from the land surface to the water table and how it moves in the water table, Nye County is conducting extensive tests at drill hole UE-25 ONC#1. Nye County has installed and is currently monitoring pressure and temperature instruments in boreholes UE-25 ONC#1 and USW NRG4 (Figure 1-2) to evaluate the long-term pneumatic conditions at strategic depths in the subsurface both in response to fluctuations in atmospheric conditions and in response to other possible disturbances resulting from site characterization activities such as the ESF tunnel and ECRB drift construction. Nye County has also installed instruments to measure temperature, pressure, humidity and wind speed within the ESF tunnel and ECRB drift to characterize the air being used to ventilate the tunnel which could potentially impact the performance of the repository. Additionally, Nye County has collected gas samples from the vadose zone in UE-25 ONC#1 at three separate occasions to establish background conditions and to evaluate changes in the chemical composition of the gases. Changes in the chemical compositions of the gases in the vadose zone with time may be used to evaluate the impact of the ESF construction and obtain transport properties of the rock mass at the site. Finally, Nye County is conducting numerical simulations to evaluate factors (including tunnel ventilation) which affect both short-term and long-term pneumatic and moisture conditions in the repository host rock.

1.3 OTHER ACTIVITIES

Nye County has also been evaluating new critical data and information as it becomes available from the DOE's Yucca Mountain Project studies. In the past year, Nye County has observed water usage in the tunnel and its potential impact on the repository horizon and the scientific investigation results. The interpretation of the results of the ^{36}Cl and other environmental and geological isotope studies such as ^{14}C, ^{13}C, and ^{3}H have been the focus of many meetings attended by Nye County which has resulted in several letter reports to DOE during the past year. Some of these communications have resulted in DOE's increased attention, focusing on some of the issues raised by Nye County. Specifically, these issues related to the need for more detailed studies in the ESF tunnel, limiting the use of construction water, and enhanced interpretation of the results of the isotope sampling.

Nye County evaluated procedures and methods used by DOE to conduct air-permeability tests in the unsaturated zone of YMS. As a result of several interactions between Nye County and DOE, satisfactory procedures were developed and used by DOE in more recent testing efforts. The results of these tests were analyzed and reported (Advance Resources International, 1995).

Water resources of the county are one of its most important assets. Nye County has been conducting research as to the potential impact of the construction and operation of the Yucca Mountain Repository on its water resources. As part of this task, a regional model of the Death Valley Hydrologic Basin has been developed and is undergoing refinement. As a result of these efforts, Nye County has identified data gaps in the regional hydrologic system and specific to the Yucca Mountain Site (YMS).

1.4 PROPOSED FUTURE INVESTIGATIONS

Nye County is planning to perform several investigations in the near future to clear some of the issues that were outlined above by installing new wells in both the saturated and unsaturated zones, testing and sampling these wells, and performing data analysis and modeling. These issues are related to the steep gradients in the saturated zone north and west of the site, the potential for dilution in the saturated zone as unsaturated zone moisture enters the saturated zone, the need for hydrogeologic data in Amargosa Valley downgradient from the YMS, compilation of geologic and geophysical data related to deep aquifers in the vicinity of the YMS, the atmospheric and pneumatic boundaries in the Solitario Canyon that might impact the repository performance, the merits of a naturally-ventilated repository, and the large-scale transport properties of the fractured formations in both saturated and unsaturated zones.

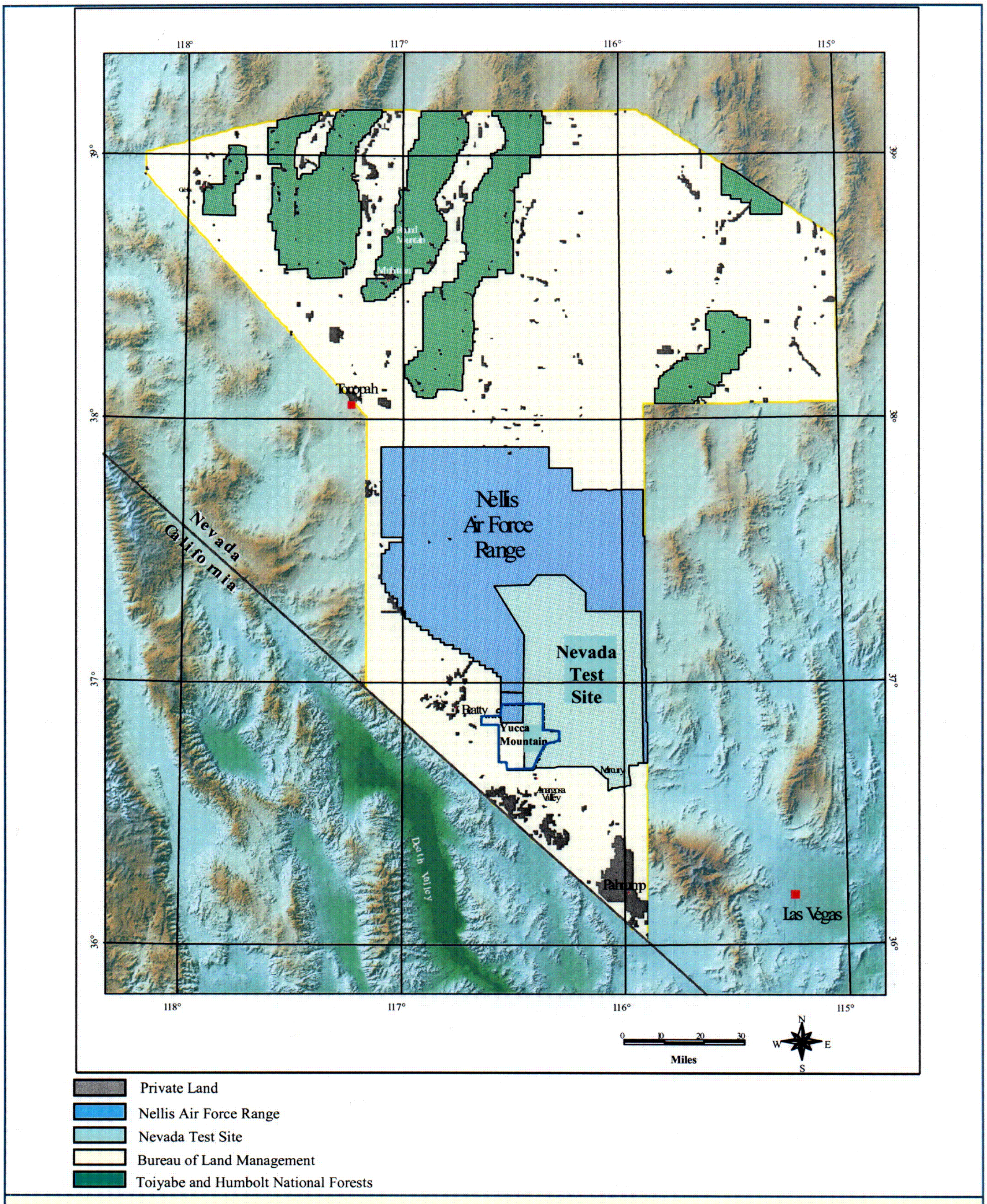


Figure 1-1 Location of Yucca Mountain Site in Nye County, Nevada.

C-01

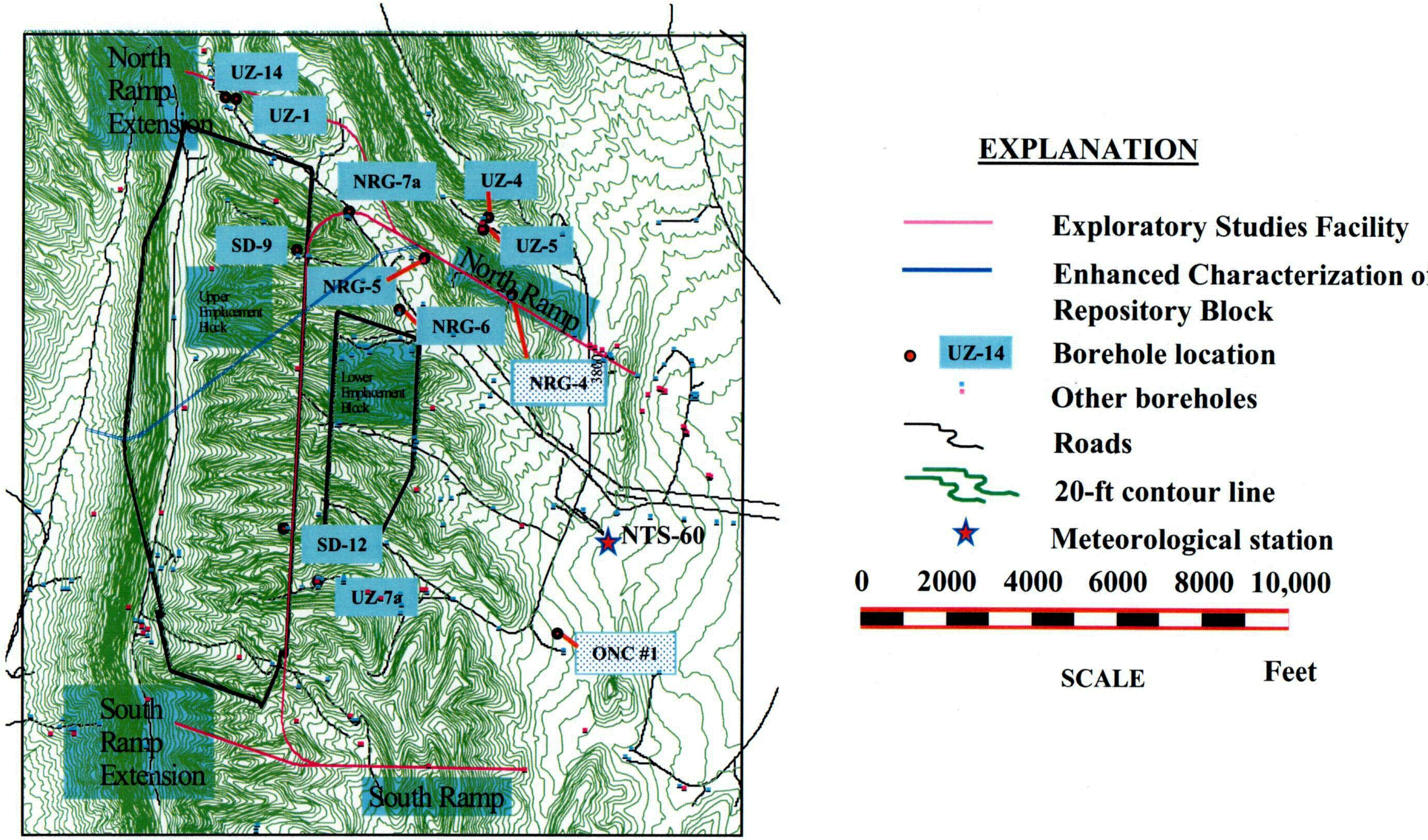


Figure 1-2 Topography, location of selected boreholes, ESF centerline, and ECRB at Yucca Mountain Site.

C-02

2.0 PETROGRAPHIC STUDIES OF UE-25 ONC#1

2.1 INTRODUCTION

The mechanics of water movement through the fractured volcanic aquifers at Yucca Mountain is an important consideration in assessing the performance of a repository at this site. To reduce the uncertainties in how water moves from the land surface to the water table and how it moves in the water table, Nye County is conducting extensive tests at drill hole UE-25 ONC#1. These tests include detailed petrographic studies, chemical tests, and well tests. In this section, the results obtained to date from the petrographic studies are presented and discussed.

In a fracture dominated flow system like Yucca Mountain, the pore characteristics and fracture characteristics govern the rates of groundwater flow and transport of radionuclides. With respect to the pore spaces, the contrast in pore space in different volcanic units and the effects of mineralization of the pore spaces can result in considerable variation. For fractures, the number of fractures present, their connectivities, apertures, and degree of fracture filling can have a pronounced affect on the flow of groundwater. One of the methods Nye County is using to investigate the volcanic rock properties are scanning electron microscopic studies of the actual pores and mineral deposits. These studies are focused on defining the pore and fracture characteristics at UE-25 ONC#1. The results will be used in conjunction with the geochemical and well testing to provide the data needed to support analytical or numerical models of flow and transport processes.

2.2 PURPOSE OF ACTIVITY

Analysis of cuttings from drill hole UE-25 ONC#1 are focused on the petrographic characterization of past and present fluid pathways that support transport from the ground surface through the vadose and saturated zones. The ultimate goal of this study is to acquire a comprehensive understanding of the

fluid pathways and therefore the stratigraphic distribution and interconnectivity of fracture conduits and matrix pore space through time at the UE-25 ONC#1 location. The spatial attributes of the pathway system impart a significant knowledge concerning the rate of fluid transport in the system. This understanding includes the characterization of the authigenic mineral history associated with the transport pathways for two distinct purposes: 1) the study of porosity changes as the filling and opening of pore and fracture space is controlled by dissolution and authigenic mineralization; and 2) the study of the potential for radionuclide retardation due to presence of authigenic products in and along these pathways.

2.3 METHODOLOGY

Nye County's studies have utilized standard petrographic microscope examination of petrographic thin sections and polished mounts of drill hole cutting samples. In addition to these activities, we examined cutting samples by cathodoluminescence on the scanning electron microscope (Dave Krinsley at University of Oregon, Department of Geology). To the County's knowledge, there are no other cathodoluminescence studies for Yucca Mountain samples. This technique provides us with a unique ability to study paleo-authigenic mineralization events with respect to fluid pathways.

2.4 SUMMARY OF FINDINGS

Nye County's petrographic studies have concentrated on welded and poorly welded tuffs, and for the most part, have excluded non-welded tuffs due to drill hole cuttings availability. Consequently, non-welded tuff samples must be obtained through other field situations. For welded and poorly welded tuffs in UE-25 ONC#1, the dominant mode of fluid transport in the past and in the present is by fracture flow. Transport by matrix porosity had been more dominant in the past than in the present due to the pore filling of authigenic minerals in the past under

active matrix transport conditions. The findings are summarized in the following topic areas:

1. Authigenic mineralization (neomineralization)

   The authigenic minerals recognized as either fracture filling or matrix pore filling material are as follows:

   a. quartz

   b. opal-CT

   c. zeolites dominated by clinoptilolite-heulandite

   d. clays

   e. manganese oxyhydroxides

   f. iron oxyhydroxides

   g. calcium carbonate (calcite among other minerals)

2. Dissolution (as a function of present and past transport)

   Dissolution of feldspar, cristobalite and tridymite in addition to any matrix glass that was not reorganized during devitrification occurs where previous porosity, either as matrix pore space or as fracture conduits, have supported fluid transport. Dissolution occurs along fracture walls in bleached zones. Neomineralization occurs within these zones generally utilizing material mobilized during dissolution. There is a net change in both mineral species and porosity associated with these reactions. In addition there is a net change in overall volume.

3. Classification of fluid pathways

   a. Open fracture pathways in welded and poorly welded tuffs.

b. Open fracture pathway in non-welded tuffs.

c. Open matrix pore space in welded and poorly welded tuffs. Pore space formed during devitrification events.

d. Open matrix pore space in non-welded tuffs. Pore space formed during devitrification events.

e. Open matrix pore space in welded and poorly welded tuffs. Pore space formed during authigenic mineralization due to past fluid transport events.

f. Open matrix pore space in non-welded tuffs. Pore space formed during authigenic mineralization due to past fluid transport events.

g. Open matrix pore space in welded and poorly welded tuff fracture bleach zones. Pore space formed during authigenic mineralization and tuff dissolution of fracture walls during past transport events.

h. Closed fracture pathways due to authigenic mineralization as a function of past transport events. For welded, poorly welded and non-welded tuffs.

i. Closed matrix pore space due to authigenic mineralization as a function of past transport events. For welded, poorly welded and non-welded tuffs.

j. Pathways that combine one or more of the above situations.

4. Characterization of past fracture filling and opening events

Thus far we have only been able to recognize fracture filling, refracturing, and refilling sequential events in fractures that have been initially filled with quartz. This is likely an artifact of the analytical procedure, which allows us to investigate quartz, opal and calcite by cathodoluminescence,

but does not support the analysis of oxyhydroxide phases. Nye County has not encountered much calcite fracture and pore filling material in the drill hole studied.

5. Identification of pore space formed as a function of neo-mineralization

   Zeolitic morphologies favor the formation of pore space at the boundaries between crystal faces. In many cases this pore space is interconnected, and in some cases, the matrix pore space is associated with fracture conduits, so that there is continuity between fracture flow and zeolitic pore space within the matrix. What has been quite obvious though, is that the zeolitic pore space in welded tuffs is local and not interconnected to other matrix pore space.

6. Interactions between matrix pore space and fracture conduits

   There are several situations where we can observe the interconnectivity of matrix pore space with fractures:

   a. Interconnectivity of matrix pore space in the fracture walls of bleach zones with the centralized aperture opening of the fracture itself; and

   b. Interconnectivity as local inter-crystal zeolite pore space tied to fracture conduits. Fracture conduits are apparently responsible for the transport of reacting fluids to the localized zones that once held glass. This glass has since undergone dissolution as a function of fracture transport of fluids. The precipitation of zeolites dominated by clinoptilolite-heulandite is a function of the ionic components and the stability of these phases after glass dissolution.

7. Fracture bleached zones and their relevance to:

   a. Past conditions

1. Fluid transport by fracture flow has dominated the paleo-transport environment in these areas.

2. Fluid transport was responsible for matrix dissolution within the fracture walls.

3. Authigenic mineralization occurred within these higher porosity zones in response to mobilized ionic species made available by dissolution reactions.

b. Potential retardation by sorption along fracture conduits

1. Bleached zones are dominated by quartz, opal-CT, zeolites (clinoptilolite-heulandite), clay and some manganese oxyhydroxides. The zeolites, clays and manganese oxyhydroxides have the potential to provide radionuclide sorption.

2. Since these authigenic mineral suits occur within the matrix walls of the fractures and are connected to the fracture by matrix porosity, they have all of the prerequisites necessary for providing sorption. This includes access to the transporting fluids. The residence time of fluid within the bleached zone has not been investigated relative to the rate of transport in the open fracture.

3. The bleached zones can be as much as 500 microns thick on either side of a fracture whose original aperture is generally less than a millimeter. Consequently, the bleached zone provides extensive porosity beyond that which is provided by the fracture itself.

c. Spatial distribution of present conductivity

Bleached zones occur in fractures that have been actively transporting fluids. These functioning pathways are tied into the overall transporting fracture flow network, and are therefore part of the main transporting pathway system.

8. Unanswered questions

   a. How does the effective porosity at this location (UE-25 ONC#1) differ from other drill hole locations at Yucca Mountain?

   b. How do the pathways change at the stratigraphic boundaries between welded and non-welded tuffs? In other words, what does the authigenic mineralogy show, and what do the interconnectivities look like (for matrix pore space and fracture conduits), at the boundaries of these rock types?

   c. From authigenic mineralogy past-events-data along fluid pathways, what are the likely porosity and fracture changes that might occur if: 1) conditions remain the same; 2) temperatures are elevated to repository conditions; 3) if there was a net evaporation of water vapor in the near-field; 4) if there is a climate change to wetter conditions?

3.0 REGIONAL HYDROGEOLOGY

This section presents an overview of Nye County's Fiscal Year 1998 activities related to the hydrogeologic conditions of the region surrounding Yucca Mountain. A thorough understanding of the groundwater conditions of the region is a prerequisite to accurately predicting the long-term performance and impacts of siting a high-level waste repository at Yucca Mountain. Nye County is particularly interested in the losses and damages that have already occurred to the water resources of the region and the additive losses that might result from impacts associated with the location of a repository at Yucca Mountain.

In the Department of Energy's evaluations of the regional groundwater conditions, an emphasis has been placed on the use of numerical models that simulate the hydrologic processes at work so groundwater flow paths and travel times can be predicted. These models are then used to determine the migration of contaminants from pollution sources such as the underground nuclear testing areas on the Nevada Test Site and Yucca Mountain.

Nye County recognizes the need for these modeling efforts and believes that a well-calibrated flow model of the region would provide a powerful tool for use in water resources planning and management. The "ideal" model would provide an accurate predictive capability for managing the County's water development over the coming decades. Such a model would be able to accurately simulate the presence of existing and future contaminant sources and the locations and durations of groundwater withdrawals. The results of models that have been completed to date, while encouraging, indicate that there is still considerable uncertainty and that further refinement is needed before regional groundwater models can provide such tools. However, Nye County recognizes that there should be a balance between the amount of effort placed in development of the groundwater models and the in-situ data needed to support the models. Groundwater models should initially be used as a guiding tool for collecting data.

Results of data-collection activities should be used to update the models on a regular basis. The usefulness of the models is primarily dictated by the adequacy and quality of the data.

3.1 EVALUATION OF YUCCA MOUNTAIN WATER SUPPLY AND DEMAND ISSUES

In planning for future water demands, Nye County, Nevada is faced with a formidable task. As a result of national demographic trends, Nye County is one of the fastest growing areas in the United States, yet the county is faced with ever diminishing water supplies. Population forecasts that have been made by the county and the state both indicate that rapid growth will continue over the next half-century or more. Meeting the demand for future water supplies is a top priority for the county. Careful evaluations and planning must be done to determine how the proposed repository at Yucca Mountain may affect, or be affected by, future water developments within the region.

Nye County is also the situs county for a number of other facilities. The facilities include the underground nuclear testing areas on the Nevada Test Site, Department of Defense installations and ranges, hazardous and radioactive wastes disposal facilities, an important National Monument, National Forests, and National Wildlife areas. Large areas of Nye County have already suffered the irrevocable and irretrievable loss of natural resources and reduced water resource availability as a result of the presence of these facilities. Careful evaluations must be done to determine the additive losses that will occur should the proposed repository at Yucca Mountain become a reality.

In this section, an overview is presented of Nye County's Fiscal Year 1998 activities related to water supply and demand, land use, and other environmental issues. Nye County's efforts on these issues can be broadly categorized into three areas:

1. Definition and evaluation of water supply and demand issues
2. Regional groundwater modeling
3. Evaluations of the Total System Performance Assessment, Viability Assessment, and the Environmental Impact Statement for the Yucca Mountain Project.

Another task involves the acquisition, synthesis, analysis, and dissemination of the data needed in conducting studies related to these three areas.

3.1.1 DEFINITION AND EVALUATION OF NYE COUNTY'S WATER SUPPLY AND DEMAND ISSUES

In this section, the key issues related to the changing patterns of water supplies in southern Nevada are defined and discussed along with the impacts and constraints imposed by Yucca Mountain on the development of those water supplies. The three key issues related to Yucca Mountain from a water supply point of view are: 1) the protection of the county's drinking water supplies and wildlife habitats; 2) future water availability; and 3) the cumulative impacts of federal actions on water resources.

3.1.1.1 PROTECTION OF DRINKING WATER SUPPLIES AND WILDLIFE HABITATS

Protection of drinking water supplies is, of course, essential to Nye County and is required under the provisions of the Safe Drinking Water Act. Unless remedied, the existing groundwater contamination at the Nevada Test Site and elsewhere in the county poses a significant constraint on the development of new water supplies. It is incumbent upon Nye County to protect the remaining water resources from further contamination. Past actions have polluted the water resources up gradient of populated areas and future pollution of the water resources has been predicted. Actions which will result in the loss of additional

water resources through contamination must be taken into account in long-term water planning.

Additional constraints on water supply development are imposed by the environmentally sensitive areas at Devils Hole and Ash Meadows where endangered species habitats must be maintained. Federal laws require protection of these areas. Protection afforded to these areas further limits the water resources that are available. A large area of the Amargosa Desert hydrographic basin cannot be considered as a source of water because of concerns related to the continued maintenance of the habitat that supports these species. The continued preservation of these environmentally sensitive areas is also incumbent upon Nye County. It should be noted, however, that such preservation is not without cost to the county. In addition to the effective loss of natural resources for other purposes, socioeconomic impacts have already been demonstrated in employment and productivity.

3.1.1.2 WATER USE TRENDS AND FUTURE WATER AVAILABILITY

In 1996, Nye County completed a baseline water supply and demand study of the southern portion of the county. This study included evaluations of the communities of Beatty, Amargosa Valley, and Pahrump. The study concluded that water supplies are expected to be adequate to meet projected demands in Beatty and Amargosa Valley through the year 2050 but that the available supplies are not adequate to meet the projected growth in Pahrump. However, the study also pointed to the fallibility of predicting growth and noted that Amargosa Valley could begin to experience water supply shortfalls in the Amargosa Desert hydrographic basin prior to that time.

Groundwater withdrawals in Pahrump Valley have exceeded the perennial yield of 19,000 acre feet every year since at least 1983. In 1996 withdrawals of groundwater from Pahrump Valley were just under 27,000 acre feet. In 1997

almost 29,000 acre feet of groundwater were pumped from the alluvial aquifer in Pahrump, according to the records of the Nevada Division of Water Resources. This 1997 extraction rate represents a 7 percent increase from 1996. The 1997 pumping rate was well ahead of the most recent projections made by Nye County (Buqo, 1996). These projections predicted that groundwater use would not exceed 28,000 acre feet per year until the year 2010. The phenomenal growth of the community of Pahrump is fueling an ever-increasing demand for the limited available water resources. In Fiscal Year 1999, the County will reevaluate their projections based upon the latest water use inventory and growth trends in Pahrump.

Nye County has identified five alternatives for meeting future water demands in Pahrump Valley:

1. A managed overdraft of the basin;
2. Development of the carbonate aquifer that underlies the basin;
3. Importation of water from other basins;
4. Administrative actions; and
5. A combination of any of these alternatives.

The first three options (and the fifth) could potentially be affected by, or affect, the performance of a repository at Yucca Mountain. Thus, these options warrant further consideration.

3.1.1.2.1 MANAGED OVERDRAFT

The effects of an overdraft in Pahrump Basin over recent decades has been well documented. The observed effects of the overdraft in the late 1960s through 1975 included water level declines of as much as 60 feet in areas of large water withdrawals and the elimination of spring discharges at two springs. As a result

of the elimination of these springs, the natural habitat for three subspecies of the Pahrump Killifish was lost.

These observed effects occurred at a time when water withdrawals in Pahrump Valley exceeded 30,000 acre feet. (Water withdrawals peaked at 47,100 acre feet in 1968). The effects of extracting significantly higher volumes of water, estimated at 84,000 acre feet by the year 2050, have not been evaluated. However, the results of other models of the region suggest that the impacts of a long-term overdraft in Pahrump Valley could reach considerable distances, including the Yucca Mountain area.

To evaluate the plausibility and magnitude of such impacts, the potential areas where hydraulic connections between Pahrump Valley and the basins that border it (Amargosa Desert, Las Vegas Valley, Mercury Valley, Three Lakes Valley South, and Sandy Valley in Nevada and Mesquite Valley, Chicago Valley, California Valley, and Amargosa Desert in California) are being evaluated by Nye County. The areas of most concern with respect to Yucca Mountain, are Stewart Valley, Amargosa Flat, and the area along Highway 95 between Mt. Montgomery and Mt. Sterling. Preliminary evaluations suggest that there may be hydraulic communication between Pahrump Valley and other basins in these areas. Long-term stresses on the aquifer system in Pahrump Valley could result in effects beyond the basin boundaries through these areas. More detailed evaluations are needed to determine if such effects would be of concern with respect to Yucca Mountain.

