APPLICATION OF AN AREA OF REVIEW VARIANCE METHODOLOGY TO THE SAN JUAN BASIN OF NEW MEXICO

Prepared for the
American Petroleum Institute

by the

University of Missouri-Rolla
School of Mines and Metallurgy

Dr. Don L. Warner
Dr. Leonard F. Koederitz
Dr. Shari Dunn-Norman
Dr. Robert C. Laudon

Rolla, Missouri

December 1995

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF MAPS

1.0 SUMMARY AND CONCLUSIONS

A methodology developed for obtaining Area of Review variances has been applied to the San Juan Basin of New Mexico. The general concept of the methodology is shown in Figure 1. The methodology uses four basic variance criteria that were agreed to by a Federal Advisory Committee but expands upon those to provide a greater range of variance options.

Elements of this study included,

- defining the geology and hydrogeology of the San Juan Basin with respect to petroleum production and groundwater occurrence
- documenting the basin exploration and development history
- documentation and analysis of historical state regulations pertaining to well construction and abandonment
- constructing pressure and hydraulic head surfaces for petroleum reservoirs and head surfaces for underground sources of drinking water (USDWs), and preparing the resulting residual head maps for each combination of petroleum reservoirs and USDWs
- accumulation of available well data for a selected sample of producing and abandoned wells and preparation of wellbore diagrams
- application of the well evaluation procedures to the selected population of wells and analysis of the results
- evaluation of AOR variance opportunities within the San Juan Basin

USDWs were identified in six hydrostratigraphic systems, including Tertiary, Upper Cretaceous, Mesaverde, Gallup, Dakota, and Morrison. Petroleum reservoirs were grouped in a similar manner, with an additional classification for petroleum reservoirs below the Morrison. USDWs are absent at many SanJuan Basin fields.

Oil and gas development began in the San Juan Basin prior to 1900. The oldest field currently undergoing waterflooding is the Rattlesnake field, which was discovered in 1924. The most recent field is the Miguel Creek field which was discovered in 1978. A correlation has been found to exist between field age and the quality of well construction and abandonment practice as it is documented by available information. Wells constructed or abandoned in fields discovered since 1949 have been found to provide USDW protection.

Regulation of oil and gas production activity began in 1912. The New Mexico Oil Conservation Commission (NMOCC) was established in 1935. The first modern statewide rules were instituted in 1950. The current New Mexico Oil Conservation Division evolved from the NMOCC in 1975. Major revision of the rules occurred in 1981 in response to the EPA regulations developed under the Safe Drinking Water Act. It is believed that the rules established in 1950 have been effective in requiring that wellbore features are present to protect USDWs in wells constructed or abandoned since that time.

Residual hydraulic head maps were prepared for each of the petroleum reservoirs with respect to overlying USDWs. These maps are based on initial pressure surfaces and were constructed with drillstem test (bottomhole) pressures. The effects of injection were then added to injection fields for which recent injection pressures could be obtained. It appears, on the basis of publicly available information, that all fields for which injection pressures were obtained have reservoir pressures sufficient to drive fluids upward to overlying USDWs, if a flowpath exists. The study did confirm a sink zone in the Mesaverde throughout the central portion of the basin. Fluids flowing upward in wells completed below the Mesaverde in this area can therefore, be diverted by this zone.

To characterize well construction and abandonment methods, the San Juan Basin was divided into four sub-areas, within each of which oil and gas fields occur under similar circumstances. The four area were identified based on analysis of the patterns of USDW occurrence. The four basin sub-areas identified were designated Western, Southern, Interior I and Interior II.

A total of over 4000 wells were determined to have been drilled within oil fields in the four basin sub-areas. Only oil wells located within oil fields undergoing waterflooding were examined because it is unlikely that injection operations will be carried out in gas fields. Oil wells located outside designated oil fields (i.e. wildcat wells) were not considered since injection operations would probably not be initiated outside a field. Sample well populations were chosen for each of the four basin sub-areas.

Wellbore diagrams were prepared for the sample wells selected for analysis. Each well was then analyzed to determine the number of flow barriers present in the wellbore. Flow barriers include casing and cement in producing wells and cement plugs and cast-iron bridge plugs in abandoned wells. Injection fields have been analyzed with respect to the level of USDW protection provided by the well construction and abandonment characteristics in that field.

Table 22 summarizes the results of the AOR variance criteria that have been applied to the San Juan Basin of New Mexico. At least two variance criteria were found to apply to all 24 fields and are believed to provide good possibilities for variances for 20 fields, and some possibilities for the remaining four.

Table 22 shows that no single criterion applies to all fields in the basin. Criteria that apply throughout the basin include:

1. Development of the field post dates the establishment of regulations or rules that provide for adequate USDW protection.

2. Examination of a sample population of wells establishes that wells are constructed and abandoned so that they provide adequate USDW protection.

3. Sloughing and/or squeezing zones are present that may preclude upward fluid movement through an open wellbore or behind casing.

As previously stated, in this report wells constructed or abandoned after 1949 provide USDW protection. Therefore, it is suggested that fields discovered after 1949 may qualify for a regulation based variance. Twenty three of the 24 active injection fields listed in Table 22 were discovered after 1949.

The judgement that wells in fields discovered after 1949 should exhibit adequate well construction and abandonment, is supported by the finding that wells in 18 of those 20 fields provided adequate USDW protection. The remaining two may provide such protection. Adequate USDW protection was defined as the presence of one cemented casing string covering the USDW in active wells and the presence of one cement plug, for which the details of plug location and cement quantity are given in abandoned wells.

The marine Cretaceous Mancos and Lewis Shales and a series of non-marine Cretaceous shales would be expected to be both sloughing and squeezing zones. As shown in Table 22, in fifteen and, perhaps, sixteen fields one or more of these Cretaceous shales is present between the injection zone and the lowermost USDW. While it isn't certain exactly what sealing effect these shales have, in any particular wellbore, it is difficult to imagine a wellbore or annulus that passes through such shales standing open for any length of time. The experience of operators and the NMOCD may be sufficient to qualify the widespread presence of sloughing and squeezing zones as a significant basis for AOR variance throughout that part of the San Juan Basin in which producing reservoirs are overlain by Cretaceous shales. This includes most of the basin except that part identified as the Western area. This would be a particularly relevant criterion for such fields as the Rattlesnake, Hospah and Red Mountain fields that are older fields in which there may be unplugged or inadequately plugged abandoned wells and the post 1949 Hospah South field that, in part, underlies the Hospah field.

Six fields were judged to have no USDWs and two others may not have USDWs. USDWs at six fields are protected by a Mesaverde sink zone. Sixty-one AORs have been performed in eight injection fields. Twenty eight of these have been performed in the Bisti field, the basins largest oil producer. These characteristics alone or in combination with others may provide for AOR variances.

2.0 INTRODUCTION

When the Underground Injection Control (UIC) Regulations were promulgated in 1980, existing Class II injection wells operating at the time that the regulations became effective were excluded from Area of Review (AOR) requirements. EPA is examining whether additional AOR controls are necessary for Class II wells, and whether changes to regulations are needed in order to impose these controls or whether guidance would suffice.

A Federal Advisory Committee (FAC) has recommended that AORs for existing wells, not previously subject to that requirement, be performed within five years of promulgation of amended UIC regulations. The FAC has, however, recognized that conditions can exist that make it unnecessary to perform well-by-well AORs and that can allow wells in a basin, producing trend, region or field or a portion of such areas to be exempted from an AOR through a variance program. Variance could be granted because of the following conditions:

1. the absence of underground sources of drinking water (USDWs),
2. the reservoir is underpressured relative to the USDW,
3. local geological conditions preclude upward fluid movement that could endanger USDWs,
4. other compelling evidence.

A methodology for identifying areas that would be eligible for variance from AOR requirements based upon the FAC criteria has been developed and is shown in Figure 1. The methodology[16] provides for evaluation of an area for variance based upon conditions 1-3 above or based upon the manner by which wells in the area were constructed and abandoned. These methods could be used in any order, singly or in combination to exclude some or all wells from the AOR process. Wells not excluded by variance would be subject to well-by-well AORs.

This report documents the application of the AOR variance methodology that has been developed to the San Juan Basin of New Mexico. A brief summary of the methodology is contained in the next section.

3.0 AREA OF REVIEW VARIANCE METHODOLOGY

This section briefly expands upon the methodology shown in Figure 1. A detailed description of the methodology is provided in the companion report An Area of Review Variance Methodology.[16]

Variance Based on Lack of Intersection

Variance condition 1, as listed by the FAC, has been extended from providing only the absence of USDWs as a variance criterion to also include the situation where the USDW is the producing formation and the situation where the USDW has been exempted under the Safe Drinking Water Act. A further extension is to provide variance for wells that penetrate through the USDW(s) but which do not reach the injection zone. These variance conditions are collectively categorized as lack of intersection with a USDW. An area would be evaluated for lack of intersection through hydrogeologic study.

Variance Based on Negative Flow Potential

Flow from a petroleum reservoir into which fluids are being injected into an overlying USDW can only occur when the reservoir pressure is sufficient to raise a column of reservoir water to the base of the USDW and then still be sufficient to displace the water in the USDW. In the absence of such hydraulic flow potential, the area under evaluation would qualify for a variance. An area is evaluated for hydraulic flow potential by collection of USDW head data and petroleum reservoir pressure data and by comparison of those data sets, after appropriate conversions and adjustments have been made to the data to make them comparable.

Variance Based on Mitigating Geological Factors

Mitigating geological factors include, sloughing, squeezing and sink zones. A sloughing formation refers to any geological horizon which is highly incompetent and tends to fall or cave into the well. A squeezing formation is one with strata that flow plastically under the overburden stress to close an uncased borehole or close the casing-formation annulus in a cased well.

The thief, or sink zone, refers to a geological horizon which has a flow potential less than the overlying USDWs and the petroleum reservoir which contains injection operations. Thief zones are intermediate formations (located between a contamination source zone and a USDW) which act to divert the fluids flowing up the wellbore. A thief zone can also be a normally pressured formation that is so permeable and large that it diverts virtually all upward flowing fluid without experiencing significant pressure increase.

A means of assessing the presence and the effectiveness of sloughing or squeezing zones is qualitative evidence in the form of observations by operator and regulatory agency personnel. The presence of sink zones may be known as a result of experience by operators with lost circulation during drilling or such zones may be known to geologists or engineers through basinal or regional studies of aquifer/reservoir fluid potentials.

Variance Based on Well Construction and Abandonment Methods

Well construction and abandonment methods can also be considered as a factor for an AOR variance. This is because the manner in which a well is constructed and abandoned may preclude fluid migration, even if a positive hydraulic flow potential does exist.

States which have oil and gas production have historically set forth standards for well construction and abandonment. These standards detail the correct use or placement of casing, cement, bridge plugs, and other mechanical barriers in a wellbore. They have generally evolved from a series of accepted practices, adapted over the years to accommodate new technology and new regulatory practice.

1. Field discovery and development post dates well construction and abandonment standards, providing protection.

2. Sufficient AORs exist and provide statistical evidence that all wells protect the USDW(s).

3. Representative sample of wells are found to provide adequate protection to USDW(s). Wells are evaluated with respect to flow barriers and plugs.

Variances could be available through each of the approaches for all wells in an area or for only those wells in the area that meet the variance criteria. For example, under the first approach listed above, if a field was discovered and entirely developed after the date of adoption of construction and abandonment standards that provide adequate USDW protection, all wells would meet variance criteria. If the field was discovered and partially developed prior to such standards but part of the development post dated such standards then those wells constructed/ abandoned after standards adoption would meet variance criteria and the older wells would have to be examined through another approach.

Under the second approach, it is conceived that older fields will exist where sufficient new injection wells have been drilled or sufficient production wells converted to injection since promulgation of UIC regulations to provide an adequate number of AORs and wells within those AORs to statistically characterize the entire field.

The third approach requires that a representative sample of wells be selected from the total population of area wells and that all wells in that sample be evaluated with respect to their construction/abandonment characteristics.

The evaluation process that is proposed will provide data on the number of flow barriers in abandoned wells, producing wells and injection wells and the number of plugs in abandoned wells included in the selected sample of wells from the area under study.

Current AOR procedures require a well-by-well analysis of all production, injection and abandoned wells that penetrate the injection zone and are within 1/4 mile or within the calculated "zone of endangering influence" of the single injection well under consideration. If all wells are determined to have been satisfactorily constructed and/or abandoned, then the injection well has complied with present AOR requirements.

It is proposed here that evaluation of a statistically representative population of wells, through the procedures that have been developed, can substitute for the well-by-well process and can provide "other compelling evidence" for variance. This methodology can be applied to geographic areas much larger than a single AOR and including a producing basin, trend, region or field or a portion of such areas.

If, for example, evaluation of the statistically selected random sample of wells shows them to provide protection, then there is compelling evidence for variance since it would have been demonstrated that it is statistically probable that all wells have been constructed and/or abandoned by acceptable standards.

It is also suggested that, as a refinement of the variance concept, specific identified categories of wells could be excluded from the AOR process even though a total variance could not be granted. For example, it might be determined that all wells constructed and/or abandoned since a certain historical date have been satisfactorily constructed and/or abandoned whereas earlier wells require a well-by-well analysis. Such a partial variance could greatly reduce the level of effort that would be required for complete well-by-well AORs.

The remainder of this report will document the application of the methodology that has been described to the San Juan Basin of New Mexico.

4.0 APPLICATION OF AREA OF REVIEW VARIANCE METHODOLOGY TO THE SAN JUAN BASIN

4.1 Geological Description of the Basin

The San Juan Basin is a nearly circular basin that covers approximately 15,000 square miles in the Four Corners Region of New Mexico (Figure 2). Most of the basin is located in New Mexico, although outer margins are located in Colorado, Utah and Arizona.

The basin contains more than 15,000 feet of sedimentary section overlying Precambrian granite and metamorphic rocks. The geology of the basin is well known because of the extensive outcrops that rim the basin, the large number of wells that have been drilled in the basin, and because the basin is structurally quite simple. The stratigraphy and geometries of the different formations (especially Upper Cretaceous and Tertiary formations) have been mapped in great detail because of their extensive gas, oil and coal resources.[1,2]

4.1.1 Structure

The San Juan Basin lies in the southeastern part of the Colorado Plateau. It is an asymmetric depression (Figure 3) that formed principally during Laramide deformation, in latest Cretaceous to Early Tertiary time. The basin is flanked by a number of complex uplifts such as the Nacimiento Uplift to the east, the San Juan Mountains to the north, the Defiance Uplift to the west and the Zuni uplift to the south. Within the basin, several monoclines, such as the Hogback monocline to the northwest and the Archuleta monocline to the northeast, are present (Figure 3). These monoclines separate the deep interior of the basin from very shallow dipping shelf areas such as the Four Corners platform area to the northwest and the Chaco slope to the south. The basin is asymmetric in that the deepest part of the basin is to the north and east of the geographic center of the roughly circular basin (Figure 4). Dips on the north flank of the basin are relatively steep (average of 8-10 degrees and as much as 60 degrees along the Hogback monocline), while dips in the Chaco slope area (southern area) are less than 2 degrees. The basin is relatively unfaulted, although buried faults have been mapped in the Puerco fault zone in the southeastern part of the basin and along the Nacimiento uplift. Major monoclines are probably also related to faults in the Precambrian basement.

A number of anticlines are present in the basin, principally in the Four Corners Platform area (northwest part of Figure 3) and along the Chaco Slope. However; a very small portion of the oil and gas reserves in the basin are related to structural traps. The majority of the oil and gas reserves in the basin are found in stratigraphic traps associated with lenticular sandstone bodies of Cretaceous age.

4.1.2 Stratigraphy

Figure 5 is a generalized stratigraphic column for the basin. It also shows the principal oil and gas producing horizons for the basin as well as the six major USDW designations used in this study.

The following sections include a short discussion of the principal oil and gas producing horizons for the basin as well as a description of the USDWs.

4.1.2.1 Oil and Gas Horizons

Oil in the basin is primarily produced from three zones, the Gallup, Paleozoic and Dakota. The largest volume of oil comes from a series of sandstone lenses that occur at or near the Gallup Sandstone level (Figure 6 and Map 4). The true Gallup Sandstone occurs just below an angular unconformity (Figure 6) and is not present in the northern part of the basin. Included as Gallup equivalents in this report are a number of other sandstone lenses including the Tocito Sandstone. The Tocito-Gallup combination is the single largest producer of oil in the basin and occurs along a fairway that trends northwest-southeast down the middle of the basin. The Bisti field (Figure 2) produces primarily from these lenses. Other significant oil production is from Paleozoic rocks in the northwest part of the basin and from the Cretaceous Dakota Sandstone throughout the basin.

The largest volumes of gas in the basin have been produced from a number of different Cretaceous-age sandstones, including the Dakota, Point Lookout, Cliff House and Pictured Cliff Sandstones. (Figures 5 and 6). The largest gas field in the basin is the vast Blanco field (Figure 2) which produces from stratigraphic and hydrodynamic traps all through the deepest part of the basin. The Blanco field contains gas in a number of different formations including the Cretaceous Dakota, Point Lookout, Cliff House and Pictured Cliffs Sandstones, plus less significant production from the Tertiary Fruitland, Kirtland and Nacimiento Formations. In these hydrodynamic-stratigraphic traps, gas commonly occurs over water where the gas-water contact is tilted and the salinity of the water is variable. With the exception of the Tertiary USDWs, all formation waters contain greater than 10,000 milligrams/liter dissolved solids nea the center of the basin (Maps 1-6). Salinities of all formation waters decrease towards the margins of the basin where recharge occurs at the outcrops.

4.1.2.2 USDWs

The New Mexico Department of Natural Resources in its report on the Hydrogeology and water resources of San Juan Basin, New Mexico[3] identified six major aquifer (USDW) groups in the San Juan Basin (Figure 5 and Maps 1-6). Descriptions of these USDWs are summarized in the Stone et. al. report[1] and are outlined herein in the order of youngest to oldest as follows:

1. Tertiary USDW - Map 1 and Figures 4 and 5:

Tertiary sediments are exposed at the surface over the deepest part of the basin (northeast part) and dip toward the central part of the basin. Their thickness varies from zero at the outer edge of the outcrops, to 3,500 feet in the deepest part of the basin. Principal geologic formations include the San Jose Formation (central part of the basin), the Nacimiento Formation (south-central part of the basin) and the Animas Formation (northern part of the basin - principally Colorado)[3,4].

These formations are Paleocene and Eocene in age, although the Ojo Alamo Sandstone Member of the Nacimiento Formation is considered to be Cretaceous in age according to some authors. All of the formations thin toward the edges of the basin and were deposited in a complex of fluvial-deltaic-lacustrine environments as the basins subsided during Laramide deformation. The Animas Formation contains a great deal of volcaniclastic sediments derived from the San Juan Mountains to the north, and sandstone development (USDW quality) in all formations is best in the northern part of the basin.

Salinities in the Tertiary USDWs are typically in the 500 to 1000 mg/l range with a maximum of 6,800 mg/l occurring along the San Juan and Animas Rivers in the north-central part of the basin[3]. Not discussed in the Stone report[3] is an alluvial valley fill sequence called the Chuskam Formation of Eocene/Oligocene age in the far western part of the San Juan basin (Map 1).

It is a local gravel derived from the Chuska Mountains and is a source of water for this remote area.

<u>2. Upper Cretaceous USDW -</u> Map 2 and Figures 4,5 and 6:

Immediately underlying the Tertiary sequence are the Fruitland, Kirtland and Pictured Cliffs Formations of Late Cretaceous age[3,5,6]. The combined Kirtland-Fruitland Formations vary in thickness from zero along the eastern margin of the basin to 2,000 feet in the northwest part of the basin. The combined Fuitland-Kirtland Formations were deposited on a coastal plain sequence and consist of a repetitive sequence of non-marine channel sandstones, siltstones, shales and claystones. The Fruitland Formation contains several coal and carbonaceous shale horizons. The coal horizons are significant because they are commonly over-pressured and also because they are the subject of ongoing coalbed methane projects.

The Pictured Cliffs Sandstone is a regressive sandstone that represents the end of marine deposition in the San Juan basin. The sandstone pinches to zero thickness near the eastern boundary of the basin and is of irregular thickness (maximum of 400 feet) throughout the rest of the basin. As a regressive sandstone it becomes younger to the east and grades laterally into the marine

Lewis Shale. To the west it grades into the non-marine Fruitland Formation (Figure 6).

The Lewis Shale is a marine wedge that thins to the west. It is approximately 1,200 feet thick near the eastern edge of the basin, and it thins to zero to the west. The lower part of the Lewis Shale is laterally equivalent to the Mesaverde Group (Figure 6). The Lewis Shale is included with the Upper Cretaceous USDW unit in this study.

Salinities in the Upper Cretaceous USDW are highly variable, but generally increase toward the north-central part of the basin. The maximum salinity recorded[5,6] is 55,600 mg/l near Farmington, New Mexico.

3. Mesaverde Group USDW - Map 3 and Figures 4,5 and 6:

The Mesaverde Group consists of a large number of different and complicated stratigraphic units with formation and member names[3,7,8]. Overall, it is an eastward thinning sequence of coastal plain deposits (Crevasse Canyon Formation, Cleary Coal Member and Menefee Formation) that are similar to the Kirtland and Fruitland Formations. They contain irregularly distributed, non-marine channel sandstones alternating with siltstones, shales, claystones and some coals. To the east, all of these formations are bounded by nearshore or shoreline sandstones. The Dalton Sandstone and the Point Lookout Sandstone are regressive sandstones that are younger to the east. The Hosta Tongue, Cliff House Sandstone and La Ventana Tongue were deposited under transgressive or still-stand conditions. To the east, all of these sandstones grade laterally into marine shales (Lewis or Mancos) and to the west they grade into coastal plain environments.

Map 3 shows two outcrop patterns that converge and actually overlap to the north and east. The outer outcrop pattern is the outcrop for the Dalton and Point Lookout regressive sandstones. The inner pattern is the outcrop for the overlying Cliff House and La Ventana transgressive sandstones. The area between is the outcrop pattern for the Crevasse Canyon, Cleary and Menefee Formations which thin and disappear to the north and east.

The overall thickness of the Mesaverde USDW varies from approximately 3,000 feet in the southwestern part of the basin to 70 feet in the northeast. The combined Crevasse Canyon-Cleary-Menefee coastal plain sequence is approximately 3,000 feet thick in the southeastern part of the basin and thins to zero in the northern and eastern parts of the basin. Thicknesses of the Hosta and Point Lookout regressive sandstones are fairly consistent and vary between 50 to 200 feet. Thicknesses of the Cliff House and La Ventana Sandstones are highly variable, ranging from zero to approximately 1,000 feet thick.

The Lewis and Mancos Shales are marine shales that thin to the west and southwest. The upper part of the Lewis Shale is laterally equivalent to the Upper Cretaceous sequence, and the lower part of the Mancos is equivalent to the Gallup and Dakota Sandstones. (Figure 6) The Mancos Shale is included with the Mesaverde Group USDW in this study.

Salinities for this unit are variable but generally increase from the outer margins of the basin to a maximum of 40,000 mg/l near Farmington, New Mexico in the north-central part of the basin.

4. Gallup Sandstone - Map 4 and Figures 4,5 and 6:

The true Gallup Sandstone consists of a series of discontinuous offshore sand bars (lower) and a relatively continuous regressive sandstone (upper) that are all truncated against an angular unconformity in the northeastern part of the basin (Figure 11)[3,9]. Isolated sandstone bodies have different names; hence the plethora of names. The regressive Gallup is up to 200 feet thick, continuous, open to groundwater recharge at the surface and is an important USDW. The discontinuous sandstones form important stratigraphic traps for oil production in the basin.

Just above the angular unconformity, the Tocito Sandstone Lentils occur as discontinuous sandstone bodies that are also important as stratigraphic traps for oil. In a strict stratigraphic sense they are not part of the true Gallup Formation. In this report and in the Stone report[3] everything below the Niobrara resistive marker has been included as part of the Gallup. Thus, the Tocito Sandstone Lentils have been included with the Gallup USDW because they occur at approximately the same stratigraphic horizon as the true Gallup and their reservoir and USDW behavior are similar to the discontinuous sandstones of the true Gallup. The discontinuous sandstones of the Gallup are considered to be offshore bars and are generally quite thin. Maximum thickness of individual sandstones is about 40 feet.

Limited salinity data are available for the Gallup Sandstone. In this study, downdip limits for the USDW were placed at the boundary between water wells and hydrocarbon wells on the Gallup map (Map 4)[3,9].

<u>5. Dakota Sandstone -</u> Map 5 and Figure 4,5, and 6:

The Dakota Sandstone occurs immediately above an unconformity that separates Jurassic-age rocks from Cretaceous-age rock[3,10]. It is a transgressive sandstone that formed during the initial opening of the Cretaceous interior seaway as overthrusting occurred in the western overthrust belt. The Dakota Formation consists of at least four different sandstone bodies that are complexly intertongued with the Graneros and Mancos Shales. The Dakota ranges in thickness from a few tens of feet to as much as 500 feet, with the thicker parts occurring in the south and southwest parts of the basin. Typically it is from 200 to 300 feet thick.

The base of the Dakota commonly contains gravel as it was deposited on an erosional surface. Upward, the formation grades in a complicated manner from alluvial gravels to shoreline sandstones and into siltstones, shales, and marls of the marine Greenhorn Formation.

Salinity data for the Dakota Formation are sparse, but again, salinities clearly increase toward the center of the basin. Downdip limits of the USDW have been placed at the downdip limits of existing water wells which coincide reasonably well with the 10,000 mg/l line of existing data[3,10].

<u>Morrison USDW -</u> Map 6 and Figures 4 and 5:

The Morrison Formation is of Late Jurassic age and is present throughout the San Juan basin[3,11]. Its thickness varies from 200 feet thick in the southern part of the basin to approximately

1,100 feet in the northeast part of the basin. It is divided into five members, the most important of which is the Westwater Canyon Member. This member is from 100 to 300 feet thick and is an important USDW in the southwest part of the basin. The Morrison Formation is composed of yellow-tan sandstones and siltstones plus shales and rare limestone beds. Sandstones were deposited primarily in stream channels while shales were deposited primarily on flood plains and in lakes.