A first step in addressing the relationship between water withdrawals in Pahrump Valley and water level declines is establishing a comprehensive baseline of information on water wells, water level measurements, water withdrawals, and other related data. Nye County has compiled and is evaluating the water well, water rights, water use, and water level data available from the U.S. Geological Survey and the Nevada Division of Water Resources. In total, these records provide basic hydrologic data for the more than 7,200 wells that have been drilled

in the Nevada portion of the basin, the major areas of withdrawals, and the quantity of those withdrawals. These data sets are presented in the accompanying media. Based upon the data sets for Pahrump Valley, Nye County prepared large scale maps that show the distribution of wells and water level variations between 1944 and 1997 for each developed section of land within the basin. Nye County is further analyzing these data sets to determine the responses of the water table to historic water withdrawals. These analyses will be used in evaluations of the hydraulic communication between basins, leakance between aquifer systems, and the long-term effects of an overdraft in Pahrump Valley.

3.1.1.2.2 CARBONATE AQUIFER DEVELOPMENT

The development of the carbonate aquifer in Pahrump Valley also has the potential to be impacted by, or impact Yucca Mountain. The impacts of large-scale water withdrawals from the carbonate aquifer have not been well defined but the results of some models and long-term aquifer tests suggest that the effects will be widespread. Careful planning of any water withdrawals from this aquifer will be needed to prevent the spread of contamination or adverse impacts on sensitive habitats.

Nye County has conducted preliminary discussions with the Nevada State Engineer concerning the potential for development of the carbonate aquifer in southern Pahrump Valley. Based upon the results of a U.S. Geological Survey evaluation, groundwater pumping from the alluvial aquifer in the community of Pahrump only captures a negligible quantity of water from the carbonate aquifer. A redistribution of water withdrawals from the alluvial aquifer to the carbonate aquifer might be used to mitigate, in part, the impacts of a long-term overdraft of the basin. Alternatively, water could be withdrawn from the carbonate aquifer in the undeveloped portions of Pahrump and injected into the alluvial aquifer in areas where the alluvial aquifer is being over-drafted. This approach could be

used to mitigate the adverse impacts of over-pumping the alluvial aquifer in the populated areas. However, the quantity of water that could be managed in this method is limited, estimated at 19,000 acre feet per year.

Nye County has discussed the potential for carbonate aquifer development with the Nevada State Engineer. Based upon these discussions, it was concluded that such an approach could only be used if existing water rights from the alluvial aquifer in Pahrump were obtained and transferred to the carbonate aquifer; i.e., no new water rights will be permitted for groundwater withdrawals from the carbonate aquifer. The estimated 19,000 acre feet per year of groundwater that could be "captured" in this manner are inadequate to meet the projected long-term demand in Pahrump. Therefore, it is considered likely that groundwater will ultimately have to be imported to Pahrump from other basins within the Death Valley flow system unless water can be obtained from an external source.

3.1.1.2.3 INTERBASIN TRANSFERS OF WATER

Nye County is hardly the first area in the desert southwest to experience water shortfalls. In recent decades, the use of interbasin transfers of water has become an accepted technique for meeting the demand for water in urbanized basins. In this approach, water supplies are developed in "water rich" but largely unpopulated basins and conveyed to the "water poor" basins where cities are located. Prime historic examples of this approach include the development of water resources in Owens Valley, California by the Los Angeles Department of Water and Power and the transfer of water from Avra Valley, Arizona to augment groundwater short falls in metropolitan Tucson.

In southern Nevada, interbasin transfers of water have been limited but large-scale transfers of this type have been considered in the past and some are still actively under consideration. In the early 1970s, the potential for transferring water from Amargosa Valley to metropolitan Las Vegas was considered. In the late 1970s and

early 1980s the U.S. Air Force proposed large-scale interbasin transfers to provide water supplies for the proposed MX Missile System racetrack deployment in Nevada and Utah. In the late 1980s, the Las Vegas Valley Water District filed massive water right applications in a number of basins in eastern and central Nevada with the intent of transferring water from the rural areas of Nevada to Las Vegas. This proposal is still under consideration by the Southern Nevada Water Authority but has been "placed on the back burner" while the authority attempts to obtain greater shares of the Colorado River water stored in Lake Mead.

Existing interbasin transfers convey water from the carbonate and alluvial aquifers in the Muddy Springs Area hydrographic basin for power generation at Nevada Power Company's Hidden Valley generating station and for public drinking water supplies in Logandale and Overton. Recent water right filings in this region have been made for power generation and quasi-municipal purposes that could significantly increase the quantities of groundwater being managed through basin transfers.

Given the magnitude of projected water shortfalls in Pahrump Valley by the year 2050, the development of water in other basins for conveyance to Pahrump seems (on the surface at least) to be feasible. If groundwater is to be developed beyond the limits of Pahrump Valley, the closest basins with unappropriated groundwater are Mercury Valley, Rock Valley, and Jackass Flats. Unappropriated groundwater is present in each of these basins and the results of historic water developments in these basins suggest that there are areas where productive water supply wells could be located. As portions of Mercury Valley may be hydraulically up gradient of Devils Hole and the wetland areas at Ash Meadows, it is likely that any future water withdrawals would have to be limited. Such constraints have not been identified for Rock Valley or Jackass Flats.

The combined perennial yields of Mercury Valley, Rock Valley, and Jackass Flats are 20,000 acre feet per year. It is important to note however, that these perennial yields are not based upon the recharge derived over the basins, but rather on

subsurface flow through each of the basins. If it is assumed that the entire perennial yields of these three basins could be captured and transferred to Pahrump, then the projected shortfall in water availability in Pahrump in the year 2050 could be reduced from 65,000 acre feet to 45,000 acre feet. The remaining shortfall could be addressed through managed overdrafts of the three basins or by importing water from more distant basins or from sources beyond the boundaries of Nye County.

Nye County recognizes that there are a myriad of issues associated with interbasin transfers of water in this manner. Careful evaluations are needed to identify source areas and to determine the impacts of implementing such an approach. However, given the overall water supply situation in southern Nevada, transfers of water between basins may be the only internal source of water available to the county.

3.1.1.2.4 METHODS

The methods used in identifying the water supply and demand issues related to Nye County and Yucca Mountain included the review of literature and program documents germane to the topic and both formal and informal discussions with a number of agencies and the public. Nye County has consulted with the Nevada State Engineer, the Nevada State Water Planner, the Pahrump Regional Planning Commission, and Inyo County, California. Discussions have been held with the U.S. Department of Energy, the U.S. Department of Defense, the National Park Service, the U.S. Fish and Wildlife Service, the U.S. Department of Justice, farm representatives from Amargosa Valley, and interested parties and individuals from the general public.

In April 1998, Nye County hosted the Devil's Hole Workshop. A half-day field trip to Nye County's well UE-25 ONC#1 was made to introduce participants to the County's important data collection activities at this monitoring site. The workshop also included a full day of formal presentations. These presentations

were invited from farm organization representatives from Amargosa Valley, the Nevada State Engineer and State Planner, the National Park Service, the U.S. Department of Justice, the U.S. Geological Survey, and U.S. Department of Energy contractors. The focus of the workshop presentations was on water issues in southern Nye County. Nye County presented the preliminary results of their modeling efforts and the specific issue of preservation of the sensitive habitats at Devil's Hole and Ash Meadows in light of the projected water supply shortfalls for the southern part of the county. The workshop was well attended with more than 85 participants. The 1998 Devil's Hole Workshop provided an important venue for the sharing of ideas between many of the groups involved in planning and use of the water resources of the region.

Nye County has also been an active participant in the Citizens Advisory Board. At the request of this board, a formal presentation was made in January 1998. This presentation was on Nye County's Perspective on Nevada Test Site Programs and identified the key water supply issues along with the County's concerns. The focus on this presentation was on the existing contaminated groundwater at the Nevada Test Site and the issues associated with that contamination including the continuing loss of natural resources, future water demands and resource availability, and other actions taken by federal agencies, including Yucca Mountain.

Nye County has taken a proactive approach in working with other groups and interested parties. The County has informally helped coordinate the flow of information between the farm interests in Amargosa Valley, county and city planners, and federal and state agencies. For example, when the U.S. Geological Survey announced their intent to expand their monitoring program in Amargosa Valley, the County facilitated a meeting with interested farmers in the area. The County provided both parties with comprehensive lists of water wells in the basin, identified areas for conducting aquifer tests, and planned future cooperative efforts. The County has also been a participant at Town Boards, Regional

Planning Commissions, and other local meetings. Nye County maintains a presence at these meetings to provide information concerning Yucca Mountain and to explain its ongoing programs and data collection efforts. The county's involvement in these meetings has helped to define the issues that are important to planners and the public.

3.2 REGIONAL GROUNDWATER MODELING

Numerical models are being used to simulate and define flow paths and travel times between existing and future contaminant sources, such as the Nevada Test Site (NTS) and Yucca Mountain, and potential receptor populations. The results of these simulations are then used in estimating the risk associated with that contamination. The Department of Energy has recently published the results of two models, one for the Yucca Mountain Program (D'Agnese et al, 1997), and one for the Nevada Test Site Environmental Restoration Program (U.S. Department of Energy, 1997). Previously, the U.S. Geological Survey, published the results of their regional model of the carbonate rock province which encompasses a large area in Nevada and Utah and which includes the areas modeled by the Department of Energy (Prudic, Harrill, and Burbey, 1993).

Nye County is developing its own numerical models of the groundwater flow regime in the vicinity of Yucca Mountain. A necessary first step in this effort is the evaluation of the regional models that have already been developed by the Department of Energy and the U.S. Geological Survey. These evaluations are aimed at identifying the strengths and weaknesses of the modeling approaches that were used and identifying the areas where more data are needed. The three models being evaluated are:

1. The U.S. Geological Survey Death Valley regional groundwater flow system model developed by D'Agnese et al, (1997). This model was developed to assist in the characterization of the hydrologic regime in the region surrounding the proposed high-level nuclear waste repository at Yucca

Mountain. This model is hereafter referred to as the Yucca Mountain Project (YMP) regional model.

2. The Nevada Test Site underground test area (UGTA) regional groundwater flow and tritium transport model (U.S. Department of Energy, 1997). The purpose of this model was to identify groundwater pathways and travel times to aid in the assessment of the effects of underground nuclear weapons testing at the Nevada Test Site and the risk associated from the release of tritium during the tests. This model is hereafter referred to as the UGTA regional model.

3. The U.S. Geological Survey's regional carbonate aquifer-system model developed by Prudic, Harrill, and Burbey (1993). The purpose of this model was to provide a mathematical simulation of the regional aquifer system to serve as the basis for the conceptual evaluation of regional groundwater flow in the carbonate-rock province of Nevada and Utah. This model is hereafter referred to as the NTS regional model.

By carefully examining these models, Nye County's scientists are identifying the relative strengths and weaknesses of each model. The predictive capability of these models rests in large part upon two key factors: 1) the ability of numerical models to be reliably used in lieu of data; and 2) the database and assumptions that were used in developing the computer simulation. In areas where data are lacking, assumptions must be made concerning the key hydraulic parameters that govern the output from the models. No numerical model is able to reliably predict the response of a hydrologic system at all locations. They are merely tools to evaluate the gaps in data and to provide means of estimating potential responses of a portion of the system to various changes in the boundary conditions in the system.

Numerical models simply provide a mathematical representation of the basic processes of a groundwater flow regime. The reliability of a calibrated model is

dependent to a large extent on the data used and assumptions made to arrive at the results. The groundwater models under review are constrained by the precision to which the basic hydrologic processes can be measured or estimated. For example, transmissivity values calculated using aquifer test data and accepted analytical procedures still only offer order-of-magnitude estimates. The recharge to the aquifer systems is the driving force behind all models, yet it is one of the least understood hydrologic processes. Over the last two decades, new methods for estimating evapotranspiration have helped reduce the uncertainty of this process, the largest source of discharge in the Death Valley flow system. Because of the importance being placed on the numerical models, Nye County is identifying the need for further analysis of existing data and the collection of new data concerning the basic hydrologic processes that are known to occur in the region. These evaluations are aimed at increasing the predictive capability of the models by reducing the uncertainty in the underlying factors that control all groundwater flow models.

3.2.1 DATA LIMITATIONS

The existing numerical models of the Yucca Mountain region and the Death Valley flow system are limited in their capability to portray the groundwater regime. Evaluations are underway by Nye County that are comparing the published models and identifying those areas where additional data or evaluations are needed. The models that have been developed to date only include portions of the Death Valley flow system and disregard the contribution of water from basins north, south, and west of Death Valley. Nye County is conducting a preliminary evaluation of the western most portions of the Death Valley flow system. This evaluation includes the compilation and synthesis of published materials and data sets, and reconnaissance level surveys of the hydrographic basins located west of Death Valley. Nye County, in cooperation with Inyo County, is also investigating springs in the Funeral Range to determine their sources and the potential contribution of water from this recharge area to Death Valley. The data collected

during these evaluations is being used to determine if the contributions of groundwater to Death Valley from the west are truly negligible, as assumed in the numerical models.

The models are based upon limited data sets, especially in the region immediately down gradient of Yucca Mountain. Figure 3-1 shows the locations of wells and the available data for southern Jackass Flats and Rock Valley and the northern part of Amargosa Desert. A large gap exists between the southern limit of Yucca Mountain characterization wells and boreholes and the water supply wells located on the Nevada Test Site and to the south, in the community of Amargosa Valley. The data for this gap is primarily limited to that collected using non-intrusive techniques such as detailed mapping of surficial units and geophysical methods. Even in areas to the south, where public and private water wells are present, very little primary hydrologic data is available and is generally limited to Well Drillers Reports, water level measurements, and water chemistry data for the uppermost part of the top aquifer in the groundwater system. Aquifer test data is lacking, as is information on the aquifers present, their extent, and their hydraulic properties. As a consequence, the models that have been developed have had to rely upon assumed, rather than measured aquifer properties for the entire area down gradient of Yucca Mountain.

Although deep subsurface data is generally lacking, the data that are available indicate that the models do not provide the level of detail necessary to simulate the groundwater flow paths between the proposed repository site and potential receptor populations. The published results for an oil and gas exploration test holes and geophysical surveys indicate that the valley-deposits down gradient of Yucca Mountain are not just alluvial gravels, sands, and clays, but also include basalts, volcanic tuffs and ash deposits, lacustrine limestones, and carbonate boulder breccias. Each of these units may be expected to exhibit differing hydraulic characteristics with respect to groundwater storage and flow.

Other data gaps are located between the proposed repository site and the nearest populated areas in Oasis Valley and Pahrump Valley. Nye County is currently evaluating geophysical data and interpretations for Oasis Valley and has entered into a cooperative agreement with the U.S. Geological Survey to conduct additional geophysical surveys and to conduct detailed geologic mapping of portions of Pahrump Valley. These cooperative efforts will provide important new data sources that will be used in characterizing the hydrogeologic conditions between Yucca Mountain and these populated areas.

3.2.2 DEATH VALLEY REGIONAL FLOW SYSTEM BOUNDARIES

The boundary conditions selected play a major role in setting the controls on a mathematical simulation of groundwater flow within a basin. The basis for the boundary conditions varies for each of the three models. These variations are based in part upon the purpose of the model, and in part on the assumptions made in developing the model grids and boundary conditions. As a consequence, the differences between the actual flow system boundaries and the model boundaries warrant further consideration. Because of the thickness of the aquifers and complexity of the hydrogeologic system, the boundary conditions are different for various hydrogeologic units. The surface-water hydrologic basin boundaries may be a reasonable no-flow boundary for the shallow aquifers, but may not apply to aquifers that are at depths of 1000 feet or more. The carbonate aquifers in the region have a very complex structural configuration. Their extent and thickness vary from place to place depending on the proximity to faults which may be normal or thrust faults. Overturned sections of the carbonates are not uncommon in the area. Major faults and fracture zones in the area play an important role in controlling the hydrologic boundaries of the system.

The Death Valley flow system, as discussed by Harrill et al (1988), comprises 15,800 square miles and 30 individual hydrographic basins. The extent of the

flow system and the hydrographic basins within it are graphically presented in Figure 3-2. The boundaries shown on this map have come to be the accepted extent of the Death Valley flow system.

Although the boundaries of the flow system have become accepted, there are questions about the hydraulic characteristics of those boundaries. In defining the Death Valley flow system boundary, Harrill et al (1988) noted that "the character of the northeast boundary is not well understood" and these workers characterized the flow system boundary from Tikaboo Valley to the Las Vegas Valley as uncertain. The basis for defining the western boundary of the flow system is not well documented. Plume and Carlton (1988) state that the Great Basin regional aquifer system is bounded on the west by the Sierra Nevada and on the south by the Mojave Desert. These workers defined the boundary of the aquifer system as the mountain divide immediately east of Death Valley (the Panamint Range).

Further, there may be areas beyond the flow system boundaries which contribute water, via subsurface flow, into the Death Valley flow system. D'Agnese et al (1997 pp. 59, 60-61) note that there are at least eleven locations where regional inflows cross the flow system boundaries, and state that good estimates of these inflows are not available except for flow from Pahranagat Valley (east of Tikaboo Valley). However, Pal Consultants, Inc. (1995) provided flux estimates for other areas including flows from Saline Valley (and potentially Panamint Valley), Soda Lake Valley, and Las Vegas Valley into the Death Valley flow system (Pal Consultants, Inc., 1995, Appendix B, pp. 87, 89-91).

Pal Consultants, Inc. (1995, p., 89) conducted an evaluation of water budgets for the flow system and concluded that "the concentration of discharge in Mesquite Flat [in northwestern Death Valley] could be best explained by subsurface inflow of about 8,000 acre feet per year from Saline Valley (some of this inflow may be from Panamint Valley)". Flow from Las Vegas Valley into the flow system was estimated at 5,000 acre feet per year (Pal Consultants, Inc., 1995, p. 91). A lesser contribution was estimated for inflow from Soda Lake Valley, about 450 acre feet

per year, but it was noted that "additional information will be needed to develop a more credible quantitative estimate" (Pal Consultants, Inc., 1995, p. 90).

To further evaluate these inflows, additional analyses are being performed as part of Nye County's model reviews. Water level data for Inyo County, California was obtained from the U.S. Geological Survey District Office in San Diego (see tables in database provided on the accompanying media package). These data must be considered qualified insofar as they are provisional. Nonetheless, it is the best available water level data set that was identified. This data set is being used in conjunction with water level data for some portions of the flow system in Nevada basins to evaluate the need for further data collection in these areas. An important aspect of this data is the significant fluctuations in water levels over the last fifty years (1944-1997). This observation indicates that there are short-term transient conditions that may discredit the steady-state assumption. Furthermore, data from the spring deposits in the area indicate that flow of the springs continued for several thousands of years after retreat of Pleistocene glaciation. This would indicate that there are long-term delays between recharge and discharge in the groundwater system. This would also emphasize the transient nature of the groundwater system in the area.

3.2.3 MODEL BOUNDARIES

Figure 3-3 shows the Death Valley flow system and the extent of the three modeled areas. It is interesting to note that none of the regional models include the entire Death Valley flow system as defined by Harrill et al (1983).

The NTS model (Prudic, Harrill, and Burbey, 1993) is by far the most extensive model and includes almost the entire carbonate aquifer system stretching from the Idaho border on the north to westernmost California on the south and from Lander and Esmeralda counties in Nevada on the west to the Great Salt Lake in Utah on the east. With respect to the Death Valley flow system, the NTS model includes all of the flow system except for the area southwest of the Death Valley saltpan.

The model includes Pahrump Valley in Nevada as well as Lower Amargosa Valley, Chicago Valley, Valjean Valley, and Shadow Valley in California.

The UGTA regional model domain is much smaller, encompassing a large portion of the Death Valley flow system. As with the regional NTS model, the UGTA model does not include the area southwest of the Death Valley saltpan. The UGTA regional model does not include Pahrump Valley nor Chicago, Valjean, and Shadow valleys in California.

The Yucca Mountain regional model domain is intermediate between the NTS model and the UGTA model. The YMP model includes most of the Death Valley flow system but excludes Shadow and Valjean valleys. As with the other two models, the YMP model does not include the area to the southwest of the Death Valley saltpan.

Although these models cover somewhat different areas, it is interesting to note that none of the models include the portions of the flow system to the southwest of the Death Valley saltpan. As discussed previously, recent published evaluations suggest that there may be considerable contributions of groundwater from the areas to the southwest of the regional hydraulic sink that is present in Death Valley. The effects of excluding such contributions could include unnecessary adjustments of key model parameters during calibration to achieve acceptable water balances or to achieve some level of fit with observed water levels. Nye County, in coordination with Inyo County, is evaluating the significance of disregarding potential contributions from other areas toward the sink at Death Valley.

3.2.4 BOUNDARY CONDITIONS

This discussion is limited to the areas located hydraulically down gradient of Yucca Mountain, the key area of concern to Nye County.

The NTS model includes two types of boundary, no-flow boundaries and general-head boundaries. In the Death Valley area, the head-dependent boundaries were set to coincide with the Death Valley salt pan (Prudic et al, 1995, p. 18-20).

Conversely, the UGTA regional model includes a no-flow boundary condition around almost the entire model domain including the entire area down gradient of Yucca Mountain. These no flow boundaries were implicitly defined between active and inactive cells along the entire model boundary except at a few locations where other boundary types were used to simulate wells, inflow from Pahrump Valley across the Resting Springs Range, and discharge near Eagle Mountain (U.S. Department of Energy. 1997, p 7-11 - 7-12).

The Yucca Mountain regional model uses yet a third approach and sets a constant head boundary that coincides with the Death Valley saltpan and Sarasota Springs (D'Agnese et al, 1997, p.76- 77). Constant head boundary in this area is not justified over a long period of time. Fluctuations in the water level in the saltpan are well known. The connection between the shallow aquifers and the deep carbonate aquifer in this area is not well known. Therefore, the fact that there is a controlling head boundary near ground surface in this area does not translate into a corresponding head boundary in the deeper aquifers. The recharge to the deeper aquifers may be lagged by geologic times as opposed to short-term lag between recharge and discharge of the shallower aquifers.

All three models, through the selection of boundary conditions, were developed in a manner that mathematically simulates heads in the Death Valley sink on the basis of the recharge derived solely in Nevada. Thus, the majority of this recharge is via subsurface flow through Nye County. The effects of selecting the boundary conditions that exclude the contribution of groundwater from areas west of the Death Valley regional groundwater sink could include unnecessary adjustments of key model parameters during calibration.

3.2.5 RECHARGE

Groundwater recharge is a dominating parameter in the development of any numerical model. The treatment of recharge in the NTS model is described by Prudic et al (1995, p. 23 & 25). The recharge was estimated by first determining the areas within precipitation zones in the mountainous regions where recharge was believed to be a significant process. The estimated recharge over the mountainous areas was then further evaluated and revised to be consistent with the estimated recharge for individual hydrographic basins or groups of areas. (Presumably, this comparison was with Maxey-Eakin recharge estimates in some areas, but this is not explicitly stated by the authors.) The totaled recharge to the model was about 1.5 million acre feet which represented about three percent of the precipitation.

Recharge in the UGTA regional model was treated differently. A modified Maxey-Eakin method was used that is described in some detail by the U.S. Department of Energy (1997, p. 5-22 – 5-30). The recharge rates used in the model were developed by first reevaluating the precipitation data with data that has become available since the Maxey-Eakin method was developed. Surprisingly, this reevaluation did not find any large difference between total precipitation using the new data sets when compared to similar estimates presented by Scott et al (1971) using the older data sets.

Based upon the revised precipitation distribution, the recharge to each cell in the model was initially estimated using Maxey-Eakin derived coefficients for areas with more than 11.8 inches of rainfall. For the zone with between 7.9 inches and 11.8 inches of rainfall, the Maxey-Eakin coefficient was reduced by 33 percent. This reduction resulted in a lower overall recharge rate than that estimated using the Maxey-Eakin method.

The next step in the approach to recharge in the UGTA model consisted of the redistribution of recharge from the upland areas to canyon wash recharge areas

such as along Fortymile Wash. The issue of whether recharge along stream beds and canyons should be additive to recharge over mountainous areas is being evaluated by Nye County.

The Yucca Mountain regional model uses a third approach to recharge that is described in detail by D'Agnese et al (1997, p.51-56). In brief, this approach used a digital terrain model to classify altitude zones and slope-aspect zones, defined vegetation zones, and used small-scale geologic maps to define parent material zones. After these zones were defined, recharge ratings were selected for each zone. These ratings serve as weighting factors. Maps of the recharge potential were then made for the four factors and overlain and the results reclassified to derive a "refined" recharge potential map for the Death Valley region.

In developing the recharge potential map, no recharge was assigned to any areas below an altitude of 5,000 feet. Further, no recharge was assigned to any area that was not vegetated with coniferous forests, pinon-juniper or mixed shrub. This may have resulted in a reduction in recharge over the Spring Mountains and other high-altitude areas where the vegetation was unclassified because little or none is present. Recharge is not excluded in such areas and further evaluation of the model is needed to determine if this was indeed the case. More information on the specific methodology used in converting from a pixel-based vegetative classification to a model cell-based recharge value is needed for such an evaluation.

The net result of this approach varied little from the Maxey-Eakin approach. The only difference was in areas above altitudes of 9,000 feet where the recharge factor was increased by about 17 percent. Without further evaluation, the effects that may have resulted from eliminating areas above 5,000 feet and that do not have one of the three vegetative assemblages cannot be ascertained. Reductions of recharge in such areas may have effectively offset the use of the increased recharge coefficients in the areas above 9,000 feet elevation, thereby reducing the differences with the Maxey-Eakin method.

3.2.6 DISCHARGE

Each model simulated discharge from natural processes (evapotranspiration processes by plants, springs, and underflow out of the model). The Yucca Mountain model also included consumptive use of water discharge via water wells. Because of the differences in areas, a direct comparison of the total discharge rate of each model is of little utility. It is interesting to note, however, the implications of the approaches that were used both in terms of the distribution of discharge and the discharge rates.

The NTS simulated evapotranspiration as a head-dependent flow boundary in the upper model layer which essentially relies on the extinction of evapotranspiration as a function of depth (Prudic et al, 1993, p. 20). A modified function was used to reduce the number of numerical simulations and adjustments were made to transmissivities and leakance rates to reduce evapotranspiration in areas where the model simulated springs that were considered unrealistic. Without information concerning the specific model cells that were affected, it is not possible to evaluate the overall effect of these adjustments. It should be noted however, that the initial model results may not have been in error. The initial results may have been indicating that appreciably more discharge occurs under true steady-state conditions.

The UGTA model was simulated using the drain package of the model code as described in U.S. Department of Energy (1997, p. 7-16 – 7-19). Estimated and target discharge ranges were establish based on published estimates and on a single measurement of spring discharge at Indian Springs. That the simulated evapotranspiration so closely matched the target rates suggests that this approach may have resulted in effective constant discharge boundaries wherein unnecessary adjustments are needed in some model parameters to force a high level of calibration. That is not to say that the approach used is incorrect or inaccurate. The previously discussed problems encountered with the NTS model may have been eliminated using this approach. The drain package may have a better ability

to simulate evapotranspiration estimates. If so, the accuracy of the simulation may hinge totally upon the accuracy of those estimates.

The Yucca Mountain regional model used an extinction-based algorithm to simulate evapotranspiration in some areas. The extinction rate varied according to the plant type and ranged from 0 to about 50 feet; the basis for assigning these values was not provided.

Of particular note is the unusual treatment of the evapotranspiration in Death Valley where the model approach abandoned evapotranspiration in favor of a constant head boundary (D'Agnese et al, 1997, p. 78). This approach needs further evaluation as it suggests that simulated values of discharge of a portion of a flow system can be used in lieu of measured and estimated evapotranspiration rates for the entire flow system.

Also of note is the treatment of evapotranspiration in Pahrump Valley. The Yucca Mountain regional model distributed evapotranspiration in a few isolated cells rather than across a large area and then used pumping wells to simulate water withdrawals from the basin. The use of this novel approach in a steady-state simulation is noted; further evaluations of this approach are being conducted by Nye County. D'Agnese (1997, p 84) noted that different well parameters were used for Pahrump Valley versus the rest of the model and then went on to state:

"These parameters were not estimated [using a coded parameter estimator within the model] because their inclusion created an unrealistic source of recharge to the model. That is, when regression was applied, the wells became a source of water instead of discharge locations."

Of further note is the manner in which these well withdrawals were simulated. The overall final water budget for the model includes a simulated discharge of 88,000 m3/d (with return flow included). This simulated value corresponds with an annual extraction rate of only 26,000 acre feet per year for the entire flow system. This value is compared to an estimated value of 89,400 m3/d or about

26,500 acre feet per year. A comparison with the conceptualization for this model indicates that the pumping rates in just Pahrump Valley ranged from about 65,000 to 162,000 m3/d between 1962 and 1992 (19,000 to 48,000 acre feet per year). These rates were reduced by fifty percent to calculate an overall average annual rate (D'Agnese et al, 1997, p. 47). More recent water use data indicates annual water withdrawal rates from Pahrump Valley now exceed that simulated for the entire flow system.

Comparing the simulated value of 88,000 m3/d with an estimated value of 89,400 m3/d leads to additional questions insofar as the estimated value is based upon the removal of groundwater from storage rather than as pumping wells. (See D'Agnese et al. 1997, Table 17, p. 112; and Table 13, p. 71.) The basis for this value is not given but the uncertainty associated with the estimate is characterized as "considerable" (D'Agnese et. 1997, p. 71).

The Yucca Mountain regional model uses changes in storage under transient conditions to simulate discharge from the Pahrump basin rather than simulating evapotranspiration under steady-state conditions as is done for the rest of the model. As such, the quantity of water removed from storage should be additive to the natural evapotranspiration rate, estimated at 10,000 to 14,000 acre feet per year (Harrill, 1986, Table 7, p. 46). It is not surprising, therefore, that the regression based parameter estimation technique required that wells become sources of water rather than as points of discharge. The overall effect of using a constant head boundary or wells to model the removal of storage in lieu of using the extinction approach on the model results is not clear at this point. Additional evaluation is needed along with an evaluation of the manner in which crop evapotranspiration rates should be factored into the approach used in the Yucca Mountain model.

3.2.7 RECHARGE OVER DISCHARGE AREAS

None of the models account for the natural phenomenon of rainfall over discharge areas or evapotranspiration losses over recharge areas. The NTS model report does recognize that recharge may occur over discharge areas and states that rivers and lakes that border the carbonate province, as well as the Death Valley playa may be either a source of recharge or a source of discharge (Prudic et al, 1993, p. 92). The report notes that this is one of the simplifying assumptions of the model although it could as easily be characterized as a complicating factor.

Hunt (1975, pp. 15 and 30-35) provides an excellent discussion of discharge in Death Valley and a 1969 flood event. This author also noted that while the potential evaporation rate is 150 inches per year, the actual evaporation rate depends upon the water that is available in a given year and "there is no deficit spending". Any runoff of surface waters or precipitation directly over the Death Valley saltpan is likely to provide direct recharge to the hydrologic system through two processes, direct infiltration into storage, and through the replacement of evapotranspiration losses of groundwater with evaporation losses of surface water. The significance of the long-term interactions between the coupled groundwater-surface water processes in Death Valley needs further evaluation.

Similarly, rainfall over other discharge areas such as Ash Meadows and areas of shallow groundwater in southern Amargosa Valley may be contributing recharge directly into discharge areas. Further evaluation is needed to determine the significance of such recharge in numerical simulations. If recharge must equal discharge for a model to be considered calibrated, then it is important that the recharge and discharge components be differentiated so that it is not assumed that all discharge from an area is solely derived from distant regional recharge areas.

3.2.8 STEADY STATE VERSUS TRANSIENT CONDITIONS

At the Devil's Hole workshop, the issue of steady-state versus transient conditions was identified by Nye County. In essence, this issue stems from the implied assumption in each of the models that steady-state conditions prevail across the model domain. This assumption may be in error as climatic conditions and the development of water by man have significantly altered the hydrologic regime and that the period over which these changes have occurred represent transient conditions rather than steady-state.

True steady-state conditions probably last occurred during the Pleistocene. During Pleistocene time, more precipitation resulted in more runoff and more recharge. As a result, there were large lakes present in Pahrump Valley, Death Valley, and a smaller lake in the Amargosa Flat area. The Pleistocene environment over much of the Amargosa Desert basin was marshland with water at, or near, the land surface over much larger areas than today. As more arid conditions prevailed, corresponding declines in water levels and spring discharge rates occurred. These changes represented transient conditions that should be accounted for in regional models.

The error that arises from the assumption of steady state during calibration is significant. If a particular basin is in a transient rebound mode, that is water levels are rising due to reduced pumping activity (which may be the case in Pahrump Valley), calibration assuming a steady state condition generates erroneous results in estimating the hydraulic conductivity values. In this case, the estimated hydraulic conductivity values from steady state would be smaller than the actual values.

3.2.9 CALIBRATION

Nye County notes that none of the models have been shown to meet the calibration requirements under ASTM Standard D 5490-93 (ASTM, 1994).

3.2.10 METHODS USED

In conducting the review of the three models, the methods used included literature review, discussions with some of the authors of the models, and direct comparisons between the published reports of the three models. Additional water level data sets for Inyo County and Nye County were reviewed along with published information for oil and gas wells, water wells, and the published and preliminary results of geophysical surveys that have been made in the region.

3.3 MODELING EFFORT BY NYE COUNTY

In the reporting period, Nye County focused on development of a saturated zone model for the Death Valley Region (Multimedia Environmental Technology, 1998) in an effort to mitigate some of the concerns outlined in the previous subsections. The initial effort entailed re-creation of the Yucca Mountain regional model by D'Agnese et al, 1997. In this effort, T2VOC (Falta et. al., 1995) was used for the simulations. T2VOC is based on TOUGH2 (Pruess, 1991). TOUGH2 is a robust code that allows simulation of multiphase flow of fluids coupled with energy transport. The domain of discretization can be one, two, or three dimensional in irregularly spaced grid system. A variably-saturated system can be simulated using various capillary pressure and permeability characteristic curves. Simulation of the Yucca Mountain Site-Scale unsaturated-zone has been performed using this code (Bodvarsson et al, 1996). T2VOC is an extension of TOUGH2 which allows simulation of transport of a chemical component dissolved in air, water, or as a free non-aqueous phase fluid. Adsorption and interchange between the phases is allowed based on the thermodynamic state of the computational cells (nodes). T2VOC's gridding system is fully compatible

with TOUGH2. Therefore, integration of the unsaturated zone model with the saturated zone model can be done relatively easily. The ventilation model, which will be discussed in Section 8.0 of this report, is performed using T2VOC and the modified unsaturated zone site-scale input file (Multimedia Environmental Technology, 1998a).

The attempted mesh for the regional saturated-zone model developed by Nye County is shown in Figure 3-4. This mesh has 39744 nodes (108 wide, 92 long, and 4 layers). The mesh is finer around Yucca Mountain, Amargosa Valley, and Pahrump Valley. The initial attempt was to evaluate the calibrated parameters of the YMP regional model. All boundary conditions, sources and sinks were set identical to the YMP model. The initial conditions were set as the steady-state results of the YMP model. The only difference in the Nye County Death Valley Basin Model (NCDVB) was that it was set to run in transient mode. The storage properties were set based on typical values for the rock types. Values from pumping tests were used where possible, but only a very small portion of the model has storage property data. T2VOC was set to run in saturated, isothermal mode only. In this mode, the results of T2VOC should closely match those of MODFLOWP (the code used for simulation of YMP regional model) because the basic equations solved are identical (darcy and continuity equations).

Many attempts were made to achieve steady state with T2VOC by running the model for a long period of time. Convergence in calculated pressures was not possible after a maximum period of 100 years. This is because, in transient simulations, the code (T2VOC) attempts to calculate pressure head distributions based on the calibrated hydraulic conductivity values. Storage coefficients were changed to allow for variations in the transient effects. It was concluded that the steady-state calibration results were not suited for a transient run because of the time lag necessary for the model to equilibrate the inflow and outflow. In steady state simulations, because the change in storage is set to zero, equilibration is instant in the model. In transient simulations, depending on the storage

properties, the time lag between the inflow and outflow dictates the equilibration process. Because of long time lags between the recharge (inflow) and discharge (outflow) points, in the transient runs, the model supplies water from the nodes nearest to the discharge points. These nodes tend to desaturate until the effect of recharge is detected by the model. Either unrealistically large storage coefficients had to be assumed to provide large amounts of water near the discharge points or very small storage coefficients had to be assumed to minimize the time required for the inflow-outflow equilibration. Neither one of these assumptions could be justified based on the observations and the known values of the storage properties of the aquifers involved. Therefore, it was concluded that the hydraulic conductivity values calibrated to the transient conditions must be incorrect.

Observations in the basin support the conclusion that the lag-time between recharge and discharge are too large to assume equilibrium conditions. The most significant evidence is the discharge from paleosprings. The paleosprings in the Amargosa Valley flowed at least three thousand years after the retreat of the Pleistocene glaciation. This means that the system has a storage capacity to supply water to the springs for at least three thousand years, once recharged. The current water level beneath some of these spring deposits exceed 300 feet, which means that there must have been additional time required for the water table to drop another 300 feet after the springs ceased to flow.

Water level data available for the Death Valley Hydrologic Basin for the past fifty years was compiled into a database. Hydrographs and selected contour maps for this data are provided in the attached electronic media package (see WaterLevelData.xls, RegionAllWells.ppt, 10yr_maps.ppt and AllYr_maps.ppt). The series of figures beginning with Figures 3-5a through 3-5i shows the contour maps of the water levels combined for 10-year intervals. Figures 3-6a through 3-6j show contour maps for water levels combined for the entire 50-year time interval. Figures 3-6k through 3-6m are water elevation contour maps for all the hydrographic areas combined for the entire data collection period. Selected

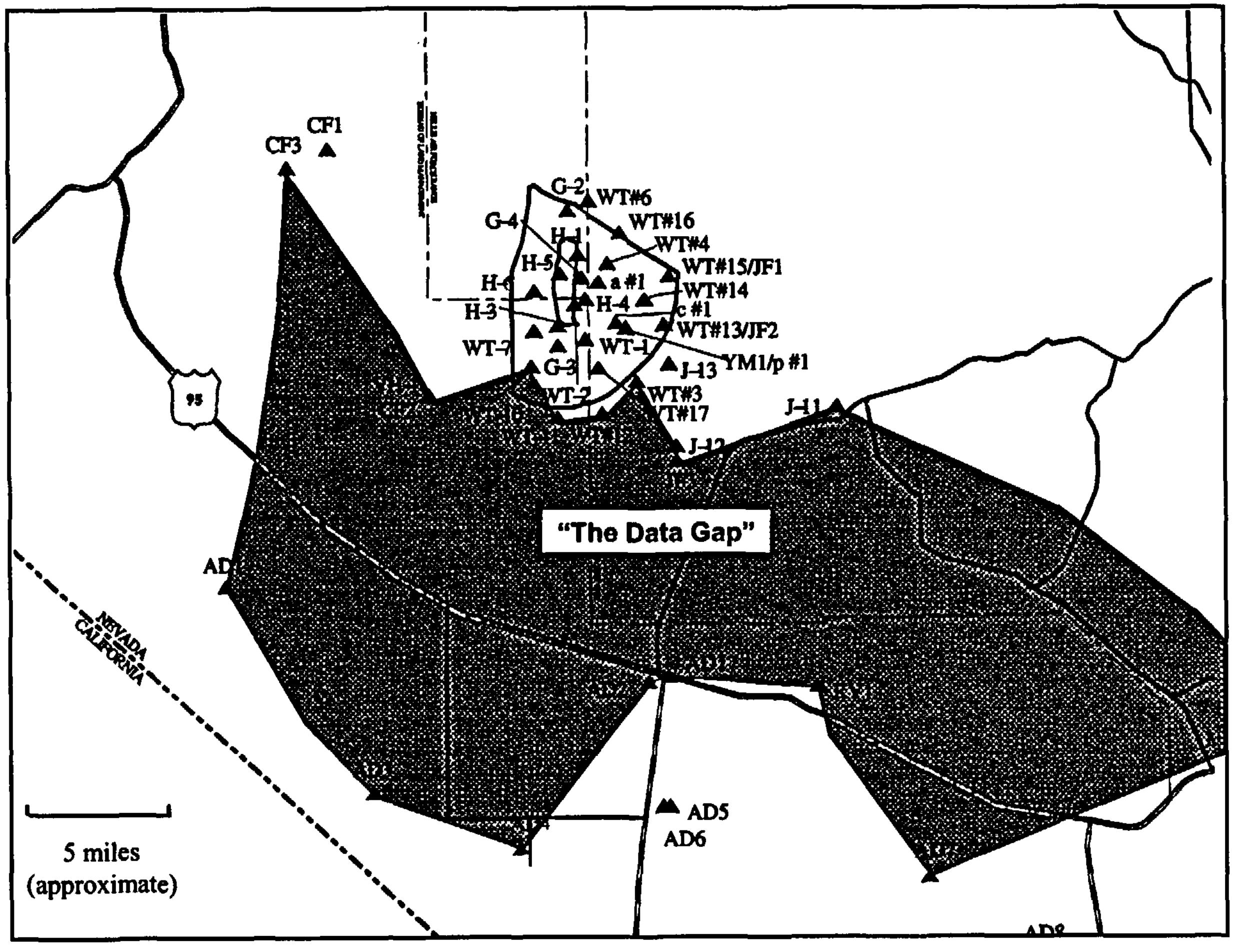
hydrographs are shown in Figures 3-7a through 3-7c. From these figures, it is evident that in the time period for which data is available, the piezometric levels have been fluctuating in excess of 100 feet. It is particularly interesting that the fluctuations to the north (the recharge areas) are not synchronous with the water levels in the south. This indicates that there is a short-term time lag between the recharge and discharge, as well as the long-term lag deducted from the paleohydrological records.

The initial modeling exercise indicated that the present steady-state calibration is not representative of the Death Valley groundwater system. Transient calibration of such a complex system is not practical at this time. Therefore, it was concluded that smaller model domains should be used in Nye County's future modeling efforts.

3.4 SUMMARY

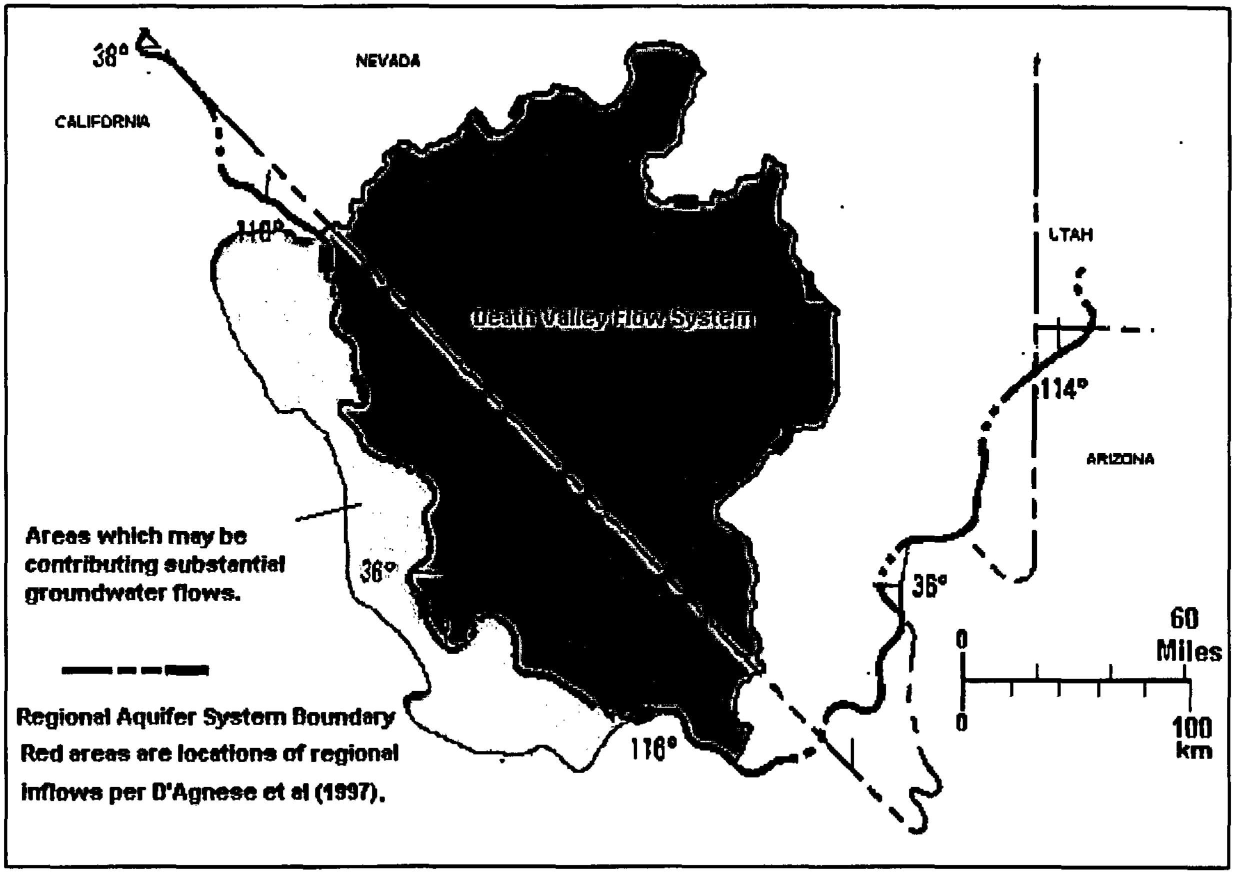
The water resources available for use in southern Nye County are constrained by a number of environmental, regulatory, and economic factors. The development of new water supplies will have to be planned in a manner that protects the rights of senior water right holders and the important wildlife values at Ash Meadows, Devils Hole, and Death Valley National Monument, while continuing to provide reliable supplies of safe drinking water. These planning efforts must also take into account the legal availability of water and the location of contaminated area and waste disposal units at the Nevada Test Site, the U.S. Ecology site near Beatty, and other potential point sources of contamination. The interrelationships with a proposed repository at Yucca Mountain must then be taken into consideration as a new constraint. These evaluations must be done in a manner that recognizes the fast-changing nature of water demand and allocations within the region and the likelihood that the demand for water in the region will significantly alter the current hydrologic conditions over the next fifty years, or less.

As existing numerical models of the Yucca Mountain and the Death Valley flow system are limited in their capability to portray the groundwater regime, Nye County is developing its own saturated zone model for the Death Valley Region. Based on an initial modeling exercise, it was determined that smaller model domains should be used in future modeling exercises



The labeled symbols represent springs and wells that are monitored as part of the Department of Energy's monitoring efforts for Yucca Mountain. Where the map is shaded, information on a primary hydrologic monitoring data (depth to groundwater) is entirely lacking as is information concerning the number and types of aquifers and their properties. The boundaries for the gap will vary somewhat for different data parameters. For example, the data gap would be much larger for aquifer test data. Modified from Map YMP97-05-04 of the U.S. Department of Energy's Yucca Mountain Site Atlas (Rev. 12/31/97).

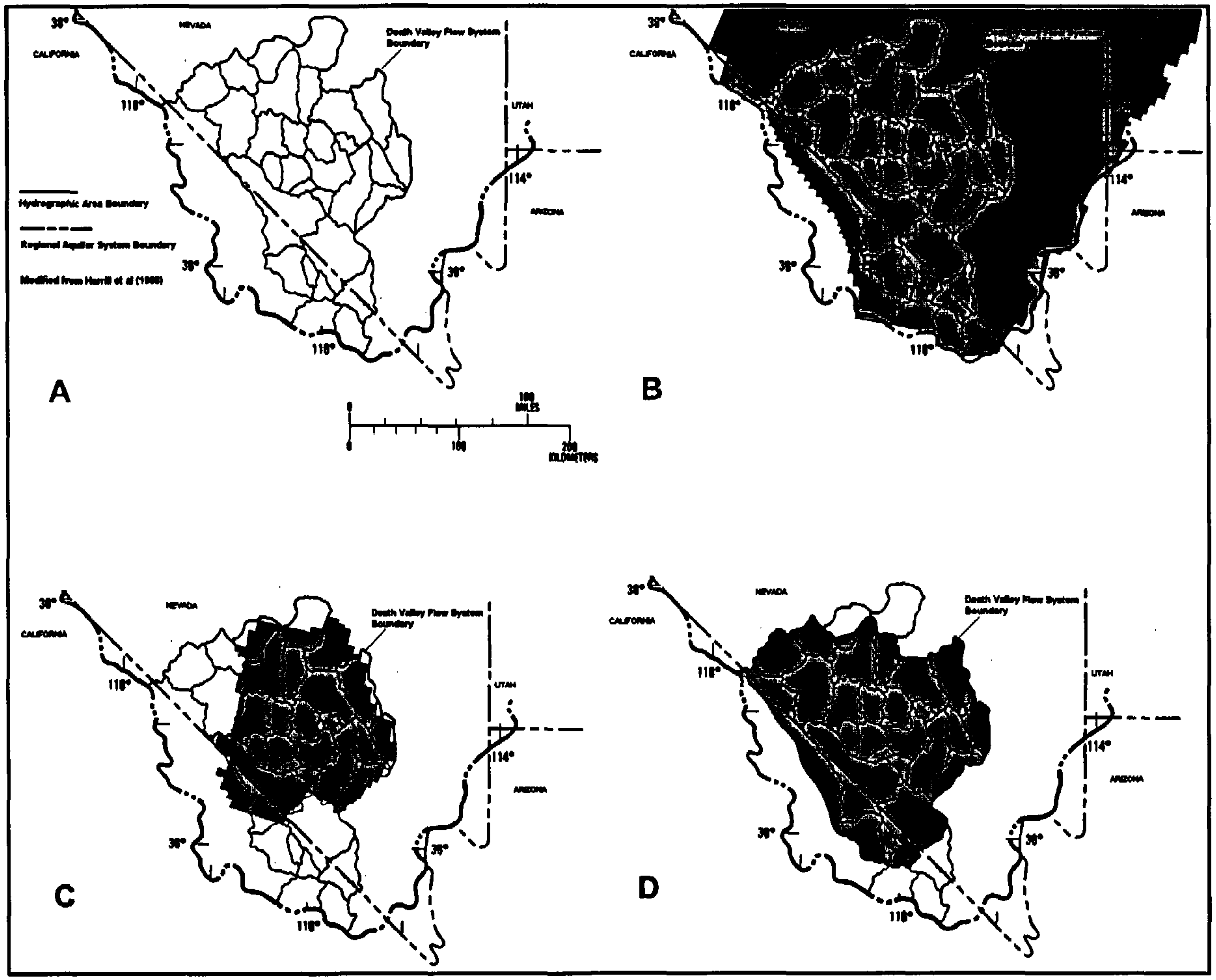
Figure 3-1 The "Data Gap" located down gradient of, and near to Yucca Mountain.



The boundaries of this flow system are indefinite in some areas. A large area to the southwest, including Saline and Panamint valleys, may be contributing appreciable quantities of recharge, via subsurface flow, into the system. In other areas along the north and eastern boundaries, subsurface recharge may also be entering the flow system. Although the recharge from these areas has not been quantified, it may total a significant amount that is not accounted for in the mass balance comparisons of recharge and discharge for the regional models. Failure to account for this recharge may result in unnecessary adjustments to other model parameters to achieve an acceptable level of calibration.

Note: All boundaries and locations shown are approximate.

Figure 3-2 The Death Valley flow system as defined by Harrill et al (1988).



Map A shows the Death Valley flow system boundaries as defined by Harrill et al (1988). Map B shows the southern extent of the regional carbonate model. The domain for this model extends more than 200 miles to the north of the area shown. Map C shows the domain for the NTS regional model. Map D shows the extent of the Yucca Mountain regional model. As shown, none of the models include the entire Death Valley flow system.

Note: All model boundaries shown are approximate.

Figure 3-3 Comparison of extent of model domains (shaded areas) for the three regional models.