Salinity data again indicate that fresh waters are present near outcrops in the outer parts of the formation, and that salinities increase toward the center of the basin. At the outer margins of the basin, salinities range from 116 to 2300 milligrams/liter, and increase to 5000 milligrams/liter moving toward the center of the basin. No salinity data are reported[3,11] from the deepest part, or central portion of the basin.

<u>7. Deeper horizons -</u> Map 7 and Figure 4 and 5:

Map 7 shows new field wildcat locations for production from the Morrison Formation and from formations below the Morrison. These are deeper horizons which are known to have produced water, but which are not included in a completed USGS Hydrologic Atlas.

A. Jurassic Entrada Sandstone
B. Triassic Sonsela Sandstone of the Chinle Formation
C. Permian Glorieta Sandstone - San Andres Limestone
D. Permian Yeso Formation
E. Permian De Chelly Sandstone
F. Permian Cutler/Abo Formations
G. Pennsylvanian Strata (undifferentiated)
H. Lower Paleozoic (undifferentiated)

Little is known about the water quality of these deeper zones because the zones are largely untested. In general, they have yielded small amounts of water and are not considered to be important aquifers.

4.1.2.3 Confining Beds and Sloughing Zones

Confining beds are stratigraphic horizons that inhibit vertical and lateral migration of water and other fluids. They are zones of lower permeability such as shales and evaporites. Carbonates may act as confining beds, but typically they do not because most carbonates are fractured.

Squeezing and sloughing zones are incompetent rock layers that flow or collapse in uncased holes. They can cause serious problems during drilling, and tend to close off holes after pulling of casing during abandonment. Sloughing zones also cave in and close off the annulus between the borehole and casing. Shales (especially bentonitic shales) and evaporites are the most common rock types associated with squeezing and sloughing.

Although the Paradox basin which lies immediately to the northwest and is partially connected to the San Juan basin contains extensive evaporites in Permian, Triassic, and Jurassic rocks, no major evaporite deposits have been documented in the San Juan Basin. Minor gypsum is known in the Jurassic Todilto Formation which was probably formed by either a lake or an inland sea during flooding of the Entrada dune fields. The Todilto Formation is predominantly limestone, and is not considered to be a major confining bed or sloughing zone.

The most important confining beds and squeezing and sloughing zones in the San Juan Basin are the Mancos and Lewis Shales, which vary from 0 to 2100 feet thick. The Mancos and Lewis are both marine shales associated with Cretaceous delta systems. They are very thick in the northeastern part of the basin and thin to the southwest (Figure 6). Other shales that may act as confining beds or squeezing and sloughing zones include the:

Cretaceous -	Kirtland Formation--Upper and Lower Shale Members Non-marine shale members of the Menefee and Crevasse Canyon Formations
Jurassic -	Shale members and bentonitic zones of the Morrison Formation.
Triassic -	Petrified Forest Member of the Chinle Formation which also contains bentonitic zones.

4.1.3 Geologic History

The following section is a short summary of the principal tectonic and depositional events that occurred in the San Juan basin. It is provided here principally to help explain the geometries of many of the principal (particularly Cretaceous) stratigraphic units.

Little is known about the early Paleozoic history of the basin. Ordovician and Silurian rocks are complëtely missing from the basin. Cambrian, Devonian, and Mississippian shelf type sandstones and limestones are present in parts of the basin.

During Pennsylvanian and Permian time, differential uplift throughout the western United States caused local basins to form and be filled with sediments from nearby uplifts. Most of the rocks are alluvial deposits derived from local uplifts, although evaporites formed in a few basins, such as the Paradox basin of Utah and the Permian basin of Texas. No significant evaporites formed in the San Juan Basin.

During Triassic and Jurassic time, the San Juan Basin experienced a complicated history of marine invasion, marine withdrawal, lake development, and clastic deposition under hot and dry conditions at near sea level. The Triassic and Jurassic sequence is noted for its redbeds that were deposited in lakes, tidal flats, and braided streams (Morrison Formation), local limestones that are marine in origin (Todilto Limestone), and dune fields (Entrada Formation) that formed in desert conditions.

An unconformity exists between all Jurassic and Cretaceous rocks in the San Juan basin as no Lower Cretaceous rocks have been identified in the basin. During Late Cretaceous time, the San Juan Basin subsided as the Sevier Orogenic belt (Western Overthrust belt) rose to the west. Late Cretaceous time is noted for a global rise in sea level culminating in an extremely high sea level stand at the end of Cretaceous time. Thus, as the basin subsided, the seas entered the Cretaceous interior seaway from Texas and transgressed generally to the west across the Dakotas, Wyoming, Utah, and the to the southwest across New Mexico. The Upper Cretaceous Dakota Sandstone marks this transgression over the Lower Cretaceous unconformity.

As the Sevier Orogenic Belt rose to the west (southwest in New Mexico) of the seaway, sediments were shed eastward from the orogenic belt into the seaway. In the southwestern part of the San Juan basin, Cretaceous sediments are mainly non-marine braided stream, meandering stream, and coastal plain sediments (Menefee, Fruitland and Kirtland Formations) that thin to the northeast (Figure 6). In the northeastern part of the basin, Cretaceous sediments are mainly prodelta marine shales (Mancos and Lewis Shales) that thin to the southwest. In the middle of the basin a series of sandstones were deposited as the shoreline passed back and forth on a series of regressions and transgressions. The Gallup (true Gallup), Dalton, Point Lookout and Pictured Cliffs Sandstones are regressive sandstones formed as delta front sandstones on wave dominated deltas. The Hosta Tongue and the Cliff House Sandstones are transgressive sandstones. The Tocito Sandstone Lentils, often mis-correlated with the Gallup, are considered to be offshore bars.

At the end of Cretaceous time, the interior seaway dried up, and the basin continued to subside. The end of the Cretaceous is marked by an unconformity followed by deposition of lake and alluvial deposits that continued to fill the basin throughout Tertiary time.

4.2 Basin Exploration and Development History[1]

The first oil and gas activity in the San Juan Basin occurred between 1890 and 1900 in the Durango area of Colorado, when a group of Durango businessmen and a professor from the Colorado School of Mines drilled a 1500 ft well in the vicinity of Durango. The well had shows of oil and gas, but eventually the tools were lost in the hole and drilling resources were depleted[12]. In1901, a second Colorado well was drilled near Pagosa Springs, to a depth of 1000 feet. It was reported that this well produced 12 barrels of oil per day from a shallow pay, and while deepening the well, a large water flow was encountered which could not be controlled. The well was subsequently abandoned.

At the time the Colorado wells were being drilled, exploration of the basin was also beginning in other states. In Utah, oil was discovered at Medicine Hat in 1908, and it was this discovery which helped to trigger other exploration activity in the Four Corners region.

In New Mexico, oil was first discovered in 1909, at Dayton, eight miles south of Artesia. The discovery was similar to those in Colorado in that the oil production was limited, and artesian water again prevented the well from being completed.

Other exploratory wells drilled between 1900 and 1920 in New Mexico also discovered oil, although the production was not always promising. In 1911, a water well was drilled at Seven Lakes in McKinley County, about 65 miles south of Farmington. Oil was encountered in the Menefee formation at approximately 300 feet. Production was only a few barrels per day, although the discovery spurred drilling activity in the area. Over the next several years about 50 wells were drilled in the Seven Lakes area, but most of the wells were non-commercial due to low production rates and the distance to market (60 miles over dirt roads).

The first period of intense exploration activity began during the 1920s. In 1921, the Aztec (Farmington sand) gas field was discovered. This field was the first commercial gas field in the San Juan Basin. The discovery of this field spurred exploration drilling throughout the remainder of the decade and into the early 1930s. As a result, gas was also discovered in the Dakota formation at Ute Dome in 1921 and Barker Dome in 1925, and in the Mesaverde formation at Blanco in 1927.

Although a significant amount of gas was discovered in the 1920s, development of these early gas fields was minor until late 195113. During 1951, the El Paso Natural Gas Company installed a 24-inch pipeline to California, thus establishing the first major gas market. The development of this market had a dramatic impact on gas field developments in the basin. As of 1 January 1952, there were about 300 producing gas wells serving local New Mexico and Colorado markets. As of 1 January 1963, there were 5608 wells producing gas. By 1971, the number of gas wells had increased to more than 7500.

Many oilfields were also discovered during the 1920s, including Hogback, Table Mesa, and Rattlesnake. In these and other fields, oil was principally produced from the Dakota, Farmington, Gallup and Mesaverde zones. Later in the decade, oil and gas were discovered in the deeper Hermosa (Pennsylvanian) formation at Rattlesnake.

The first oil pipeline in the San Juan basin was built between the Hogback field and Farmington in 1924. The oil was then moved from Farmington to market by rail. The following year, refineries were constructed at Aztec, Bloomfield and at Farmington.

Exploration drilling began to slow in the late 1930s and into the early 1940s, even though geophysical exploration was introduced with a magnetometer survey in 1927. In part, the decrease in exploration activity occurred due to the fact that most of the field discoveries were gas and only limited, local gas markets existed until 1951. The most significant finds of the period were the discovery of Paradox (Pennsylvanian) gas at Barker Dome in 1945 and at Ute Dome in 1948. These large gas reserves ensured that the transmission line would be built to serve the gas-hungry west coast.

Following and concurrent with installation of the gas pipeline, a second period of intense exploration activity occurred during the late 1940s and early 1950s[14]. Development of the Blanco gas field, plus deeper drilling resulted in a number of important discoveries during this time period. Mississippian oil was discovered from deep tests at Table Mesa in 1951 and at the Hogback field in 1952. The Gallup sandstone became an important oil producing horizon with the discovery of Bisti, Horseshoe, and Gallegos. Bisti field was the first significant stratigraphic pool discovered and led to further exploration of shoreline trend oil accumulations.

During this period, several oil and gas pools were found in the Dakota, Mesaverde and younger formations. Smaller gas fields were consolidated to form three large gas fields: Blanco, Basin and Ballard. For example, the Northwest La Plata, Cedar Hills, and East Largo fields were all consolidated into the Blanco Mesaverde field, and the Blanco Dakota, West Kutz Dakota, Campanero, South Los Pinos and Huerfano Dakota pools were consolidated to form the Basin Dakota field. In addition to these field groupings, there were field discoveries (Aztec, Gallegos, and West Kutz) in the Fruitland formation during this time.

The late 1950's and early 1960's saw several small oil discoveries in the Gallup, Mesaverde, and Entrada. Gas discoveries were made in the Dakota, Mesaverde, Pictured Cliffs, Fruitland, and Chacra. Pennsylvanian oil was found at Table Mesa, and both Pennsylvanian oil and gas were found at Tocito Dome. However, by the mid 1960's, most exploration was by field extensions and step-outs.

During the 1970s and early 1980s, many fields experienced increased development activity, as exploration drilling slowed. In 1975, the natural gas shortage led the New Mexico Oil Conservation Division to allow a second well to be drilled on each 320-acre spacing unit in the Blanco Mesaverde pool. Development drilling increased as operators took advantage of these new rules, which were subsequently expanded to other pools. Then, in 1976 a Federal Power Commission ruling increased the gas price for new gas. This action also accelerated in fill drilling.

As a result, in 1978 the Blanco gas field was second in the nations top 25 fields in the number of completions due to the infill drilling programs, and San Juan County was first in the Rocky Mountain Region in total completions for both 1979 and 1980. Unfortunately this burst of development activity ended in 1982, due to the nationwide natural gas glut.

Since 1982, exploration and development of the San Juan basin has significantly decreased, reflecting a nation-wide downturn in industry activity. However, most recently there has been significant development of coal bed methane as a source of new gas. This has occurred as a result of Federal incentives.

It should be emphasized that, although there was drilling activity in the San Juan basin throughout this century, the majority of the producing wells have been drilled since the end of 1949. A report of the New Mexico Bureau of Mines and Mineral Resources shows approximately 233 producing wells in the basin as of the end of 1949. Using data on the total numbers of producing wells in the basin at various intervals from that year, it is estimated that only 1.4 percent of the producing wells were drilled prior to 1949. This relatively small number of early wells is fortunate, since there are few well records from this period and the methods used to complete and abandon these wells were less rigorous.

In summary, greater than 18,000 wells have been drilled in the San Juan Basin since the initial discovery well in 1909. These wells have found and delineated 257 oil and gas pools (discoveries by formation through 1982, New Mexico only[2]). A listing of these pools and their discovery dates is shown in Table 1. A time distribution of the discoveries is shown in Figure 7.

4.3 Regulatory and Statutory History

States with significant petroleum production have government agencies whose primary purpose is to oversee oil and gas operations throughout the state. In New Mexico, that regulatory body is the Oil Conservation Division (NMOCD) of the Energy, Minerals and Natural Resources Department. This agency is responsible for enforcing laws with respect to oil and gas operations; approving and overseeing various well operations such as drilling, completion and plugging; and for maintaining well records.

The NMOCD is under the direction of the State Petroleum Engineer. He and most of the administrative staff are located in Santa Fe, New Mexico. District offices are located in Santa Fe, Artesia, Hobbs, and Aztec, with the main district office located in Santa Fe (Figure 8). Each district is under the, supervision of a district supervisor and is staffed by technical, field and administrative personnel. Each district also employs a number of inspectors, who are in the field on most days to witness well operations.

4.3.1 Evolution of the State Regulatory Body

The NMOCD has its origins with the enactment of the first oil and gas law, which was approved by the state legislature on June 8, 1912. Although this law does not state who is responsible for its enforcement, the creation of this law sets the stage for future development of the state regulatory authority.

In 1925, the state legislature created the position of "State Geologist". The purpose of this position was to supervise and regulate the drilling and production of oil and gas on State and private lands. The State Geologist was to prescribe and enforce rules governing drilling, casing and abandonment of wells. The law indicated that the State Geologist was expected to adopt the rules currently in use by the U.S. Bureau of Mines on Federal lands, and formulate such other rules as he deemed proper.

The State Geologist appointed inspectors and staff to carry out provisions of the law. County Commissions could carry out enforcement of the law themselves on private land or delegate their authority to the State. Inspectors were given broad authority to enforce compliance even to the point of causing the necessary work to be completed and collecting the costs of this work from the well owner.

Authority for overseeing oil and gas operations remained with the State Geologist until 1935. At that time, authority was transferred to a new agency, the Oil Conservation Commission (commonly referred to as the "Commission" or OCC). The Commission was comprised of the Governor, the Commissioner of Public Lands and the State Geologist. The State Geologist continued to be the supervisor of OCC employees and the director of all agency operations.

The OCC operated as the state's regulatory agency from 1935 to 1975. During this period, there were many changes in both the OCC's authority and state regulations. OCC powers were expanded to cover a wider range of activities, including ancillary operations such as the disposition of waters produced during drilling. The first statewide rules were adopted in 1950 under the OCC, and a myriad of well operations were brought under regulation or reporting requirements. In addition to these changes, the district offices of the OCC were formed, and the modern day language of the agency's goals was adopted.

In 1975, the regulatory authority passed to an agency within the Energy and Minerals Department. This agency was designated the New Mexico Oil Conservation Division. The head of the NMOCD was redesignated the State Petroleum Engineer, and this individual was to be appointed by Secretary of the Department rather than the Governor. The original Commission continued in existence but with a role essentially reduced to hearing cases referred by the Director or appealed from the Division.

Since 1975, the NMOCD continues to be the regulatory body responsible for overseeing all oil and gas operations in the State of New Mexico. The only change of significance is that a reorganization altered the regulatory agency name to the Energy, Minerals and Natural Resources Department. However, this change did not impact the function or structure of the NMOCD.

4.3.2 State Regulations - Well Construction and Abandonment

The state of New Mexico has enacted a number of rules regarding the manner in which oil and gas wells should be constructed and abandoned. These rules cover a wide range of activities. For example, there are rules with respect to filing notices to drill, complete or abandon a well; rules with respect to the actual drilling, completion or abandonment plan; and rules regarding testing operations such as testing the pressure integrity of the casing after cementing operations. The state rules concerning the protection of USDWs were the only regulations considered significant in the study. These rules cover the use and placement of casing strings, casing pulling, the use and placement of casing cement, the use of mud-laden fluid, well plugging and abandonment requirements, and the sealing of strata.

At the outset of the study it was believed that the state regulations would provide a high level of detail and have a clear date of enactment. Further, it was believed that if all laws were sufficiently detailed, then one could predict a well's construction and abandonment configuration based simply on the age and depth of the well. More importantly, one could use the current regulations to develop a set of practices describing the manner in which a well should be completed and abandoned. Such practices could then used as a basis for comparing and evaluating active and abandoned wells.

After reviewing the earliest state laws and the various changes enacted over the past 80 years, it was apparent that the language of the well construction and abandonment laws was not specific. Only special field rules enacted for Lea County pools in Southeast New Mexico between 1935 and 1949 contained specific details regarding the use of various casing strings, casing setting points, and cement volumes and tops. The language of all other relevant laws was very general, and could be interpreted or applied in more than one way. For example, the abandonment law of 1935 states "when abandoned, wells shall be plugged in a manner which will permanently confine all oil, gas, and water in the separate strata originally containing them. This shall be accomplished by the use of mud-laden fluid, cement and plugs used singly or in combination as may be approved by the Commission." This language does not give details about the volumes of the cement plugs to be set or their exact locations. Hence, it is not possible to use this law as an abandonment "standard", or to identify a plugging method for that time period.

In addition to finding that the language of the state regulations was general, it was also found that the language of many state oil and gas regulations has not changed significantly since inception. For example, the abandonment regulation of 1935 cited above is essentially the same as the current (1990) well abandonment regulation, i.e. Rule 202 (Table 2).

Since the current state laws do not provide specific details, it was not possible to use the regulations to develop a set of modern standards for well construction and abandonment. Instead, the director of the Aztec district office of the OCD was contacted to identify the construction and abandonment standards, or practices, which operators are currently expected to employ. The practices identified are detailed in section 4.3.3.

Figure 9 presents a timeline summary of major well construction and abandonment requirements, such as the point when casing cement was first required.

4.3.3 Well Construction and Abandonment Standards

A set of current, recommended practices for current well construction in the San Juan Basin was provided by the OCD supervisor of the Aztec District Office. These practices are summarized in Figure 10.

Wells are expected to be constructed with surface casing and the surface casing cemented back to the surface. The length of the surface pipe is linked to the well depth, or to the depth of fill in valley fill areas. Presumably these casing depths are sufficient to protect shallow USDWs, i.e. there is no written requirement to case through a particular USDW in the guidelines.

An intermediate casing string is optional but, where one is run, it should be cemented in place. Production casing may be set either through or on top of the projected producing interval, but should also be cemented in place.

One interesting requirement is that casing cement should be circulated back 100' into the previous string, which could be either surface pipe or intermediate casing. The OCD supervisor indicated that this practice was recommended since casing corrosion has been encountered in older wells, and also for protective measures since there is now extensive development of gas in the Fruitland Coal.

These recommended construction practices shown in Figure 10 were developed in 1990. No written guidelines existed prior to this time. Wells completed or abandoned prior to 1990 were, therefore, reviewed and permitted on a case-by-case basis.

Surprisingly, there were no written abandonment guidelines in existence for the San Juan Basin. Rather, the OCD supervisor indicated that each plugging request was reviewed individually, and either approved as submitted or altered to meet expectations of the state agency. Abandonment standards therefore had to be developed through querying the OCD with respect to specific abandonment situations, such as the use of cement spacer plugs and mud in an abandoned dry hole. Figure 11 details the recommended well abandonment practices identified.

As shown in Figure 11, an abandoned well is expected to have a bottom plug which could be either a cement plug or a cast iron bridge plug (CIBP) covered with cement. This plug should be placed across the hydrocarbon bearing or injection zone.

If the casing is cut and retrieved from the well, then a stub plug should be placed at the point where the casing is cut. The stub should be cemented in such a way and with sufficient volume to leave 50' of cement both inside and outside the stub.

If the casing is not retrieved, or if the casing is cut above the point where USDWs exist, and if the primary casing cement placed during well construction did not cover the USDWs, then a remedial cement squeeze is required to cover the USDWs. Intermediate casing should also be cement squeezed if it was not originally cemented back to surface.

In an open hole, cement spacer plugs must be used to cover fresh water and hydrocarbon bearing zones. These plugs should be a minimum of 100' in thickness. These plugs may be separated by either water or mud. If mud is used, the mud density should be greater than 9 ppg to improve accuracy in placing the spacer plug.

The recommended abandonment practices detailed by the OCD have evolved during the development history of the San Juan basin. However, many of the wells examined in the study met the current practices. Therefore, it is believed that the abandonment practices cited herein have been widely employed in the San Juan Basin since the 1950s.

4.4 Basin Pressure Study

An evaluation of petroleum reservoir and USDW pressures was conducted as part of the San Juan Basin study. The objective of this work was to identify areas of positive flow potential ("positive residual") and negative flow potential ("negative residual") within the basin. It is important to identify these areas, because a positive residual must exist between a petroleum reservoir and a USDW if there is to be any risk of abandoned wells contaminating USDWs.

To identify residuals throughout the basin, differences were computed between head maps of petroleum reservoirs and head maps for overlying USDWs. The data used to prepare the petroleum and USDW head maps, the method of computing residuals, and the results of this work are discussed herein.

4.4.1 Method of Constructing Petroleum Reservoir Head Maps

The pressure data used to construct head maps for petroleum reservoirs were taken from drillstem tests (DSTs) of wells located throughout the San Juan Basin. Only drillstem test data were used for the study because these data directly reflect bottomhole pressures. Other data, such as surface shut-in pressures, could also have been used, but it was believed that these data would be substantially less accurate because the fluid gravities for correcting surface shut-in pressures to bottomhole pressures were unknown.

The DST data used in the study were purchased from Petroleum Information Corporation (PI). The data set contained 2,594 drillstem tests for 1,368 wells in the San Juan Basin. The drillstem tests were found to describe pressures for 69 different petroleum reservoirs.

To construct the head maps, the DST data were first divided into seven geological groups as shown in Figure 12. The geological groupings, i.e. Tertiary, Upper Cretaceous, Mesaverde, Gallup, Dakota, Morrison and below Morrison, are the same stratigraphic groupings used for classifying USDWs. By adopting these groupings, it was possible to compare USDWs to underlying petroleum reservoirs.

After segregating the DST data by geological group, the data were reviewed to examine characteristics of the drillstem test and the type of pressures reported. This review was intended to screen unacceptable data, since it is known that only wells with late-time, or final shut-in pressures provide accurate representations of reservoir pressure. Wells with only initial shut-in pressures (pressures reported immediately after the flowing period), or wells with short shut-in periods (less than twice the flow period) were deemed unacceptable and were eliminated from further consideration. As a result, 786 wells were found to have acceptable final shut-in data and these wells were used to begin the study.

Pressure data from the 786 wells were converted to head values, in units of feet. Two sets of head values were calculated, one assuming a salt water gradient (0.45 psi/ft) and another assuming a fresh water gradient (0.433 psi/ft). Because analyses of reservoir waters from the various producing fields were not available, it was not possible to determine an actual reservoir fluid density for computing heads. In the study, the fresh water gradient represents the "worst case" scenario (i.e. tends to overestimate the actual head) for converting pressures in the hydrocarbon bearing formations. The salt water gradient of 0.45 psi/ft was selected on the basis of the few petroleum reservoir water analyses that were available.

Head values were calculated according to the following equation:

head = (DST pressure/gradient) + elevation . . . . (1)

where,

head = feet of fresh or salt water
DST = late time shut-in pressure from buildup test, psi
gradient = fluid density expressed as a pressure gradient, psi/ft
elevation = point where the pressure measurement is taken relative to datum, ft

The mid-point elevation of the zone tested was selected as the elevation for pressure correction in equation 1. Although it was recognized that one should correct from the depth of the DST tool, i.e. the point where the reservoir pressure was measured, it was not possible to do this in the study because the actual position of the DST tool was not reported on most of the buildup tests. However, most of the zones tested were not extremely thick, which suggests that there was probably not a significant depth difference between the DST and the mid-point of the reservoir. Therefore, minimal error should be introduced by correcting heads to the mid-point elevation.

After formation pressures were converted to head values, a number of steps or iterations were employed to edit the head data. The first step was to identify wells which had multiple, valid

DSTs within a single geologic group. For these wells, the maximum head value was selected as the representative value for the particular formation and the lower head values were eliminated. By editing the data in this manner, the most conservative (highest) head was maintained for the residual, calculation.

Another step in analyzing the head data was to determine whether time significantly effected or altered the reservoir pressure surfaces. To determine the potential effect of time, the DST data, which spanned a time period from 1944 to 1991, were sorted into three periods of approximately equal length (1944-1960, 1961-1975, 1976-1991). Data from each time period were then plotted and contoured. Results of this work did not reveal any correlation between pressures and time, which is not surprising since wells are often drilled into non-depleted reservoir locations throughout the development history of the reservoir. From this work, it was concluded that there was no basis or reason for time-sorting the head data in the remainder of the study.

The head data were then edited to eliminate low head values. Low head values existed due to depleted reservoir DSTs and also because of low pressure regions. These values created unusual lows on the head maps. These "local lows" were eliminated by first discarding all head values less than 3000' and, afterward, eliminating all head values less than 4000'. This editing procedure is, again, consistent with the philosophy of selecting the most conservative pressures for the residual calculation.

Although one of the early steps in editing the data did eliminate multiple DSTs for a single well, some of the remaining well tests were extremely close to each other. This effectively resulted in multiple head values being plotted at the same location. In these cases, the maximum pressure again was selected. This step in the editing process smoothed the map contours and eliminated problems associated with the contouring of multiple, dissimilar head values at the same location.

When the head maps for the various hydrocarbon groups were considered generally acceptable, the head data were edited to eliminate high head values. This editing was not extensive, i.e. only five local highs were removed from the head maps. These values were eliminated either because the values were unreasonable (e.g. a value of over 12,000 ft when the next nearest head value was in the 7,000 ft. range), the test data were suspect ("0" flow times reported), or the data were associated with gas wells.

After all editing, 233 data points remained in the data set (see Table 5), and these points were used to generate head maps for six petroleum reservoirs (Upper Cretaceous, Mesaverde, Gallup, Dakota, Morrison, Below Morrison). The data were found to be adequately distributed throughout the geological groups, although some geological groups did have more datapoints available than other groups. Table 3 lists the final head data used in preparing each of the petroleum reservoir head maps. The data is regrouped and presented by field in Table 4.