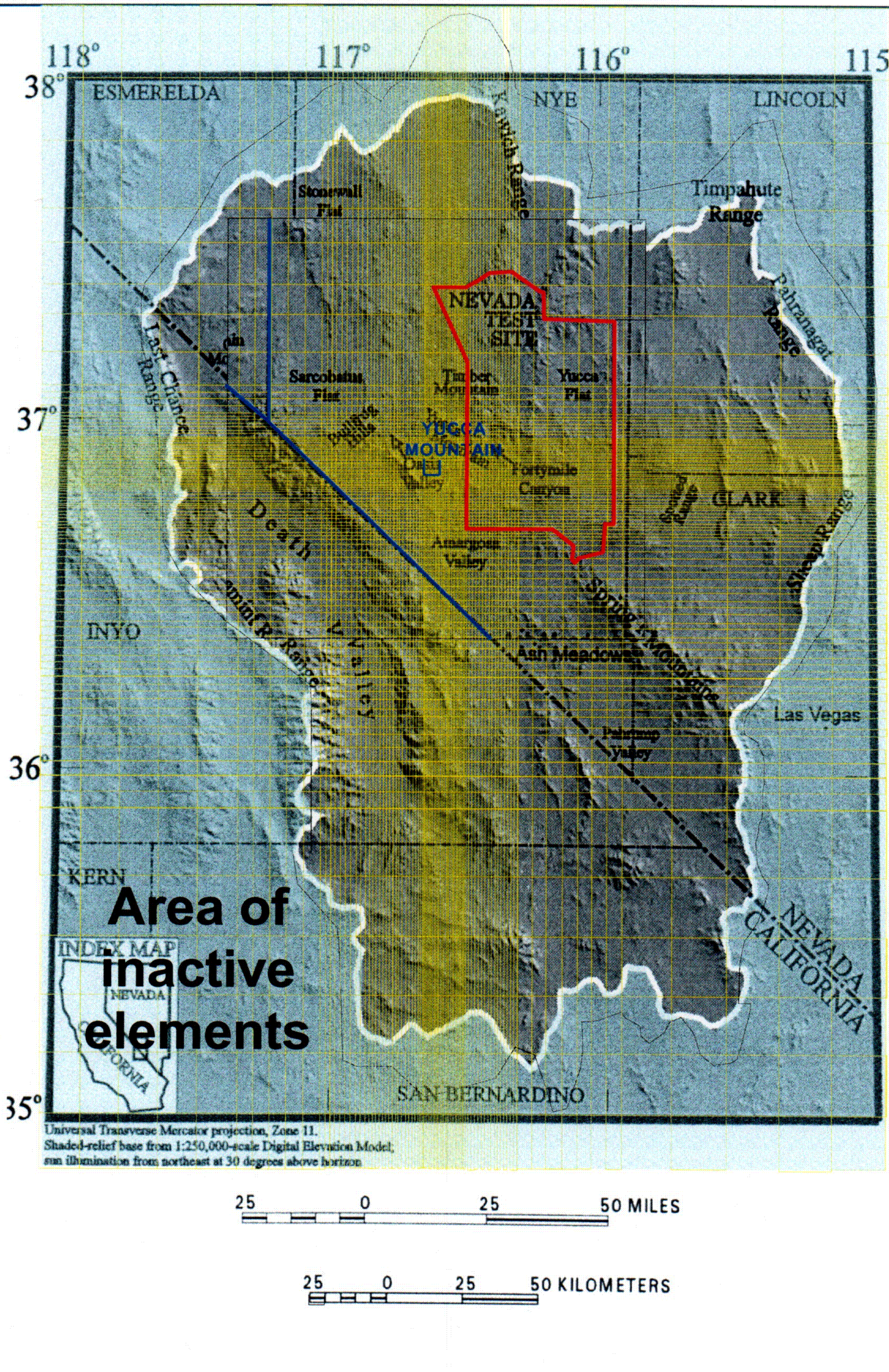


Figure 3-4 **Attempted mesh for the regional saturated-zone model.**

C-03

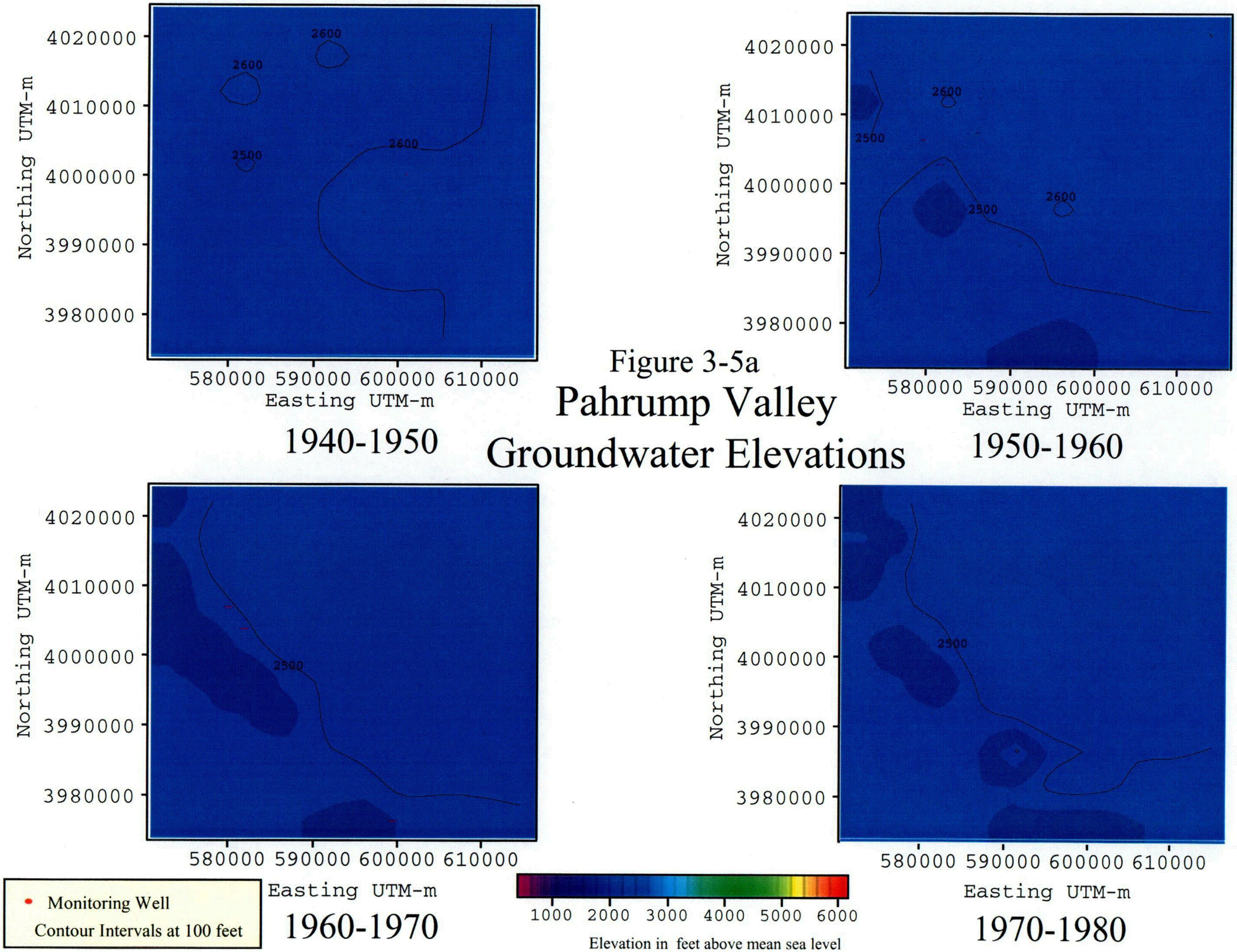
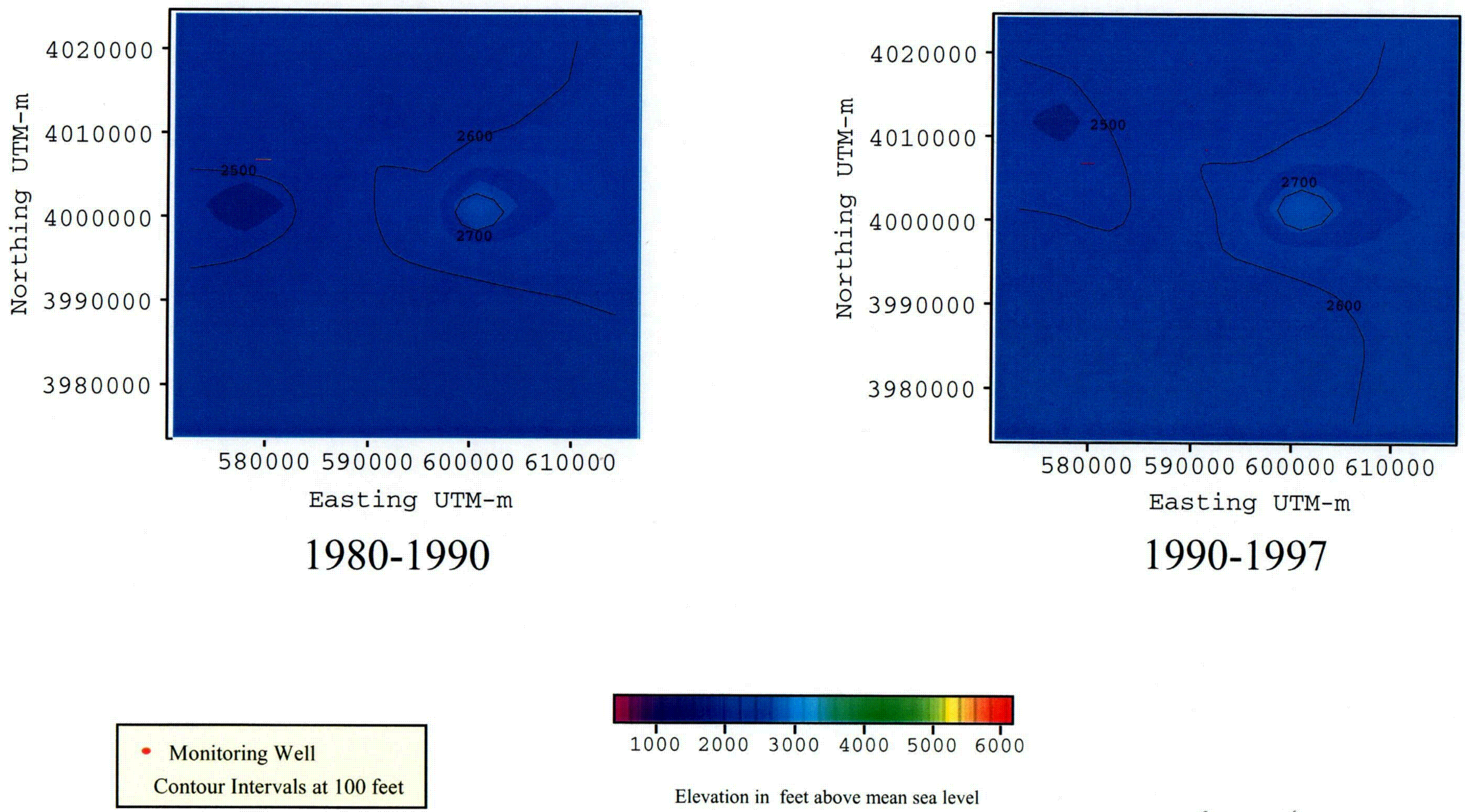


Figure 3-5a
Pahrump Valley
Groundwater Elevations

C-04

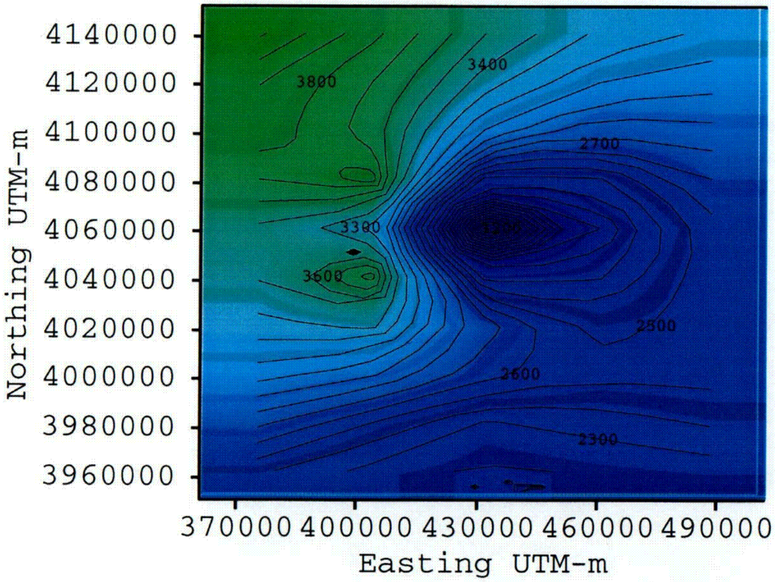
Figure 3-5b

Pahrump Valley
Groundwater Elevations

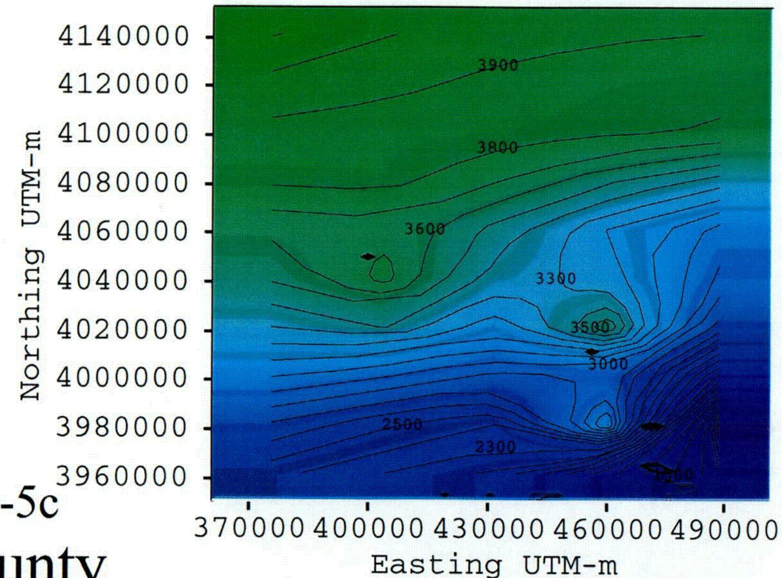


C-05

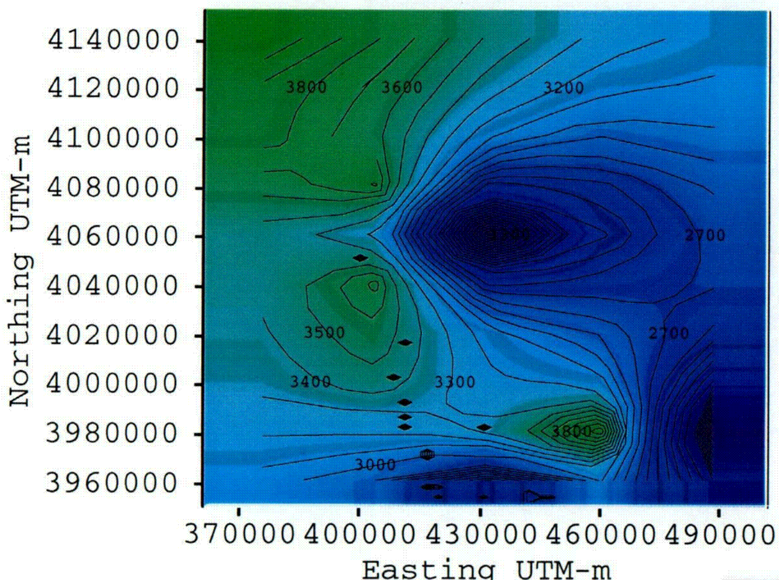
Figure 3-5c
Inyo County
Groundwater Elevations



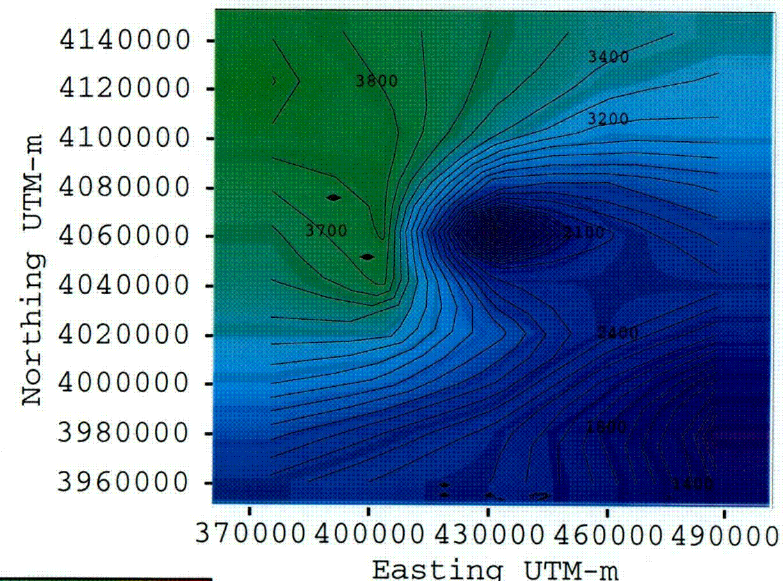
1950-1960



1960-1970

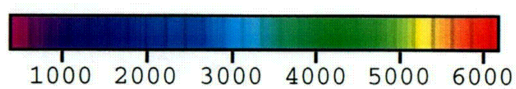


1970-1980



1980-1990

• Monitoring Well
Contour Intervals at 100 feet

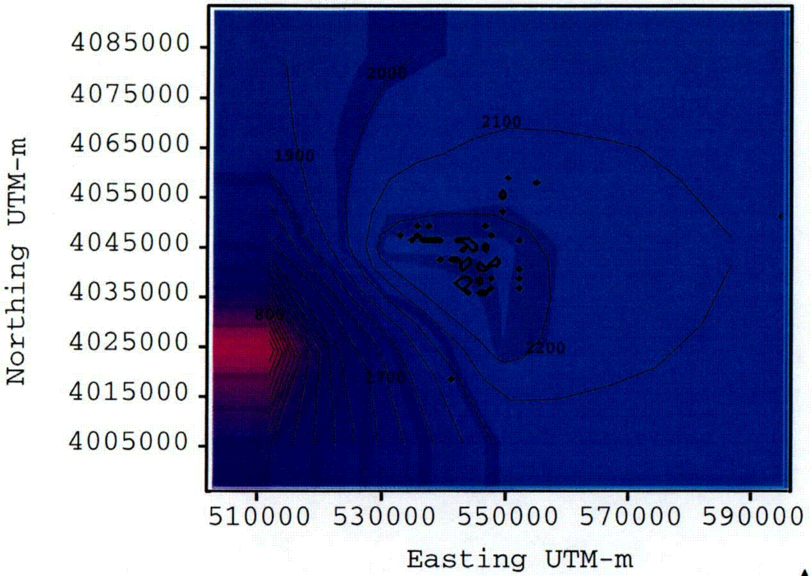


Elevation in feet above mean sea level

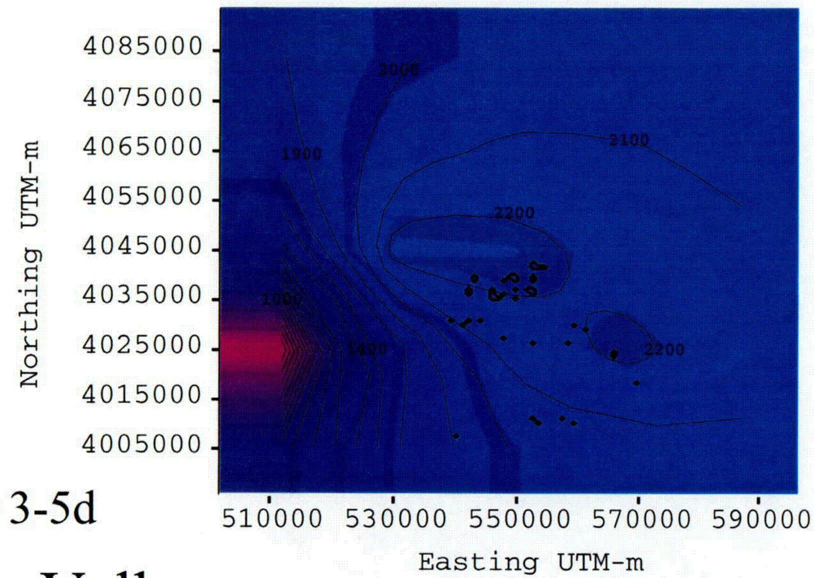
C-06

Figure 3-5d

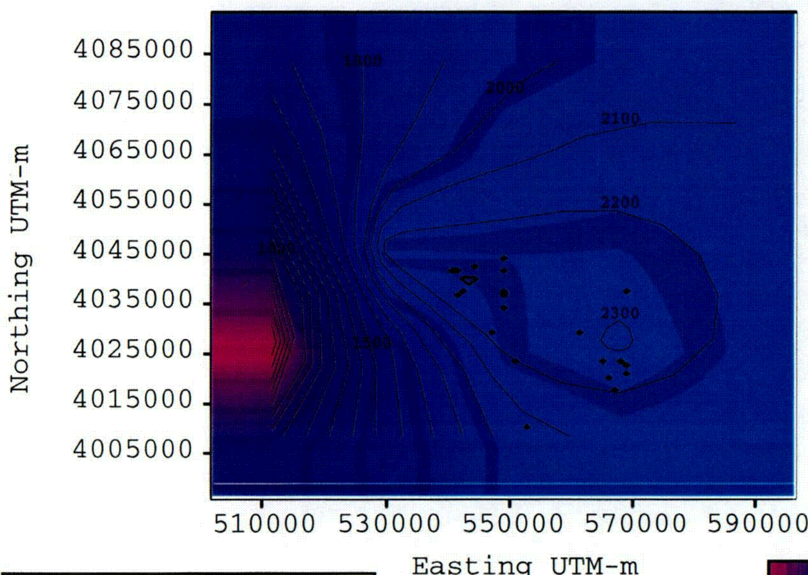
Amargosa Valley Groundwater Elevations



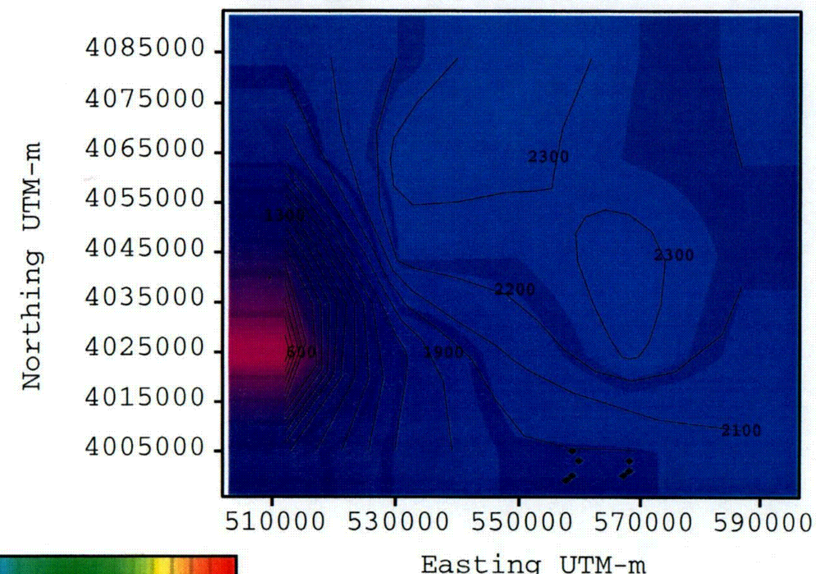
1950-1960



1960-1970

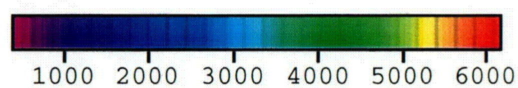


1970-1980



1980-1990

• Monitoring Well
Contour Intervals at 100 feet

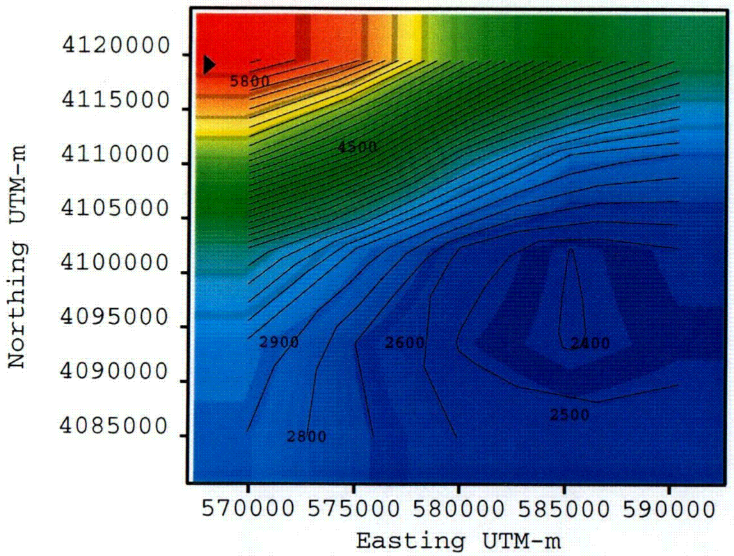


Elevation in feet above mean sea level

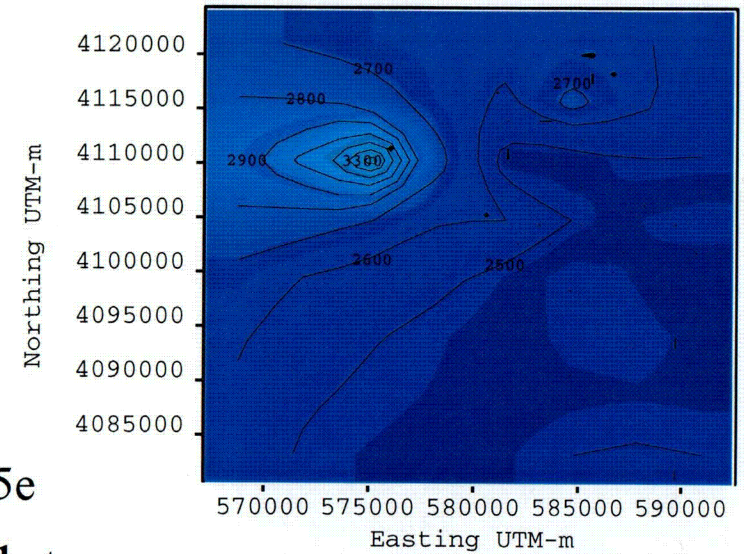
C-07

Figure 3-5e

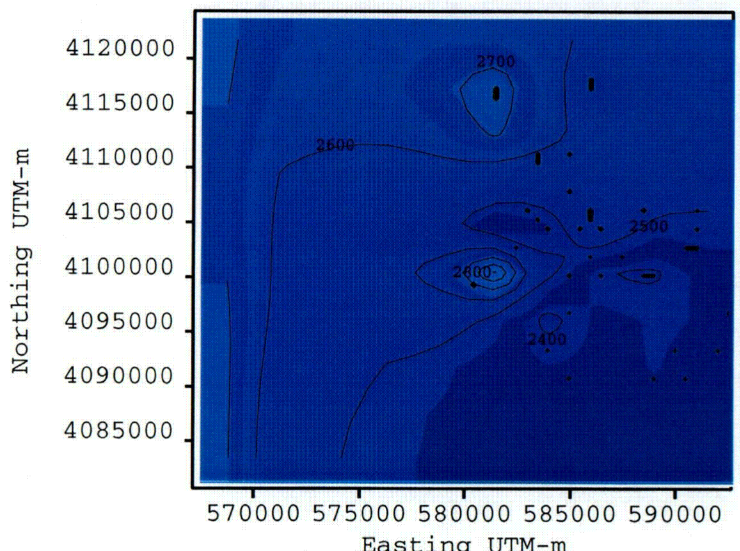
Yucca Flat Groundwater Elevations



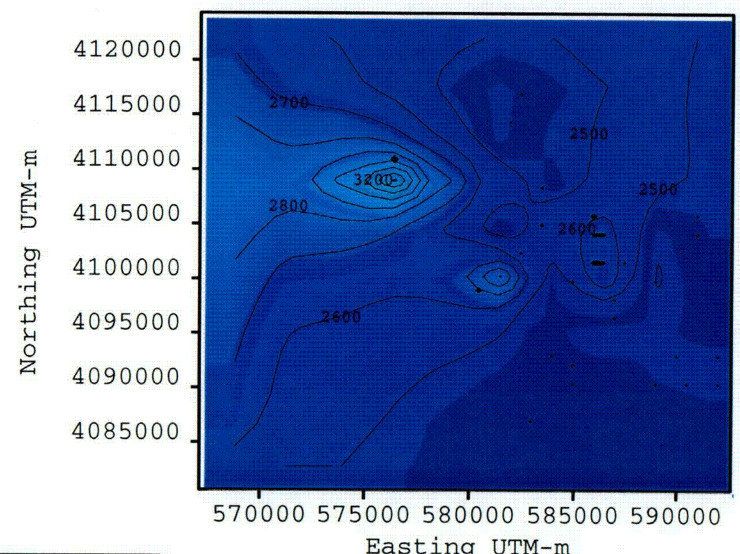
1950-1960



1970-1980

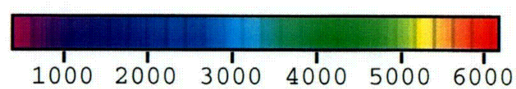


1980-1990



1990-1997

• Monitoring Well
Contour Intervals at 100 feet



Elevation in feet above mean sea level

C-08

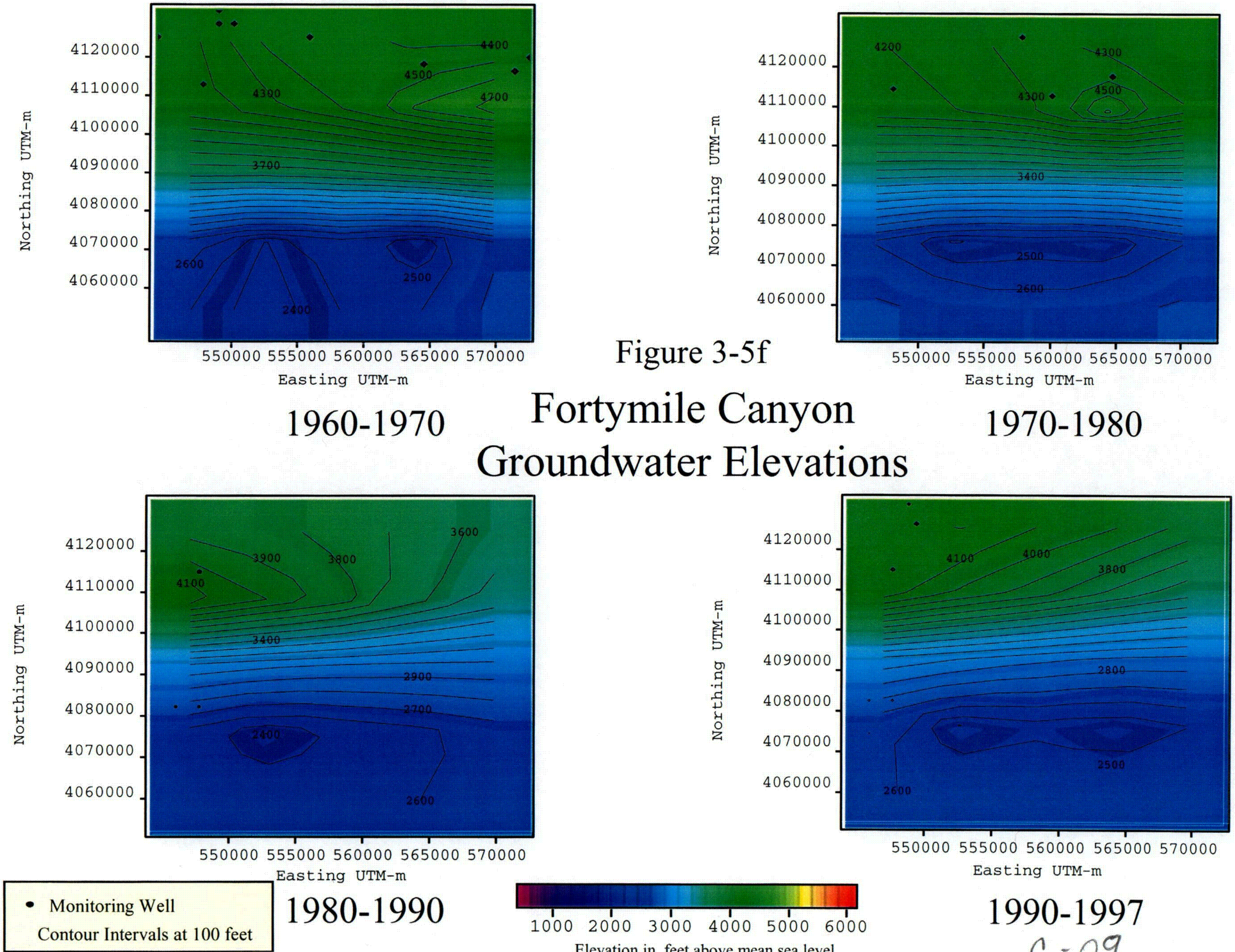


Figure 3-5f

Fortymile Canyon Groundwater Elevations

C-09

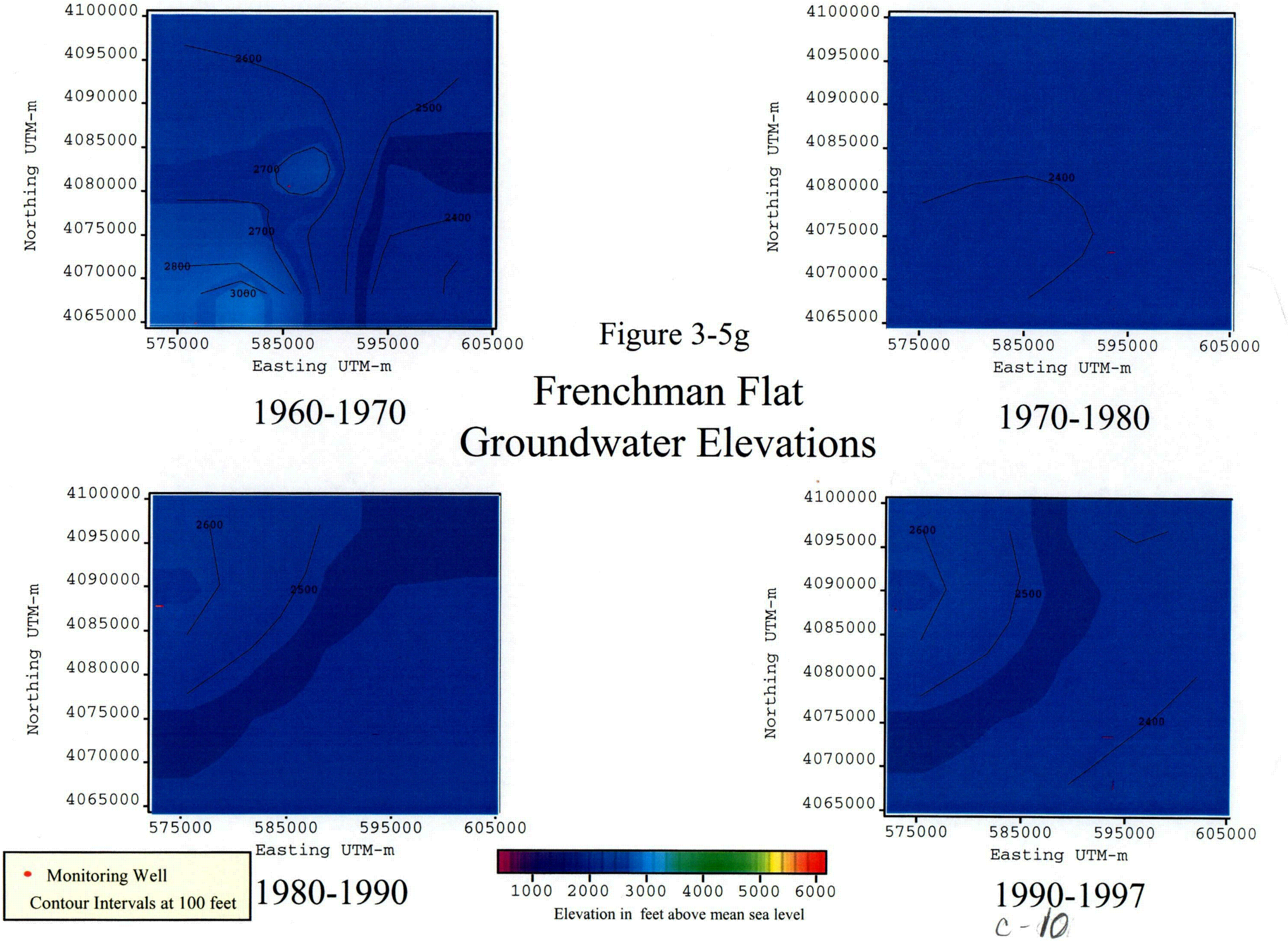
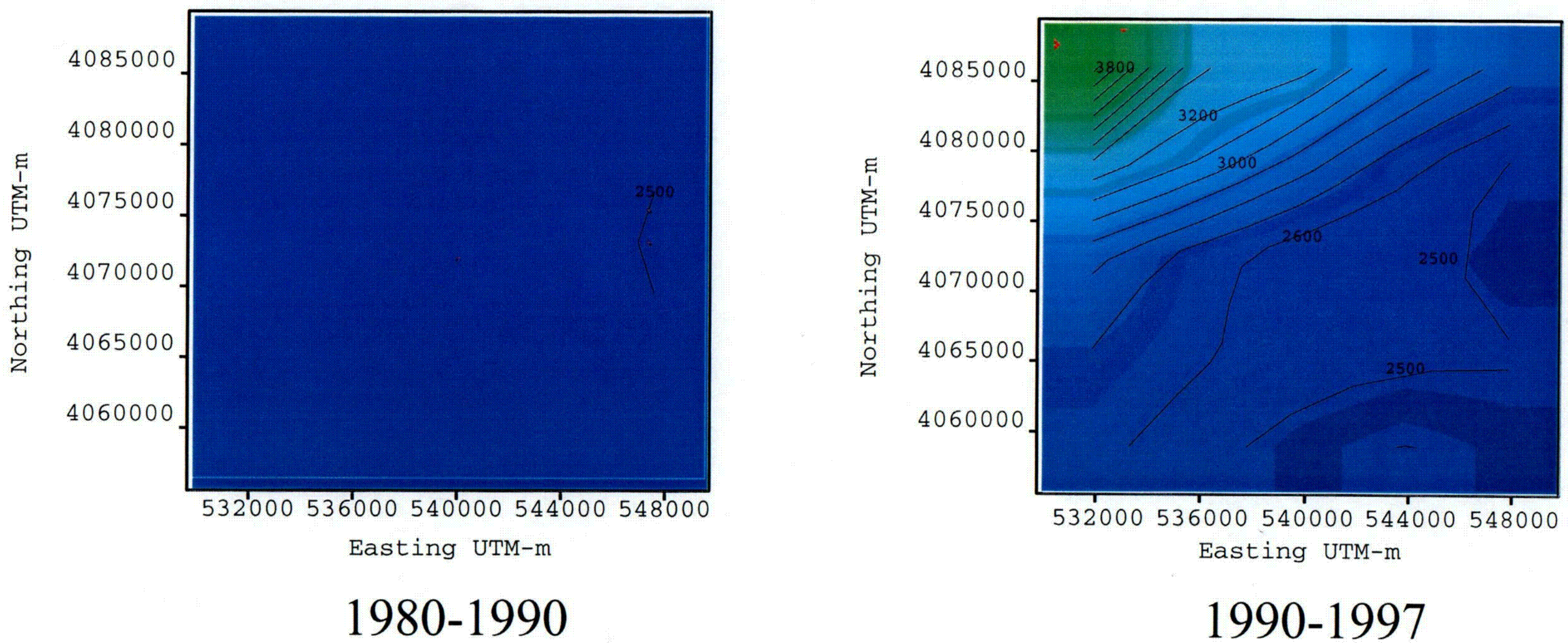


Figure 3-5g

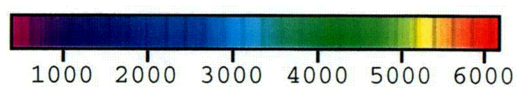
Frenchman Flat Groundwater Elevations

Figure 3-5h

Crater Flat
Groundwater Elevations



• Monitoring Well
Contour Intervals at 100 feet

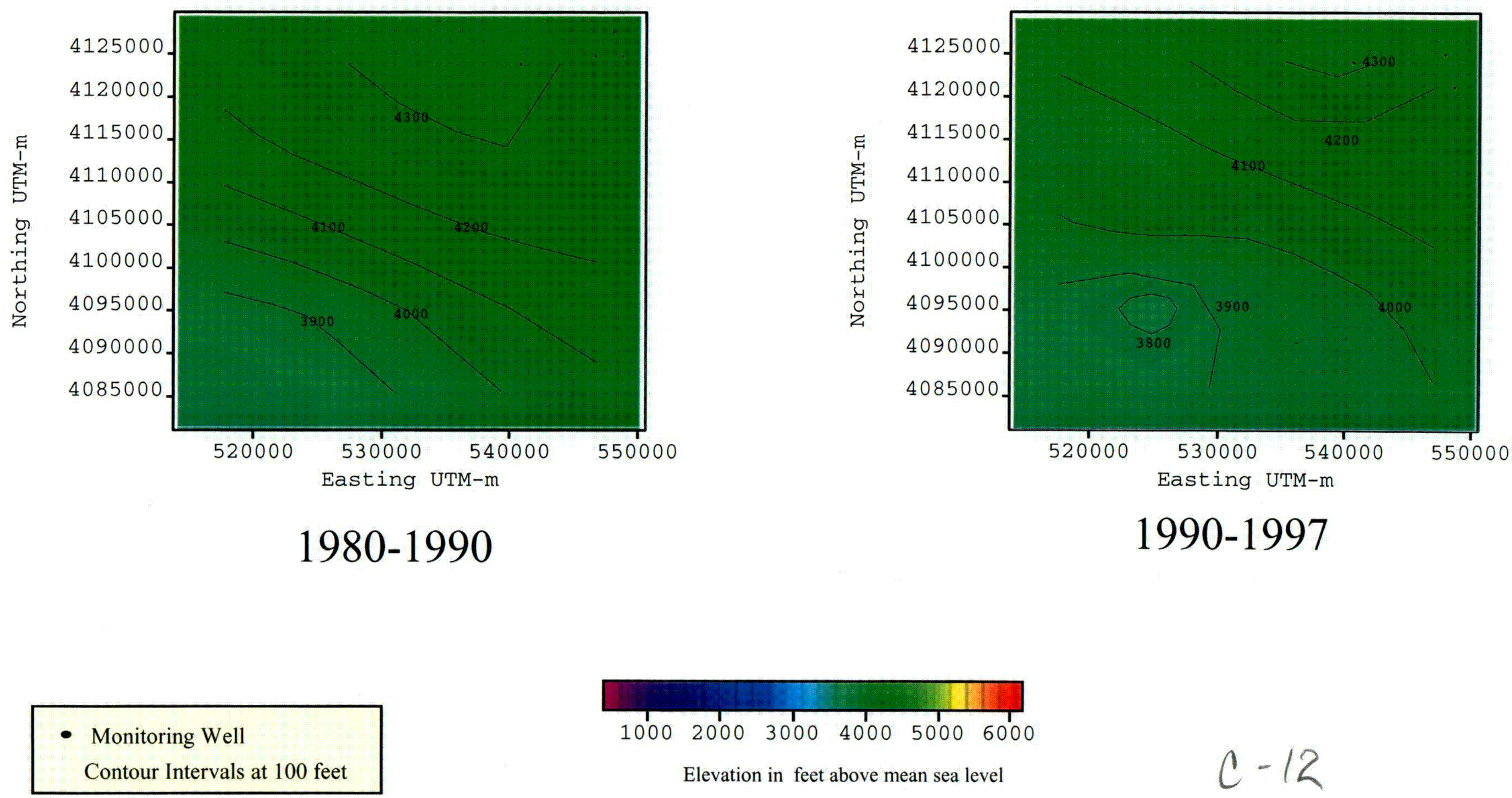


Elevation in feet above mean sea level

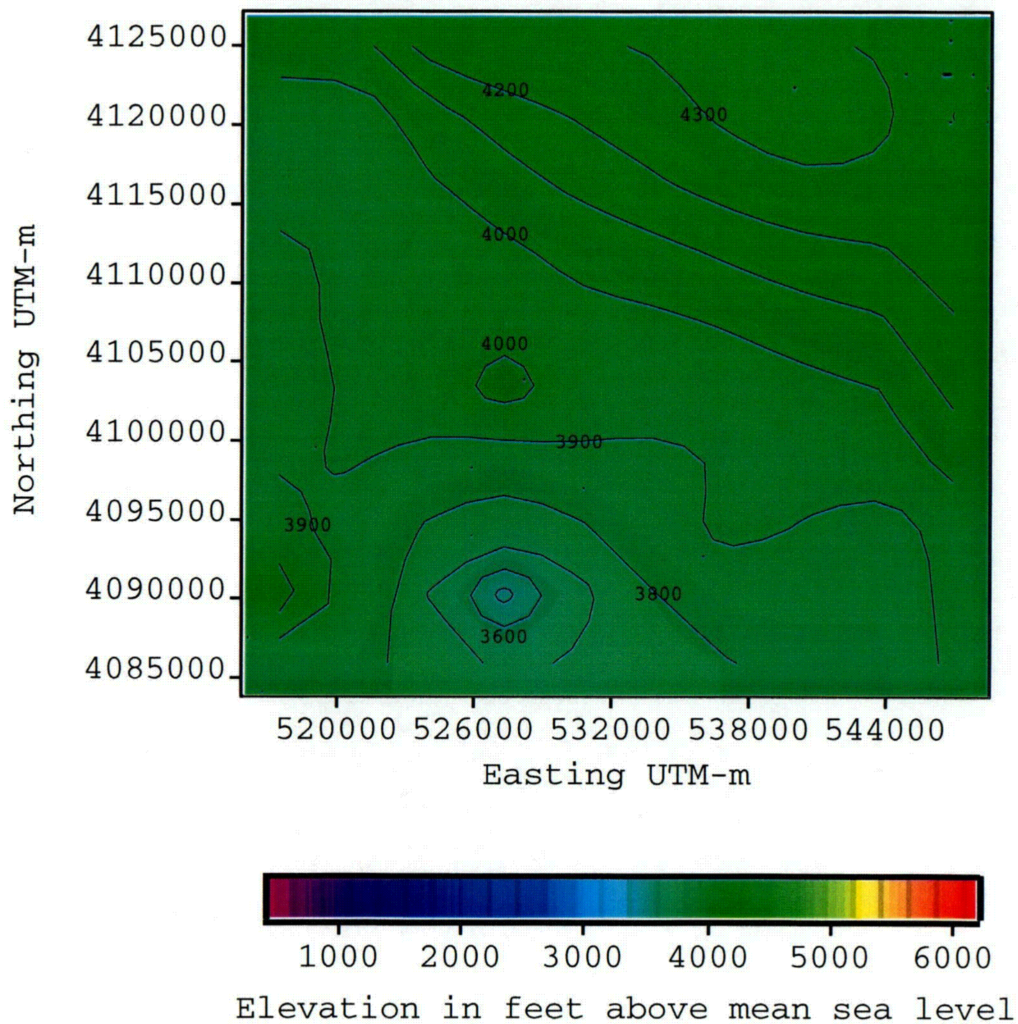
C-11

Figure 3-5i

Oasis Valley
Groundwater Elevations



C-12



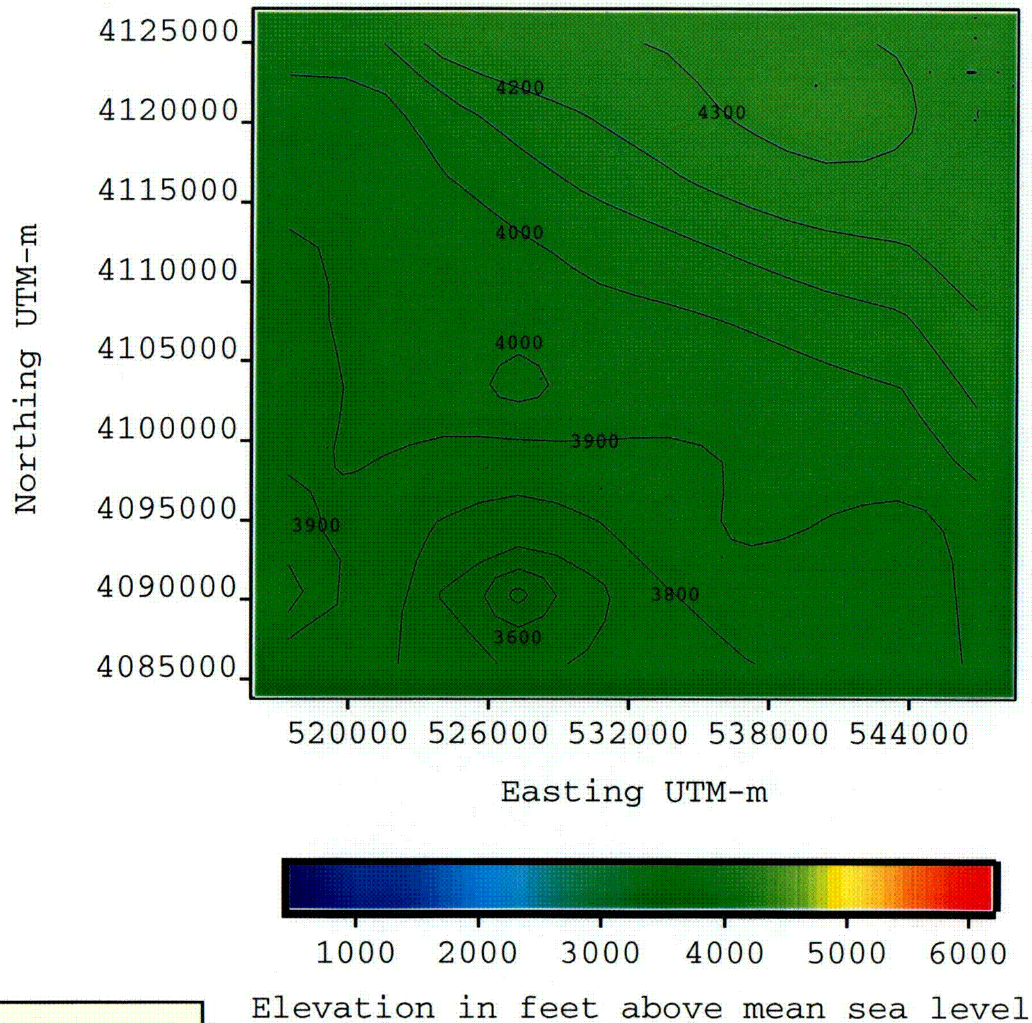
- Monitoring Well

Contour Intervals at 100 feet

C-13

Figure 3-6a Oasis Valley groundwater elevations, 1964 - 1997.

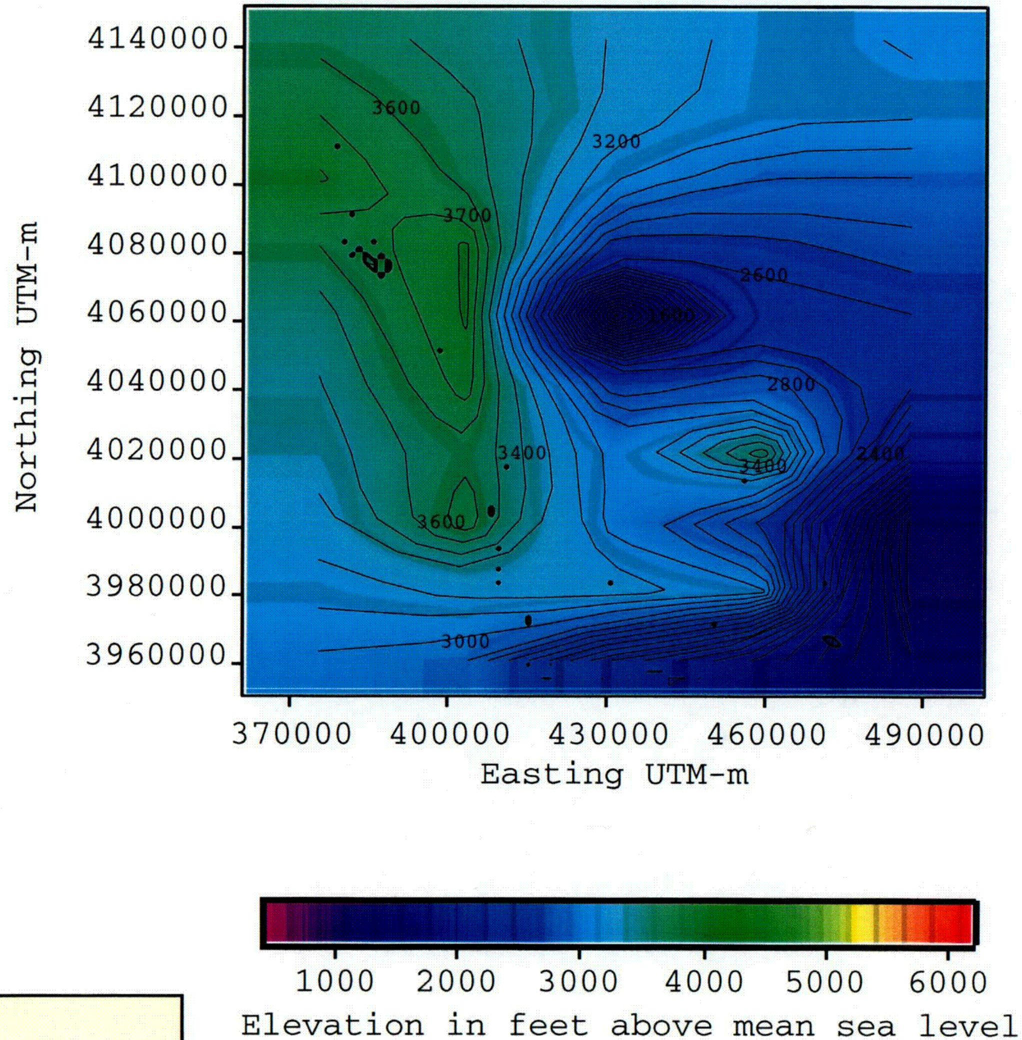
Oasis Valley Groundwater Elevations
1964 - 1997