Contours on the final head maps generated for the six petroleum reservoirs were quite smooth, with the exception of a few points which were "local highs" over 7000 ft. (These were points which could not justifiably be removed from the data set.) At this point the maps were deemed acceptable and were used in computing residuals.

For brevity, copies of the petroleum reservoir head maps have not been included in this report, but the location of the wells for which data are given in Tables 3 and 4 are shown on the residual head maps (Maps 15-26).

4.4.2 Method of Constructing USDW Head Maps

Head maps were prepared for USDWs in a manner similar to that described for the petroleum reservoirs. The values used to create the maps were USDW head data provided to UMR by the Texas Bureau of Economic Geology (BEG). The BEG obtained these data from the U.S. Geological Survey's Regional Aquifer System Analysis (RASA) data base for the San Juan Basin.

The USDW data were assigned to six hydrostratigraphic systems: Tertiary, Upper Cretaceous, Mesaverde, Gallup, Dakota and Morrison. Since more than one of these USDWs can be open in a well, and since it was desired to map each USDW separately, it was important to ensure that a water well's head value represented only a single USDW. For this reason, the BEG eliminated wells with combined heads or heads reported for more than one USDW.

Static water elevation, or head, was reported for each well in the BEG data set, along with the corresponding well location, formation name, surface elevation, well depth, and depth to water. Initially, this dataset contained head values for 488 water wells as shown in Table 5.

After reviewing these data, it was determined that in several cases (particularly the Mesaverde), wells were mis-classified with respect to the hydrostratigraphic system. Where this occurred, the data points were reassigned to the correct USDW. In some instances, data points were eliminated because the appropriate USDWs could not be identified.

Maps were then prepared for each of the six USDW hydrostratigraphic units. The data were gridded using a 0.025 latitude and longitude rectangular grid between 35.0 to 37.5 north latitude and 106.0 to 109.5 west longitude. All data were contoured using a search limit radius (SLM) of 1.0 degree latitude and longitude and an extrapolation distance (DEL2) of 0.1 degrees latitude and longitude. A contour interval of 200 feet was used on all maps.

The maps were generated for only the New Mexico portion of the San Juan Basin and, consequently, water well data for wells located outside New Mexico were generally eliminated from the data set. However, some water wells in Colorado between 37.0° and 37.1° north latitude were retained in the mapping because they are in close proximity to the New Mexico state line (37.0° north latitude) and, therefore, affect contouring in the northern portion of the basin.

After the USDW maps were prepared, they were edited to remove anomalously high values and other points which differed significantly from surrounding data. Six Quaternary-

Tertiary data points from the Chuska Mountain area (36.2 to 36.5 North Latitude near the Arizona State line) were eliminated because the values were very high (7,000 to 9,000 feet). These values differ significantly from all other data because the points are from alluvial aquifers in the Chuska Mountains which are geologically and geographically separate from the main Quaternary-Tertiary USDWs of the San Juan Basin.

Although other anomalous high values were also edited from the initial USDW head maps, the USDW data were not edited extensively. As shown in Table 5, only 46 of the initial water well data points were removed prior to generating the final maps. Of these 46 data points, the majority were removed from the Tertiary and the Mesaverde groups. No points were removed from the Gallup, Dakota and Morrison USDW data sets.

The USDW maps generated after editing are included as Maps 9-14 in this report. Map 9 depicts heads for the Tertiary, i.e. the shallowest USDW. Each succeeding map incorporates the previous USDW surface, e.g. Map 10 includes both the Upper Cretaceous and the Tertiary head data. By successively adding USDWs, the final head map (Map 14) incorporates all six of the USDWs.

The six USDW head maps were generated in vertical stratigraphic sequence, from highest to lowest, to allow comparison with the head of the immediately underlying petroleum reservoirs. For example, the heads of the Tertiary USDW were plotted and contoured (Map 9) for comparison with the calculated saline and fresh water heads of the immediately underlying Upper Cretaceous petroleum reservoir. Similarly, the Tertiary and Upper Cretaceous head data in Map 10 are combined for comparison to the underlying Mesaverde petroleum reservoir. This sequential development of USDW maps was determined to be necessary to avoid comparing petroleum reservoir head data with the same or stratigraphically lower USDWs.

To minimize confusion in data presentation, only the head data for the newly added USDW group are shown on each successive USDW map. For example, Map 10 combines head data for both the Tertiary and Upper Cretaceous USDWs. However, the Tertiary head values plotted on Map 9 are not repeated in Map 10, even though those values are included in generating Map 10. Table 6 summarizes the water well data used to generate Maps 9-14.

Examination of the USDW head maps in sequence from Tertiary to Morrison shows that, as each USDW group is added, there is little overlap with the map areas covered by the stratigraphically higher USDWs. Also, as each new USDW group is added, the contours of the previous map change very little and then only around the outer margins. However, the USDW head contours in Maps 9-14 generally show systematic decline from the basin margins toward the center of the basin.

With the exception of the southeastern area, the head maps generated (Maps 9-14) do not exhibit significant closed highs or lows. Consideration was given to editing data in the southeastern area of the basin. In that area, a number of Mesaverde data points (Map 11) are quite high (7,800 ft. range) and many of the Gallup and Dakota points (Maps 12 and 13) are quite low (5,500 ft. range). These data when combined in Maps 12, 14 and 13 give some peculiar results (closed highs and lows). These data were not edited because no oil and gas production exists in the area, and the data do not affect any of the residual maps.

4.4.3 Method of Constructing Residual Maps

To construct residual maps throughout the basin, USDW heads were subtracted from petroleum reservoir heads. Comparisons were made between USDWs and both the salt water and fresh water petroleum reservoir heads. These comparisons yielded the salt water and fresh water residual head maps (Maps 15-26).

The sequence of steps employed in creating of the residual head contour maps was as follows:

1. Generate two gridded data sets for each petroleum reservoir from the salt water and fresh water head data listed in Table 3.
2. Using the USDW head data listed in Table 6, generate gridded data sets for the USDWs overlying each petroleum reservoir with the same grid parameters applied to the petroleum reservoir head data in step 1.

3. Subtract the grid data generated in step 2 from the grid data generated in step 1.

4. Machine contour the residuals obtained in step 3.

Using this procedure, two sets of oil and gas head data were derived, one using a 0.45 psi/ft gradient and the other using a 0.433 psi/ft gradient. Thus, residual maps exist for the following cases:

Producing Formation	0.45 psi/ft	0.433 psi/ft	Against Overlying USDW
Quaternary	No map	No map	No map
	(4 pressures only & no overlying USDW)		
Upper Cretaceous	Map 15	Map 21	QT
Mesaverde	Map 16	Map 22	QT, UK
Gallup	Map 17	Map 23	QT, UK, MV
Dakota	Map 18	Map 24	QT, UK, MV, GL
Morrison	Map 19	Map 25	QT, UK, MV, GL, DK
Below Morrison	Map 20	Map 26	QT, UK, MV, GL, DK, MR (All USDW data)

Interpretation of Results

Any petroleum reservoir pressure map or ground water head map represents only the conditions that existed at the time that the data were obtained. In this study, it was attempted to obtain and selectively use petroleum reservoir drillstem test data that represented the original reservoir pressure, before petroleum production began. While it is believed that objective was fulfilled, there has been no field-by-field confirmation of that fact.

The USDW head data are measured water level elevations obtained over a period of years from water wells and, in some cases, oil wells. By selective editing of these data, it was attempted to sort out data sets for each USDW group that seemed to present a reasonable pattern of systematic head variations across the basin and without large local variations that would be expected to be caused by local centers of ground water pumping or by erroneous data points. The resultant USDW head surfaces are intended to represent original aquifer head conditions.

When the gridded USDW heads are subtracted from the gridded heads for the immediately underlying petroleum reservoir as described in section 4.4.3, a residual surface is computed. Where the residual is positive, there is a potential for upward flow of salt water into the USDW while a negative residual indicates the lack of such potential. Neither the salt water or fresh water residual head maps presented for each combination of USDW(s) and petroleum reservoir is an exact representation of the flow potential between the reservoir and the USDW(s). The values of two residual maps do, however, bracket the correct residual values.

As discussed above, these residuals are based upon what are believed to be original conditions for both the USDWs and the petroleum reservoirs. Therefore, residual head maps (Maps 15-26) cannot be used to indicate the flow potentials that exist presently or may exist in the future because they do not account for the local effect of petroleum or groundwater extraction, injection for secondary/enhanced oil recovery, or brine disposal. The head and residual head maps presented here are believed to be useful in that they establish original conditions on a basin-wide scale from which current or future conditions can more confidently be determined on a local scale.

While the head and residual head maps presented herein are not intended to allow judgements to be made, without further analysis, concerning the potential for flow in the immediate vicinity of a Class II injection well, the maps do show basin-scale relationships that can be very important for area-of-review (AOR) considerations. A specific example of this is presented by the Mesaverde residual maps (Maps 16 and 22). Those maps show that the Mesaverde petroleum reservoir is underpressured (i.e. a negative residual is indicated) relative to the overlying Upper Cretaceous and Tertiary USDWs. Thus, salt water moving upward from any deeper petroleum reservoirs through an uncased abandoned well would be expected to be diverted into the Mesaverde rather than to continue on upward to either the Upper Cretaceous or Tertiary USDWs. This is believed to be an excellent example of the presence of a sink zone as shown in the AOR Evaluation Methodology of Figure 1.

The presence of the Mesaverde as a sink zone is supported by the work of Berry[15]. Berry showed a pronounced underpressured condition to have existed prior to oil and gas development for the Mesaverde and Dakota reservoirs in the central San Juan Basin of New Mexico. Berry's maps show much more dramatic underpressuring effects than the Mesaverde residual maps presented here (Maps 16 and 22). That is because Berry used gas well surface shut-in pressure data for the central part of the basin, while only drillstem test data from around the margins of the basin were used in this study.

4.4.5 Effects of Injection within Mesaverde Negative Residual Area

An attempt was made to evaluate the effects of injection for injection fields with reservoirs in the Mesaverde and deeper formations and within the area overlain by the Mesaverde negative residual described in Section 4.4.4 and shown in Maps 16 and 22. Data on reported and maximum allowable injection pressures for those fields were obtained from the New Mexico Oil Conservation Division (NMOCD). The maximum allowable surface injection pressures provided by the NMOCD are given in Table 7.

Table 7 shows the heads calculated from the maximum allowable surface pressures. By simple reasoning, those heads would be expected to be higher than the USDW heads in the Mesaverde and overlying aquifers. That is because when surface injection pressure is imposed it will necessarily result in heads that are above the ground surface. In comparison, USDW heads will be below ground surface except in the case of confined artesian aquifers in which the artesian heads can, in some cases, be above ground level. By inspection of Table 7 it can be seen that the calculated heads are in the vicinity of 2,000 feet above the surface elevations.

Maps 27 and 28 are modified versions of Maps 16 and 22 with the residuals resulting from the injection field heads added to the maps and contoured. Because the contours are so closely spaced, they merge into spots. One such spot on Map 28 for the Cha Cha field has been blown up to show, by example, what all would look like on close examination. It is clear that all of the fields would, at the injection wells, have positive residual heads. It is not known what the heads are at the production wells in those same fields.

In spite of the fact that, as far as it could be determined, all San Juan injection fields have positive residual heads, the presence of the general negative residual area in the Mesaverde qualifies this unit as a possible sink zone for injection fields underlying it. In Maps 27 and 28, the Bisti, Blanco South, Cha Cha, Escrito, and Rio Puerco fields are overlain by the underpressured Mesaverde. The Totah field, which does not appear on the maps, is also within the Mesaverde sink zone. Any upward moving fluids from these fields could, therefore, be diverted by the Mesaverde and thus prevented from moving into a shallower USDW.

The Media, Papers Wash and Red Mountain fields are within the area where the Mesaverde is a USDW and, thus does not qualify as a sink zone, but rather, as an aquifer to be protected.

4.5 Evaluation of Well Construction and Abandonment Characteristics

An evaluation of the methods or techniques used to complete and abandoned oil wells in the San Juan Basin was conducted as part of the study. This evaluation was a significant aspect of the work, since it was recognized that a properly constructed and abandoned well can prevent the upward flow of contaminating fluids and eliminate the chance of USDW contamination.

In the evaluation, the San Juan Basin was sub-divided into four principal areas based on the location and areal extent of USDWs. Abandoned and active wells located within oilfields with active injection operations in each of the four basin sub-areas were sampled and analyzed according to the AOR Variance Methodology[16]. Results of these analyses are described herein.

4.5.1 Identification of Sub-areas

Several classifying factors were considered as the basis for dividing the basin into sub-areas. These factors included the location and depth of USDWs, the location and depth of major petroleum reservoir types, location and depth of abandoned wells, and the location and depth of injection formations. Of these factors, the location of USDWs was initially considered to be of principal importance. This selection proved to be satisfactory. Hence, the combined areal extent of the USDWs was the factor subsequently used for sub-dividing the basin.

To define the sub-areas, basin maps were prepared for each of the six USDWs: Morrison, Dakota, Gallup, Mesaverde, Upper Cretaceous, and Tertiary. (Maps 1-6) The maps were prepared using USDW head data obtained from the Texas Bureau of Economic Geology (BEG), and outcrop and water quality data from US Geological Survey hydrologic atlases.[4-11]

Oil and gas fields were also plotted on each of the six USDW maps. BEG data for the location of oil and gas fields was used and accepted as correct. For clarity, each map (Map 1-7) shows only those oil and gas fields whose deepest zone of production is found within, or below, the respective USDW.

The 10,000 mg/liter total dissolved solids limit for USDWs within each stratigraphic system was determined from U.S. Geological Survey hydrologic atlases and that limiting boundary transferred to Maps 1-6. This boundary represents the areal extent of 10,000 mg/liter water within each stratigraphic system, or within each USDW. As the salinity boundaries on each map (Maps 1-6) indicate, the fresher water is generally located at the outer extremities of the basin, where groundwater recharge occurs. The water in stratagraphic units older than the Tertiary tend to become more saline toward the middle of the basin.

On each of the six overlay maps, the area of possible contamination for each of the USDWs lies between the outer edge of the outcrop and the 10,000 milligram/liter salinity line. Any well which lies outside of the outcrop of the USDW can pose no contamination risk since the USDW is not present. Similarly, any well located inside the 10,000 milligram/liter salinity line cannot contaminate the USDW, since the formation is by definition not a USDW.

With the exception of the base map (Map 7), which locates all new field wildcat locations below the Morrison, each USDW map was prepared as a transparency by plotting the various features on mylar. This facilitated the use of an overlay technique whereby each USDW map was successively placed on top of one another, in order of decreasing depth. With this technique, fields producing from deeper stratigraphic units can easily be seen on the maps of shallower units, to verify their position with respect to the various USDWs.

Using the overlay technique, a pattern emerged which defined five areas of USDW distribution. These five areas are regions where distinct groups of one or more USDWs exist over producing oil and gas fields. For purposes of the research, these areas have been named Western, Southern, Chuska, Interior I and Interior II. Their position and areal extent is shown on Map 8 and Figure 13. Details regarding the determination of each area's boundaries are presented in section 4.5.4.

Once the basin sub-areas were defined, the oil and gas fields located within each area were identified, and listed as shown in Table 8. One hundred and forty-five oil and gas fields were identified. Of these, only oil fields with active injection operations were considered further, since these fields would be subject to AORs. Twenty four injection fields were identified for further study. These fields are highlighted in Table 8.

4.5.2 Area Sampling Technique(s)

As detailed in the AOR Variance Methodology[16], it is proposed that a representative sample of wells be examined for a field or an area, and the well construction and abandonment methods used for the sampled wells be accepted as representative of the total well population. Further, if the sampled wells demonstrate adequate protection of overlying USDWs, then it is proposed that the area associated with the sampled population should qualify for an AOR variance. This approach was applied in studying the 24 injection fields.

4.5.2.1 Abandoned Wells

Sample populations of abandoned wells located in fields with active injection operations were selected and examined from the Western, Southern, Interior I and Interior II areas. No analysis was performed on the Chuska area, because the area contains only one oilfield and is therefore of minor importance.

Dwight's Well Data System (April 1991 release) was used to determine the total number of abandoned wells present in the San Juan Basin and, consequently, the total population of wells available for sampling. The system was found to contain data for 33,354 wells in the entire San Juan Basin, although only 30,134 of these wells were located in New Mexico. Of the wells located in New Mexico, 7,256 were classified as abandoned wells. These wells were further differentiated as follows:

Well Count	Classification
7,256	Total wells classified as abandoned wells.
-2,465	Abandoned locations (wells permitted but never drilled) and cancelled plans.
4,791	Total number of inactive wells (includes plugged and abandoned "P&A", dry and abandoned "D&A", junked and abandoned, temporarily abandoned "TA", and suspended "SUSP").
- 227	Total number of suspended and temporarily abandoned wells. These wells were eliminated from the total number of inactive wells since the abandoned well study did not include wells which were not actually plugged.
4,564	Total number of abandoned wells available for evaluation in the study.

Of the 4564 abandoned wells available for study, 511 wells were located within 24 fields with active injection operations in the Western, Southern, Interior I and Interior II basin sub-areas..

Six fields with active injection were located in the Western area. These fields were found to contain 155 abandoned wells. Twenty of these wells were sampled for analysis. All ten deep abandoned wells, i. e. those which intersected both an injection zone and a USDW were examined in the Western area. Ten shallow wells were examined in the Western area to confirm their construction characteristics. The remaining shallow wells were not considered since they do not exhibit an intersection with a USDW.

The Southern area included six injection fields which contained 164 abandoned wells. One hundred and fourteen abandoned wells were examined. This sample included all abandoned wells in five fields, and a random sample of abandoned wells in the Red Mountain field.

A sample of abandoned wells was examined in the injection fields located in the Interior I and II areas. The procedure utilized in these areas involved selecting a representative sample of the total abandoned well population.

Initially, it was expected that the well population would be stratified based on one or more physical characteristics (e.g. age), and that each strata would be sampled. This approach could not be adopted due to limitations of the database. As a result, random sampling of the abandoned well population was used as the sampling technique.

To select each sample well population, abandoned oil wells from Dwight's database were numbered, and a random number generator was used to select the sample population. The random number generator was initiated by the current hundredth of a second (computer clock time) to select wells from a list of the entire well population. This method of starting the random number generator avoids any bias, either predetermined or unknowing. A t-test was employed with a minimum acceptance of 95% confidence level. Repeated sampling indicated both randomness and confidence level consistency.

Sample sizes were selected in accordance with guidelines provided by the Underground Injection Practices Research Foundation of the Ground Water Protection Council23. For a population of 250 wells, a sample size of 39 wells would yield a 90% probability that the proportion of "bad" wells in the population was less than or equal to 5% (Table G-1)[23]. As the well population increases from 250 to 500 wells, the sample size required increases from 39 to only 41 wells. In each of the basin sub-areas, sample populations exceeded a 95% probability that the proportion of "bad" wells was less than or equal to 5%.

In the Interior I area 13 abandoned wells were examined in three injection fields which contained a total of 29 abandoned wells. In the Interior II area, 9 injection fields were found to contain 163 abandoned wells, and 37 of these wells were examined in the study.

The sample populations used in the study were based on well counts available in the Dwight's Well Data System. Although Dwight's system was believed to be complete, the data of Michie and Associates[1] indicates a slightly greater number of abandoned wells (6366). To ensure that the sample sizes used in the study are valid even in the event the total populations are greater than those indicated by Dwights, a sampling evaluation was conducted. In this evaluation, the, total abandoned well count of Michie and Associates was used as the total abandoned well population.

This well count was adjusted to estimate the total number of abandoned oil wells, by ratioing on the basis of active producers (3070 oil wells, 13,449 gas wells). This resulted in an estimate of of 1184 abandoned oil wells in the San Juan Basin.

The number of wells sampled in the study was then compared with the estimated number of abandoned oil wells. The total number of sampled abandoned wells was 186. This sample size was found to be statistically valid for the total estimated abandoned well population. That is, applying the random sampling algorithm with a sample size of 186 to the total abandoned oil well population of 1184 wells yielded 10 out of 10 random samples falling within the 95% confidence interval.

4.5.2.2 Active Wells

The basin-wide study also includes an evaluation of active wells sampled from the 24 injection fields in the four basin sub-areas. Both production and injection wells were included in the active well sample for each field.

The minimum number of active wells required for each field was based on the field's abandoned well sample, since the abandoned wells located within injection fields would also reflect the types of well construction methods employed in that field. Three or more active wells were sampled from each field and their construction methods compared to those used in the abandoned wells. If the construction methods were similar to those used in abandoned wells, the active sample was deemed to be sufficient. Alternatively, if there were well construction discrepancies, or if the abandoned well sample was predominantly dry holes, additional active wells were chosen to augment the original sample.

In the Western area, 712 active wells were identified within six injection fields. Five hundred and ninety one of these wells are located in shallow fields and therefore have no intersection with USDWs. The other 121 wells are located in a field with both deep and shallow production. A total of 30 active wells were sampled from the Western area active well population. Twenty seven of these wells were shallow and three wells were deep completions.

The Southern area was found to have six injection fields containing 418 active wells. Fifty six of these wells were sampled in the study.

In the Interior I area, 21 active wells were identified in three injection fields. Eleven of these wells were examined in the study. Nine injection fields are located in the Interior II area. These fields contain 891 active wells, of which 499 are located in a single field (Bisti). A total of 45 active wells were sampled from these fields.

4.5.3 Preparation of Well Construction and Abandonment Diagrams

Well diagrams were prepared for each of the sampled wells. These diagrams show the casing, cementing and plugging practice used for each well. To the extent possible, geological tops are also summarized on the wellbore drawings. Two sources of construction and abandonment data were used to prepare the drawings for abandoned wells in the San Juan Basin. These two sources were Dwight's Well DataSystem and the state records of the New Mexico Oil Conservation

Division.

Dwight's Well Data System was used to identify the names and locations of abandoned wells located within the San Juan Basin fields. For each field considered in the study, wells listed as plugged and abandoned or dry and abandoned were retrieved from the database and investigated in detail. Wells listed as temporarily abandoned or suspended were not considered as part of the study, although data for these wells were often retrieved and checked as a result of questions concerning well status.

Figure 14 depicts an example of the data obtained from the Dwight's database. As shown, Dwight's information was generally limited to drilling and completion details such as formations tops, casing size and setting points, total depth, spud date, completion date, cement volumes and status at completion. These data were used to prepare the wellbore sketches found in the appendices of this report.

Unfortunately, a large number of wells in the Dwight's database did not have complete construction information. An example of this is shown in Figure 15. Initially it was believed that if the Dwight's report did not provide drilling and completion details for a well, then the data simply did not exist. Subsequent work proved that this assumption was not always correct (Figures 16 and 17) and, as a result, state or federal completion records were ordered for all wells with incomplete Dwight's reports.

Many of the state completion reports obtained, particularly the reports for wells drilled prior to 1950, indeed had no details of the drilling, casing and completion operations. An example of this type of well report is shown in Figure 16. Wells drilled after 1950 generally had adequate drilling and completion details available.

Dwight's database did not contain abandonment details for the plugged and abandoned wells. Abandonment details were available only occasionally for wells which were abandoned immediately at the end of the drilling operation, i.e. dry holes. Therefore, abandonment records for each well considered in the study had to be ordered from the state of New Mexico. As with the completion records, abandonment information was generally available for wells drilled after 1950, and only sometimes available for wells drilled prior to this time. An example of the type of abandonment data which was obtained is shown in Figure 18.

The state abandonment reports were used to obtain data such as cement volumes for plugs, squeezed zones and plugging depths, and casing cutting points. This information was used with the well construction data to prepare the wellbore sketches given in the appendices.

In general, diagrams were prepared for all wells which had at least some casing record. However, in cases where no construction or abandonment details could be obtained, or where there was no intersection between a petroleum reservoir and an overlying USDW, no drawing was prepared. Therefore, some of the wells listed as "no information" or "no intersection" in Appendices B-E do not have drawings available.

4.5.4 Western Area Results

The Western area was determined using the map overlay technique described in section 4.5.1. Morrison and Dakota maps were examined first, and from these overlays it was found that these two USDWs have outcrops which lie essentially on top of one another near the western extremity of the basin. Further, the Morrison and Dakota have 10,000 mg/l salinity boundaries which trace similar paths over a substantial portion of the basin. Their salinity boundaries do diverge in the northwest, with the Dakota boundary lying east of the deep Paleozoic fields. (Maps 5 and 6)

By placing the Gallup formation map (Map 4) on top of those for the Morrison and Dakota, it can be seen that the Gallup formation outcrops slightly east of the Morrison and Dakota. The Gallup salinity boundary divides the basin diagonally, running from the northwest to the southeast.

As a result, the Gallup salinity line falls to the west of the Dakota salinity boundary in the northwest portion of the basin, but follows the same trend as the Dakota and Morrison near the center and southeastern portion of the basin.

If the overlay maps for shallower USDWs are superimposed on the Gallup, it is apparent that the shallower USDWs outcrop east of the Dakota salinity boundary. Hence, there are no shallower fresh water USDWs in the northwestern portion of the basin. As a result of this analysis, one can define an area of the basin in which only Morrison, Dakota or Gallup fresh water exist. This area has been designated the Western area, as shown in Figure 13. The limits of this area are defined by the Morrison or Dakota outcrops to the west, and by the Dakota salinity boundary to the east.

There are 6 oil fields with active injection operations located within the boundaries of the Western area. These fields produce primarily from the Cretaceous Dakota and Gallup formations, although there is also production from Paleozoic zones. A summary of pertinent facts for the Western area fields is given in Tables 9 and 10.

Wells completed in the Paleozoic formations are considered to be "deep" Western area wells, while those completed in only the Gallup or shallower formations are referred to as "shallow" Western area wells. This distinction is important because the deep wells have different construction configurations than the shallow wells. The distinction between "deep" and "shallow" wells is also important because the number of USDWs intersected is a function of depth. Four of the six injection fields in the Western area have only shallow production, i.e. USDWs are not present.

A total of 52 abandoned and active wells were sampled in the Western area. All of these wells were analyzed according to the AOR Variance methodology[16]. Results of this evaluation and the combined Western area well counts are presented in Table 11.