- Monitoring Well

Contour Intervals at 100 feet

C-1H



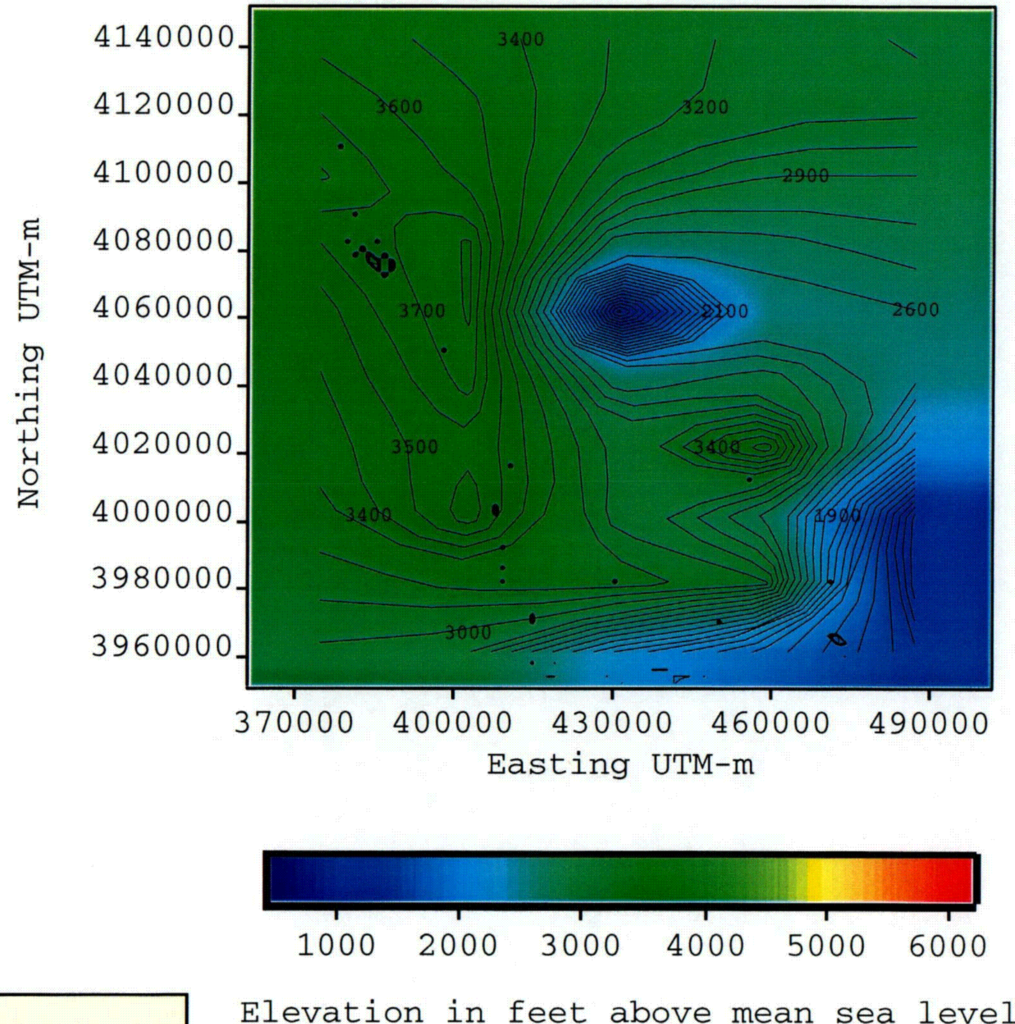
- Monitoring Well

Contour Intervals at 100 feet

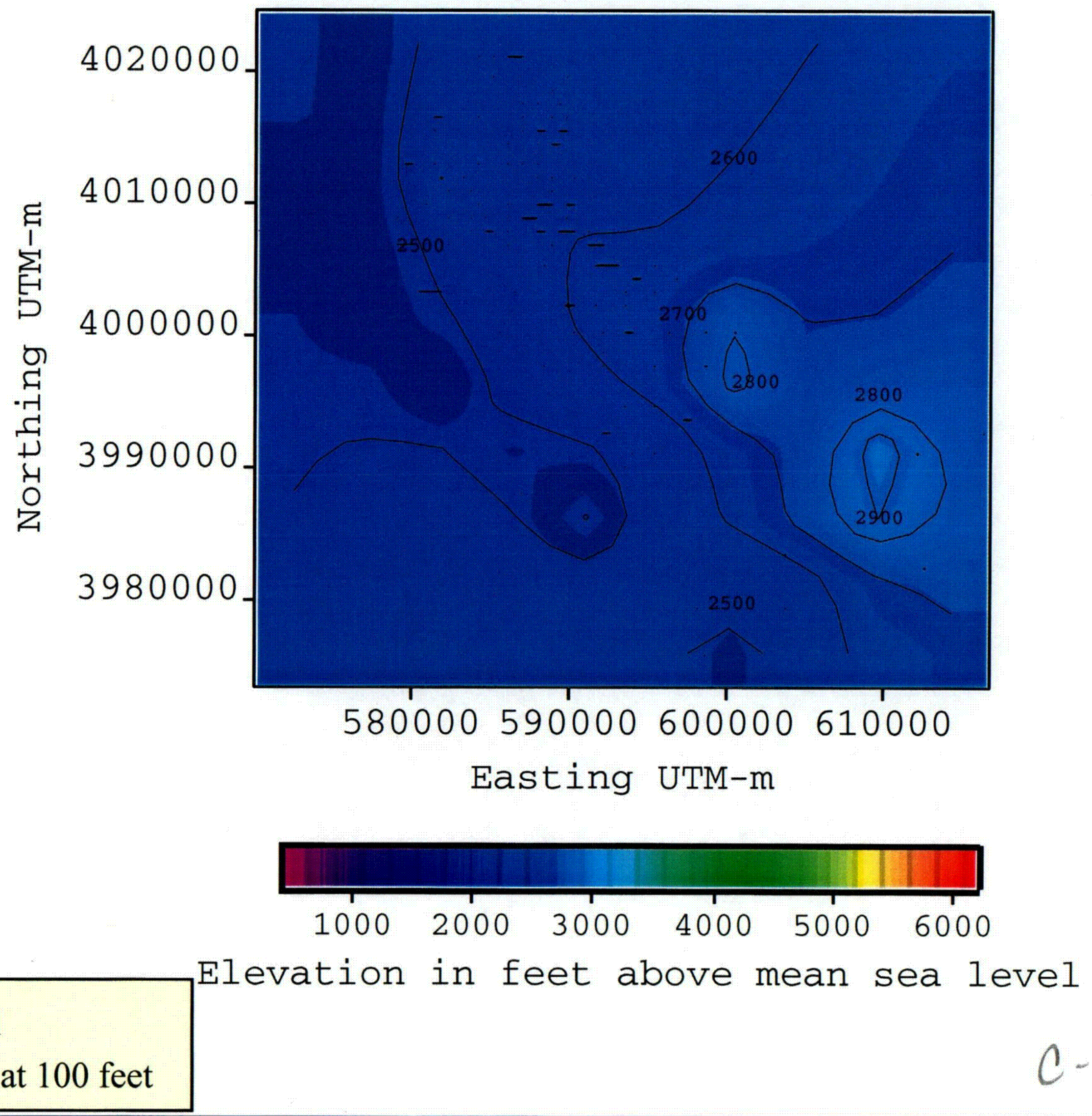
C-15

Figure 3-6b Inyo County groundwater elevations, 1921 - 1991.

Inyo County Groundwater Elevations
1921 - 1991



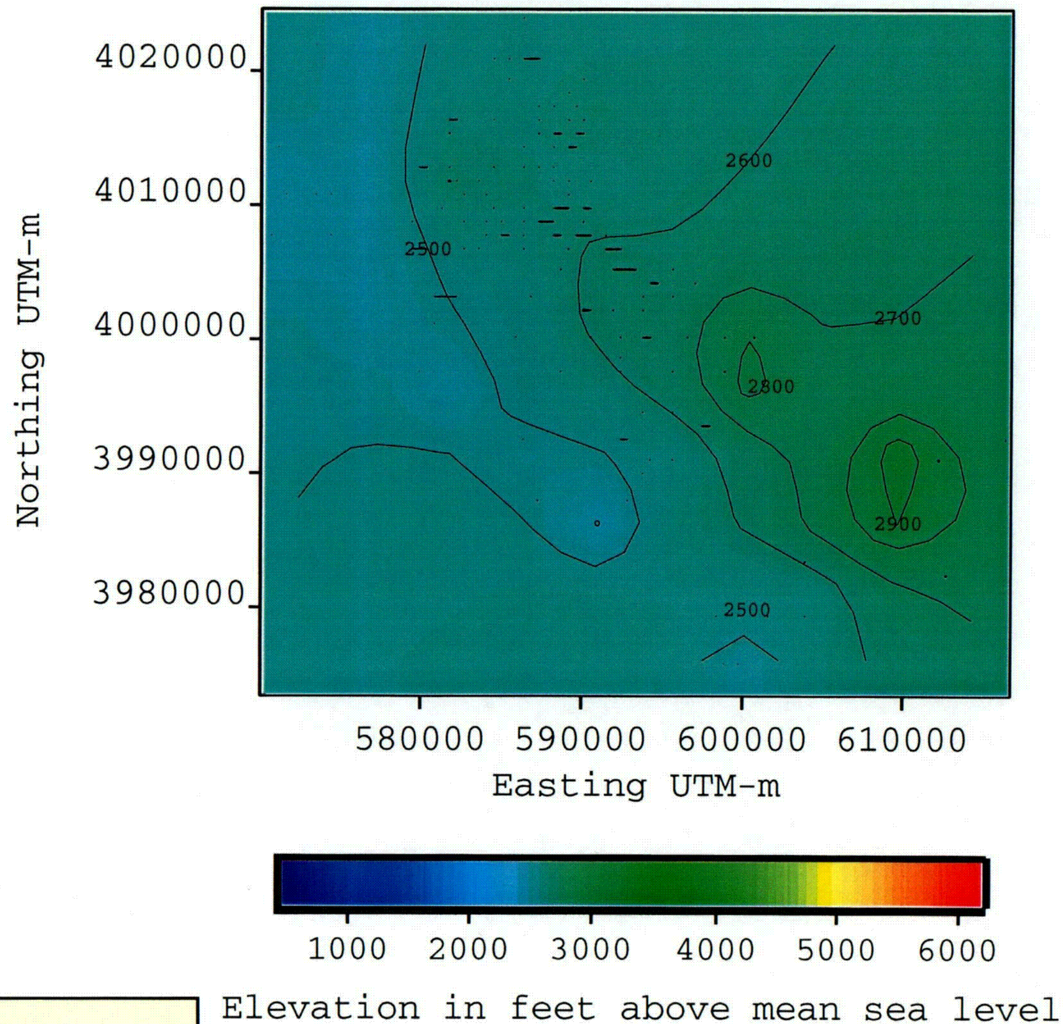
• Monitoring Well
Contour Intervals at 100 feet



C-17

Figure 3-6c Pahrump Valley groundwater elevations, 1944 - 1997.

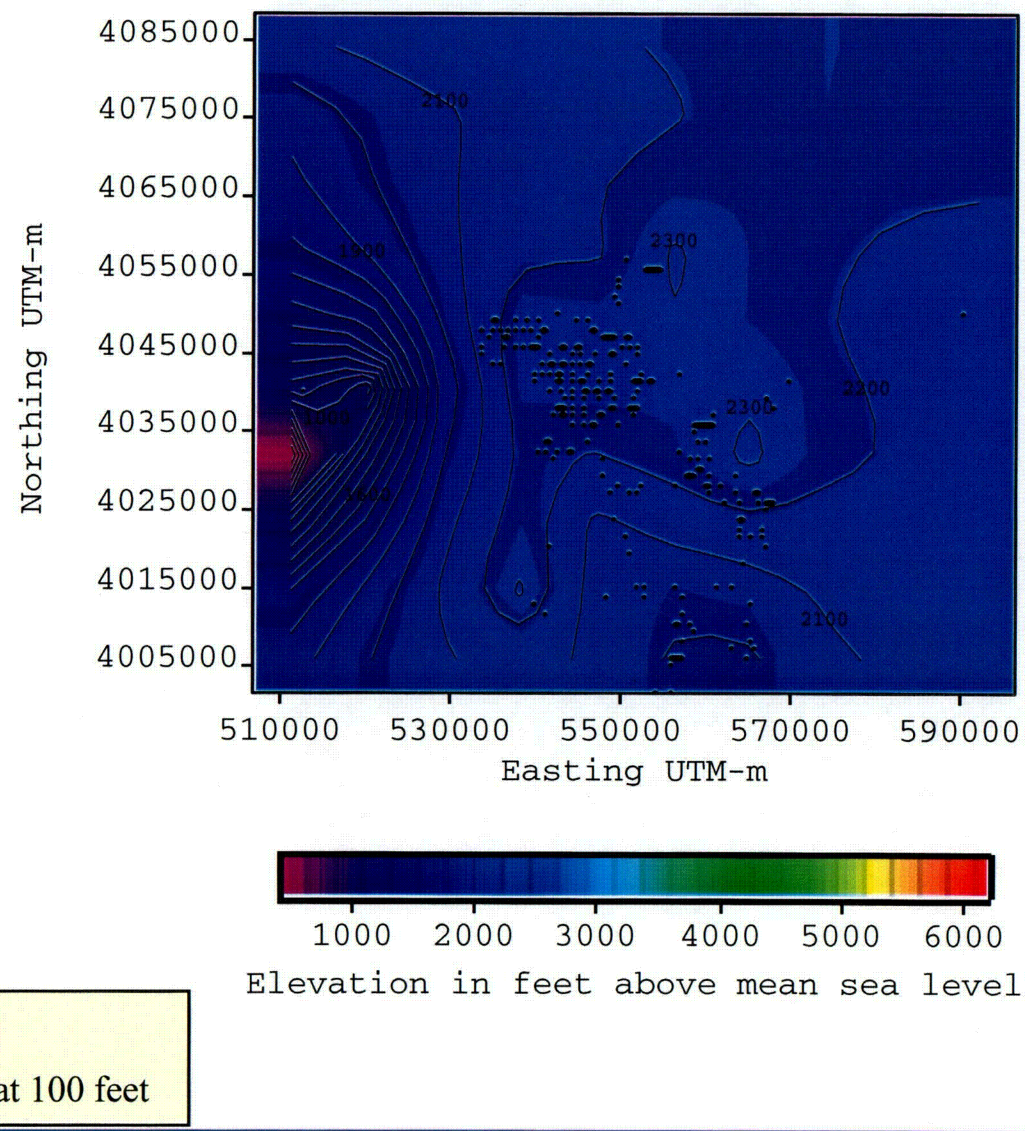
Pahrump Valley Groundwater Elevations
1944 - 1997



- Monitoring Well

Contour Intervals at 100 feet

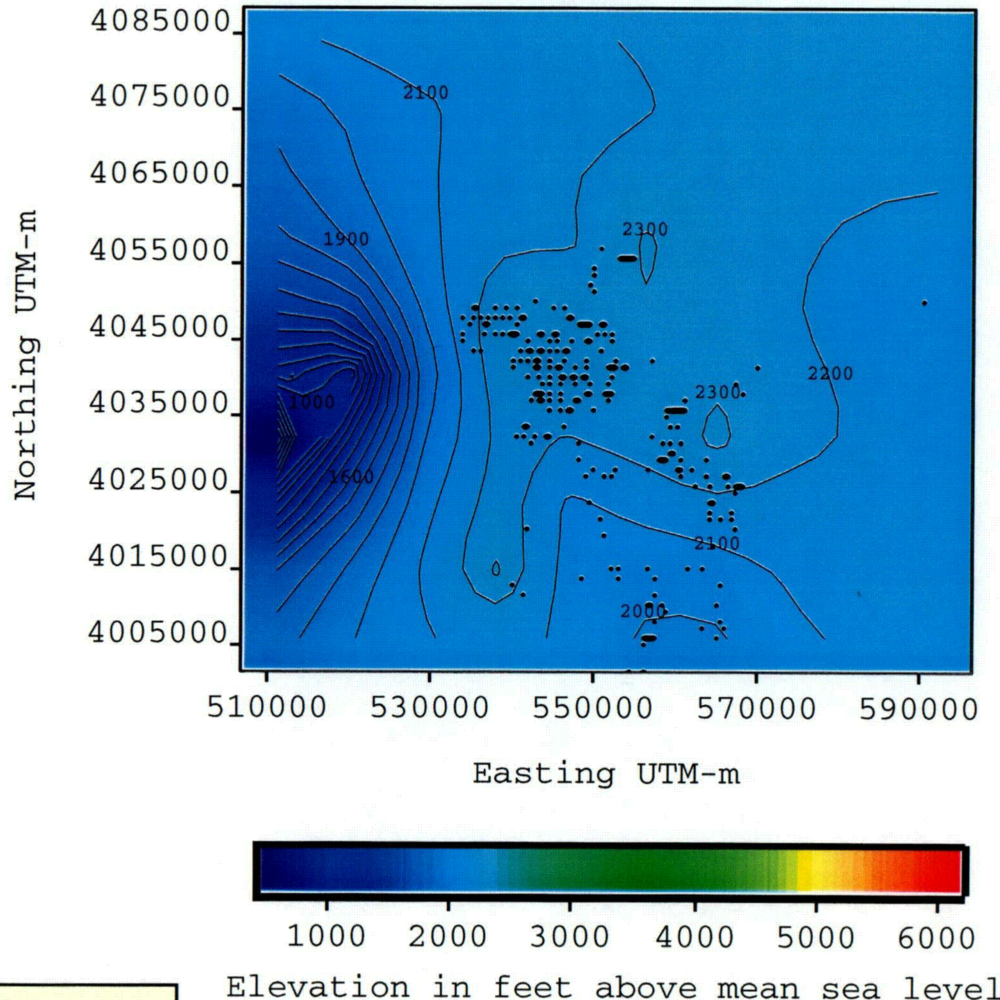
C-18



C-19

Figure 3-6d Amargosa Valley groundwater elevations, 1952 - 1997.

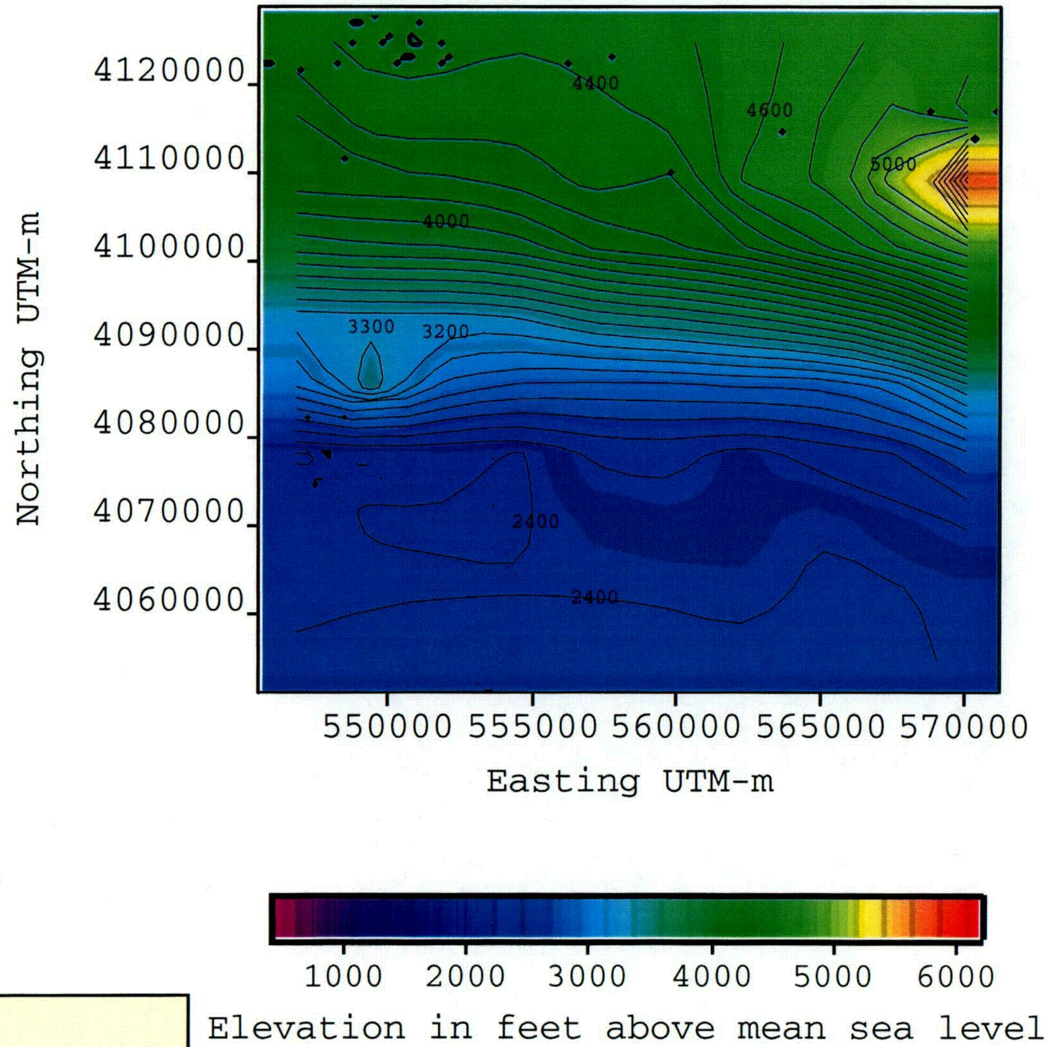
Amargosa Valley Groundwater Elevations
1952 - 1997



- Monitoring Well

Contour Intervals at 100 feet

C-20

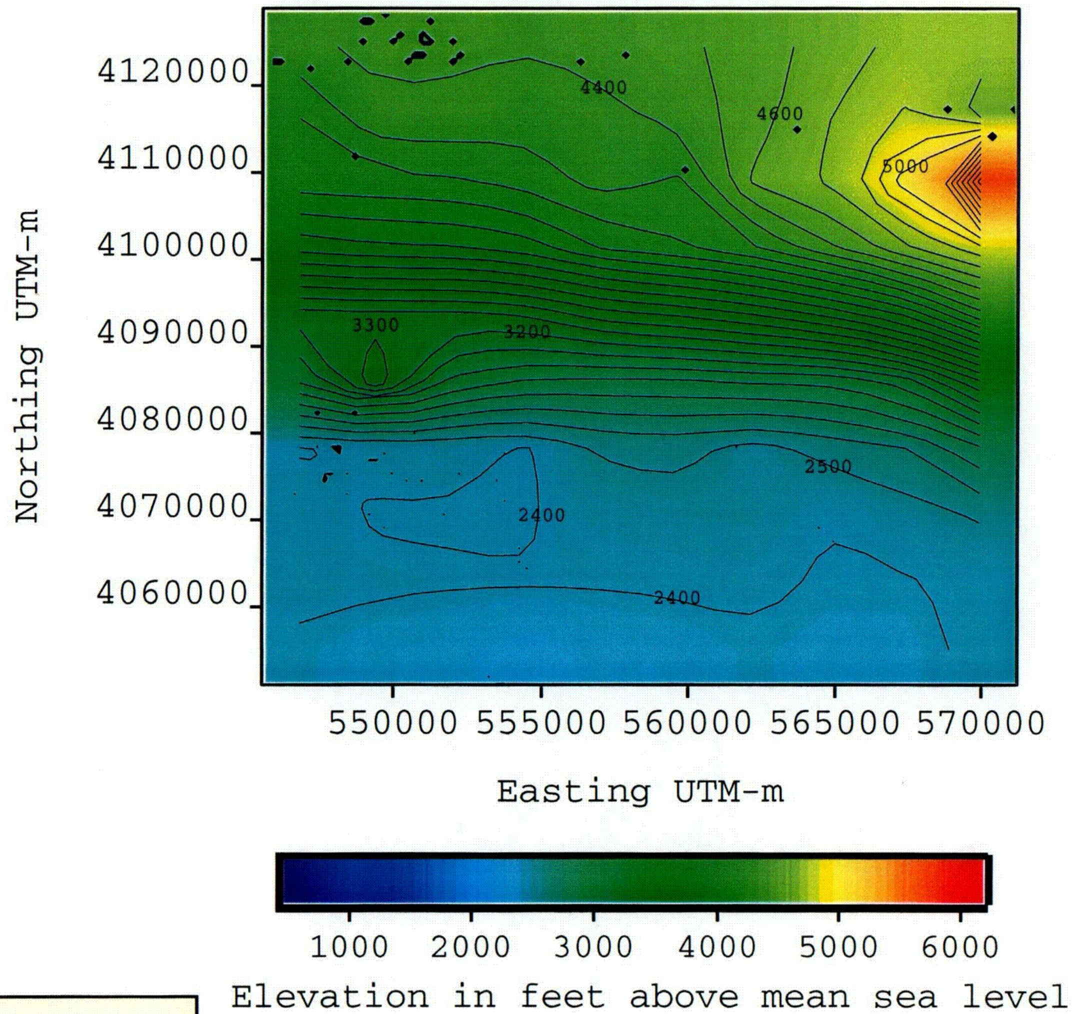


• Monitoring Well
Contour Intervals at 100 feet

C-21

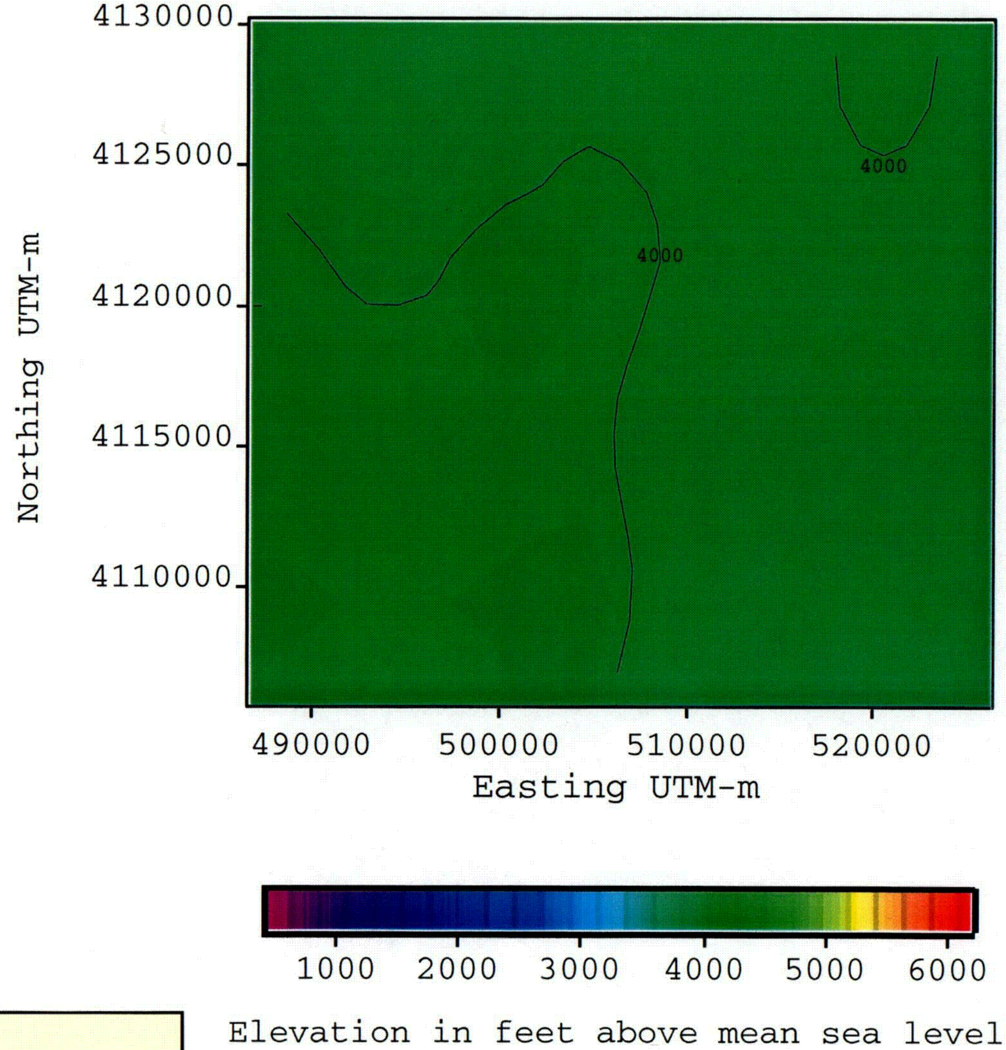
Figure 3-6e Fortymile Canyon groundwater elevations, 1952 - 1997.