Since the Paleozoic formations were found to be initially overpressured with respect to USDWs, it is believed that the injection fields will remain overpressured with respect to USDWs.

Thus, all wells are assumed to have a positive flow potential from the injection zone into the overlying USDW and could not be excluded from further evaluation on this basis. Wells which did not intersect with a USDW or an injection formation, or wells which were found to have hydrocarbon production from the USDWs units were excluded from further evaluation according to the AOR Variance methodology. Thirty-three, or more than half of the sampled well population, were excluded on this basis. This reflects the fact that there are entire fields within the Western area which exhibit no intersections with USDWs.

Wells with insufficient data for assessment were labeled as "no info" wells. Only 5 wells of the total sampled well population were found to have incomplete data. Fourteen wells were evaluated with the borehole evaluation program, ABE, to determine the number of flow barriers present in the wellbore. Results of this evaluation are presented in Table 12.

4.5.4.1 Injection Fields

4.5.4.1.1 Horseshoe Field

The Horseshoe field is located in T30-32N, R15-17W, San Juan County, New Mexico. The field was discovered in 1956, and produces from the Cretaceous Gallup Sandstone. The field is undergoing waterflooding.

The Mancos Shale occurs at the surface at this field and the first aquifer is the Gallup which contains saline water and is the producing formation. Thus, there are no USDWs and the field should qualify for an AOR variance on that basis.

Three producing wells and two injection wells were examined for their construction characteristics. The wells examined had total depths ranging from 1100 to 1900 ft. Surface casing was set in all of the wells, between 100 and 500 ft. Surface casing was cemented to surface in all of the active wells examined. 5-1/2" production casing was set through the Gallup, cemented, and the Gallup was perforated. A 2-3/8" tubing string was used to complete the wells, and some wells were fractured when completed.

Two abandoned wells were examined for their abandonment characteristics. These wells had TDs similar to the active wells. Both abandoned wells had cemented surface casing, but only one well had the surface casing cemented back to surface. One abandoned well had 2-7/8" pipe set and cemented at the top of the Gallup, and the Gallup was tested open hole. This well was abandoned with a cement plug from TD to 1230 ft, which was sufficient to cover the injection zone. The other abandoned well was a dry hole. This well was abandoned with multiple cement plugs sufficient to cover the injection zones and surface casing shoe.

No formal ABE evaluations were made in the Horseshoe Field, since there is no USDW. However, all of these wells examined would all provide protection to a shallow USDW such as a minor sand in the Mancos Shale or fresh water in fractured Mancos Shale should those USDWs be present.

Records of the NMOCD show that four AORs have been performedfor injection wells in this field. That sample may be sufficient to provide an additional basis for a variance for the field.

4.5.4.1.2 Many Rocks Field

The Many Rocks field is located in T31-32N, R16-17W, San Juan County, New Mexico. The field was discovered in 1962, and produces from the Cretaceous Gallup Sandstone. The field is undergoing waterflooding.

The Mancos Shale occurs at the surface at this field and the first aquifer is the Gallup which contains saline water and is the producing formation. Thus, there are no USDWs and the field should qualify for an AOR variance on that basis.

Three producing wells and two injection wells were examined for their construction characteristics. The wells examined had total depths ranging from 1200 to 1900 ft. These wells were completed with surface casing set between 22' and 74', and all of the surface strings were cemented back to surface. 4-1/2" or 5-1/2" production casing was run, set through the Gallup reservoir, and cemented with sufficient volumes to bring cement several hundred feet above top of the reservoir. Producing wells were perforated and completed with 2-3/8" tubing. One injection well was completed with tubing and a packer while the second injection well had no indication of tubing.

Two abandoned wells were examined for their abandonment characteristics. These wells had TDs similar to the active wells. Both abandoned wells had surface casing set between 30 and 40 feet, and the surface casing was cemented back to surface. One well was a dry hole which was abandoned with a cement plug from TD to 100' above the Gallup, and a surface plug. The other well was completed with production casing set to the top of the Gallup. This well was abandoned by retrieving the casing to a depth of 700 ft. A cement bottom plug was placed from TD to approximately 70' above the top of the Gallup. The well also had a cement plug at the production casing stub and at surface.

No formal ABE evaluations were made, since there is no USDW. However, these wells would all provide protection to a shallow USDW such as a minor sand in the Mancos Shale or fresh water in fractured Mancos Shale should those USDWs be present.

4.5.4.1.3 Many Rocks North Field

The Many Rocks North field is located in T32N, R17W. The field was discovered in 1963, produces from the Cretaceous Gallup Sandstone. The field is undergoing waterflooding.

Three producing wells and two injection wells were examined for their construction characteristics. The wells examined had total depths ranging from 1500 to 1800 ft. These wells were completed with surface casing set between 30' and 90', and all of the surface strings were cemented back to surface. 4-1/2" production casing was run, set through the Gallup reservoir, and cemented with sufficient volumes to bring cement several hundred feet above top of the reservoir.

Producing wells were perforated and completed with 2-3/8" tubing. One injection well was missing construction information and the other injection well had no indication of tubing. The second injection well was also found to have been abandoned.

Two abandoned wells were intentionally sampled and examined for their abandonment characteristics, and one well initially reported to be an injector was found to have been abandoned.

These wells had TDs similar to the active wells. Both of the abandoned wells which were intentionally sampled were dry holes. These wells had surface casing, set at approximately 30' and cemented to surface. The wells were abandoned with cement plugs from TD to at least 100 ft above the Gallup, and with surface plugs. Once surface plug had sufficient volume to extend below the surface casing shoe. The injection well was abandoned by retrieving the production casing to a depth of 904 ft, and setting a cement plug across the casing stub. A bottom cement plug was set across perforations. A surface plug was present and this plug extended below the surface casing shoe.

As in the other shallow fields, no formal ABE evaluations were made, since there is no USDW. However, these wells would all provide protection to a shallow USDW such as a minor sand in the Mancos Shale or fresh water in fractured Mancos Shale should those USDWs be present.

4.5.4.1.4 Mesa Field

The Mesa field is located in T32N, R17-18W, San Juan County. The field was discovered in 1961 and produces from the Cretaceous Gallup Sandstone. The field is undergoing waterflooding.

The Mancos Shale occurs at the surface in this field and the first aquifer is the Gallup which contains saline water and is the producing formation. Thus, there are no USDWs and the field should qualify for an AOR variance on that basis.

Three producing wells and five injection wells were examined for their construction characteristics. The wells had TDs ranging from 1000' to 1800'. Surface casing was set between

12' and 105' in these wells, and all wells had the surface string cemented back to surface. The producing wells had 4-1/2" casing set through the Gallup, and the production casing was cemented with sufficient volumes to bring the cement top at least 100' above the Gallup. 2-3/8" tubing was used to complete the producing wells. Injection wells had production strings cemented in a similar manner, and were completed with 2-3/8" tubing and a packer.

Four abandoned wells were examined for their abandonment characteristics. These wells had TD's similar to the active wells examined. The abandoned wells all had surface casing set between 15' and 50', and the surface string was cemented to surface. All four of the abandoned wells examined were dry holes. These wells were abandoned with cement bottom plugs, extending from TD to at least 50' above the Gallup. Surface plugs were also used in the wells, but only one of the three wells had a surface plug which extended below the casing shoe. One abandoned well examined had cement which completely filled the borehole.

No formal ABE evaluations were made, since there is no USDW. However, these wells would all provide protection to a shallow USDW such as a minor sand in the Mancos Shale or fresh water in fractured Mancos Shale should those USDWs be present.

The five injection wells that were examined were all converted from production to injection during 1990-1991. This suggests that sufficient AORs may be available to qualify the field for a variance on that basis.

4.5.4.1.5 Rattlesnake Field

The Rattlesnake field is located in T29N R19W, San Juan County. The field was discovered in 1924, and originally produced from the Cretaceous Dakota Sandstone. Production was subsequently obtained from the Pennsylvanian Hermosa Group in 1929, the Mississippian Leadville Limestone in 1943 and the Cretaceous Gallup in 1968. The field is undergoing waterflooding of the Dakota.

From the information available, it appears that the Gallup, Dakota and Morrison may be

USDWs at the location of the Rattlesnake field. However, because the Dakota is the principal producing formation and is undergoing waterflooding, it should, logically, not require protection.

The Morrison is below the Dakota and, therefore, would not be intersected by Dakota wells but would be intersected by the few abandoned wells that were drilled to the Pennsylvanian and Mississippian reservoirs. The Gallup is probably a USDW and has been evaluated as such, but the Gallup has been a producing reservoir in the past and, thus, may not require protection.

Three producing wells and two injection wells were examined in the Rattlesnake field. All of these wells had TDs between 700 and 1000 ft in the Dakota reservoir. Four of these wells had surface casing reported, and the surface casing was cemented back to surface. Two of the three producing wells were open hole completions, and these wells had no casing cement details. One producing well was cased through the Dakota, cemented, and perforated. All three wells were completed with tubing, or tubing and a packer. The two injection wells were constructed in a manner similar to the producing wells and were cased through the Dakota. The production string was cemented and perforated. One injection well was completed with tubing and a packer. The second injection well was evaluated on the basis of construction data only, because details concerning conversion to an injector were not available.

The active wells were evaluated with the borehole program ABE (Table 12) and were found to provide protection of both the Morrison (below) and Gallup (above). Five wells received positive ABE values. Two wells are considered 'no info' wells because casing cement details were not known. These wells were completed in 1926 and 1936. Although they are older wells, it is likely that cement was used behind the production string.

A total of seven abandoned wells were examined in the Rattlesnake field. These wells were all deep completions. No abandonment reports were found in the NMOCD files for three of these wells, but four wells had sufficient data for analysis. The wells were typically constructed with surface casing set between 200 and 300 feet, an intermediate casing string set between 3500 and

4500 feet (below the Morrison) and production casing or a 7" liner set through or to the top the Pennsylvanian Paradox (6000 and 7000 feet). All of the wells examined had surface casing cemented back to surface. In one well the intermediate string was also cemented back to surface, but two wells had intermediate casing cement points below the shoe of the surface string. All four wells reported several hundred feet of cement behind the producing casing string or liner.

All four of the abandoned wells with sufficient data for analysis had plugs in the wellbore. The wells were typically abandoned by retrieving part of the intermediate casing string, and by placing cement plugs at the bottom of the well, the intermediate casing stub, and at one or more intermediate points in the well. Surface plugs were also reported.

The four abandoned wells were evaluated with the borehole program ABE (Table 12). Two of the wells had positive ABE results, and two wells were assigned '0' ABE values. Although these wells do have plugs present in the wellbore, there is no plug above the uppermost injection zone. Both of these wells, however, have surface casing that covers the Gallup and, therefore, should provide protection to the Gallup, if that is needed.

Because of the age of this field, the complexity of the USDW/producing-reservoir situation and the lack of information on some abandoned wells, judgment with respect to the need for AORs will need to be made by the NMOCD. AORs may not be needed if it is determined that neither the Gallup or the Morrison require protection as USDWs.

4.5.4.1.6 Tocito Dome North Pennsylvanian "D" Field

The Tocito Dome North Pennsylvanian "D" field is located in T27N R18W, San Juan County. The field was discovered in 1963, and produces from the Pennsylvanian Paradox Member of the Hermosa Formation. The field adjoins the Tocito Dome field which is not reported as an active injection field. However, water injection is reported in the Tocito Dome North field area.

It can be inferred from Maps 4,5, and 6 that the Gallup, Dakota and Morrison are, most likely, USDWs at the location of the Tocito Dome field. Logs from the field show that the lowermost USDW, the Morrison, occurs at a depth of about 1100 feet.Three producing oil wells were evaluated for their construction characteristics. One other active well was sampled as a representative injection well, but injection details were not found and a data search revealed that the well was actually abandoned. Hence, no injection wells were evaluated for their construction characteristics.

The three producing wells were completed with surface casing set at approximately 100 feet, intermediate casing set at approximately 1500' (below the Morrison) and production casing set through the Pennsylvanian formation (6000-7000 feet). Surface casing was cemented back to surface in well three wells. One well had intermediate cement to surface; the other two wells had intermediate cement tops below the surface casing shoe. All wells reported several hundred feet of production casing cement behind pipe. The well initially sampled as an injector was constructed in a similar manner.

The three producing wells were evaluated with the borehole program ABE and were found to provide adequate USDW protection (Table 12).

Three abandoned wells were evaluated. These wells were constructed in a manner similar to the active wells and were abandoned with bottom hole plugs (bridge plugs plus cement), surface plugs, and multiple producing casing squeezes. One well had part of the intermediate string retrieved. A cement plug was used at the intermediate stub in this well.

The injection well had abandonment details available and a drawing was prepared for this well. The well was abandoned with a bottom cement plugs, a bridge plug, multiple cement spacer plugs, and a surface plug.

Three ABE analyses were made for the abandoned wells intentionally sampled. All of these wells had positive ABE results (Table 12) and were found to provide adequate USDW protection. An abandoned ABE analysis was also prepared for the well initially sampled as an injector. This well also provides protection to USDWs. Variance from AORs may be available for the Tocito Dome field on the basis of well construction and abandonment characteristics.

4.5.4.2. Western Area Well Construction and Abandonment Methods

The wells sampled from the injection fields were compared with other wells from Western area fields which did not have active injection operations, in order to ascertain that the well sample from injection fields typified construction and abandonment methods in Western area wells.

A total of 381 abandoned wells were identified in the Western area. Of these, 344 were shallow wells and 37 were deep. A total of 58 abandoned wells were sampled from all Western area fields (injection and non-injection) and examined in the study. Twenty two of these wells were located in injection fields and 36 wells were examined from non-injection fields.

A total of 44 active wells were sampled from all fields (injection and non-injection) and examined in the study. Thirty of these were active wells located in injection fields.

4.5.4.2.1 Deep Wells

Construction techniques used to complete both the deep abandoned wells and deep active wells were found to be similar among the wells examined. In particular, the deep wells were all constructed with surface pipe. The surface pipe was set at 100 to 200 feet, which was sufficient to protect only the outcrop formations such as the upper sections of the Gallup. The surface casing in all wells was cemented, with volumes sufficient to give cement returns to surface.

The deep Western area wells were also constructed with an intermediate casing string. In many wells, particularly those in Tocito Dome North, the intermediate string was set at approximately 1500'. This casing depth completely covers the Dakota USDW, but not the Morrison. For example, the Morrison formation top at Tocito Dome varies from 900-1100 ft. and the formation is approximately 1000 ft thick. Tocito Dome North wells have intermediate casing points varying from 1400 to 1600 ft, which is not sufficient to cover the entire Morrison section.

A number of the wells did have deeper intermediate casing strings, for example setting depths of 3350', 4600' and 5294' were reported. Wells with deeper intermediate strings are located in the Rattlesnake and Beautiful Mountain fields, near the western limits of the basin. In cases where the longer intermediate string is run, both the Dakota and Morrison USDWs are covered by this casing.

For wells with intermediate casing strings set around 1500-2000 ft, the casing was normally cemented with volumes sufficient to give cement returns to surface. Deeper intermediate strings were also cemented, but the volumes of cement reported in these wells were not sufficient to bring the cement back 100' into the previous (surface) casing string.

Production casing was run in the deep wells which were either productive or initially believed to be productive. Wells which were dry holes usually did not have production casing set.

Where production casing was run, it was set through the producing horizons and cemented in place. The cement volumes reported indicate that few wells have production casing cemented with sufficient volumes to bring the cement back 100' into the intermediate string.

Active producing wells were typically completed with tubing set to the deepest perforated interval. Injection wells were also completed with tubing strings, although some deep injection wells did not report a packer in the wellbore.

Figure 19 summarizes the most frequently encountered construction configurations for the deep Western area wells.

Abandonment configurations for the deep wells varied, depending on whether the well was completed as a producer or whether the well was a dry hole. Wells which had been completed with production casing were either abandoned with the casing left in place, or were abandoned by cutting and retrieving the casing above its free point. Dry holes were abandoned with cement plugs and mud left in the hole. These three configurations are summarized in Figure 20.

Although deep Western area wells were abandoned in three different ways, the abandonment configurations do exhibit similar characteristics. Bottom plugs were used in essentially all wells. This was normally a cement plug spotted across the reservoir, but bridge plugs were also set above the hydrocarbon zones in some wells. All wells also had surface plugs set, with minimum cement volumes which met current modern standards. The majority of deep wells, especially the abandoned dry holes, had a series of intermediate cement plugs. A cement plug was normally set at the casing shoe of the intermediate string, and a cement plug was placed inside and outside of the casing stub in cases where the production casing had been pulled. Spacer plugs were set between 2000 and 4000' in both the dry holes and in wells with production casing. These spacer plugs may correlate to particular water bearing zones, although this determination was beyond the scope of the study.

4.5.4.2.2 Shallow Wells

After reviewing the producing horizons and USDWs within the fields in the Western area, and the locations of the fields with respect to each USDW 10,000 mg/l salinity boundary, it was observed that only one field with shallow production could possibly have intersections with a USDW. In all the other shallow fields, the overlying USDW formation was either absent, was too saline (> 10000 mg/l) for the formation to be considered a USDW, or was an oil bearing formation. As a result, 338 of the 344 shallow wells were found to have no intersections and, according to the AOR Variance Methodology, did not require further analysis.

Although the majority of shallow wells in the Western area did not require analysis, 61 shallow wells were examined to identify frequently used construction and abandonment techniques. As previously noted, 21 of these wells were abandoned and 40 were active wells.

Construction methods for shallow Western area wells differ from the deep wells in that intermediate casing was not run, and the production casing was normally set on top of the producing horizon rather than through the zone. Also, when production casing was run it was frequently not cemented in place, thus enabling the entire string to be pulled rather than cut at abandonment Construction methods used in the shallow abandoned and active wells were similar. Typical methods include the use of surface casing, cemented with sufficient volumes to give cement returns to surface. Wells which were deemed commercial were typically completed with a string of cemented production casing either set through or on top of the producing zone. Where production casing cement volumes were reported, the volumes were not sufficient to bring the TOC back 100' into the surface string. Dry holes were frequently identified before the production casing was set and, therefore, this string is not present in many of the abandoned wells.

Active wells were completed with tubing strings, normally set to the Gallup or deepest producing formation. Some active wells were reported to have been placed on pump immediately. Injection wells were also typically completed with tubing and injecting beneath a packer. The most frequently encountered construction configurations for the Western area shallow wells are shown in Figure 21. Abandonment methods for the shallow Western area wells were found to be similar to those for the deep wells. (Figure 22) Wells which had produced, or had production casing set were abandoned either by retrieving the casing or by abandoning with the string in place. A bottom cement plug was normally set across the hydrocarbon bearing zone and a surface plug was also set in the wells. However, few intermediate cement plugs were placed in these wells. In particular there was a noted absence of plugs across the surface casing shoe.

4.5.4.3. Western Area Summary

The 52 wells (22 abandoned, 30 active) wells sampled from the injection fields in the Western area were found to be representative of the construction and abandonment methods used in Western area wells. Further, the wells sampled from the injection fields were found to provide a high level of protection to USDWs. ABE numbers for the wells evaluated ranged from 0-10.

Most of the abandoned wells received an ABE number greater than 1, indicating that there were multiple flow barriers present in the wellbore. This reflects that high level of construction and abandonment techniques employed in Western area wells.

As shown in Table 22, the Western area is characterized by fields at which USDWs are not present. Four of the six field with active injection operations fall into this category. Variances should be available for these four fields on that basis. The same four fields plus the Tocito Dome North "D" field may also qualify for variances based upon date of discovery and upon the quality of construction and abandonment of the wells in the fields.

The Horseshoe field has had four AORs performed and the Mesa field, because of its very recent vintage, may also have had AORs or some equivalent form of analysis for its injection wells. This type of evidence may, also, qualify or assist in qualifying those fields for variance.

The remaining field, the Rattlesnake field, was discovered in 1924 and has abandoned wells for which no abandonment reports are available. The injection zone is the Cretaceous Dakota. The only likely overlying USDW is the Gallup. The underlying Morrison may, also, be a USDW. The Gallup could be protected by the sloughing and squeezing Mancos shale, but it is likely that AORs will be needed for this field because of its complexity.

4.5.5 Southern Area Results

The Morrison, Dakota and Gallup map overlay, which identified the western area, also defined an area in the southern portion of the basin where these three USDWs exist. This area is bounded on the north by the 10,000 mg/l salinity lines for the three USDWs, and to the south by the Morrison and Dakota outcrops. By superimposing the Mesaverde USDW map (Map 3) on this area, it was found that the outer portion of the Mesaverde coincides directly with the fresh water area of the combined Morrison, Dakota, and Gallup. Hence, the southern area was defined to be that portion of the basin where fresh water exists in the Morrison, Dakota, Gallup, and the Mesaverde. This area is shown in Figure 13.

There are 6 oilfields with active injection operations located within the boundaries of the southern area. These fields produce primarily from the Cretaceous Dakota and Gallup formations (Tocito Lentil, etc.), or from shallow zones within the Mesaverde. A summary of pertinent facts for the Southern area fields is given in Table 13.

A total of 164 abandoned and active wells wells were sampled in the Southern area. All of these wells were analyzed according to the AOR Variance methodology[16]. Results of this evaluation and the combined Southern area wells counts are presented in Table 14.

As in the Western area, the producing formations were found to be initially overpressured with respect to USDWs and it is believed that the injection fields will remain overpressured with respect to USDWs. Thus, wells in the Southern area are assumed to have a positive flow potential from the injection zone into the overlying USDW.

Wells which did not intersect either a USDW or an injection formation, or wells which were found to have hydrocarbon production from the USDWs units were excluded from further evaluation according to the AOR Variance methodology. Fifty-seven of the total sampled well population were excluded on this basis.

Wells with insufficient data for assessment were labeled as "no info" wells. In the Southern area there were 34 wells with incomplete data. This large number of no information wells may be attributed to the fact that several of the Southern area fields are old and, therefore, have limited well records.

After excluding wells with no intersections and wells with insufficient information, the remaining 73 Southern area wells were evaluated with the borehole evaluation program, ABE, to determine the number of flow barriers present in the wellbore. Results of this evaluation are presented in Table 15.

4.5.5.1 Injection Fields

4.5.5.1.1 Chaco Wash

The Chaco Wash field is located in T20N R9W. The field was discovered in 1961, produces from the Cretaceous Menefee Formation (Mesaverde Group), and is undergoing waterflooding.

From Map 3 it can be inferred that the producing reservoir is fresh-water bearing. Maps 4,5, and 6 indicate that the Gallup, Dakota and Morrison should be USDWs. These aquifers, however, underlie the Menefee producing reservoir. Producing wells in the field are, typically, 300-500 feet in total depth and do not penetrate to the Gallup and deeper USDWs.

Because oil production from the Chaco Wash field is from the uppermost fresh-water aquifer, it is considered that the aquifer is not a USDW and the field should be eligible for a variance from AORs.

Seven active wells were examined for their construction characteristics. The wells examined had total depths ranging from 340 ft to 900 ft. Typically, the wells were completed with either 4-1/2" or 5-1/2" casing run to TD and cemented. Separate surface casing strings were not run. A 2-3/8" tubing string was normally run, with or without a downhole pump.

Thirty two abandoned wells were examined for their construction characteristics. These wells were constructed in a manner similar to the active wells. Abandonment drawings were not prepared for the shallower wells, but two abandoned dry holes were drilled deeper (Point Lookout 1583'). Both of these wells were abandoned with cement plugs across the bottom zones, and would provide protection to USDWs if required. However, neither well is actually intersects both an injection zone and a USDW.

No formal ABE evaluations were made in the Chaco Wash Field, since there is no USDW. (Table 15).

4.5.5.1.2 Hospah

The Hospah field is located in T17N R8W, McKinley County. The field was discovered in 1927 and produces from the Cretaceous Hospah Upper Sandstone of the Mancos Shale.

Waterflooding of the field began in 1966 and continues today. Oil was discovered in the deeper Dakota Sandstone in 1967, but the Dakota has, apparently, not been waterflooded.

It can be inferred from Maps 3-6 that the Mesaverde, Gallup, Dakota and Morrison may all contain fresh water at this location. Water from the Hospah Sandstone is reported to have a total dissolved solids content of 1000-2000 ppm, which confirms that the overlying Mesaverde is, most likely, a USDW.

A total of 25 active wells (fourteen producing wells and eleven injection wells) were sampled and examined for their construction characteristics. Records obtained from the state indicated that three of the injection wells had actually been abandoned. These wells were evaluated for both their construction and abandonment characteristics using ABE, and are included in the abandoned well count shown in Table 14. Hence, there were actually 22 active wells available for study in the Hospah field.

Of the 22 active wells, construction information was not available from the NMOCD files for seven of the producing wells, and casing cement data was not available for one producing well and one injection well. These 9 wells were classified as 'no info' wells in the analyses.

The remaining 13 active wells (six producing wells, seven active injection wells), and the three abandoned wells evaluated for their construction characteristics, had sufficient information available to prepare wellbore diagrams and these wells were examined. Typically, the wells were drilled to depths between 1600 ft and 1800 ft. Surface casing was run and set at approximately 100 ft in all of the wells examined, and the surface string was cemented back to surface. The wells were completed with either 4-1/2" casing or 5-1/2" casing, which was cemented either through the producing zone, or set and cemented above an open hole completion in the producing zone. A

2-3/8" tubing string was run in producing wells, both tubing and a packer were typically run to complete the injectors.

The 13 active wells and three abandoned injection wells were evaluated for their construction characteristics, and all wells had positive ABE results. These wells are considered to provide protection to the Mesaverde USDW.

The seven oil wells for which construction information was not available were all completed during 1941-1942. Their locations and total depths are given in the Dwight's data base and, also, appear on scout cards from the NMOCD. The wells for which information was available were completed during 1946-1989. Information for one 1946 well was in the Dwight's data base but was not found in the files of the NMOCD. Information for the six wells completed during 1965-1989 was available from both sources.

Abandonment characteristics of 49 wells were studied (46 abandoned wells intentionally sampled plus 3 injectors found to be abandoned). Of these 49, 4 wells did not have intersections with both the injection formation and a USDW and 19 wells had insufficient data for analysis.

State records for the 19 wells lacking information varied from none at all to complete. Plugging and abandonment reports were not available from state files. Most of these wells were drilled during 1927-1949, but a few were relatively recent wells (1953-1971). Some of the wells drilled during 1927-1928 were reported to have been abandoned upon completion on scout cards obtained from the NMOCD. However, no information concerning the plugging method was given.