Fortymile Canyon Groundwater Elevations
1952 - 1997



• Monitoring Well
Contour Intervals at 100 feet

C-22

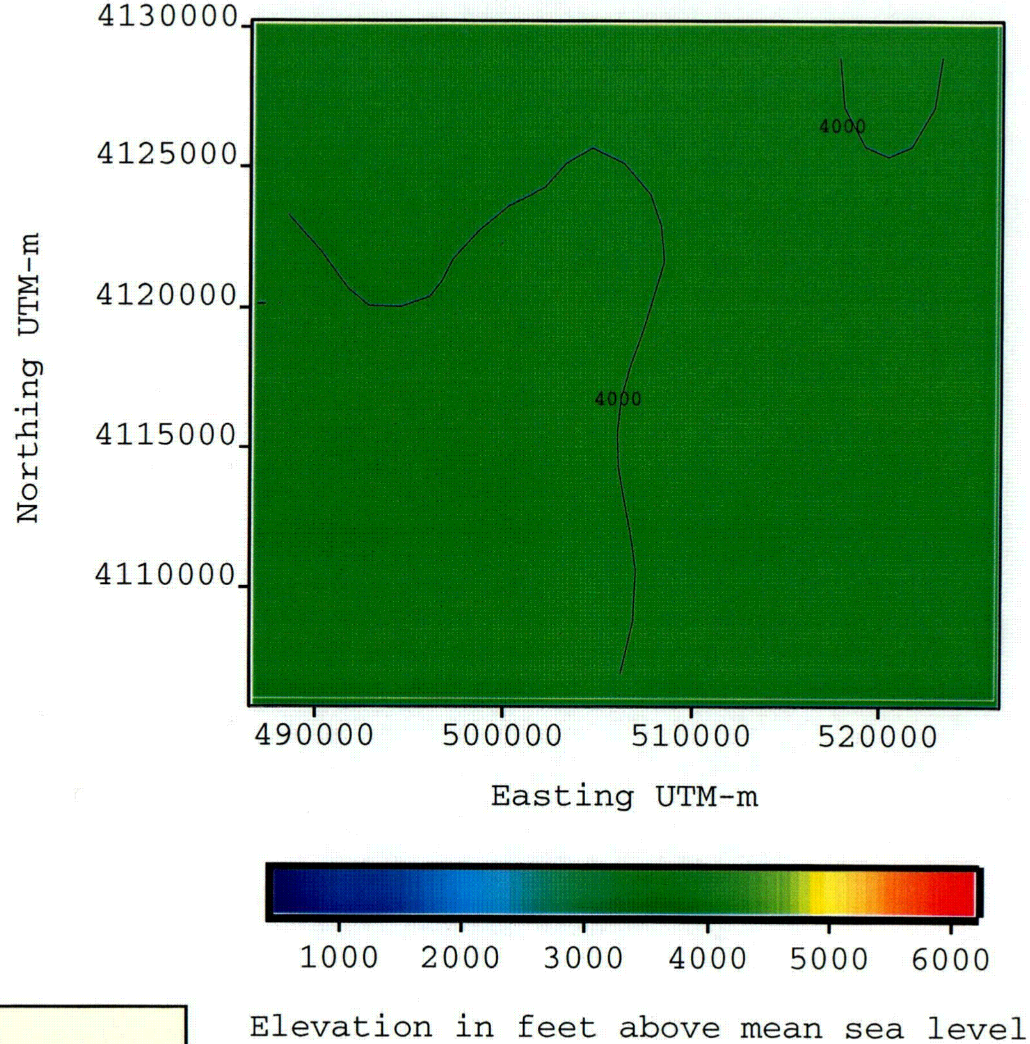


• Monitoring Well
Contour Intervals at 100 feet

C-23

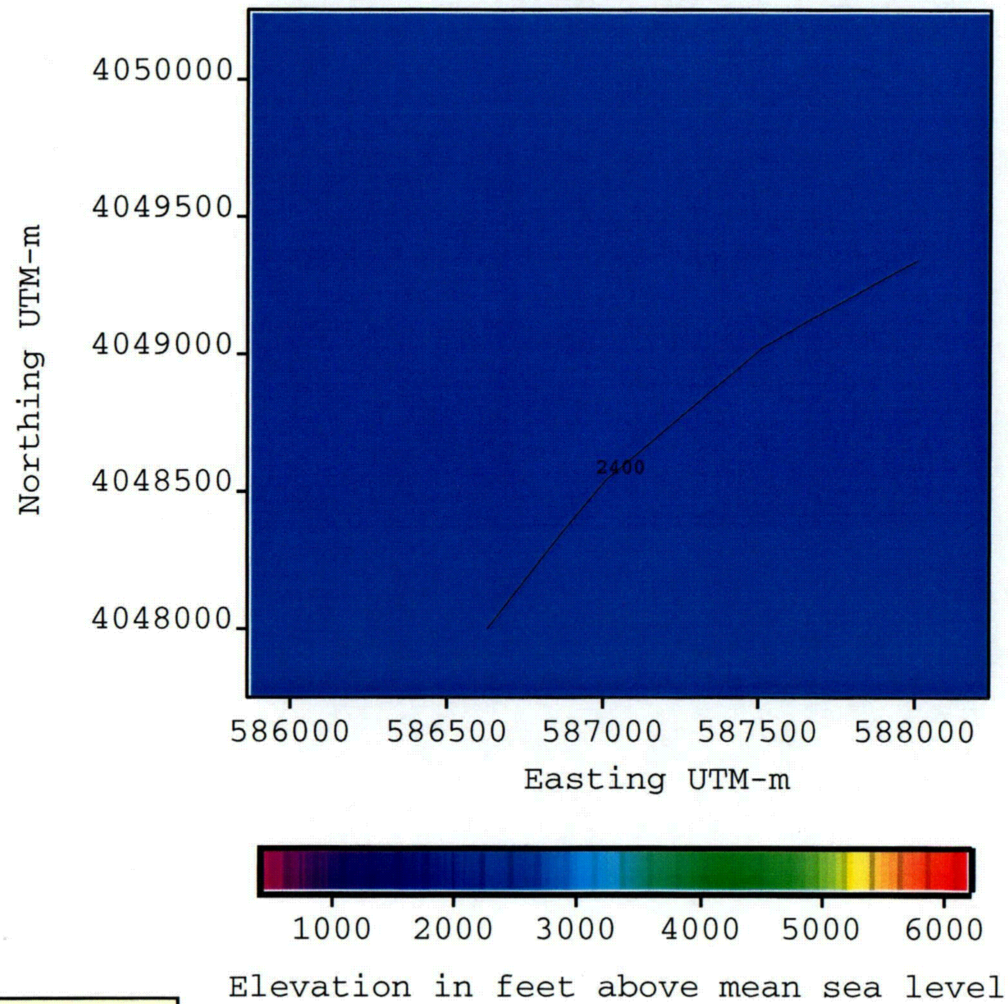
Figure 3-6f Sarcobatus Flat groundwater elevations, 1952 - 1997.

Sarcobatus Flat Groundwater Elevations 1952 - 1997



• Monitoring Well
Contour Intervals at 100 feet

C-24

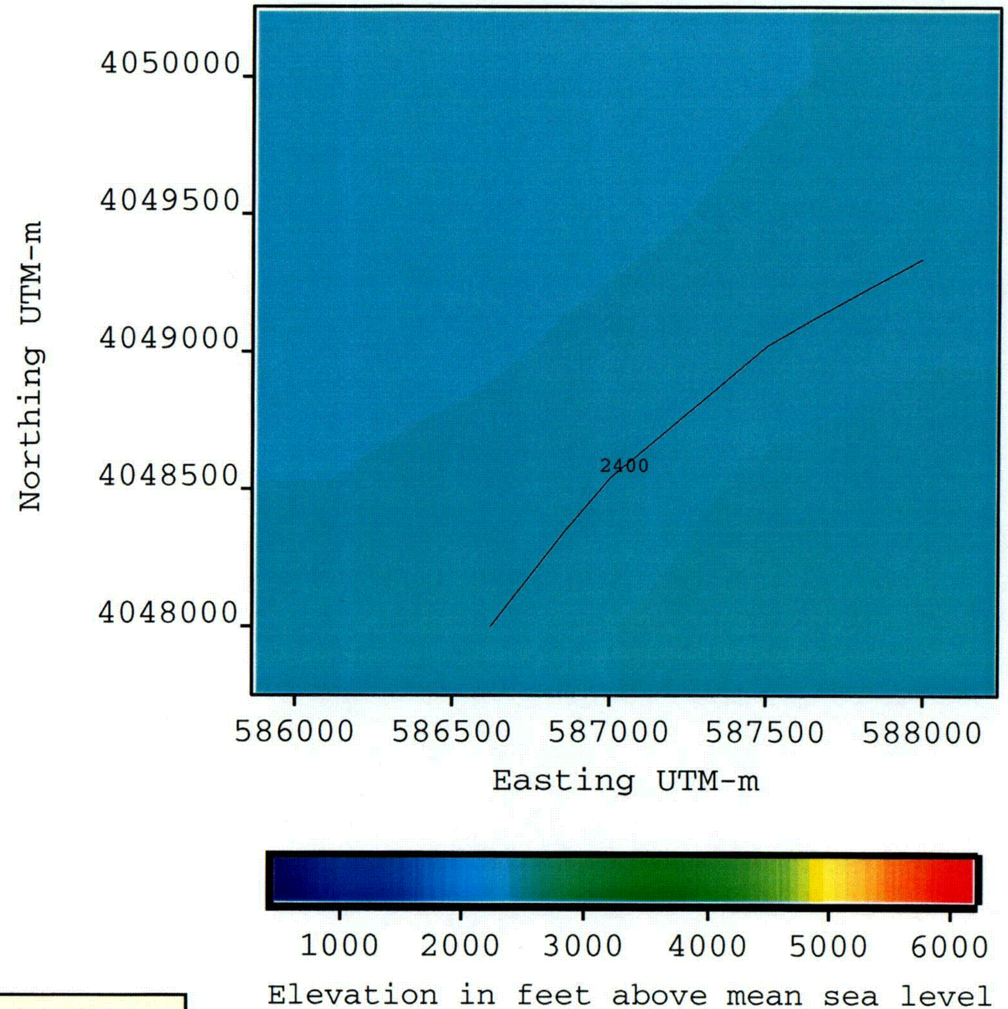


• Monitoring Well
Contour Intervals at 100 feet

C-25

Figure 3-6g Mercury Valley groundwater elevations, 1958 -1997.

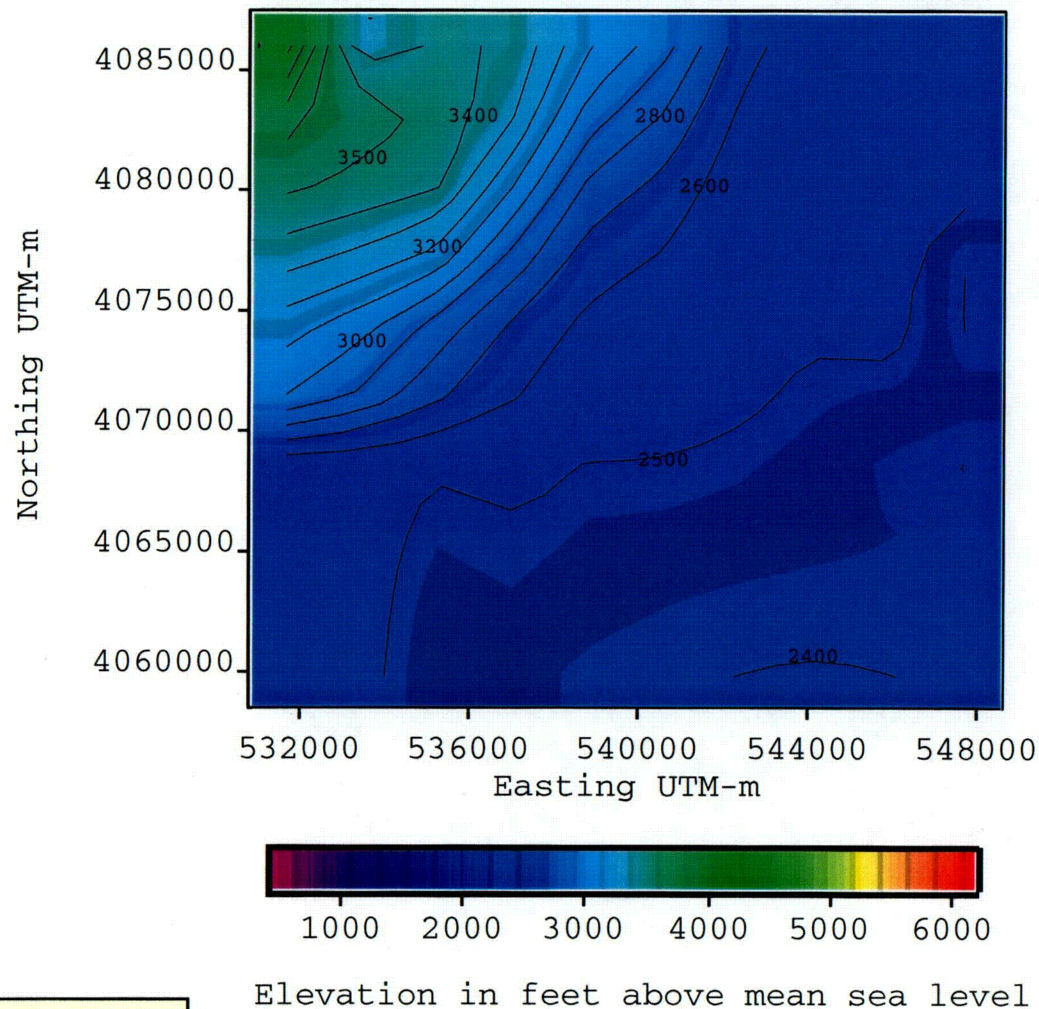
Mercury Valley Groundwater Elevations
1958 -1997



- Monitoring Well

Contour Intervals at 100 feet

C-26

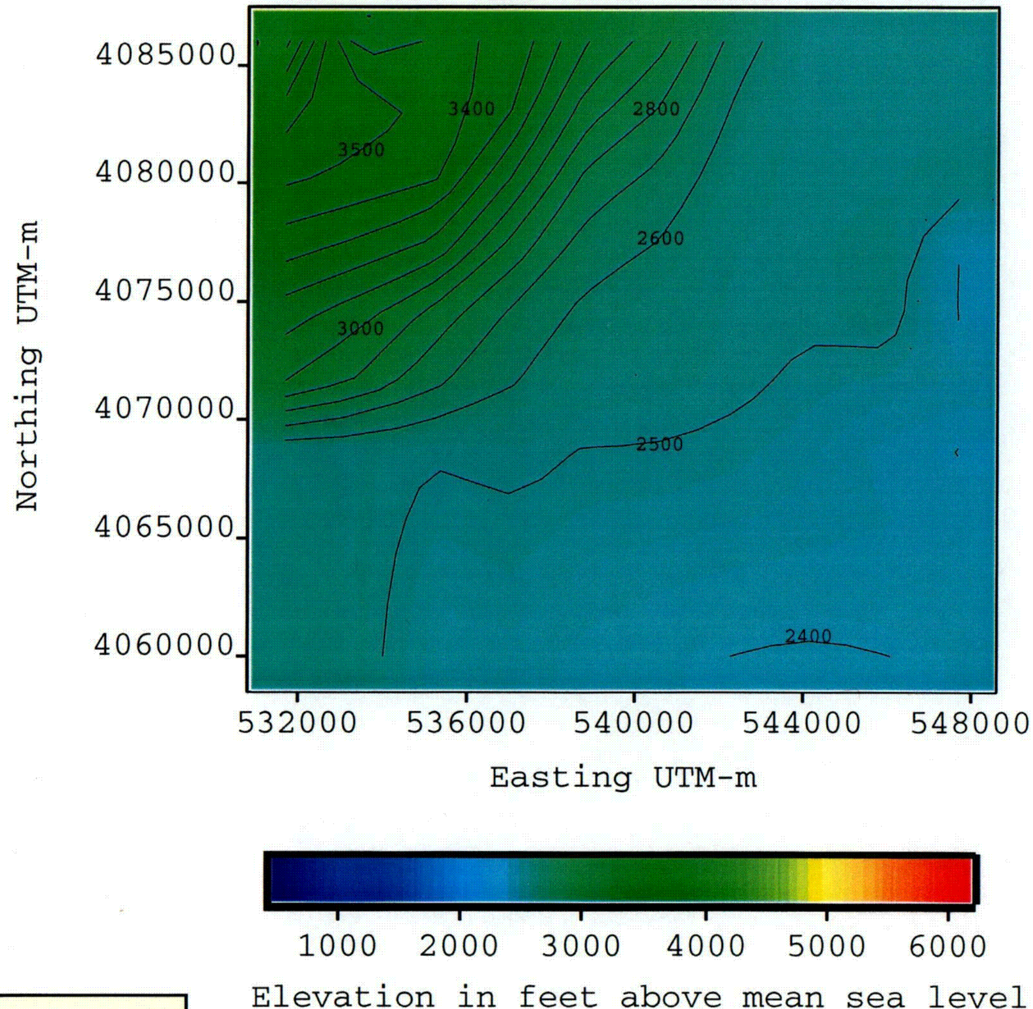


• Monitoring Well
Contour Intervals at 100 feet

C-27

Figure 3-6h Crater Flat groundwater elevations, 1980 - 1997.

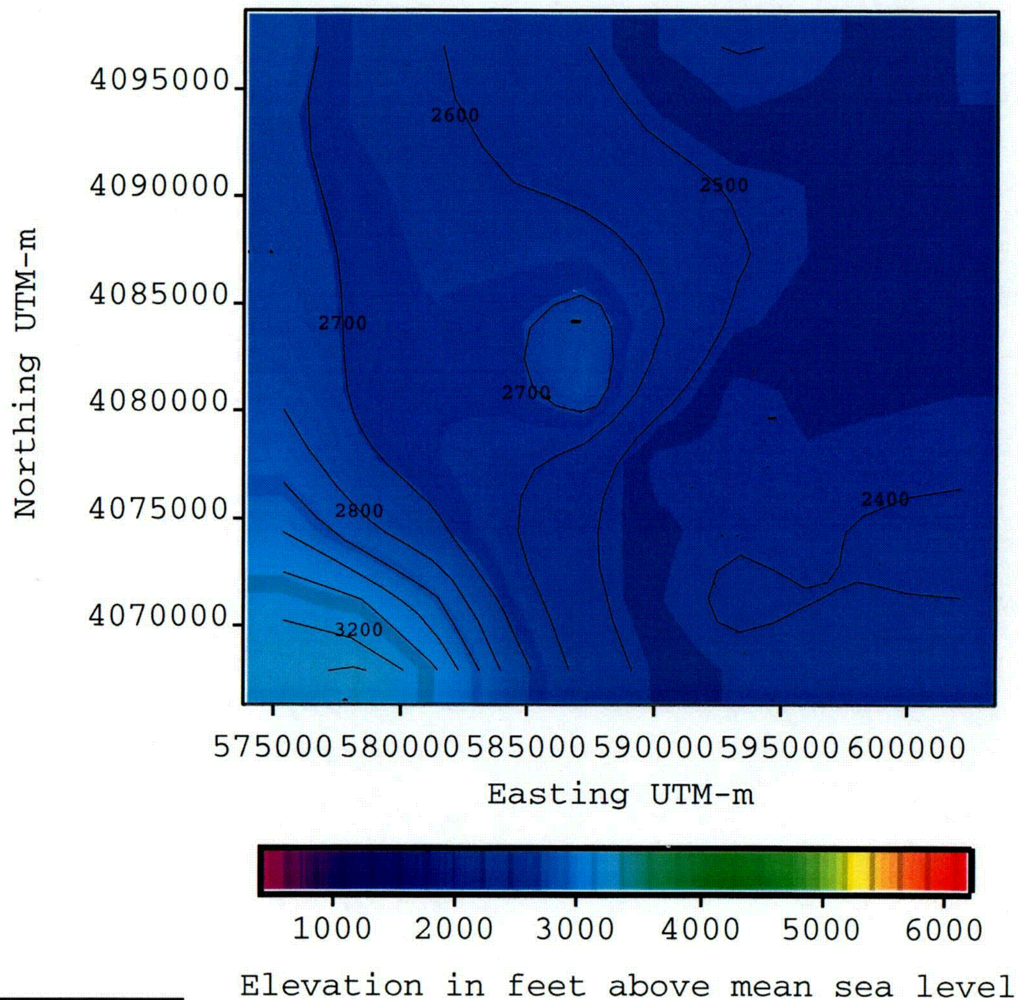
Crater Flat Groundwater Elevations
1980 - 1997



- Monitoring Well

Contour Intervals at 100 feet

C-28



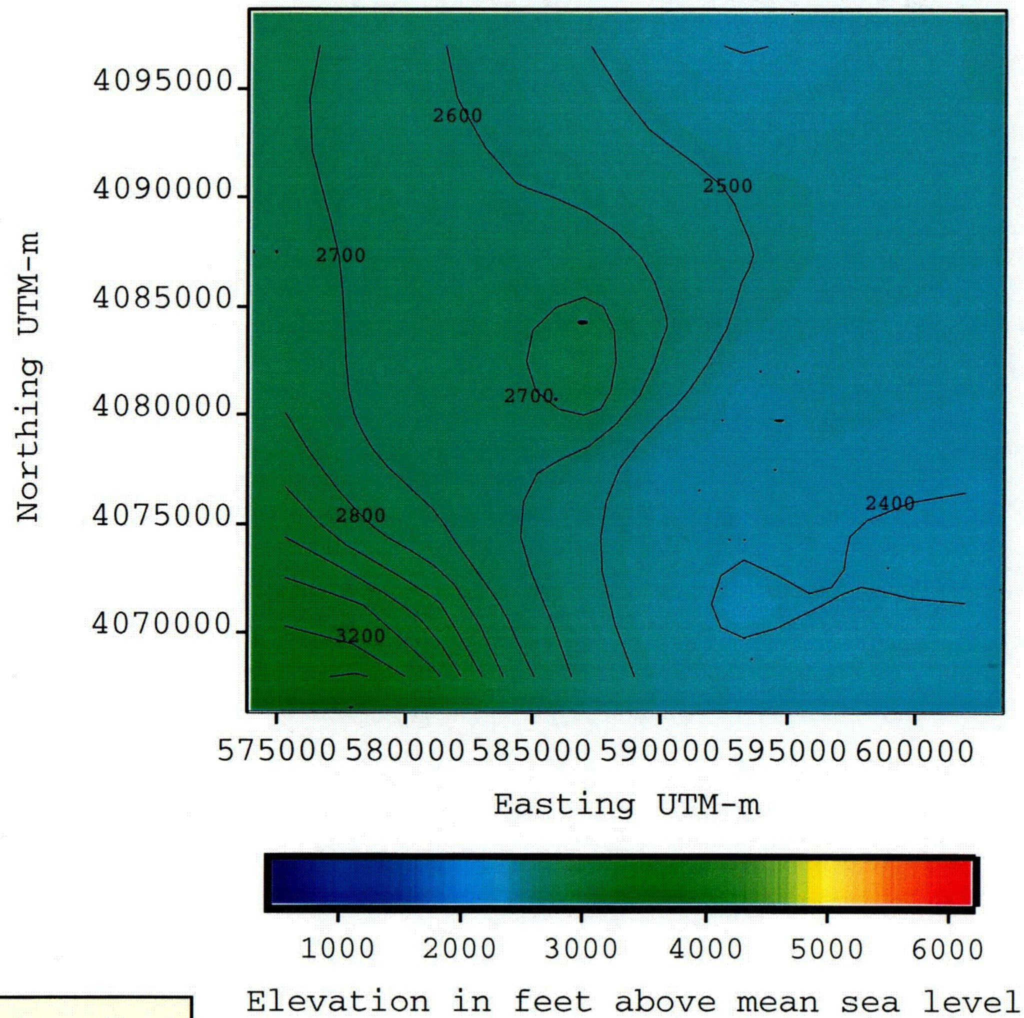
- Monitoring Well

Contour Intervals at 100 feet

C-29

Figure 3-6i Frenchman Flat groundwater elevations, 1950 - 1997.

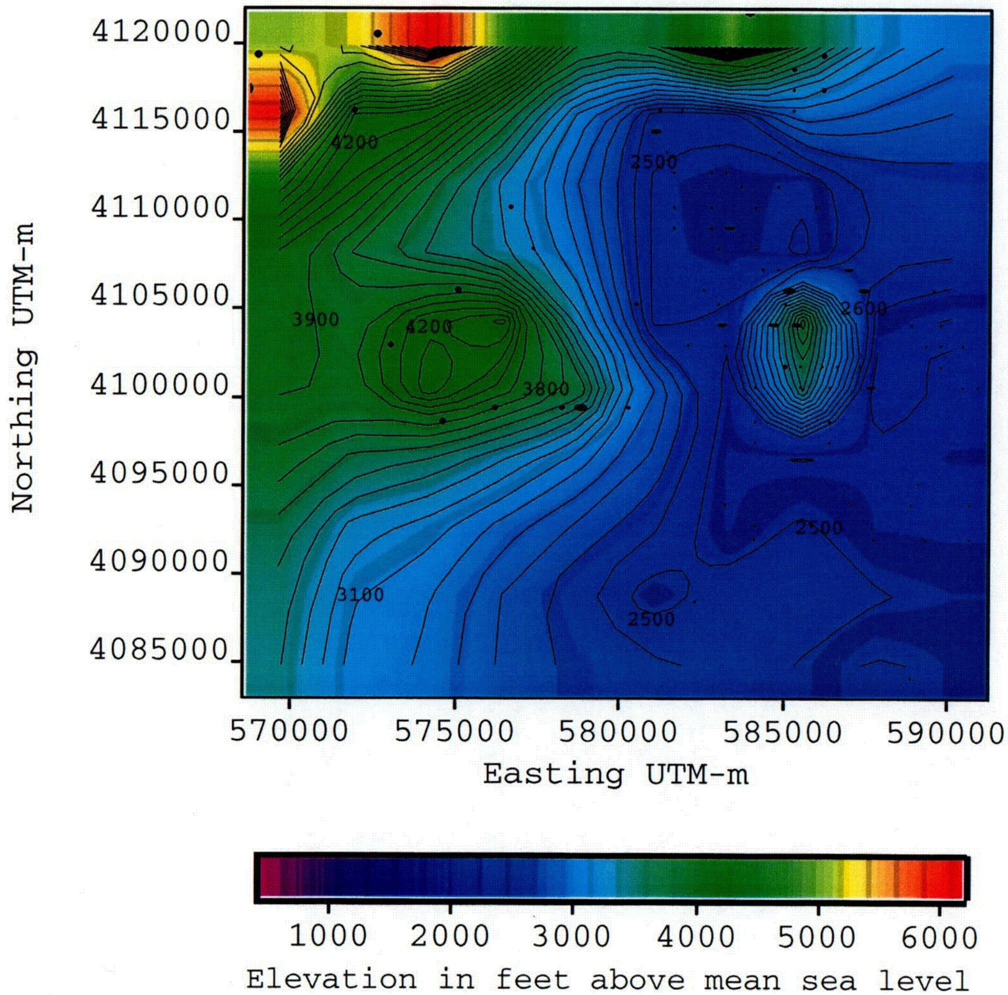
Frenchman Flat Groundwater Elevations
1950 - 1997