Twenty six abandoned wells (23 wells intentionally sampled plus 3 injectors found to be abandoned) had sufficient data for analysis. Typically these wells were abandoned with a bottom plug, surface plug and one or more spacer plugs located at the Point Lookout sand.

The 26 abandoned wells were evaluated with the borehole program ABE. Twenty four had positive ABE results indicated that these wells provide protection to USDWs. Two wells, plugged and abandoned in 1962, were assigned 0 ABE values. State reports indicated that 50 foot cement plugs were spotted but did not report the actual plug depths. On the basis of available information, it would seem that AORs will be needed for the Hospah field. According to the NMOCD records, ten AORs have been performed in this field and the adjoining Hospah South field.

4.5.5.1.3 Hospah, South

The Hospah Lower Sand, South field was discovered in 1965. Production is from the Cretaceous lower Hospah Sandstone which underlies the upper Hospah.Sandstone. The lower Hospah is currently undergoing waterflooding.

It can be inferred from Maps 3-6 that the Mesaverde, Gallup, Dakota and Morrison may all contain fresh water at this location. Water from the Hospah Sandstone is reported to have a total dissolved solids content of 1000-2000 ppm, which confirms that the overlying Mesaverde is, most likely, a USDW. Water from the lower Hospah Sandstone is reported to contain 11,200 ppm sodium chloride.

Eight active wells (5 producers, 3 injectors) were evaluated in the Hospah South Field.

These wells were constructed in a manner similar to that described for the Hospah Field. State data obtained for one injection well actually indicated the well to be abandoned (Table 15). For purposes of well counts (Table 14) this well was listed with the abandoned well population. One other injection well had insufficient data for analysis.

All of the seven wells (5 producing wells, one injector, plus the abandoned injector) had sufficient data for analysis and were evaluated with the borehole program ABE. All wells had positive ABE results indicating adequate USDW protection.

Four wells were evaluated for their abandonment characteristics. Three of these wells were sampled abandoned wells, the fourth well is the abandoned injection well previously described. These wells had sufficient data for analysis, and exhibited abandonment characteristics similar to those described for the Hospah Field. All four wells were evaluated with the borehole program ABE and all were considered to provide USDW protection.

The Hospah, South field may qualify for consideration for variance from AOR requirements on the basis of well construction and abandonment. The qualification to this will be the need to assess the extent to which some wells drilled in the older Hospah field may have been drilled through the lower Hospah Sandstone and may be inadequately plugged and abandoned.

Records of the NMOCD show that at total of ten AORs have been performed in the Hospah and Hospah South fields. These AORs may provide evidence to determine if the Hospah South field will qualify for a construction and abandonment based variance.

4.5.5.1.4 Lone Pine

The Lone Pine field is located in T17N R8-9W, McKinley County. The field was discovered in 1970 and produces from the Cretaceous Dakota Sandstone "A" and "D" zones. The deeper Dakota "D" is undergoing waterflooding.

It can be inferred from Maps 3-6 that the Mesaverde, Gallup, Dakota and Morrison may all contain fresh water at this location. Water from the Dakota "D" sand is reported to contain 9,000 ppm total dissolved solids.

Five active wells (3 producing wells and 2 injection wells) were evaluated for their construction characteristics. State reports indicated that the two injection wells had actually been abandoned. These wells are counted with the abandoned wells (Table 14).

The active wells examined were typically drilled to depths between 2800 ft and 2900 ft. Surface casing was run and set at approximately 70 ft in all of the wells examined, and the surface string was cemented back to surface. The wells were completed with either 4-1/2" casing or 5-1/2" casing, which was cemented either through the producing zone and perforated. A 2-3/8" tubing string was run in producing wells, both tubing and a packer were typically run to complete the injectors.

All three producing wells examined were evaluated with ABE and were found to provide protection to USDWs. The two injection wells were also evaluated on the basis of their construction and were found to provide protection to USDWs.

Ten wells were sampled and examined for their abandonment characteristics. In addition, the two abandoned wells initially sampled as injectors were evaluated for their abandonment characteristics.

The abandoned Lone Pine wells were constructed in a manner similar to the active wells. The wells were abandoned with bottom cement plugs, one or more spacer plugs (one normally across the Gallup) and a surface plug. Three wells had the production casing cut and retrieved. These wells also had cement plugs and the casing stub. One of the sampled abandoned wells lacked a formal plugging and abandonment report and could not be evaluated. However, a memorandum in the files of the NMOCD acknowledges the well to be plugged and abandoned and states that "Field inspections indicate that the P&A is approvable."

The remaining eleven wells (9 wells sampled as abandoned plug 2 injectors found to be abandoned) were evaluated with ABE, and were found to provide adequate USDW protection.

One well lacked a formal plugging and abandonment report. Variance from AORs may be available for the Lone Pine field on the basis of well construction and abandonment characteristics.

4.5.5.1.5 Miguel Creek

The Miguel Creek field is located in T16N R6W, McKinley County. The field was discovered in 1978, produces from the Cretaceous "Hospah" Gallup Sandstone and is undergoing waterflooding.

From Maps 3-6, it can be inferred that the Mesaverde, Gallup, Dakota and Morrison should all be fresh-water bearing. Analysis of water from the Miguel Creek field shows that it has a dissolved solids content of about 3,000 mg/l. Therefore, the overlying USDW is the Mesaverde with the Dakota and Morrison as underlying USDWs.

Three producing wells and three injection wells were evaluated for their construction characteristics. Information was available for five of the wells. Construction information was not available for the sixth well, an injection well, but a NMOCD Form C-103 reports the approval for conversion of this well from production to injection, establishes that the agency considered it to be satisfactorily constructed.

The five active wells examined were drilled to depths of approximately 800 ft. Surface casing was run and cemented at 85' in the two injection wells, but there was no report of surface casing in the three producing wells. A 4-1/2" production string was set, cemented and perforated.

Cement volumes in the wells with no reported surface casing were sufficient to bring the tops of cement within 200 ft or less of surface. Producing wells were completed with 2-3/8" tubing and injectors were completed with tubing and a packer.

The five active wells were evaluated with the borehole program ABE. The wells were all found to provide USDW protection. Eight abandoned wells were evaluated for their abandonment characteristics. Five of these wells had sufficient abandonment data for analysis. Plugging and abandonment reports were available for two more of the wells in the NMOCD files, but the reports do not contain the details of how the plugging was carried out. However, the reports establish that the wells were considered by the agency to be satisfactorily abandoned. The one remaining abandoned well for which no abandonment report was available had only a scout card in the files of the NMOCD. The card reported the well to have been drilled to 1540 feet which would be deeper than present Miguel Creek field wells, which are about 800 feet deep. The card had no date but is similar to other scout cards that were used prior to 1950.

The five wells with sufficient plugging data were abandoned with a bottom cement plug, at least one spacer plug, and a surface plug. One well had its borehole completely filled with cement.

The wells were evaluated with ABE, and were found to provide adequate protection to USDWs. All active and abandoned Miguel Creek field wells can be established to provide USDW protection. This is to be expected for a field discovered in 1978. Furthermore, because of the recent development of this field as a waterflood, it is likely that AORs have been performed for all injection wells. NMOCD records show that six AORs have been performed, which confirms that probability. It seems likely that a variance from AORs should be available based upon this evidence.

4.5.5.1.6 Red Mountain

The Red Mountain field is located in T20N R9W, McKinley County. The field was discovered in 1934 and produces oil from the Menefee Formation. The field is undergoing waterflooding.

From Map 3, it can be seen that the Red Mountain Field lies adjacent to the Mesaverde outcrop. Since the field is developed in the Mesaverde, it can be inferred that there are no USDWs present in the field. This conclusion is supported in several scout tickets, which report the Menefee formation at the surface. However, the location of the field brings into question whether the Cretaceous Cliff House Sandstone could be present , and more detailed analysis would be required to make this determination.

Five active wells (3 producers and 2 injection wells) were examined in the Red Mountain Field (Table 14). Construction data was available for two of the three producing wells and both of the injection wells. One producer lacked casing cement data. The injection wells did not have conversions reports available, and were evaluated on the basis of their construction.

Red Mountain is a very old field, and little well data was available (Table 15). Based on the data available, Red Mountain wells were typically constructed with production casing, set at 400 ft to 500 ft, and cemented over the producing zone. More recent wells were constructed with surface casing between 50 ft and 120 ft, and this string is cemented back to surface.

Nine abandoned wells were examined in Red Mountain. Seven of the nine had no plugging and abandonment reports available. The two wells which did have plugging showed the wells to have been abandoned with bottom cement plugs, a spacer plug and a surface plug.

No ABE analyses were performed for Red Mountain wells because it is believed that there is no USDW present. However, all of the wells with sufficient data which were examined would provide protection to a USDW if required.

It is believed that a variance should be available for the Red Mountain Field based upon the fact that hydrocarbon production is from the Menefee Formation of the Mesaverde Group and because the Mesaverde is the uppermost USDW.

4.5.5.2 Southern Area Well Construction and Abandonment Methods

The wells sampled from the injection fields were compared with other wells from Southern area fields which did not have active injection operations, in order to ascertain that the well sample from injection fields typified construction and abandonment methods in Southern area wells.

A total of 264 abandoned wells were identified in the Southern area. Two hundred and eight of these abandoned wells were sampled from all Southern area fields (injection and non-injection) and examined in the study. Of the 214 abandoned wells, 114 were located in injection fields and 100 wells were examined from non-injection fields.

Fifty active wells were sampled in the study. All of these wells were located in injection fields. Additional producing wells were not deemed necessary because the construction characteristics in non-injection fields are reflected in the abandoned well population.

Well construction and abandonment data were obtained for the abandoned and active Southern area wells, and drawings were prepared showing their wellbore configurations. From the wellbore diagrams which were made, it was apparent that the Southern area wells were typically constructed in a manner similar to the shallow Western area wells (Figure 23).

The wells were constructed with surface casing, and this string was normally cemented back to the surface. Producing wells had production casing set, although the casing setting depth is not reported in a large percentage of the wells. Hence, it is unknown whether the majority of wells had production casing set through or on top of the producing zone. What is apparent, however, is that the production casing was typically cemented in place. Cement volumes were not sufficient to bring the TOC back 100' into the surface pipe. Dry holes typically did not have production casing cemented in place.

Active wells in the Southern area were constructed similar to the abandoned wells examined in the study. Producing wells were normally completed with surface casing if the TD was greater than 400'-500'. Some wells had no report of surface casing. Where surface casing was reported, it was cemented in place with returns to surface. Production casing was either run to or through the producing formation. A few wells reported tubing run in the wellbore, but many of the well records do not provide tubing or packer information. In addition, two slim hole completions were among the sampled well population. These wells were completed with 2" tubing cemented in the hole with cement returns to surface.

The majority of Southern area wells were abandoned by setting cement across the bottom of the producing zone and by placing a cement plug at the surface. Cement volumes reported for these plugs were generally sufficient for a 100' plug. Few wells had casing pulled, and most wells (both those with casing and dry holes) had a cement plug placed across the Point Lookout formation. These abandonment configurations are shown in Figure 24.

4.5.5.3 Southern Area Summary

Fields in the Southern area occur within the outcrop band of the Cretaceous Mesaverde Group and production is from units in the Mesaverde and Mancos Shale or from the Dakota Sandstone. Except for the Chaco Wash field and, perhaps, the Red Mountain field, USDWs are present.

ABE results in the Southern area ranged from 0-4. Most of wells evaluated received an ABE number of 1 or 2, reflecting either 1 or 2 flow barriers present in the wellbore. The lower ABE numbers seen in the Southern area are a function of the fact that the wells are predominantly shallow, and require fewer casing strings in their construction or plugs at abandonment.

There were two instances of "0" ABE values in the Southern area. These wells were in the Hospah field which is currently undergoing active injection. Both Hospah wells were dry and abandoned wells with only surface plugs present.

The Red Mountain field, discovered in 1934, probably has no USDW. If the Cliff House Sandstone is present as a USDW, the AORs may be needed. The relatively recent Hospah South, Lone Pine and Miguel Creek fields may qualify for variances based upon that fact and because the wells that were examined in those fields provide USDW protection. The quality of construction and abandonment in the Hospah South field is shown as questionable because it is possible that some wells from the older and shallower Hospah field may penetrate the injection zone of the Hospah South field.

The only widely applicable variance criterion is the presence of sloughing squeezing Cretaceous shales between producing reservoirs and overlying USDWs. This may be an important mitigating geologic characteristic for the Hospah field, which was discovered in 1927 and which has abandoned wells for which abandonment reports are not available. It could, also, be important for the Hospah South field in which older wells from the Hospah field may present and for the Red Mountain field, if a USDW is present.

A total of ten AORs have been performed for the Hospah and Hospah South fields. These will provide evidence to assist in the variance determination process for these fields. Six AORs have been performed for the Miguel Creek field which may, by themselves, be sufficient evidence for a construction based variance.

4.5.6 Interior I Area Results

The Interior I area is a section of the basin located immediately north of the Southern area and east of the Western area. (Figure 13) Mesaverde and Upper Cretaceous USDWs exist over the entire Interior I area. A small portion of the area is also overlain by the Tertiary USDW.

The Interior I area was identified by superimposing the Mesaverde, Upper Cretaceous and Tertiary USDW maps (Maps 1, 2, and 3) on the combined Morrison, Dakota and Gallup overlay. The first overlay, i. e. the Mesaverde, indicated that the inner Mesaverde outcrop is nearly coincident with the Morrison, Dakota and Gallup salinity boundaries over a substantial part of the basin. As a result, the inner Mesaverde outcrop closely approximates the eastern limit of the Morrison and Dakota USDWs in the western basin sub-area. Similarly, the Mesaverde outcrop traces the northern limit of Morrison, Dakota and Gallup USDWs in the southern area.

These boundaries form the western edge of the Interior I area. (Figure 13) By superimposing the Upper Cretaceous USDW on the Mesaverde, it can also be seen that the Upper Cretaceous outcrop falls between the Mesaverde outcrop and the Mesaverde salinity boundary. The salinity boundary for the Upper Cretaceous is located inside of the Mesaverde salinity line. The Upper Cretaceous salinity line forms the northern boundary of the Interior I area.

Fresh water in the Tertiary extends over the central and northeastern portion of the basin as shown on Map 7. When this map is superimposed on the Mesaverde and Upper Cretaceous maps, it can be seen that Tertiary fresh water extends over a portion of the Interior I area. Therefore, fields located within this area must be evaluated for Tertiary USDW protection, in addition to protection of the Mesaverde and Upper Cretaceous USDWs.

There are 3 oilfields with active injection operations located within the boundaries of the Interior I area. These fields produce primarily from the Mesaverde and Gallup formations.

Twenty four active and abandoned wells were examined from the three injection field in

Interior I. The sample wells were selected according to the procedures described in section 4.5.3. All of these wells were analyzed according to the AOR variance methodology[16]. Results of this evaluation and the combined Interior I area well counts are presented in Table 17.

In the Western and Southern areas, the producing formations were found to be initially overpressured with respect to USDWs and it is believed that the injection fields will remain overpressured with respect to USDWs. Although it is not known whether this is also the case in the Interior I area, fields within Interior I have been evaluated as if a positive hydraulic flow potential does exist.

Wells which did not intersect either a USDW or an injection formation, or wells which were found to have hydrocarbon production from the USDWs units were excluded from further evaluation according to the AOR Variance methodology. Nine wells were excluded on this basis.

Wells with insufficient data for assessment were labeled as "no info" wells. In the Interior I area there were 2 wells with incomplete data.

After excluding wells with no intersections and wells with insufficient information, the remaining 13 Interior I wells were evaluated with the borehole evaluation program, ABE, to determine the number of flow barriers present in the wellbore. Results of this evaluation are presented in Table 18.

4.5.6.1 Injection Fields

4.5.6.1.1 Media

The Media field is located in T3N R16W, Sandoval County. The field was discovered in 1953, produces from the Jurassic Entrada Sandstone, and is undergoing waterflooding. From Maps 2,3 and 4, it can be inferred that the Mesaverde is the only USDW overlying the field. The Upper Cretaceous is not present and the Gallup contains saline water. The Entrada, in spite of its depth of about 5,000 feet, is reported to contain brackish water of less than 2,500 ppm total dissolved solids. Produced Entrada water is reinjected or disposed by injection into the Gallup.

Six active wells (4 producers and 2 injection wells) were sampled in the study (Table 18). One producing well, and both injection wells were actually found to have been abandoned. These wells are included in the abandoned well count in Table 17.

Four of the six wells sampled as active (3 producers and 1 abandoned injection well) had sufficient construction data for analysis. These wells were examined for their construction characteristics. Typically, Media wells were constructed with surface casing set at approximately 200 ft, and cemented back to surface. Some wells were completed with a 7" production string set through, cemented and perforated in the Entrada formation. Wells with TD's greater than 5000 ft are constructed with a 7" intermediate string set at approximately 5000 ft, and a 4-1/2" liner run to TD. The intermediate string is cemented above the Mesaverde, and the liner is cemented back to the intermediate casing shoe. The producing wells are completed with tubing, and injection wells include both tubing and a packer.

All three active wells evaluated for their construction characteristics had positive ABE results and provide protection to USDWs.

Three abandoned wells were sampled in the Media Field (Table 18). However, as noted previously, three of the active wells sampled were also found to have been abandoned. Two of the three abandoned wells intentionally sampled had sufficient data for analysis, and the third well was not found to intersect the injection zone. Only one of three additional abandoned wells (i.e. those initially sampled as active wells) had sufficient abandonment data for analysis. Hence, three Media wells were evaluated for their abandonment characteristics.

The Media wells were typically abandoned with a bottom plug and surface plug. One well had multiple spacer plugs inside the production casing. Another well had fewer spacer plugs, but the production casing was cemented above the Mesaverde. All three of these wells had positive ABE results and provide protection to USDWs.

The quality of construction and abandonment of wells in the Media field may qualify the field for a variance based upon these characteristics.

Records of the NMOCD show that two AORs have been performed in this field. These should provide additional evidence for a variance based upon construction and abandonment characteristics.

4.5.6.1.2 Papers Wash

The Papers Wash field is located in T19N R5W, McKinley County. The field was discovered in 1976, produces from the Jurassic Entrada Sandstone and is undergoing waterflooding. From Maps 2,3 and 4, it can be inferred that the Mesaverde is the only USDW overlying the field. The Upper Cretaceous is not present and the Gallup contains saline water. The Entrada, in spite of its depth of about 5,000 feet, is reported to contain brackish wate of less than 3,000 ppm total dissolved solids.

Five wells (3 producers and 2 injection wells) were evaluated for their construction characteristics. Two of the wells sampled as producers were actually found to have been abandoned. These wells are included in the abandoned well count (Table 17).

Wells in the Papers Wash Field were typically drilled to 5300 ft or 5400 ft. Surface casing was set at approximately 200 ft, and all surface strings examined were cemented back to surface. A 7" producing string was run through the Entrada. Production casing was normally cemented back with sufficient volume to cover the Point Lookout formation. Some production strings examined were fully cemented with two stage cementing operations. Producing wells were completed with tubing, and injection wells were completed with both tubing and a packer. Construction characteristics for the five active wells sampled were evaluated with ABE. These wells were found to provide adequate protection to USDWs.

Two abandoned wells were intentionally sampled in the study, and 2 of the wells sampled as producers were found to have been abandoned. Hence, four abandoned wells were examined (Table 17).

The four abandoned wells examined had bottom cement plugs, one or more spacer plugs, and surface plugs. All four wells were found to provide USDW protection. One dry and abandoned well with multiple plugs received a "0" behind pipe ABE value because the plugs do not cover the uppermost injection zone. It should be emphasized that the "0" behind pipe ABE value is not meaningful in an open hole, and that this is an adequately plugged well. The Papers Wash field may qualify for a variance based upon the construction and abandonment characteristics of wells in the field. The field is, also, overlain by the Mesaverde sink zone described in Section 4.4.6, which would qualify for a mitigating geological variance.

4.5.6.1.3 San Luis

The San Luis field is located is T18N R3W, Sandoval County. The field was discovered in 1950, produces from the Menefee Formation and may or may not be a presently active waterflood. The field is listed on the NMOCD September 1992 injection report but is reported not to have had active injection since 1982. From Map 3, it can be inferred that the USDW at the location of the field is the Mesaverde Group within which the Menefee Formations occurs. Therefore, the field should be eligible for a variance based upon the fact that production is from the uppermost USDW.

Five active wells (3 producers and 2 injection wells) were sampled and examined for their construction characteristics (Table 18). These wells were drilled to approximately 1000 ft in the Menefee. The wells were completed with surface casing set and cemented at approximately 30 ft. Production casing was run, set through the Menefee, and cemented, although three of the active wells did not have casing cement reports. Producing wells were completed with tubing, and injection wells were completed with both tubing and a packer.

Three abandoned wells were sampled and examined for their abandonment characteristics. Two wells were abandoned with bottom plugs and surface plugs. The third well had a fish in the hole and did not give abandonment details, although a surface cement plugs was reported. No formal ABE evaluations were carried out because no USDW is known to be present. The three producing wells, two injection and three abandoned wells that were examined would provide adequate USDW protection for a shallow USDW should one be present.

4.5.6.2 Interior I Area Well Construction and Abandonment Methods

The wells sampled from the injection fields were compared with other wells from Interior I area fields which did not have active injection operations, in order to ascertain that the well sample from injection fields typified construction and abandonment methods in Interior I area wells.

A total of 250 abandoned wells were identified in the Interior I area. Forty of these abandoned wells were sampled from all Interior I area fields (injection and non-injection) and examined in the study. Of the 40 abandoned wells, 29 were located in injection fields and 11 wells were examined from non-injection fields.

Twenty active wells were sampled in the study. Eleven of these wells were located in injection fields, 4 wells were located in fields without active injection operations and 5 wells were reclassified as abandoned. Additional producing wells from fields without injection operations were not deemed necessary because the construction characteristics are also reflected in the abandoned well population from non-injection fields.

Well construction and abandonment data were obtained for the sampled wells and drawings were prepared showing their wellbore configurations. From the wellbore diagrams which were made it was apparent that the Interior I area wells were constructed in a manner similar to the southern and the shallow western wells. (Figure 25).

The wells were generally constructed with surface casing, although several of the sampled wells had no surface pipe. These wells were tubingless completions. Where a surface string was run, it was typically cemented back to the surface. Producing wells had production casing set, either through, or on top of the producing zone. There were a large number of Verde field wells

(22) in the sample population, and essentially all of these wells were open hole completions (i.e. production casing set on top of the producing horizon). Production casing was cemented in place, although cement volumes were not sufficient to bring the TOC back 100' into the surface pipe. Dry holes found in the sample population typically did not have production casing cemented in place.

Active wells were completed by running tubing to the lowest producing horizon. Injection wells were typically completed with both tubing and a packer. The wells were abandoned by setting cement across the bottom of the producing zone and by placing a cement plug at the surface. In addition, many wells with surface casing had cement plugs set across the casing shoe. Cement volumes reported for these plugs were generally sufficient to meet the current modern day standards. A large number of wells also had the production casing pulled and a plug set across the stub. Again, this was a typical abandonment method used in the Verde field, and this field dominated the sampled well population. Dry holes were typically abandoned with at least two spacer plugs in addition to the other plugs noted previously. The most frequently encountered abandonment configurations for the Interior I area are shown in Figure 26.

4.5.6.3 Interior I Summary

The Interior I area was created as an area category for fields in which the outcrop is Upper Cretaceous and in which the Mesaverde is the first potential USDW. Maps 4,5 and 6 show that the fields are all located close to the USDW boundaries for the Gallup, Dakota and Morrison and that these units may or may not be USDWs. Two fields, Media and Papers Wash, produce oil from the Jurassic Entrada Sandstone. The third, San Luis, produces from the Menefee Formation, which is a unit of the Mesaverde.

As indicated above, only three injection fields are located in the Interior I area. The only general characteristics shared by all of these fields is that they were all discovered after 1949 and are all considered to have wells that are adequately constructed or abandoned. Two AORs have been performed for the Media field and one for the San Luis field. These AORs will provide additional evidence for consideration of construction and abandonment based variances for these fields. Both the Media and Papers Wash fields have Cretaceous shales between the Entrada injection zone and the Mesaverde, which is, apparently, the only USDW overlying the fields. The presence of the shales could provide USDW protection as a result of their squeezing and sloughing characteristics.

It is probable that there is no USDW present at the location of the San Luis field. Production is from the Mesaverde, which is the uppermost fresh-water aquifer. ABE numbers in the Southern area ranged from 1-4. Most of the wells evaluated received an ABE number of 1, 2 or 3. These ABE numbers are similar to those seen in the Southern area. The lower ABE numbers are a function of the fact that the wells are predominantly shallow, and require fewer casing strings. There were no actual instances of "0" ABE values in the Interior I area.

In summary, the Interior I area wells were typically shallow, and had ABE values similar to those in the Southern area. The area exhibited relatively few wells with insufficient data for analysis and most wells had intersections with the overlying USDW. Although no global factor was identified which was capable of qualifying the entire sub-area for an AOR variance, the quality of well construction and abandonment encountered in individual fields could justify their exclusion from the AOR evaluation process.

4.5.7 Interior II Area Results

Beyond the 10,000 mg/l salinity boundary for the Upper Cretaceous USDW, only the Tertiary USDW exists. This can be seen by superimposing the Tertiary map (Map 1) on top of the combined Mesaverde and Upper Cretaceous overlay. The area has been designated as Interior II, as shown in Figure 13.

There are 9 oilfields with active injection operations located within the boundaries of the Interior II area. A total of 82 abandoned and active wells were sampled from these fields. All of these wells were analyzed according to the AOR Variance methodology[16]. Results of this evaluation and the Interior II area well counts are presented in Table 20.

As in the Interior I area, it is not known whether producing formations in the Interior II area were initially overpressured with respect to USDWs. However, fields within Interior II have been evaluated as if a positive hydraulic flow potential does exist.

Interior II is unique, however, in that the area is partially overlain by a sink zone in the Mesaverde formation. Wells located within this area and whose injection zones are deeper than the Mesaverde have USDW protection from this sink zone. Six of the injection fields located within Interior II are located in the area of the Mesaverde sink zone.

Wells which did not intersect either a USDW or an injection formation, or wells which were found to have hydrocarbon production from the USDWs units were excluded from further evaluation according to the AOR Variance methodology. Twelve of the total sampled well population were excluded on this basis.

Wells with insufficient data for assessment were labeled as "no info" wells. In the Interior II area there were 8 wells with incomplete data.

After excluding wells with no intersections and wells with insufficient information, the remaining 62 Interior II wells were evaluated with the borehole evaluation program, ABE, to determine the number of flow barriers present in the wellbore. Results of this evaluation are presented in Table 21.

4.5.7.1 Injection Fields

4.5.7.1.1 Bisti

The Bisti field was discovered in 1955, produces oil from the Cretaceous Gallup Sandstone and is undergoing waterflooding. From Maps 1,2 and 3, it can be inferred that the field is overlain only by Tertiary USDWs. At that location, the Upper Cretaceous and Mesaverde contain saline water and are not USDWs.

Three producing wells, two injection wells and seven abandoned wells were evaluated with respect to their construction/abandonment characteristics are considered to have been adequately constructed or abandoned. One of the two injection wells is abandoned and was considered both for its original construction characteristics and for its characteristics as an abandoned well. This well is included in the abandoned well count given in Table 20.

As discussed above, the Bisti field produces from the Gallup Sandstone and, as shown in Figures 9,10 and 11, the Gallup underlies the Mesaverde Group. Maps 27 and 28 show that the Bisti field is within the area of negative residual head of the Mesaverde Group. Map 3 shows that, at the location of the Bisti field, the Mesaverde is not a USDW. Under these circumstances, it can be concluded that the Mesaverde qualifies as a sink zone that would be capable of diverting water flowing upward from the Bisti field through open boreholes or behind the casing of cased boreholes. The presence of the Mesaverde grant the field variance from AOR requirements.

Information provided by the NMOCD shows that 28 AORs have been performed in the Bisti field. This may be a sufficient number to provide a basis for an AOR variance for the field. The results of two of the AORs were obtained from the NMOCD. Project data for wells within the AORs were found to compare well with data supplied in the AOR applications. Both AOR applications showed all wells within the Area of Review to be adequately constructed and abandoned. Both AOR applications were approved without need for corrective action.

4.5.7.1.2 Blanco Tocito, South

The Blanco Tocito, South oil field was discovered in 1951. The field produces from the Cretaceous Tocito and El Vado Sandstones of the Mancos Shale and is undergoing waterflooding. From Maps 1, 2 and 3, it can be inferred that the field is overlain only by Tertiary USDWs and that the Upper Cretaceous and Mesaverde contain saline water and are not USDWs.

The Blanco Tocito, South oil field is overlain by gas fields that produce from Mesaverde and Upper Cretaceous strata. Wells drilled only into the Upper Cretaceous or the Mesaverde would not intersect the oil producing Tocito and El Vado and, thus, would not provide pathways from the oil reservoirs to the Tertiary USDWs.

Four abandoned wells were sampled in the Blanco Tocito, South field. Two of the abandoned wells sampled were abandoned in lower zones, but subsequently recompleted as shallow gas wells. These two wells were evaluated for their abandonment characteristics, and were found to provide adequate USDW protection. The other two abandoned wells were "no intersection" wells.

Nine active wells were sampled and examined for their well construction characteristics. Of these, three wells had insufficient data for analysis, and two wells were "no intersection" wells. The remaining four wells were evaluated with the borehole program ABE, and were found to provide adequate USDW protection.

As discussed above, the Blanco Tocito, South field produces from the Sandstones of the Mancos Shale and, as shown in Figure 4,5 and 6, the Mancos underlies the Mesaverde Group. Maps 27 and 28 show that the Blanco Tocito, South field is within the area of negative residual head of the Mesaverde Group. Map 3 shows that, at the location of the Blanco Tocito, South field, the Mesaverde is not a USDW. Under these circumstances, it can be concluded that the Mesaverde qualifies as a sink zone that would be capable of diverting water flowing upward from the Blanco Tocito, South field through open boreholes or behind the casing of cased boreholes. The presence of the Mesaverde sink zone provides additional reason to grant the field variance from AOR requirements.

4.5.7.1.3 Cha Cha

The Cha Cha field was discovered in 1959, produces oil from the Gallup Sandstone and is undergoing waterflooding. From Maps 1, 2 and 3, it can be inferred that the field is overlain only by Tertiary USDWs. The Upper Cretaceous and Mesaverde contain saline water and are not

USDWs.

Because of the relatively recent discovery date of the Cha Cha field, it is suggested that a variance may be available based upon the status of laws and regulations that existed in 1959. This suggestion is supported by the examination of three producing wells, two abandoned wells and two injection wells. One of the injection wells is abandoned, so it was evaluated for both its construction and abandonment characteristics. The abandoned injection well is included in the abandoned well count in Table 20.

All of the wells for which complete information was available were available (6 wells) were evaluated with the borehole program ABE. All are considered to have been adequately constructed or abandoned.

One well listed by Dwights to have been plugged and abandoned lacked a plugging and abandonment report in state files. Available records for this well include one on repairs done during 1988, when it was still a producing well. This recent information suggests that, if the well is plugged and abandoned, it has been P&Ad under current regulations and has adequate flow barriers.

As discussed above, the Cha Cha field produces from the Gallup Sandstone and, as shown in Figures 4,5 and 6, the Gallup underlies the Mesaverde Group. Maps 27 and 28 show that the Cha Cha field is within the area of negative residual head of the Mesaverde Group. Map 3 shows that, at the location of the Cha Cha field, the Mesaverde is not a USDW. Under the circumstances, it can be concluded that the Mesaverde qualifies as a sink zone that would be capable of diverting water flowing upward from the Cha Cha field through open boreholes or behind the casing of cased bore-holes. The presence of the Mesaverde sink zone provides additional reason to grant the field variance from AOR requirements.

4.5.7.1.4 Escrito

The Escrito field was discovered in 1957, produces from the Gallup Sandstone and is undergoing waterflooding. From Maps 1, 2 and 3 it can be inferred that the field is overlain only by Tertiary USDWs. At that location, the Upper Cretaceous and Mesaverde contain saline water and are not USDWs.

Because of the relatively recent discovery date of the Escrito field, it is suggested that a variance may be available based upon the status of laws and regulations that existed in 1957. This suggestion is supported by the examination of three producing wells, two abandoned wells and one injection well. One producing well sampled was reported as abandoned, but abandonment data was not obtained for the well. The injection well sampled was also found to be abandoned, and abandonment data was available for this well. The injection well was examined for both its construction and abandonment characteristics, and is included in the abandoned well count shown in Table 20. All of the wells examined were found to have been adequately constructed or abandoned (Table 21).

As discussed above, the Escrito field produces from the Gallup Sandstone and, as shown in Figures 4,5 and 6, the Gallup underlies the Mesaverde Group. Maps 27 and 28 show that the Escrito field is within the area of negative residual head of the Mesaverde Group. Map 3 shows that, at the location of the Escrito field, the Mesaverde is not a USDW. Under these circumstances, it can be concluded that the Mesaverde qualifies as a sink zone that would be capable of diverting water flowing upward from the Escrito field through open boreholes or behind the casing of cased boreholes. The presence of the Mesaverde sink zone provides additional reason to grant the field variance from AOR requirements.

4.5.7.1.5 La Plata

Because of the relatively recent discovery date of the La Plata field, it is suggested that a variance may be available based upon the status of laws and regulation that existed in 1959.

The La Plata field was discovered in 1959, produces from the Mancos Shale and is undergoing waterflooding. From Maps 1,2 and 3, it can be inferred that the field is overlain only by Tertiary USDWs and that the Upper Cretaceous and Mesaverde contain saline water and are not USDWs. However, it is not certain that the Tertiary is actually present in this field because data from the Four Corners Geological Survey indicates the surface formation to be Cretaceous. For purposes of this study, the wells have been evaluated based on the presence of the Tertiary.

Four abandoned wells were sampled and examined. Three of the four abandoned wells did not have intersections with an injection zone, i.e. the wells were found to be drilled to formations shallower than the Mancos so that those wells cannot provide a pathway from the Mancos injection zone to the Tertiary USDW. The fourth abandoned well was evaluated and found to be protective of USDWs.

Five active wells were sampled (4 producers and one injection well). The injection well did not have sufficient data for analysis. The four producing wells were evaluated for their construction characteristics and were found to be protective of USDWs (Table 21).

The La Plata field may qualify for a variance based upon the construction and abandonment characteristics of wells in the field.

4.5.7.1.6 Puerto Chiquito, East

The Puerto Chiquito, East field was discovered in 1960, produces from the Cretaceous Niobrara Shale interval of the Mancos Shale and is undergoing waterflooding. Although the producing interval is indicated to be the Niobrara, two of the producing wells that were examined were, also, completed in the overlying Gallup Sandstone. Although Map 1 shows the field to be just outside of the outcrop of Tertiary formation, it may be overlain by thin intervals of Tertiary deposits at some locations. The Lewis Shale is, apparently, the first bedrock unit under which occurs the Mesaverde. Because insufficient information was available to allow determination of the salinity of water in the Mesaverde it, along with the Tertiary, was considered to be a USDW. Alternatively, there may be no USDW if the Tertiary is not an aquifer and if water in the Mesaverde is saline.

Five producing wells and one injection well were evaluated for their construction characteristics. All of these were considered to provide protection for the Tertiary USDW and for the Mesaverde, if it is a USDW (Table 21).

Three abandoned wells were evaluated for their abandonment characteristics. Of the three wells, one is very shallow and does not reach the injection zone. Plugging and abandonment information was not available for another abandoned well, but this well has the Mancos reported as the surface formation. Hence, this well appears to have no intersections with a USDW, and is also counted as a "no intersection" well (Table 20).

One abandoned well was analyzed. This had a "0" behind pipe ABE designation. The well was dry and abandoned, with multiple cement plugs in the wellbore. The "0" behind pipe ABE designation has no meaning and occurs only because the cement plugs do not fully cover the USDW. However, the well is considered to be adequately plugged and to provide USDW protection.

Variance from AORs may be available on the basis of the quality of construction and abandonment of wells in the Puerto Chiquito East field. Because of the relatively recent discovery date of the Puerto Chiquito East field, it is suggested that a variance may be available based upon the status of laws and regulation that existed in 1960.

It is also possible that no USDWs are present at the Puerto Chiquito East field because the field is located on the outer margins of the basin, in the Tertiary outcrop region.

4.5.7.1.7 Puerto Chiquito Mancos, West

The Puerto Chiquito Mancos, West field was discovered in 1963, produces from the Cretaceous Niobrara interval of the Mancos Shale and is undergoing secondary recovery. The field is reported to produce no water and pressure maintenance is, apparently, by gas injection rather than by water injection.

At the Puerto Chiquito Mancos, West field, the Mancos is overlain by Mesaverde, Upper

Cretaceous and Tertiary aquifers. It can be assumed that the Tertiary is a USDW. No information has been obtained concerning the quality of water in the Upper Cretaceous and Mesaverde. Therefore, it has been assumed that they are USDWs.

Four producing wells and two injection wells were examined for their construction characteristics. All six wells were adequately constructed to protect any overlying USDWs.

Three abandoned wells were evaluated for their abandonment characteristics. One well was abandoned with multiple plugs that would protect any overlying USDWs. One well did not have abandonment data, and there is conflicting information regarding the status of this well. The third well received a "0" ABE value. The well was dry and abandoned, with multiple cement plugs in the wellbore. The "0" behind pipe ABE designation has no meaning and occurs only because the cement plugs do not fully cover the USDW. However, the well is considered to be plugged and to provide USDW protection.

Because of the relatively recent discovery date of the Puerto Chiquito Mancos West field, it is suggested that a variance may be available based upon the status of laws and regulation that existed in 1960.

A variance from AORs may be available for the Puerto Chiquito Mancos, West field on the basis of well construction and abandonment characteristics.

4.5.7.1.8 Rio Puerco

Data were found for wells described as being in the Rio Puerco field in Sandoval County, which were drilled in the 1920's and 30's. These wells were in T12N, R2W and are from 500 ft to over 6000 ft deep. These wells were, apparently spudded in the Dakota Sandstone. Other data were found for wells described as being in the Rio Puerco field in T20N, R2-3W. These wells were drilled in the 1980's and were completed in the Mancos or in the Gallup. The Mancos-Gallup Rio Puerco field in which the recent wells were drilled is overlain by Tertiary USDWs. The Upper Cretaceous and Mesaverde are shown by Maps 2 and 3 to contain saline water at that location.

Seven abandoned wells were examined in the Rio Puerco field. Three of these wells did not have intersections with an injection zone, and one well had insufficient data for analysis. The remaining three abandoned wells were evaluated and all were found to be protective of USDWs (Table 21).

Four active wells (3 producers and one injection well) were sampled. No construction information was available for the well converted to injection. ABE analyses were performed on the three producing wells, and they were all found to be protective of USDWs (Table 21).

From the well data that were retrieved, it appears that all of the wells in the current Rio Puerco field both active and abandoned provide USDW protection and that the field may qualify for consideration for a variance on that basis.

As discussed above, the Rio Puerco field produces from the Gallup Sandstone and, as shown in Figures 4,5 and 6, the Gallup underlies the Mesaverde Group. Maps 27 and 28 show that the Rio Puerco field is within the area of negative residual head of the Mesaverde Group. Map 3 shows that, at the location of the Rio Puerco field, the Mesaverde is not a USDW. Under these circumstances, it can be concluded that the Mesaverde qualifies as a sink zone that would be capable of diverting water flowing upward from the Rio Puerco field through open boreholes or behind the casing of cased boreholes. The presence of the Mesaverde sink zone provides additional reason to grant the field variance from AOR requirements.

4.5.7.1.9 Totah

The Totah field was discovered in 1959, produces from the Cretaceous Gallup and Dakota Sandstones and is undergoing active waterflooding. From Maps 1,2 and 3, it can be inferred that the field is overlain only by Tertiary USDWs and that the Upper Cretaceous and Mesaverde contain saline water and are not USDWs.

Two producing wells and two injection wells were examined for their construction characteristics and two abandoned wells were examined for their abandonment characteristics (Table 20). All of the six wells were found to provide adequate protection to the Tertiary USDWs, thus, qualifying the field for the possibility of a variance based upon construction and abandonment characteristics of wells in the field (Table 21).

As discussed above, the Totah field produces from the Gallup Sandstone and, as shown in Figures 4,5 and 6, the Gallup underlies the Mesaverde Group. Maps 27 and 28 show that the Totah field is within the area of negative residual head of the Mesaverde Group. Map 3 shows that, at the location of the Totah field, the Mesaverde is not a USDW. Under these circumstances, it can be concluded that the Mesaverde qualifies as a sink zone that would be capable of diverting water flowing upward from the Totah field through open boreholes or behind the casing of cased boreholes. The presence of the Mesaverde sink zone provides additional reason to grant the field variance from AOR requirements.

Because of the relatively recent discovery date of the Totah field, it is also suggested that a variance may be available based upon the status of laws and regulation that existed in 1959.

4.5.7.2 Interior II Area Well Construction and Abandonment Methods

The wells sampled from the injection fields were compared with other wells from Interior II area fields which did not have active injection operations, in order to ascertain that the well sample from injection fields typified construction and abandonment methods in Interior I area walls.

A total of 332 abandoned wells were identified in the Interior II area. Sixty of these abandoned wells were sampled from all Interior II area fields (injection and non-injection) and examined in the study. Of the 60 abandoned wells, 37 were located in injection fields and 23 wells were examined from non-injection fields.

Sixty-three active wells were sampled in the study. Forty-five of these wells were located in injection fields, 14 wells were located in fields without active injection operations and 4 wells were reclassified as abandoned. Additional producing wells from fields without injection operations were not deemed necessary because the construction characteristics are also reflected in the abandoned well population from non-injection fields.

Well construction and abandonment data were obtained for the sampled wells and drawings were prepared showing their wellbore configurations. From the wellbore diagrams prepared it was apparent that the Interior II area wells were constructed in a manner similar to the other shallow wells found throughout the basin (Figure 27). The wells were constructed with surface casing (only one well did not have surface pipe), and this string was typically cemented back to the surface. Producing wells had production casing generally set through the producing horizon, but several open hole completions were also found in the sampled wells. Production casing was cemented in place, although cement volumes were not sufficient to bring the TOC back 100' into the surface pipe. Dry holes found in the sample population typically did not have production casing.

As in other basin sub-areas, the active wells were completed with tubing strings normally set to the deepest producing horizon. Injection wells normally were completed with both tubing and a packer unless injection was through smaller diameter (4 1/2") casing. The Interior II area wells were abandoned by setting cement across the bottom of the producing zone and by placing a cement plug at the surface. In addition, many wells with surface casing had cement plugs set across the casing shoe. Cement volumes reported for these plugs were generally sufficient to meet the current modern day standards. Approximately one-half of the wells completed with production casing had the casing pulled at abandonment. Where the production casing was pulled, a cement plug was normally set at the stub. Dry holes were typically abandoned with at least two spacer plugs in addition to the other plugs noted previously. The most frequently encountered abandonment configurations for the Interior II area are shown in Figure 28.

4.5.7.3 Interior II Area Summary

The Interior II area underlies the outcrop of the Tertiary and the Tertiary is generally believed to be the only USDW. The Puerto Chiquito East and Puerto Chiquito Mancos, West fields may be an exception to this generalization. They are very close to the pinch-out of the Tertiary and the upper Cretaceous and even the Mesaverde could be a USDW at those fields. A prevalent characteristic of Interior II area fields is that six of the nine fields are believed to be overlain by a Mesaverde sink zone. The remaining three fields could, also, be overlain by an underpressured Mesaverde but data are not available to confirm that. The Mesaverde sink zone, alone or in combination with the universally present sloughing and squeezing zones may provide USDW protection and be the basis for variances for all Interior II fields. All Interior II area fields, except Rio Puerco, were discovered after 1949. Wells in all Interior II area fields, including Rio Puerco, are considered to be adequately constructed and abandoned.

Information provided by the NMOCD shows that twenty- eight AORs have been performed in the Bisti field. This may be a sufficient number to provide a basis for an AOR variance for the field.

ABE numbers in the Interior II area ranged from 0-5. Most of the wells evaluated received an ABE number of 1, 2 or 3, which directly reflects the number of flow barriers present in the wellbore. These lower ABE numbers are similar to those seen for shallow wells in other areas of the basin.

There were only two instances of "0" ABE values in the Interior II area. Both of these instances were abandoned wells. One was located in the Puerto Chiquito, East field and the other was located in the Puerto Chiquiteo, West field. Both wells had multiple cement plugs in the wellbore but received a "0" behind pipe ABE value since the bottom plug did not entirely cover the injection zone. Because there is no long-string casing in the well, the behind pipe ABE value is not meaningful. USDW protection is provided by the bottom plug, and any other spacer plugs present, and both wells are considered to be adequately plugged.

In summary, the Interior II area wells were typically shallow, and had ABE values similar to other shallow wells throughout the basin. The area is unique since it is partially overlain by a sink zone in the Mesaverde. This sink zone represents a mitigating geological factor capable of excluding a portion of basin area from AOR review. In addition to this protective factor, most wells examined within the Interior II exhibited adequate construction and abandonment techniques.

4.5.8. Basin Summary

Table 22 summarizes the results of application of the AOR variance methodology to the San Juan Basin. It can be seen that no single criterion applies to all fields in the basin. There are, however, criteria that apply widely throughout the basin, these include:

1. Development of the field post dates the establishment of regulations or rules that provide for adequate USDW protection.
2. Examination of a sample population of wells establishes that wells are constructed and abandoned so that they provide adequate USDW protection.
3. Sloughing and/or squeezing zones are present that may preclude upward fluid movement through an open wellbore or behind casing.

The history of New Mexico laws, regulations and rules is documented in Section 4.3.

From that documentation and from the experience gained in examining a large number of well construction and abandonment records, it was judged that wells constructed or abandoned after 1949 provide USDW protection. Therefore, it is suggested that fields discovered after 1949 may qualify for a regulation based variance. Of the 24 active injection fields listed in Table 22, 20 were discovered after 1949.

The judgment expressed above, that wells in fields discovered after 1949 should exhibit adequate well construction and abandonment, is supported by the finding that wells in 18 of those 19 fields provided USDW protection. The remaining two may provide USDW protection. USDW protection was defined as the presence of one cemented casing string covering the USDW in active wells and the presence of one cement plug, for which the details of plug location and cement quantity are given in abandoned wells.

As is discussed in Section 4.1.2.3, the marine Cretaceous Mancos and Lewis Shales and a series of non-marine Cretaceous shales would be expected to be both sloughing and squeezing zones. As shown in Table 22, in fifteen and, perhaps, sixteen fields one or more of these Cretaceous shales is present between the injection zone and the lowermost USDW. While it isn't certain exactly what sealing effect these shales have, in any particular wellbore, it is difficult to imagine a wellbore that passes through such shales standing open for any length of time. The experience of operators and the NMOCD may be sufficient to qualify the widespread presence of sloughing and squeezing zones as a significant basis for AOR variance throughout that part of the San Juan Basin in which producing reservoirs are overlain by Cretaceous shales. This includes most of the basin except that part identified as the Western area. This would be a particularly relevant criterion for such fields as the Rattlesnake, Hospah and Red Mountain fields that are older fields in which there may be unplugged or inadequately plugged abandoned wells,and the post 1949 Hospah South field that, in part, underlies the Hospah field.

REFERENCES

1. Matheny, M.L., A History of the Petroleum Industry in the Four Corners Area, "Oil and Gas Fields of the Four Corners Area", Publication of the Four Corners Geological Society, 1978.

2. Four Corners Geological Society, "Oil and Gas Fields of the Four Corners Area", A publication of the Four Corners Geological Society, 1983.

3. Stone, W.J., F.P. Lyford, P.F. Frenzel, N.H. Mizell, and E.T. Padgett, 1983, Hydrogeology and Water Resources of San Juan Basin, New Mexico: Hydrologic Report 6, New Mexico Bureau of Mines and Mineral Resources, 70 p.

4. Levings, G.W., S.D. Craigg, W.L. Dam, J.M. Kernodle and C.R. Thorn, 1990, Hydrogeology of the San Jose, Nacimiento, and Animas Formations in the San Juan Structural Basin, New Mexico, Colorado, Arizona, and Utah: Hydrologic Atlas HA-720-A, U.S. Department of the Interior Geological Survey, 2 maps.

5. Kernodle, J.M., C.R. Thorn, G.W. Levings, S.D. Craigg, and W.L. Dam, 1990, Hydrogeology of the Kirtland Shale and Fruitland Formation in the San Juan Structural Basin, New Mexico, Colorado, Arizona, and Utah: Hydrologic Atlas HA-720-C, U.S. Department of the Interior Geological Survey, 2 maps.

6. Dam, W.L., J.M. Kernodle, C.R. Thorn, G.W. Levings, and S.D. Craigg, 1990, Hydrogeology of the Pictured Cliffs Sandstone in the San Juan Structural Basin, New Mexico, Colorado, Arizona, and Utah: Hydrologic Atlas HA-720-D, U.S. Department of the Interior Geological Survey, 2 maps.

7. Thorn, C.R., G.W. Levings, S.D. Craigg, W.L. Dam, and J.M. Kernodle, 1990, Hydrogeology of the Cliff House Sandstone in the San Juan Structural Basin, New Mexico, Colorado, Arizona, and Utah: Hydrologic Atlas HA-720-E, U.S. Department of the Interior Geological Survey, 2 maps.

8. Craigg, S.D., W.L. Dam, J.M. Kernodle, C.R. Thorn, and G.W. Levings, 1990, Hydrogeology of the Point Lookout Sandstone in the San Juan Structural Basin, New Mexico, Colorado, Arizona, and Utah: Hydrologic Atlas HA-720-G, U.S. Department of the Interior Geological Survey, 2 maps.

9. Kernodle, J.M., G.W. Levings, S.D. Craigg, and W.L. Dam, 1989, Hydrogeology of the Gallup Sandstone in the San Juan Structural Basin, New Mexico, Colorado, Arizona, and Utah: Hydrologic Atlas HA-720-H, U.S. Department of the Interior Geological Survey, 2 maps.

10. Craigg, S.D., W.L. Dam, J.M. Kernodle, and G.W. Levings, 1989, Hydrogeology of the Dakota Sandstone in the San Juan Structural Basin, New Mexico, Colorado, Arizona, and Utah: Hydrologic Atlas HA-720-I, U.S. Department of the Interior Geological Survey, 2 maps.

11. Dam, W.L., J.M. Kernodle, G.W. Levings, and S.D. Craigg, 1990, Hydrogeology of the Morrison Formation in the San Juan Structural Basin, New Mexico, Colorado, Arizona, and Utah: Hydroloic Atlas HA-720-J, U.S. Department of the Interior Geological Survey, 2 maps.

12. Arnold, E.C., and T.A. Dugan, "Wildcat Near Durango Before 1900 was First San Juan Basin Activity", Western Oil Reporter, August 1971, p. 24-27.

13. Arnold, E.C., "Gas Produced Commercially in San Juan 50 Years but No Proration Until 1955", Western Oil Reporter, August 1971, p. 29.

14. Arnold, E.C., "History of Basin Oil-Gas Development inThree Parts; El Paso Hogs Post-1950 Era", Western Oil Reporter, August 1971, p. 36 ff.

15. Berry, Frederick A.F., "Hydrodynamics and Geochemistry of the Jurassic and Cretaceous Systems in the San Juan Basin, Northwestern New Mexico and Southwestern Colorado", Doctoral Dissertation, Department of Geology, Stanford University, January 1959.

16. Warner, D.L., L.F. Koederitz, S. Dunn-Norman, and R.C. Laudon, "An Area of Review Variance Methodology", April 1993, Final Report to the American Petroleum Institute, Washington, D.C., 110 p.

17. Michie & Associates, Oil and Gas Industry Water Injection Well Corrosion: Oklahoma City, 1988, report to American Petroleum Institute, 115 p.