- Monitoring Well

Contour Intervals at 100 feet

C-30



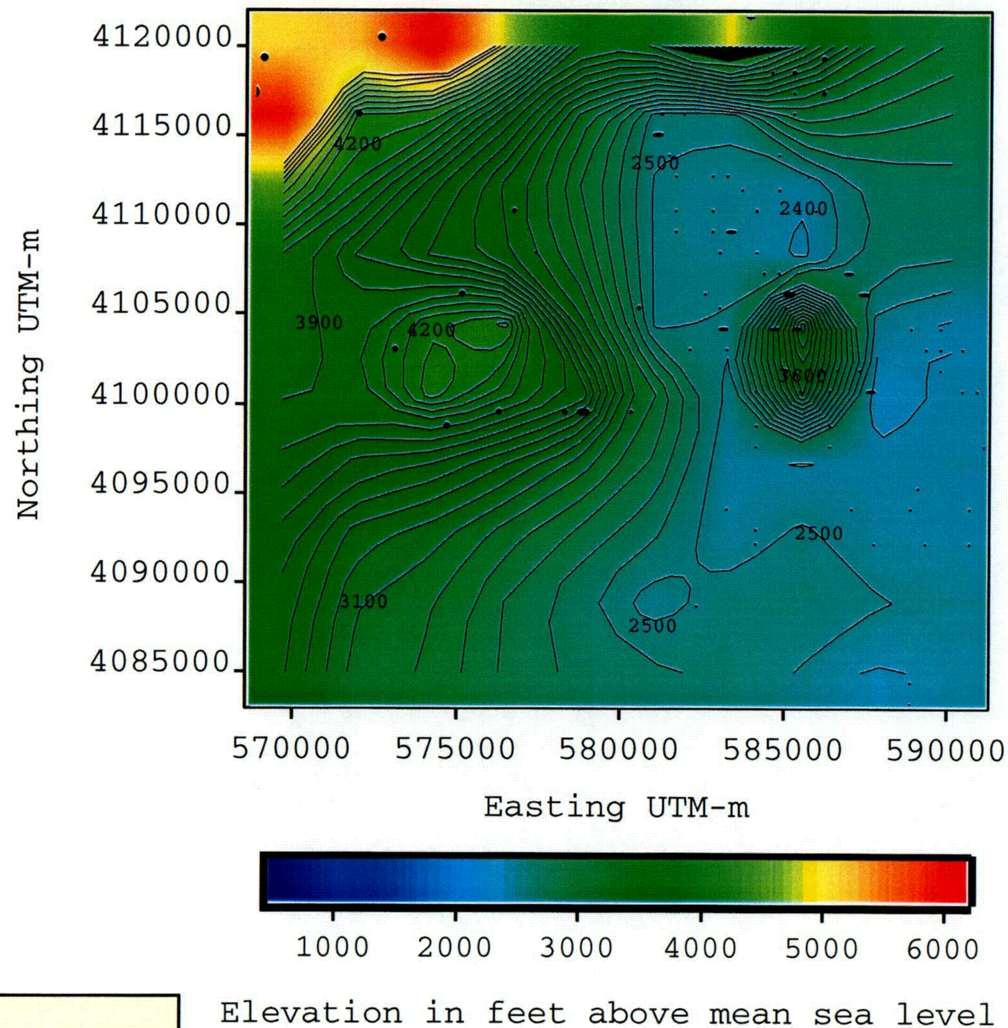
- Monitoring Well

Contour Intervals at 100 feet

C-31

Figure 3-6j **Yucca Flat groundwater elevations, 1958 -1997.**

Yucca Flat Groundwater Elevations 1958 -1997



• Monitoring Well
Contour Intervals at 100 feet

C-32

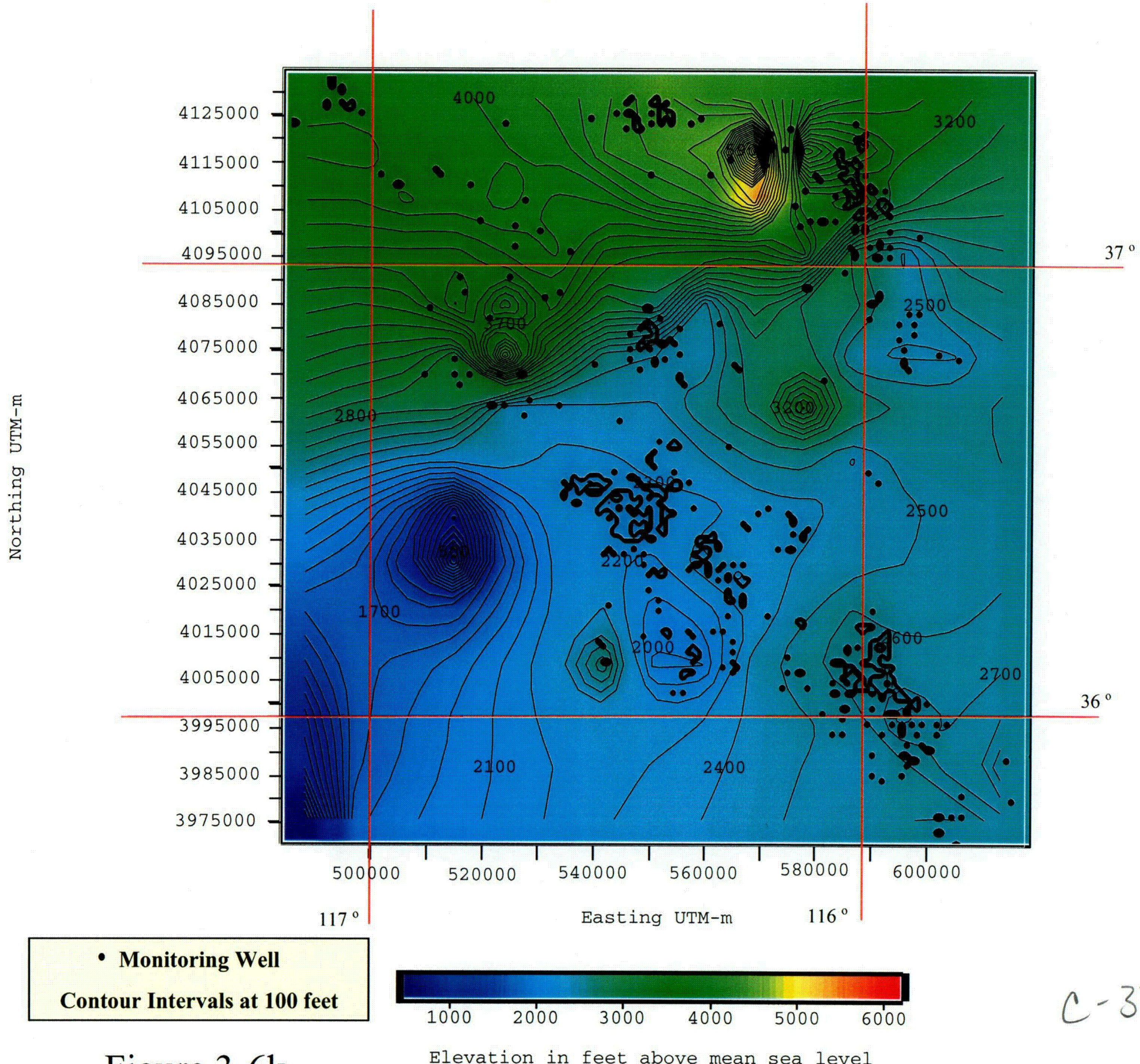


Figure 3-6k
Groundwater Elevations for Death Valley Region 1944-1997

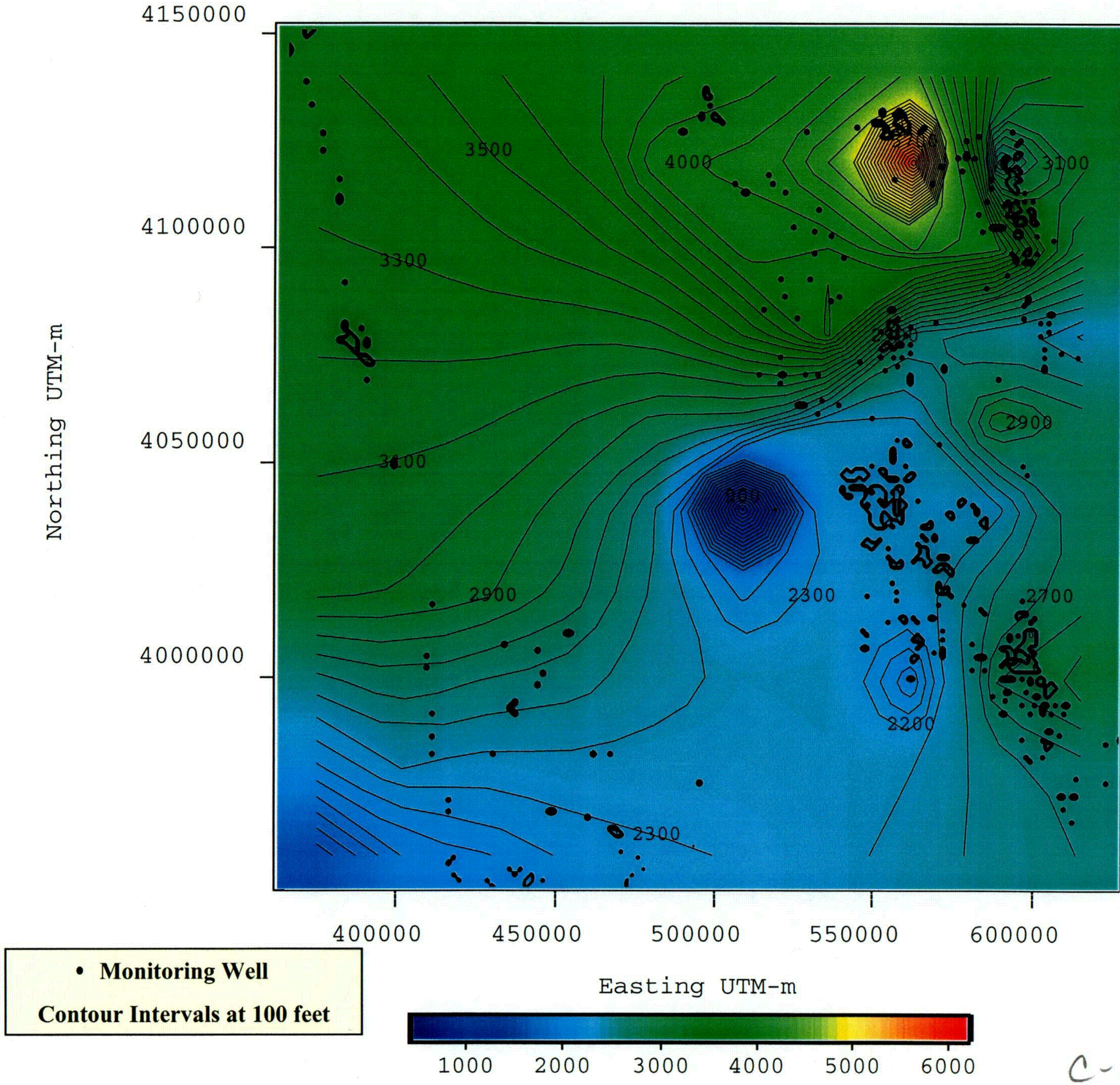
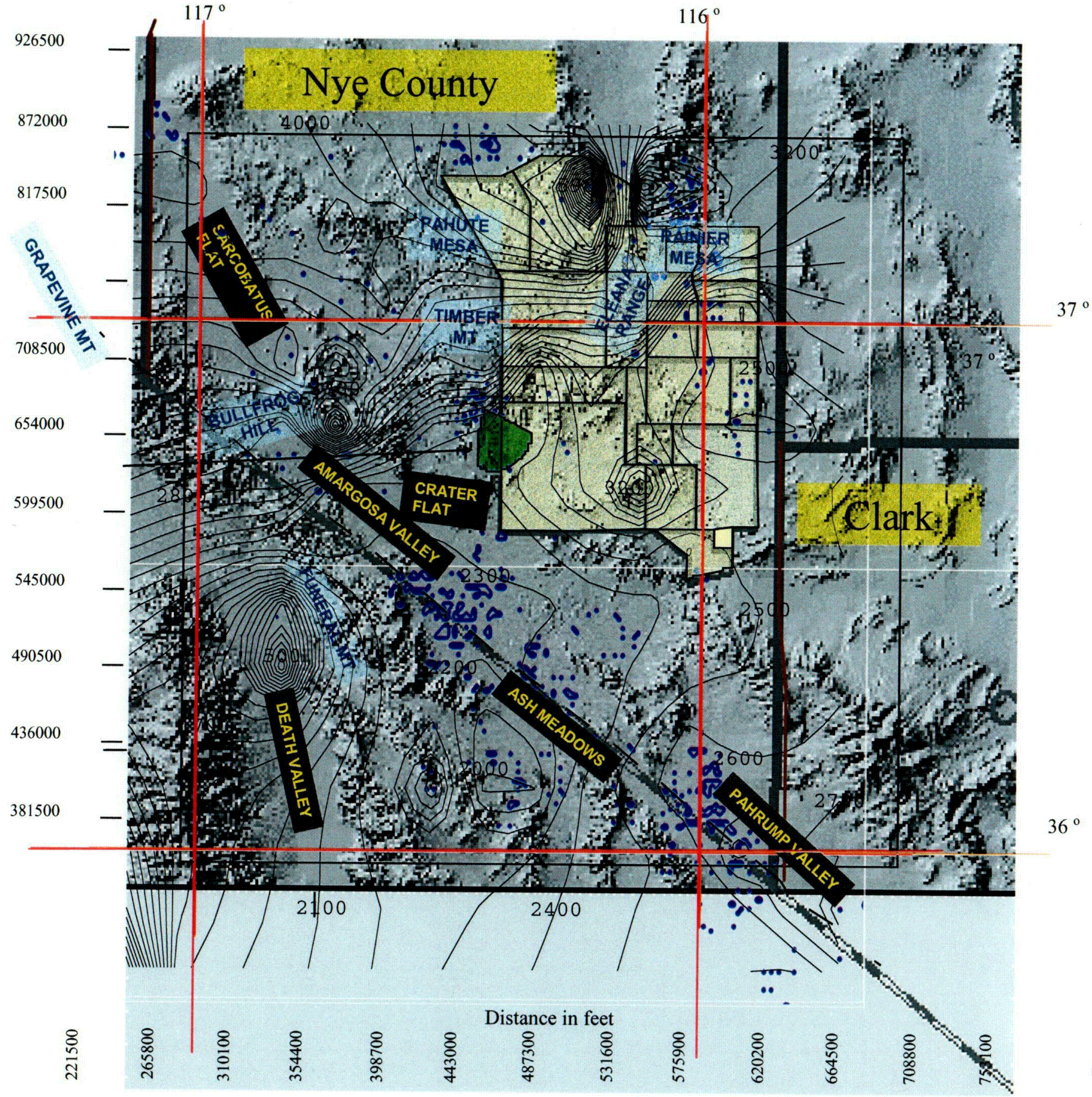


Figure 3-61

Groundwater Elevations for Death Valley Region and Inyo County 1926-1997



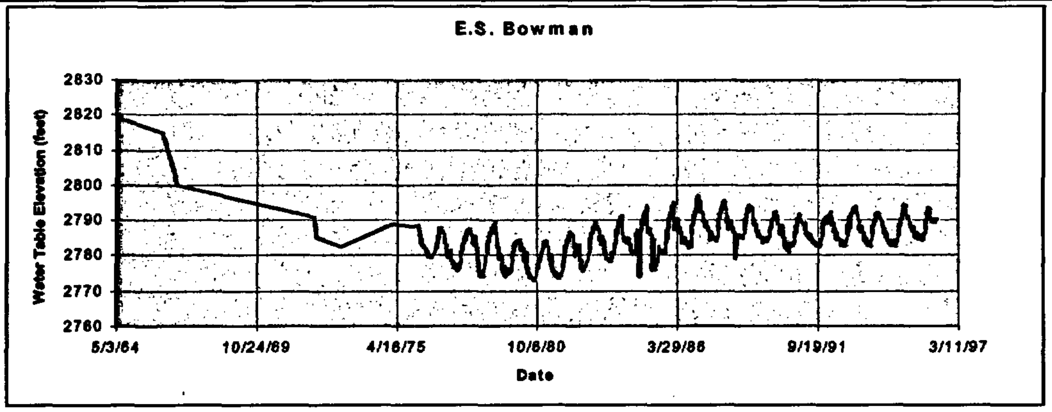
C-35

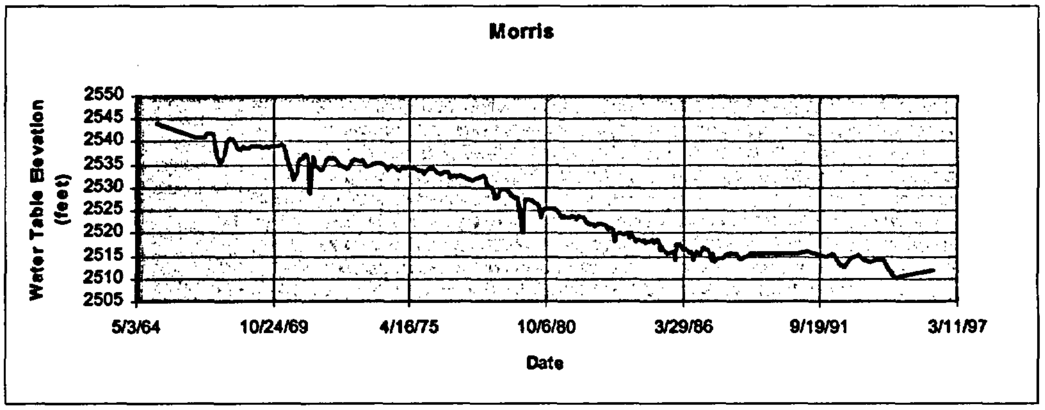
Figure 3-6m

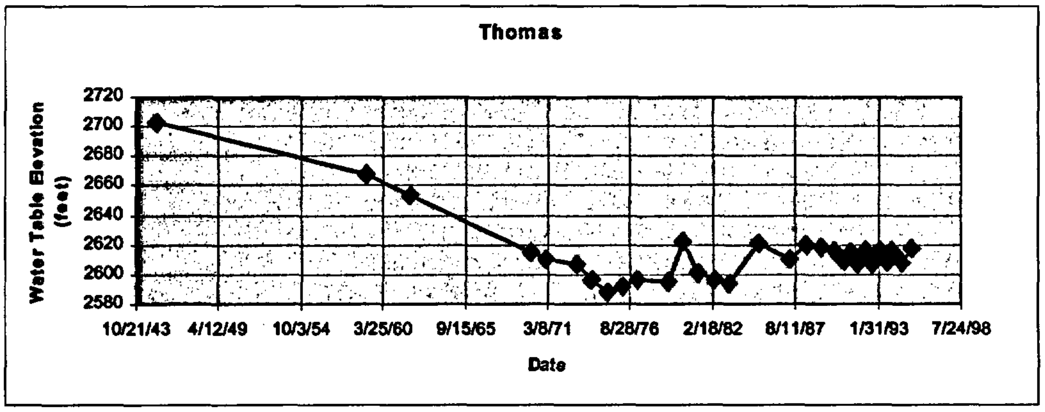
Groundwater Elevation in feet above mean sea level

Groundwater Elevations for Death Valley Region 1944-1997

• **Monitoring Well**
Contour Intervals at 100 feet







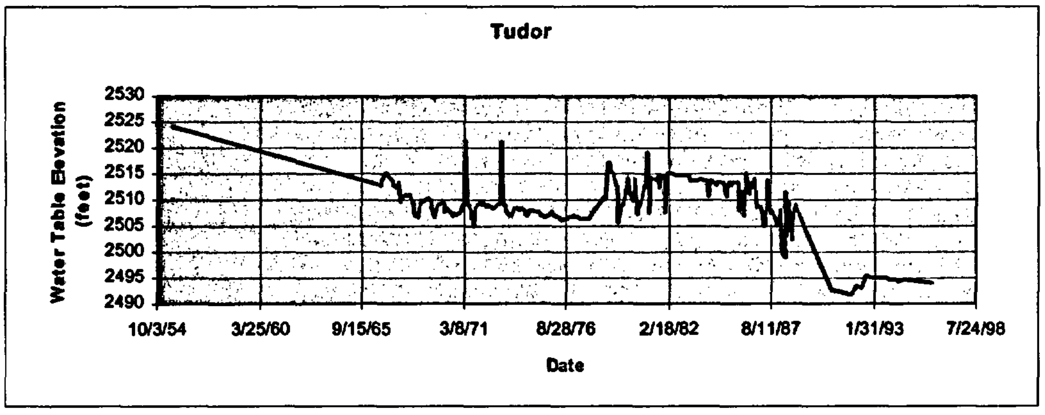


Figure 3-7a Water table elevations of selected wells in Pahrump Valley.

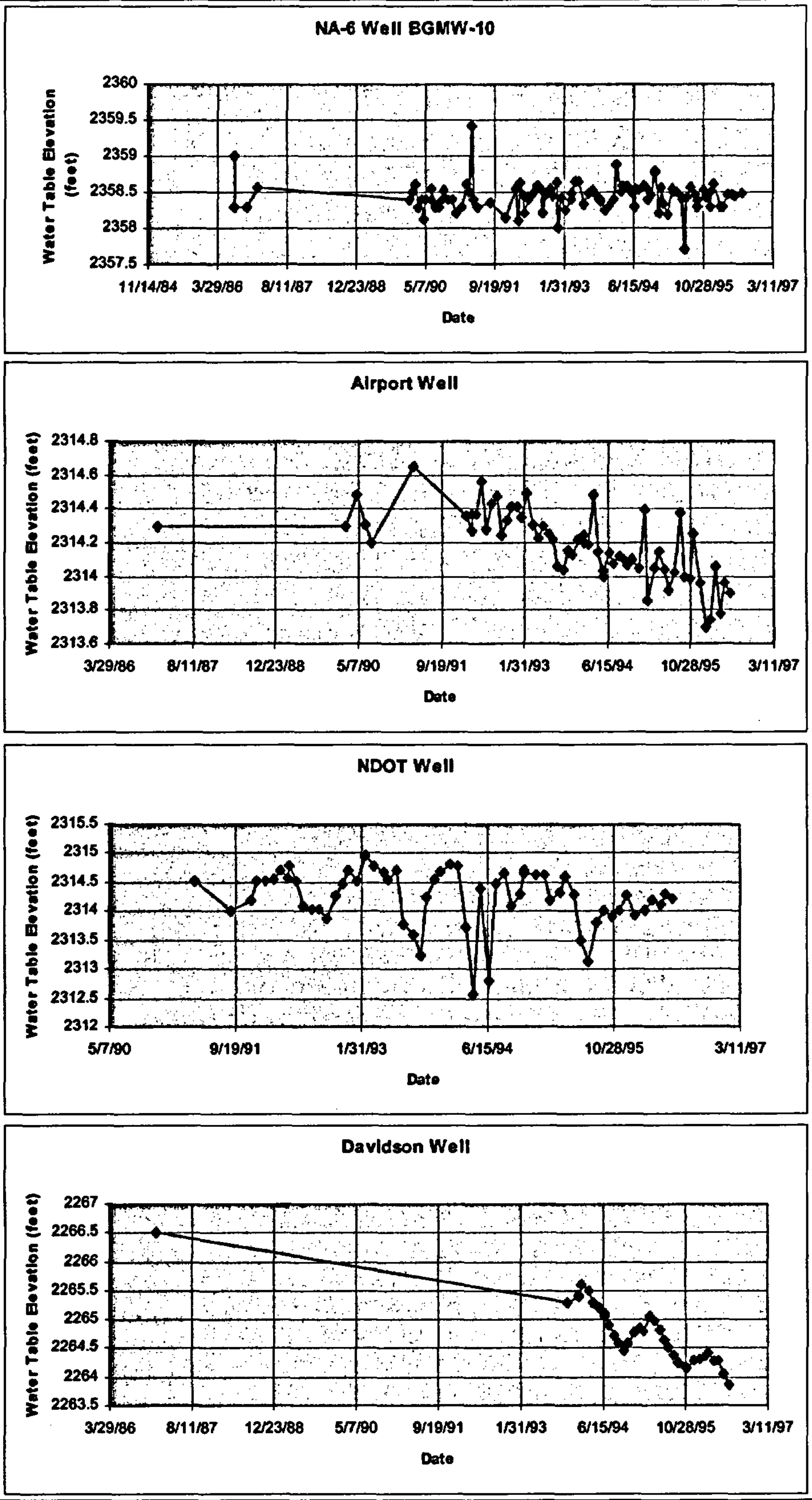


Figure 3-7b Water table elevations of selected wells in Amargosa Valley.

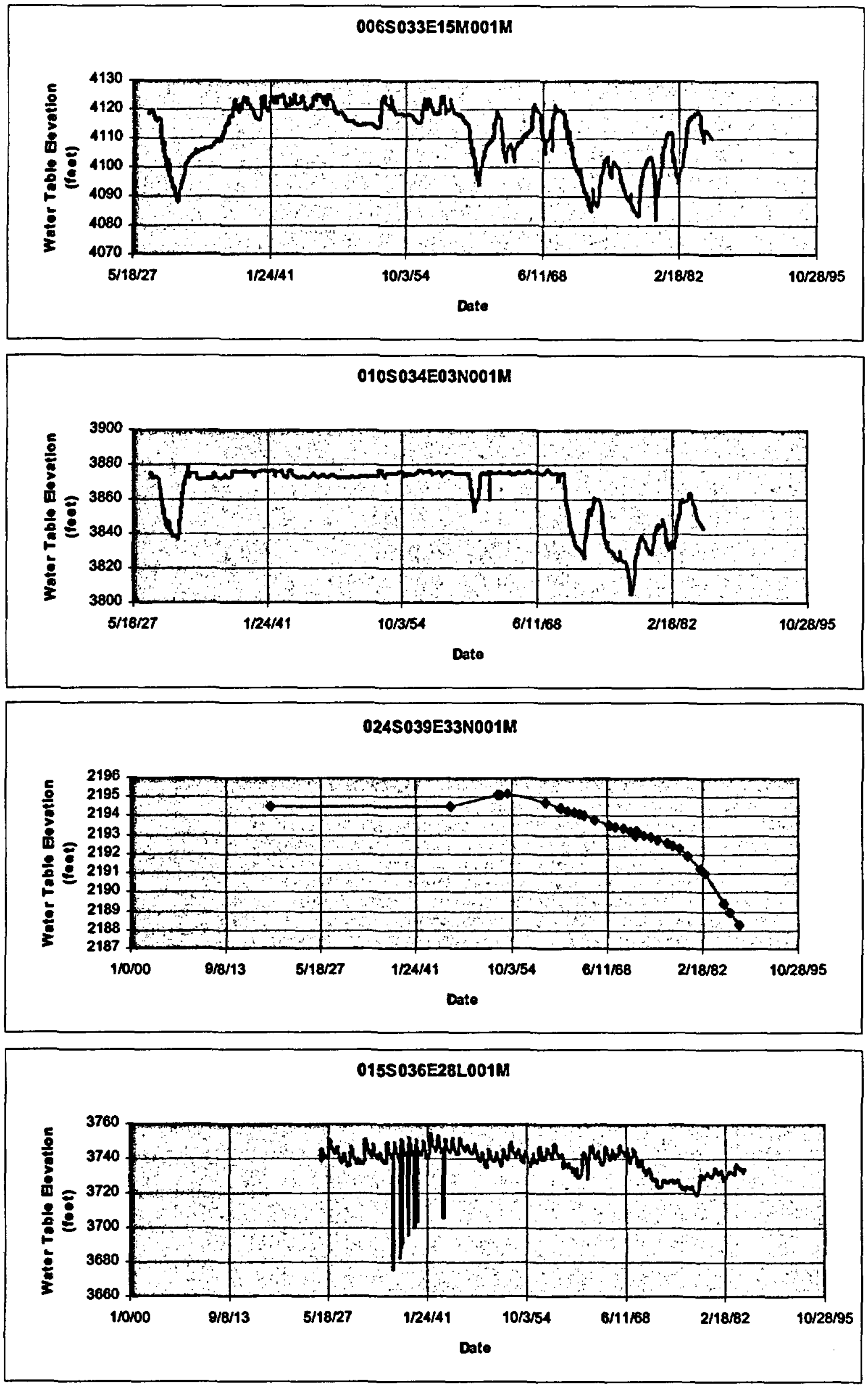


Figure 3-7c Water table elevations of selected wells in Inyo County.