18. Kuhn, Paul, J., 1958, Oil and Gas in the Four Corners:National Petroleum Bibliography, Amarillo, 298 p.

19. Fassett, J.E., Thomaidis, N.D., Mathany, M.L., and Ullrich, R.A., ed. (1978, 1978, 1983), Oil and Gas Fields of the Four Corners Area; Four Corners Geological Society, Durango, Colorado, Volumes I (1978), II (1978) and III (1983), 1142 p.

20. Kelley, V.C., 1951, Tectonics of the San Juan Basin, in Guidebook of the South and West Sides of the San Juan Basin, New Mexico and Arizona: New Mexico Geological Society, Second Field Conference, p. 124-131.

21. Landes, Kenneth, K., 1970, Petroleum Geology of the United States: Wiley-Interscience, 571 p.

22. Molenar, C.M., 1988, Cretaceous and Tertiary Rocks of the San Juan Basin, in Baars, D.L., and others, Basins of the Rocky Mountain Region, in Sloss, L.L., ed, 1988, Sedimentary Cover–North American Craton: U.S., The Geology of North America Volume D-2.

23. "Sampling Wells for Evaluation of Well Construction and Abandonment Method," Appendix G, Technical Criteria for an Area-of-Review Variance Methodology, Ground Water Protection Council, January 1994.

[1]Michie & Associates, Oil and Gas Industry Water Injection Well Corrosion: Oklahoma City,1988, Report to American Petroleum Institute, 115 p.

TABLE 1
NEW MEXICO OIL AND GAS FIELD DISCOVERY DATES

YEAR	FIELD	FORMATION	PROD	Sec-Twp-Rge
1911	Seven Lakes	Mesaverde	Oil	T18N-R11W
1921	Aztec	Farmington	Gas	16-T30N-R11W
1921	Ute Dome	Dakota	Gas	36-T32N-R14W
1922	Hogback	Dakota	Oil	19-T29N-R16W
1924	Rattlesnake	Dakota	Oil	1-T29N-R19W
1924	Bloomfield	Farmington	Oil	14-T29N-R11W
1925	Barker Creek	Dakota	Gas	16-T32N-R14W
1925	Table Mesa	Dakota	Oil	3-T27N-R17W
1927	Blanco	Mesaverde	Gas	29-T30N-R 9W
1927	Blanco	Pictured Cliffs	Gas	29-T30N-R 9W
1927	Hospah	"Upper Sand"	Oil	1-T17N-R 9W
1927	Fulcher Kutz	Pictured Cliffs	Gas	34-T29N-R11W
1928	Stoney Butte	Mesaverde	Oil	36-T22N-R14W
1929	Rattlesnake	Pennsylvanian	Oil	2-T29N-R19W
1931	Oswell	Farmington	Oil	34-T30N-R11W
1934	Red Mountain	Mesaverde	Oil	29-T20N-R 9W
1941	Aztec	Pictured Cliffs	Gas	10-T30N-R11W
1943	Rattlesnake	Mississippian	He	13-T29N-R19W
1945	Barker Creek	Pennsylvanian	Gas	16-T32N-R14W
1946	Wyper	Farmington	Oil	19-T30N-R12W
1947	Angel's Peak	Dakota	Gas	4-T27N-R10W
1948	Ute Dome	Paradox	Gas	35-T32N-R14W
1949	Gavilan	Pictured Cliffs	Gas	14-T25N-R 2W
1949	La Plata	Mesaverde	Gas	10-T31N-R12W
1949	Lindrith	Dakota	Oil	20-T24N-R 2W
1950	San Luis	Mesaverde	Oil	21-T18N-R 3W
1950	Cedar Hill	Mesaverde	Gas	21-T31N-R11W
1950	Kutz, West	Pictured Cliffs	Gas	12-T27N-R12W
1950	Huerfano	Pictured Cliffs	Gas	25-T26N-R10W
1950	Stoney Butte	Dakota	Oil	1-T21N-R14W
1951	Table Mesa	Mississippian	Oil	3-T27N-R17W
1951	Kutz, West	Dakota	Gas	22-T28N-R12W
1951	Huerfanito	Dakota	Gas	3-T26N-R 9W
1951	Blanco, South	Pictured Cliffs	Gas	15-T26N-R 6W
1951	Dogie Canyon	Pictured Cliffs	Gas	15-T26N-R 6W
1951	Blanco, South	Tocito	Oil	9-T26N-R 6W
1951	Pettigrew	Tocito	Oil	9-T26N-R 6W
1951	Huerfano	Dakota	Gas	24-T26N-R10W
1952	Blanco, East	Pictured Cliffs	Gas	18-T30N-R 4W
1952	Gallegos	Fruitland	Gas	27-T27N-R11W
1952	Campanero	Dakota	Gas	4-T27N-R 5W
1952	Aztec	Fruitland	Gas	14-T29N-R11W
1952	La Jara	Fruitland	Gas	13-T30N-R 6W
1952	Hogback	Mississippian	Oil	19-T29N-R16W
1952	Los Pinos, South	Dakota	Gas	27-T31N-R 7W
1952	Kutz, West	Fruitland	Gas	23-T29N-R13W
1952	Blanco	Dakota	Gas	27-T31N-R10W
1953	Torreon	Mesaverde	Gas	22-T18N-R 4W
1953	Blue Hill	Paradox	Gas	36-T32N-R18W
1953	Canyon Largo	Pictured Cliffs	Gas	4-T25N-R 7W
1953	Los Pinos, N.	Fruitland	Gas	18-T32N-R 7W
1953	Media	Entrada	Oil	14-T19N-R 3W
1953	Los Pinos, S.	Fruitland	Gas	17-T31N-R 7W
1953	Choza Mesa	Pictured Cliffs	Gas	35-T29N-R 4W
1953	Cottonwood	Fruitland	Gas	35-T32N-R 5W
1953	Torreon	Mesaverde	Oil	'17-T19N-R 4W
1953	Ballard	Pictured Cliffs	Gas	4-T25N-R 7W

TABLE 1 (page 2)
NEW MEXICO OIL AND GAS FIELD DISCOVERY DATES

YEAR	FIELD	FORMATION	PROD	Sec-Twp-Rge
1954	Twin Mounds	Mesaverde	Gas	4-T29N-R14W
1954	Hogback	Pennsylvanian	Oil	19-T29N-R16W
1954	Tapacito	Pictured Cliffs	Gas	14-T26N-R 4W
1954	Twin Mounds	Pictured Cliffs	Gas	33-T30N-R14W
1954	Aztec, N.	Fruitland	Gas	20-T30N-R10W
1954	Gallegos	"Gallup"	Oil	14-T26N-R12W
1954	Schmitz-Torreon	Puerco	Gas	34-T24N-R 1W
1955	Otero	Point Lookout	Oil	32-T23N-R 4W
1955	Otero	Pictured Cliffs	Gas	28-T24N-R 5W
1955	Largo	Dakota	Gas	3-T27N-R 9W
1955	Otero	"Sanastee"	Oil	1-T22N-R 5W
1955	Otero	Dakota	Gas	22-T25N-R 5W
1955	Campanero, E.	Dakota	Gas	7-T27N-R 4W
1955	Verde	"Gallup"	Oil	14-T31N-R15W
1955	Bisti	"Lower Gallup"	Oil	16-T25N-R12W
1955	Kutz	Farmington	Gas	28-T28N-R11W
1956	Otero	"Chacra"	Gas	23-T25N-R 5W
1956	Harris Mesa	"Chacra"	Gas	29-T28N-R 9W
1956	Walker Dome	Mancos	Oil	13-T15N-R10W
1956	Four Corners	Paradox	Oil	29-T32N-R20W
1956	Otero	"Gallup"	Oil	25-T25N-R 5W
1956	Kutz	Fruitland	Gas	27-T28N-R11W
1956	Horseshoe	"Gallup"	Oil	4-T30N-R16W
1956	Flora Vista	Fruitland	Gas	10-T30N-R12W
1957	Wildhorse	"Gallup"	Gas	21-T26N-R 4W
1957	Lybrook	"Gallup"	Oil	10-T23N-R 7W
1957	Escrito	"Gallup"	Oil	27-T24N-R 7W
1957	La Plata, NW	Mesaverde	Gas	35-T32N-R13W
1957	Sleeper	Pictured Cliffs	Oil	23-T26N-R 3W
1957	Chimney Rock	"Gallup"	Gas	23-T31N-R17W
1958	Lindrith, S.	"Gallup"	Oil	5-T23N-R 4W
1958	Ojito	Dakota	Oil	18-T25N-R 3W
1958	Angel's Peak	"Gallup"	Oil	34-T27N-R10W
1958	Amarillo	"Gallup"	Oil	33-T28N-R13W
1958	Cuervo	Mesaverde	Oil	28-T27N-R 8W
1958	Kutz	"Gallup"	Oil	9-T27N-R11W
1958	Salt Creek	Dakota	Oil	4-T30N-R17W
1958	Devil's Fork	"Gallup"	Oil	24-T24N-R 7W
1959	Simpson	"Gallup"	Oil	26-T28N-R12W
1959	Shiprock	"Gallup"	Oil	17-T29N-R18W
1959	Lindrith	"Gallup"	Oil	1-T24N-R 4W
1959	La Plata	"Gallup"	Oil	5-T31N-R13W
1959	Crouch Mesa	Fruitland	Gas	4-T29N-R12W
1959	Totah	"Gallup"	Oil	27-T29N-R13W
1959	Dufers Point	"Gallup"	Oil	17-T25N-R 8W
1959	Cha Cha	"Gallup"	Oil	17-T28N-R13W
1959	San Luis, S.	Mesaverde	Oil	33-T18N-R 3W
1960	Puerto Chiquito, E.	Mancos	Oil	5-T26N-R 1W
1960	Wildhorse	Dakota	Oil	27-T26N-R 4W
1961	Flora Vista	Mesaverde	Gas	22-T30N-R12W
1961	Basin	Dakota	Gas	4-T27N-R10W
1961	Crouch Mesa	Mesaverde	Gas	6-T29N-R11W
1961	Boulder	Mancos	Oil	15-T28N-R 1W
1961	Jewett Valley	"Gallup"	Oil	3-T29N-R16W
1961	Table Mesa	Pennsylvanian "C"	Oil	3-T27N-R17W
1961	Largo	"Gallup"	Gas	3-T26N-R 7W
1961	Mesa	"Gallup"	Oil	24-T32N-R18W

TABLE 1 (page 3)
NEW MEXICO OIL AND GAS FIELD DISCOVERY DATES

YEAR	FIELD	FORMATION	PROD	Sec-Twp-Rge
1961	Chaco Wash	Mesaverde	Oil	21-T20N-R 9W
1961	Meadows	"Gallup"	Oil	33-T30N-R15W
1961	Flora Vista	"Gallup"	Gas	2-T30N-R12W
1961	Ojo	"Gallup"	Gas	26-T18N-R15W
1962	Many Rocks	"Gallup"	Oil	27-T32N-R17W
1963	Tocito Dome	Pennsylvanian "D"	Oil	17-T26N-R18W
1963	Pajarito	Pennsylvanian "D"	Oil	31-T29N-R17W
1963	Puerto Chiquito, W.	Mancos	Oil	13-T25N-R 1W
1963	Many Rocks, N.	"Gallup"	Oil	18-T32N-R17W
1963	Tocito Dome, N.	Mississippian	Gas	34-T27N-R18W
1963	Waterflow, S.	"Gallup"	Oil	19-T29N-R15W
1964	BS Mesa	"Gallup"	Gas	5-T26N-R 4W
1964	Cone	Pennsylvanian	Oil	22-T31N-R18W
1965	Hospah, S.	Gallup (Upper Sd)	Oil	12-T17N-R 9W
1965	Tapacito	"Gallup"	Oil	18-T26N-R 5W
1965	Hospah, S.	Gallup (Lower Sd)	Oil	12-T17N-R 9W
1966	Table Mesa	Mississippian	Gas	9-T27N-R17W
1966	Pinon	"Gallup"	Oil	14-T28N-R12W
1966	Pinon	Fruitland	Gas	13-T28N-R12W
1966	Lindrith	"Gallup"	Gas	20-T24N-R 2W
1966	Shiprock, N.	Dakota	Oil	14-T30N-R18W
1966	Pinon, N.	Fruitland	Gas	28-T29N-R12W
1966	Slick Rock	Dakota	Oil	36-T30N-R17W
1967	Shiprock, N.	"Gallup"	Oil	14-T30N-R18W
1967	Hospah	Dakota	Oil	12-T17N-R 9W
1967	Alamo	Farmington	Oil	4-T30N-R 9W
1967	Akah Nez	Devonian	Oil	23-T23N-R20W
1967	Tocito Dome, N.	Pennsylvanian	Gas	9-T26N-R18W
1968	Blanco	Fruitland	Gas	29-T30N-R 8W
1968	Gallegos, S.	Fruitland	Gas	12-T26N-R12W
1968	Rattlesnake	"Gallup"	Oil	2-T29N-R19W
1969	Media	"Gallup"	Oil	22-T19N-R 3W
1969	Devils Fork	Mesaverde	Oil	16-T24N-R 6W
1969	Pump Mesa	Fruitland	Gas	32-T32N-R 8W
1969	Middle Canyon	Dakota	Oil	14-T32N-R15W
1969	Harper Hill	Frtlnd-Pic Clffs	Gas	1-T29N-R14W
1970	Lone Pine	Dakota "D"	Oil	18-T17N-R 8W
1970	Nenahnezad	Mesaverde	Oil	10-T29N-R15W
1970	Waw	Pictured Cliffs	Gas	32-T27N-R13W
1970	Lone Pine	Dakota "A"	Gas	13-T17N-R 9W
1970	Five Lakes	Dakota	Oil	25-T22N-R 3W
1971	Alamito	"Gallup"	Oil	31-T23N-R 7W
1971	Nageezi	"Gallup"	Oil	1-T23N-R 9W
1971	Snake Eyes	Dakota "D"	Gas	20-T21N-R 8W
1971	Venado	Mesaverde	Oil	8-T22N-R 5W
1971	Buena Suerte	Pennsylvanian	Oil	3-T25N-R11W
1971	Parlay	Mesaverde	Oil	29-T22N-R 3W
1971	Rosa	"Gallup"	Gas	20-T32N-R 5W
1971	Gonzales	Mesaverde	Gas	6-T25N-R5W
1972	Blackeye	Dakota	Oil	29-T20N-R 9W
1972	Largo	"Chacra"	Gas	23-T27N-R 8W
1972	Bloomfield	"Chacra"	Gas	18-T29N-R10W
1972	Ojo	Pictured Cliffs	Gas	36-T28N-R15W
1972	Media, SW	Entrada	Oil	22-T19N-R 3W
1972	Gobernador	Mesaverde	Oil	32-T20N-R 9W
1972	Mount Nebo	Fruitland	Gas	28-T28N-R10W
1973	Blackeye	Pictured Cliffs	Gas	24-T29N-R 5W

TABLE 1 (page 4)
NEW MEXICO OIL AND GAS FIELD DISCOVERY DATES

YEAR	FIELD	FORMATION	PROD	Sec-Twp-Rge
1973	Sedro Canyon	Fruitland	Gas	23-T31N-R 9W
1973	Wagon Mound	Dakota	Gas	15-T21N-R21E
1973	Albino	"Gallup"	Gas	26-T32N-R 8W
1973	Miguel Creek	"Gallup"	Oil	29-T16N-R 6W
1973	Albino	Pictured Cliffs	Gas	26-T32N-R 8W
1973	Campo	"Gallup"	Gas	11-T29N-R 4W
1974	Navajo City	"Chacra"	Gas	35-T30N-R 8W
1974	Shiprock, N.	Pennsylvanian	Gas	14-T30N-R18W
1974	Ojito	"Gallup"	Oil	17-T25N-R 3W
1974	Chacon	Dakota	Oil	23-T23N-R 3W
1974	Rusty	Menefee	Oil	11-T22N-R 7W
1975	Marcelina	Dakota	Oil	18-T16N-R 9W
1975	Nipp	Pictured Cliffs	Gas	17-T26N-R12W
1975	Rusty	"Chacra"	Gas	14-T22N-R 7W
1975	Franciscan Lake	Mesaverde	Oil	7-T20N-R 5W
1975	Knickerbocker Buttes	"Gallup"	Oil	17-T30N-R10W
1975	Beautiful Mountain	Mississippian	Oil	5-T26N-R19W
1975	Arch	Nacimiento	Gas	14-T31N-R10W
1975	Rusty	"Gallup"	Gas	16-T22N-R 7W
1975	Eagle Mesa	Entrada	Oil	12-T19N-R 4W
1975	Straight Canyon	Dakota	Gas	14-T31N-R16W
1975	Animas	Chacra	Gas	6-T31N-R10W
1976	Kiffen	Nacimento	Gas	34-T32N-R11W
1976	Bisti	Greenhorn	Oil	8-T24N-R 9W
1976	Potwin	Pictured Cliffs	Gas	15-T24N-R 8W
1976	Jasis Canyon	Fruitland	Gas	36-T29N-R 8W
1976	Ojo Encino	Entrada	Oil	21_T20N-R 5W
1976	Gallegos, S.	Fruitland	Gas	10-T26N-R12W
1976	Gallegos, S.	Farmington	Gas	2-T26N-R12W
1976	Unnamed	"Gallup"	Gas	6-T30N-R 1E
1976	Conner	Fruitland	Gas	1-T30N-R14W
1977	Papers Wash	Entrada	Oil	15-T19N- 5W
1977	Snake Eyes	Entrada	Oil	20-T21N-R 8W
1977	Marcelina	Gallup	Oil	18-T16N-R 9W
1977	Blanco, S.	"Gallup"	Oil	3-T23N-R 2W
1977	Unnamed	Menefee	Gas	28-T30N-R14W
1977	Unnamed	Pictured Cliffs	Gas	35-T32N-R 7W
1977	Unnamed	Dakota	Oil	32-T24N-R 3W
1977	Leggs	Entrada	Oil	11-T21N-R10W
1977	Bisti	Farmington	Gas	31-T26N-R12W
1977	White Wash	Mancos-Dakota	Oil	2-T24N-R 9W
1978	Undesignated	Pennsylvanian	Gas	29-T31N-R18W
1978	Choza Mesa	Pictured Cliffs	Gas	14-T29N-R 4W
1978	Lindrith, W.	"Gallup"	Oil	24-T24N-R 4W
1978	Undesignated	Gallup	Oil	34-T23N-R 7W
1978	Undesignated	Hospah	OIl	4T15N-R 6W
1978	Star	Menefee	Oil	16-T19N-R 6W
1979	Big Gap	Pennsylvanian	Oil	20-T27N-R19W
1979	Farmer	Fruitland	Gas	4-T30N-R11W
1979	Chacon	Dakota	Oil	10-T22N-R 3W
1979	Rusty	"Chacra"	Gas	36-T22N-R 6W
1979	Undesignated	La Ventana	Gas	4-T22N-R 8W
1980	Gavilan	Nacimiento	Gas	12-T24N-R 2W
1980	Basin	Dakota	Gas	30-T24N-R 9W
1980	Undesignated	"Chacra"	Gas	8-T21N-R 6W
1980	Undesignated	Entrada	Oil	29-T21N-R 7W
1980	Lindrith, W.	"Chacra"	Gas	3-T24N-R 4W

TABLE 1 (page 5)
NEW MEXICO OIL AND GAS FIELD DISCOVERY DATES

YEAR	FIELD	FORMATION	PROD	Sec-Twp-Rge
1980	Undesignated	Todilto-Entrada	Oil	28-T19N-R 5W
1980	Undesignated	"Gallup"	Oil	28-T23N-R 6W
1980	Glades	Fruitland	Gas	36-T32N-R12W
1980	Big Gap	Pennsylvanian	Gas	20-T27N-R19W
1980	Undesignated	"Chacra"	Gas	16-T22N-R 8W
1980	Undesignated	"Gallup"	Oil	2-T23N-R 8W
1980	Undesignated	"Gallup"	Oil	25-T26N-R 2W
1981	Adobe	"Chacra"	Gas	13-T24N-R 4W
1981	Undesignated	"Gallup"	Oil	36-T20N-R 5W
1981	Undesignated	"Chacra"	Gas	35-T22N-R 8W
1981	Undesignated	"Gallup"	Oil	35-T21N-R 4W
1981	Undesignated	"Hospah"	Gas	29-T17N-R 9W
1981	Nageezi	"Gallup"	Oil	15-T23N-R 8W
1981	Undesignated	Dakota	Gas	29-T30N-R14W
1981	Undesignated	"Gallup"	Oil	11-T20N-R 4W
1981	San Ysidro	Mancos	Oil	29-T21N-R 3W
1981	Cuervo	"Gallup"	Oil	27-T24N-R 8W
1981	Undesignated	"Gallup"	Oil	8-T23N-R10W
1981	Undesignated	"Gallup"	Gas	13-T30N-R 4W
1981	Undesignated	"Gallup"	Gas	35-T31N-R 4W
1981	Undesignated	Mancos	Oil	30-T21N-R 3W
1981	Undesignated	Pictured Cliffs	Gas	16-T21N-R 4W
1981	Undesignated	"Gallup"	Oil	15-T20N-R 3W
1981	Undesignated	"Gallup"	Oil	36-T30N-R16W
1981	Undesignated	"Chacra"	Gas	25-T23N-R 7W
1982	Undesignated	Mancos	Oil	22-T21N-R 2W
1982	Undesignated	Mancos	Oil	4-T20N-R 2W
1982	Gavilan	Dakota	Oil	26-T25N-R 2W
1982	Undesignated	Mancos	Oil	1-T20N-R3W
1982	Undesignated	Menefee	Oil	12-T19N-R 5W

TABLE 2. PERTINENT CURRENT RULES OF THE NEW MEXICO OIL CONSERVATION DIVISION
FROM RULEBOOK DATED 10-16-89, WITH AMENDMENTS OF JULY 12, 1990

Rule 106. SEALING OFF STRATA.

(a) During the drilling of any oil well, injection well or any other service well, all oil, gas, and water strata above the producing and/or injection horizon shall be sealed or separated in order to prevent their contents from passing into other strata.

(b) All fresh waters and waters of present or probable value for domestic, commercial, or stock purposes shall be confined to their respective strata and shall be adequately protected by methods approved by the Division. Special precautions by methods satisfactory to the Division shall be taken in drilling and abandoning wells to guard against any loss of artesian water from the strata in which it occurs, and the contamination of artesian water by objectionable water, oil, or gas.

(c) All water shall be shut off and excluded from the various oil-and gas-bearing strata which are penetrated. Water shut-offs shall ordinarily be made by cementing casing.

Rule 107. CASING AND TUBING REQUIREMENTS

(a) Any well drilled for oil or natural gas shall be equipped with such surface and intermediate casing strings and cement as may be necessary to effectively seal off and isolate all water-, oil, and gas-bearing strata and other strata encountered in the well down to the casing point. In addition thereto, any well completed for the production of oil or natural gas shall be equipped with a string of properly cemented production casing at sufficient depth to ensure protection of oil- and gas-bearing strata encountered in the well, including the one(s) to be produced.

Sufficient cement shall be used on surface casing to fill the annular space behind the casing to the top of the hole, provided however, that authorized field personnel of the Division may, at their discretion, allow exceptions top the foregoing requirement when known conditions in a given area render compliance impracticable.

All cementing shall be by pump and plug method unless some other method is expressly authorized by the Division.

All cementing shall be with conventional-type hard-setting cements to which such additives (lighteners, densifiers, extenders, accelerators, retarders, etc.) have been added to suit conditions in the well.

TABLE 2. PERTINENT CURRENT RULES OF THE NEW MEXICO OIL CONSERVATION DIVISION
(page 2)

RULE 107 (cont)

Authorized field personnel of the Division may, when conditions warrant, allow exceptions to the above paragraph and permit the use of oil-base casing packing material in lieu of hard-setting cements on intermediate and production casing strings; provided however, that when such materials are used on the intermediate casing string, conventional-type hard-setting cements shall be placed throughout all oil- and gas-bearing zones and throughout at least the lowermost 300 feet of the intermediate casing string. When such materials are used on the production casing string, conventional-type hard-setting cements shall be placed throughout all oil- and gas-bearing zones and shall extend upward a minimum of 500 feet above the uppermost perforation or, in the case of an open-hole completion, 500 feet above the production casing shoe.

All casing strings shall be tested and proved satisfactory as provided in paragraph (c) below.

(b) After cementing, but before commencing tests required in paragraph (c) below, all casing strings shall stand cemented in accordance with Option 1 or 2 below. Regardless of which option is taken, the casing shall remain stationary and under pressure for at least eight hours after the cement has been placed. Casing shall be "under pressure" if some acceptable means of holding pressure is used or if one or more float valves are employed to hold the cement in place.

OPTION 1
Allow all casing strings to stand cemented a minimum of eighteen (18) hours prior to commencing tests. Operators using this option shall report on Form C-103 the actual time the cement was in place before initiating tests.

OPTION 2
(May be used in the counties of San Juan, Rio Arriba, McKinley, Sandoval, Lea, Eddy, Chaves, and Roosevelt only.) Allow all casing strings to stand cemented until the cement has reached a compressive strength of at least 500 pounds per square inch in the "zone of interest" before commencing tests, provided however, that no tests shall be commenced until the cement has been in place for at least eight (8) hours.

The "zone of interest" for surface and intermediate casing strings shall be the bottom 20 percent of the casing string, but shall be no more than 1000 feet nor less than 300 feet of the bottom part of the casing unless the casing is set at less than 300 feet. The "zone of interest" for production casing strings shall include the interval or intervals where immediate completion is contemplated.

RULE 107 (cont)

To determine a minimum compressive strength of 500 pounds per square inch has been attained, operators shall use the typical performance data for the particular cement mix used in the well, at the minimum temperature indicated for the zone of interest by Figure 107(a), Temperature Gradient Curves (not shown here). Typical performance data used shall be that data furnished by the cement manufacture or by a competent materials testing agency, as determined in accordance with the latest edition of API Code RP 10 B "Recommended Practice for Testing Oil-Well Cements."

Operators using the compressive strength criterion (Option 2) shall report the following information on Form C-103:

(1) Volume of cement slurry (cu. ft.) and brand name of cement and additives, percent additives used, and sequence of placement if more than one type cement slurry is used.
(2) Approximate temperature of cement slurry when mixed.
(3) Estimated minimum formation temperature in zone of interest.
(4) Estimate of cement strength at time of casing test.
(5) Actual time cement in place prior to starting test.

(c) All casing strings except conductor pipe shall be tested after cementing and before commencing any other operations on the well. Form C-103 shall be filed for each casing string reporting the grade and weight of pipe used. In the case of combination strings utilizing pipe of varied grades or weights, the footage of each grade and weight used shall be reported. The results of the casing test, including actual pressure held on the pipe and the pressure drop observed shall also be reported on the same Form C-103.

(1) Casing strings in wells drilled with rotary tools shall be pressure tested. Minimum casing test pressure shall be approximately one-third of the manufacturer's rated internal yield pressure except that the test pressure shall not be less than 600 pounds per square inch and need not be greater than 1500 pounds per square inch. In cases where combination strings are involved, the above test pressure shall apply to the lowest pressure rated casing used. Test pressures shall be applied for a period of 30 minutes. If a drop of more than 10 percent of the test pressure should occur, the casing shall be considered defective and corrective measures shall be applied.

(2) Casing strings in wells drilled with cable tools may be tested as outlined in sub-paragraph (c) (1) above, or by bailing the well dry in which case the hole must remain satisfactorily dry for a period of at least one (1) hour before commencing any further operations on the well.

TABLE 2. PERTINENT CURRENT RULES OF THE NEW MEXICO OIL CONSERVATION DIVISION
(page 4)

RULE 107 (cont)

(d) Requirements for tubing of wells are as follows:

(1) All flowing oil wells equipped with casing larger in size than 2 7/8 inch OD shall be tubed.
(2) All gas wells equipped with casing larger in size than 2 7/8 inch OD shall be tubed.
(3) Tubing shall be set as near the bottom as practical and tubing perforations shall not be more than 250 feet above the top of the pay.
(4) The Division Director may, upon proper application, grant administrative exceptions to the provisions of sub-paragraphs (2) and (3) above, without notice and hearing, provided waste will not be caused thereby.

(e) The Division's District Supervisors or their representatives shall have authority to approve tubingless completions without the necessity of administrative approval or notice and hearing when the following conditions exist:

(1) The well is to be completed with a total depth of 5,000 feet or less,
(2) The well is not a wildcat (it is not more than one mile from and existing well producing from the same common source of supply to which it is projected),
(3) No known corrosive or pressure problems exist which might make the tubingless method of completion undesirable,
(4) The well will not be a dual completion,
(5) The tubing used as a substitute for casing will be either 2 3/8 inch OD or 2 7/8 inch OD.

RULE 110. PULLING OUTSIDE STRINGS OF CASING

In pulling outside strings of casing from any oil or gas well, the space outside the casing left in the hole shall be kept and left full of mud-laden fluid or cement of adequate specific gravity to seal off all fresh and salt water strata and any strata bearing oil or gas not producing.

RULE 202. PLUGGING AND ABANDONMENT

B. PLUGGING

(1). Before any well is abandoned, it shall be plugged in a manner which will permanently confine all oil, gas, and water in the separate strata originally containing them. This operation shall be accomplished by the use of mud-laden fluid, cement and plugs, singly or in combination as approved by the Division on the notice of intention to plug.

(2) The operator shall mark the exact location of plugged and abandoned wells with a steel marker not less than four inches (4") in diameter set in cement and extending at least four feet above mean ground level. The operator name, lease name and well number and location including unit letter, section, township, and range, shall be welded, stamped, or otherwise permanently engraved into the metal of the marker.

(3) As soon as practical, but no later than one year after the completion of plugging operations, the operator shall:

(a) fill all pits;
(b) level the location;
(c) remove deadmen and all other junk; and
(d) take such other measures as are necessary or required by the Division to restore the location to a safe and clean condition.

(4) Upon completion of plugging and clean up restoration operations as required, the operator shall contact the appropriate district office to arrange for an inspection of the well and location.

RULE 203. WELLS TO BE USED FOR FRESH WATER

When the well to be plugged may safely be used as a fresh water well and such utilization is desired by the landowner, the well need not be filled above sealing plug set below the fresh water formation, provided that written agreement for such use shall be secured from the landowner and filed with the Division.

TABLE 3. OIL WELL DST PRESSURE DATA CONVERTED TO HEADS
TERTIARY GEOLOGICAL GROUP

Well No.	Longitude	Latitude	Salt Water Head (ft.)	Fresh Water Head (ft.)	DST Shut-in Pressure (psig)	Elevation (ft.)	Date	Field	Formation
TERT 1	-107.2632	36.0473	6411	6448	426	5464	1981	Unnamed	Tertiary
TERT 2	-106.9504	36.28408	6260	6318	680	4748	1957	Blanco South	Tertiary
TERT 3	-107.8318	36.50548	6257	6310	615	4890	1957	Basin	Farmington
TERT 4	-108.2392	36.80429	4846	4863	205	4390	1957	Basin	Farmington

TABLE 3. OIL WELL DST PRESSURE DATA CONVERTED TO HEADS
UPPER CRETACEOUS GEOLOGICAL GROUP

Well No.	Longitude	Latitude	Salt Water Head (ft.)	Fresh Water Head (ft.)	DST Shut-in Pressure (psig)	Elevation (ft.)	Date	Field	Formation
CRET 1	-107.2989	36.06522	6468	6508	460	5446	1956	San Juan Basin	Pictured Cliffs
CRET 2	-107.3075	36.17009	6969	7036	775	5246	1955	Lindrith	Ojo Alamo
CRET 3	-107.4616	36.11869	6573	6615	495	5472	1955	Wildcat	Kirtland
CRET 4	-107.0857	36.21857	6671	6765	75	4282	1955	Lindrith	Kirtland
CRET 5	-107.354	36.229	6303	6371	780	4570	1954	Ballard	Pictured Cliffs
CRET 6	-107.5331	36.2096	6334	6379	525	5167	1956	Bisti	Pictured Cliffs
CRET 7	-107.9124	36.22859	5630	5669	460	4607	1958	Wildcat	Pictured Cliffs
CRET 8	-106.923	36.26534	6613	6771	805	2602	1954	Lindrith	Lewis /SD/
CRET 9	-107.0489	36.2934	6534	6619	975	4367	1952	Blanco South	Fruitland
CRET 10	-106.9974	36.28642	6328	6405	885	4361	1957	Blanco South	Kirtland
CRET 11	-107.5593	36.27873	6250	6305	635	4838	1957	Bisti	Pictured Cliffs
CRET 12	-107.6753	36.28715	6349	6403	625	4960	1957	Bisti	Pictured Cliffs
CRET 13	-107.1814	36.39396	6417	6531	320	3483	1957	Tapacito	Pictured Cliffs
CRET 14	-107.8242	36.36208	6051	6095	500	4940	1955	Wildcat	Pictured Cliffs
CRET 15	-108.1276	36.42108	6090	6221	499	2759	1956	Bisti	Pictured Cliffs
CRET 16	-107.7903	36.45655	5944	5965	245	5399	1951	Huerfano	Pictured Cliffs
CRET 17	-108.2576	36.46822	5130	5142	137	4826	1956	Wildcat	Pictured Cliffs
CRET 18	-108.208	36.47189	5351	5370	215	4873	1956	Wildcat	Pictured Cliffs
CRET 19	-107.2669	36.61843	6386	6587	300	1275	1953	Wildcat	Pictured Cliffs
CRET 20	-108.2114	36.63781	5249	5283	390	4382	1956	Gallegos	Pictured Cliffs
CRET 21	-108.2182	36.61428	5232	5263	355	4443	1957	Basin	Pictured Cliffs
CRET 22	-107.1675	36.70055	5836	5935	130	3325	1952	Blanco	Fruitland
CRET 23	-107.2458	36.75868	6266	6378	275	3433	1955	Wildcat	Fruitland
CRET 24	-107.9479	36.75152	5258	5319	697	3709	1988	Basin	Fruitland
CRET 25	-108.2547	36.76053	5012	5041	325	4290	1958	Basin	Pictured Cliffs
CRET 26	-108.3448	36.76057	5103	5122	225	4602	1959	Gallegos	Pictured Cliffs
CRET 27	-108.3267	36.74619	5091	5111	225	4591	1954	Twin Mounds	Pictured Cliffs
CRET 28	-107.3224	36.83129	6674	6809	550	3229	1953	Blanco East	Fruitland
CRET 29	-107.8575	36.82188	5491	5577	990	3291	1953	Blanco East	Pictured Cliffs
CRET 30	-108.2547	36.78	5131	5160	340	4375	1951	Blanco	Pictured Cliffs
CRET 31	-107.4106	36.8886	5993	6077	966	3846	1988	Basin	Ojo Alamo
CRET 32	-107.5095	36.86816	6709	6849	598	3158	1990	Basin	Fruitland
CRET 33	-107.5523	36.88216	6891	7030	586	3367	1985	Los Pinos	Kirtland
CRET 34	-107.6198	36.97657	6888	7033	657	3206	1988	Basin	Kirtland
CRET 35	-107.7182	36.93601	6906	7052	675	3184	1976	Blanco	Fruitland
CRET 36	-107.8741	36.96575	6670	6793	420	3514	1954	Blanco	Fruitland
CRET 37	-107.8719	36.95858	6742	6880	589	3210	1981	Basin	Fruitland
CRET 38	-107.9197	36.95351	6749	6878	479	3462	1975	Blanco	Fruitland

TABLE 3. OIL WELL DST PRESSURE DATA CONVERTED TO HEADS
MESA VERDE GEOLOGICAL GROUP

Well No.	Longitude	Latitude	Salt Water Head (ft.)	Fresh Water Head (ft.)	DST Shut-in Pressure (psig)	Elevation (ft.)	Date	Field	Formation
MVRD 1	-107.5421	35.59333	6562	6609	545	5350	1957	Wildcat	Hospah
MVRD 2	-107.4476	35.6841	6466	6485	220	5977	1956	San Juan Basin	Hosta
MVRD 3	-107.7543	35.73126	6536	6585	562	5287	1969	Hospah	Hospah
MVRD 4	-107.398	35.88582	6365	6417	595	5043	1960	Unnamed	Menefee
MVRD 5	-107.3955	35.88372	6288	6350	703	4726	1958	Torreon	Menefee
MVRD 6	-107.3992	35.84666	6335	6392	655	4879	1960	Wildcat	Point Lookout
MVRD 7	-107.0969	35.96914	6216	6332	335	3249	1957	Wildcat	Mancos
MVRD 8	-107.3144	35.92924	6456	6580	422	3296	1976	Wildcat	Point Lookout
MVRD 9	-107.8078	35.94418	6468	6576	245	3701	1958	Wildcat	Hospah
MVRD 10	-107.0256	36.03715	6609	6738	480	3320	1956	Wildcat	Point Lookout
MVRD 11	-107.2191	36.04363	6234	6351	345	3245	1961	Wildcat	Point Lookout
MVRD 12	-107.4578	36.0737	6362	6401	453	5355	1976	Wildcat	Chacra
MVRD 13	-107.4221	36.0292	6250	6338	7	4012	1977	Wildcat	La Ventana
MVRD 14	-107.0722	36.09359	6192	6331	600	2636	1955	Wildcat	Point Lookout
MVRD 15	-107.1307	36.16985	6229	6379	720	2407	1961	Wildcat	Menefee
MVRD 16	-107.3953	36.1536	6170	6298	478	2885	1971	Venado	Menefee
MVRD 17	-107.3377	36.14486	6257	6386	494	2936	1971	Wildcat	Point Lookout
MVRD 18	-107.6339	36.28268	6033	6160	455	2800	1980	Lybrook	Menefee
MVRD 19	-107.0993	36.40247	6118	6306	155	1329	1957	Blanco South	Point Lookout
MVRD 20	-108.1231	36.4247	5955	6090	540	2533	1956	Bisti	Point Lookout
MVRD 21	-108.1276	36.42108	5809	5938	485	2508	1956	Bisti	Point Lookout
MVRD 22	-108.1366	36.40985	5617	5740	405	2495	1956	Bisti	Point Lookout
MVRD 23	-108.0333	36.47898	5503	5630	460	2258	1956	Gallegos	Menefee
MVRD 24	-108.1767	36.45022	6180	6325	660	2491	1957	Bisti	Point Lookout
MVRD 25	-106.9142	36.64511	6593	6639	530	5415	1960	Boulder	Mesa Verde
MVRD 26	-108.1156	36.81679	5440	5570	485	2140	1960	Basin	Cliff House
MVRD 27	-108.0905	36.7931	5538	5671	530	2138	1961	Blanco	Mesa Verde
MVRD 28	-108.0732	36.78274	5449	5579	485	2149	1961	Basin	Mesa Verde
MVRD 29	-108.0876	36.78613	5490	5620	495	2167	1961	Blanco-Basin	Cliff House
MVRD 30	-108.0964	36.78137	5515	5646	500	2182	1961	Basin	Cliff House
MVRD 31	-108.3444	36.8035	5592	5775	100	925	1958	Wildcat	Mancos
MVRD 32	-108.3444	36.76546	5774	5905	500	2441	1954	Blanco	Mesa Verde

TABLE 3. OIL WELL DST PRESSURE DATA CONVERTED TO HEADS
GALLUP GEOLOGICAL GROUP

Well No.	Longitude	Latitude	Salt Water Head (ft.)	Fresh Water Head (ft.)	DST Shut-in Pressure (psig)	Elevation (ft.)	Date	Field	Formation
GLLP 1	-107.5421	35.59333	6980	7042	725	5368	1957	Wildcat	Gallup
GLLP 2	-107.7567	35.71333	7075	7146	807	5282	1967	Unnamed	Gallup
GLLP 3	-107.7599	35.69436	6464	6546	944	4366	1970	Lone Pine	Gallup
GLLP 4	-107.814	35.67673	6592	6634	483	5519	1979	Wildcat	Gallup
GLLP 5	-107.4714	35.78898	6364	6457	70	3986	1982	Wildcat	Gallup
GLLP 6	-107.1203	35.87091	6493	6591	120	4004	1962	Media	Gallup
GLLP 7	-107.8078	35.94418	7115	7260	665	3415	1958	Wildcat	Gallup
GLLP 8	-107.8956	35.99704	6257	6446	176	1421	1980	Wildcat	Gallup
GLLP 9	-108.1502	36.04465	6098	6204	215	3398	1957	Wildcat	Gallup
GLLP 10	-107.6848	36.22163	6364	6578	450	920	1955	Bisto	Sanastee
GLLP 11	-108.0906	36.21152	6712	6899	135	1968	1957	Wildcat	Gallup
GLLP 12	-107.0611	36.29061	6460	6685	578	731	1952	Lindrith	Tocito
GLLP 13	-107.4249	36.34641	6650	6878	620	827	1960	Basin	Gallup
GLLP 14	-107.6635	36.34568	6771	6998	604	984	1957	Bisti	Gallup
GLLP 15	-107.7466	36.32341	7131	7355	575	1408	1957	Bisti	Gallup
GLLP 16	-108.1256	36.29544	6344	6522	50	1788	1957	Bisti	Gallup
GLLP 17	-108.2497	36.30621	6539	6713	997	2101	1956	Wildcat	Niobrara
GLLP 18	-108.4541	36.26932	6442	6646	335	1253	1956	Wildcat	Sanastee
GLLP 19	-108.6057	36.33844	5817	5965	695	2050	1962	Chaco River Area	Gallup
GLLP 20	-107.8813	36.3558	6467	6665	275	1411	1957	Bisti	Gallup
GLLP 21	-107.9618	36.37026	6889	7100	425	1500	1956	Bisti	Gallup Lower
GLLP 22	-108.2114	36.36725	6207	6384	26	1705	1975	Wildcat	Gallup
GLLP 23	-108.5529	36.43524	5802	5957	785	1835	1957	Wildcat	Gallup
GLLP 24	-107.8318	36.50548	6999	7243	805	765	1957	Basin	Gallup
GLLP 25	-108.0063	36.47877	6718	6939	540	1073	1957	Gallegos	Gallup
GLLP 26	-107.9673	36.4635	6371	6581	410	1015	1957	Basin	Gallup
GLLP 27	-108.0682	36.49266	5977	6176	285	899	1957	Gallegos	Gallup
GLLP 28	-108.3608	36.5269	5801	5937	550	2357	1958	Wildcat	Gallup
GLLP 29	-107.1587	36.75134	5516	5750	674	-426	1984	Unnamed	Gallup
GLLP 30	-108.1071	36.75378	5650	5874	570	-61	1959	Basin	Gallup
GLLP 31	-108.5622	36.71397	6554	6833	200	-557	1952	Hogback	Gallup Upper
GLLP 32	-108.6244	36.92097	6279	6347	785	4534	1959	Basin	Gallup

TABLE 3. OIL WELL DST PRESSURE DATA CONVERTED TO HEADS
DAKOTA GEOLOGICAL GROUP

Well No.	Longitude	Latitude	Salt Water Head (ft.)	Fresh Water Head (ft.)	DST Shut-in Pressure (psig)	Elevation (ft.)	Date	Field	Formation
DKOT 1	-107.9696	35.54928	6508	6545	416	5584	1981	Wildcat	Dakota SD
DKOT 2	-107.8389	35.60773	6537	6580	499	5428	1975	Marcelina	Dakota SD
DKOT 3	-107.2614	35.73841	6148	6264	324	3206	1978	Wildcat	Dakota SD
DKOT 4	-107.4476	35.6841	6198	6297	135	3676	1956	San Juan Basin	Dakota SD
DKOT 5	-107.7327	35.70828	6555	6639	960	4422	1970	Lone Pine	Dakota SD
DKOT 6	-107.8277	35.68985	6402	6480	895	4413	1979	Wildcat	Dakota SD
DKOT 7	-107.814	35.67673	6455	6529	852	4561	1979	Wildcat	Dakota SD
DKOT 8	-107.2395	35.77865	6794	6948	770	2860	1953	Wildcat	Dakota SD
DKOT 9	-107.4714	35.78898	6354	6472	361	3329	1982	Wildcat	Dakota SD
DKOT 10	-107.6958	35.8015	6536	6646	265	3725	1985	Wildcat	Dakota SD
DKOT 11	-107.6845	35.93043	6387	6524	571	2896	1971	Wildcat	Dakota SD
DKOT 12	-107.348	36.08309	6135	6336	311	999	1990	Wildcat	Dakota SD
DKOT 13	-107.5161	36.07867	6435	6634	281	1366	1977	Wildcat	Dakota SD
DKOT 14	-107.7215	36.0467	7597	7819	546	1939	1972	Snake Eyes	Dakota SD
DKOT 15	-107.8654	36.0623	6369	6538	939	2060	1977	Leggs	Dakota SD
DKOT 16	-107.8687	36.11701	6215	6391	20	1726	1958	Wildcat	Dakota SD
DKOT 17	-108.2777	36.10314	6151	6307	790	2173	1971	Wildcat	Dakota SD
DKOT 18	-108.5164	36.14532	6479	6668	175	1645	1955	Wildcat	Dakota SD
DKOT 19	-107.7466	36.2397	6139	6344	350	917	1957	Wildcat	Dakota SD
DKOT 20	-107.7608	36.23029	6387	6597	400	1054	1955	Chaco	Dakota SD
DKOT 21	-107.9787	36.2309	6101	6289	160	1301	1956	Wildcat	Dakota SD
DKOT 22	-108.0906	36.21152	6710	6915	350	1488	1957	Wildcat	Dakota SD
DKOT 23	-108.2362	36.2446	6657	6859	320	1501	1971	Wildcat	Dakota SD
DKOT 24	-107.3891	36.3315	5623	5853	630	-221	1959	Blanco South	Dakota SD
DKOT 25	-107.4286	36.34725	6332	6594	1	-337	1958	Blanco South	Dakota SD
DKOT 26	-107.6102	36.3233	6407	6655	842	91	1960	Escrito	Dakota SD
DKOT 27	-107.9056	36.31777	6242	6455	443	813	1974	Unnamed	Dakota SD
DKOT 28	-108.0186	36.27945	5980	6172	210	1068	1956	Wildcat	Dakota SD
DKOT 29	-108.1256	36.29544	5994	6186	200	1105	1957	Bisti	Dakota SD
DKOT 30	-108.164	36.29102	5941	6134	216	1016	1975	Wildcat	Dakota SD
DKOT 31	-108.4541	36.26932	6054	6247	209	1145	1956	Wildcat	Dakota SD
DKOT 32	-108.6057	36.33844	5704	5880	24	1206	1962	Chaco River Area	Dakota SD
DKOT 33	-107.3519	36.4104	5963	6224	0	-704	1957	Otero Gallup	Dakota SD
DKOT 34	-107.3886	36.38109	5916	6163	835	-384	1960	Basin	Dakota SD
DKOT 35	-107.3419	36.37494	6121	6386	35	-623	1957	Basin	Dakota SD
DKOT 36	-107.3863	36.36672	5986	6235	850	-347	1958	Basin	Dakota SD
DKOT 37	-107.4425	36.35185	5813	6053	754	-307	1962	Basin	Dakota SD
DKOT 38	-107.7332	36.39186	6236	6483	820	-30	1957	Wildcat	Dakota SD
DKOT 39	-108.0325	36.42528	5605	5809	343	398	1973	Basin	Dakota SD
DKOT 40	-107.4879	36.51428	5585	5831	820	-682	1953	Basin	Graneros
DKOT 41	-107.5563	36.51973	6249	6523	145	-740	1959	Basin	Dakota SD

TABLE 3. OIL WELL DST PRESSURE DATA CONVERTED TO HEADS DAKOTA GEOLOGICAL GROUP (cont)

Well No.	Longitude	Latitude	Salt Water Head (ft.)	Fresh Water Head (ft.)	DST Shut-in Pressure (psig)	Elevation (ft.)	Date	Field	Formation
DKOT 42	-107.9939	36.48497	6677	6934	947	128	1981	Basin	Dakota SD
DKOT 43	-108.0663	36.46317	5959	6184	574	239	1973	Basin	Dakota SD
DKOT 44	-108.3987	36.46857	5763	5972	405	418	1958	Wildcat	Dakota SD
DKOT 45	-107.5025	36.54115	5560	5811	880	-840	1951	Basin	Dakota SD
DKOT 46	-107.7755	36.59875	6385	6661	165	-648	1955	Basin	Dakota SD
DKOT 47	-108.1581	36.57986	5345	5560	460	-121	1956	Kutz West	Dakota SD
DKOT 48	-108.0741	36.55559	5442	5661	500	-113	1958	Basin	Dakota SD
DKOT 49	-108.1767	36.58451	5412	5629	485	-110	1957	Wildcat	Dakota SD
DKOT 50	-108.6504	36.59399	5325	5378	610	3969	1955	Table Mesa	Dakota SD
DKOT 51	-107.1587	36.6219	6567	6873	500	1210	1960	Wildcat	Dakota SD
DKOT 52	-107.8953	36.63727	5266	5488	545	-390	1957	Basin	Dakota SD
DKOT 53	-108.012	36.66614	5209	5437	605	-579	1958	Basin	Dakota SD
DKOT 54	-107.985	36.64288	5054	5274	522	-550	1959	Fulcher Kutz	Dakota SD
DKOT 55	-106.8894	36.72315	6700	6800	145	4156	1961	Wildcat	Dakota SD
DKOT 56	-107.1607	36.70599	6480	6782	455	1197	1960	Unnamed	Dakota SD
DKOT 57	-108.5883	36.74639	5413	5460	550	4190	1954	Hogback Area	Dakota SD
DKOT 58	-108.2896	36.76509	5885	6131	825	-393	1961	Basin	Dakota SD
DKOT 59	-108.5179	36.80482	5098	5178	920	3053	1960	Horseshoe Canyoı	Dakota SD
DKOT 60	-108.7835	36.77967	5010	5036	300	4343	1955	Wildcat	Dakota SD
DKOT 61	-106.8935	36.88979	6958	7010	599	5627	1973	Wildcat	Dakota SD
DKOT 62	-108.1612	36.85385	5626	5884	960	-952	1960	Wildcat	Dakota SD
DKOT 63	-108.4333	36.88058	5180	5262	950	3068	1956	Barker Creek	Dakota SD
DKOT 64	-108.5535	36.8667	5187	5255	790	3431	1959	Horseshoe	Dakota SD
DKOT 65	-108.6244	36.92097	5065	5121	640	3643	1959	Basin	Dakota SD
DKOT 66	-108.4965	36.94286	5359	5440	932	3288	1976	Wildcat	Dakota SD

TABLE 3. OIL WELL DST PRESSURE DATA CONVERTED TO HEADS
MORRISON GEOLOGICAL GROUP

Well No.	Longitude	Latitude	Salt Water Head (ft.)	Fresh Water Head (ft.)	DST Shut-in Pressure (psig)	Elevation (ft.)	Date	Field	Formation
MRSN 1	-106.999	35.83559	5658	5765	225	2936	1953	Wildcat	Morrison
MRSN 2	-107.368	35.94842	6160	6367	371	891	1977	Ojo Encino	Morrison
MRSN 3	-107.8691	36.1376	6222	6442	521	620	1983	Wildcat	Morrison
MRSN 4	-107.2673	36.18515	5750	5969	510	172	1955	NW NW	Morrison
MRSN 5	-107.7371	36.25912	6373	6598	575	651	1952	Wildcat	Morrison
MRSN 6	-108.0906	36.21152	6214	6408	230	1258	1957	Wildcat	Morrison
MRSN 7	-107.0611	36.29061	5704	5952	840	-607	1952	Lindrith	Morrison
MRSN 8	-107.0656	36.28339	5848	6096	840	-463	1950	Lindrith	Morrison
MRSN 9	-107.3634	36.28893	5889	6130	755	-233	1951	Blanco South	Morrison
MRSN 10	-107.5415	36.28558	6273	6514	770	117	1957	Bisti	Morrison
MRSN 11	-107.5025	36.54115	6303	6591	300	1030	1951	Basin	Morrison
MRSN 12	-107.5196	36.52321	6107	6385	180	-959	1954	Blanco South	Morrison
MRSN 13	-107.877	36.57955	6492	6770	175	-563	1951	Fulcher Kutz	Morrison
MRSN 14	-108.2182	36.61428	5884	6128	795	-327	1957	Basin	Morrison
MRSN 15	-108.2356	36.70657	5407	5645	735	-671	1961	Totah	Morrison
MRSN 16	-108.6494	36.83809	4971	5018	550	3748	1952	Wildcat	Morrison
MRSN 17	-107.353	36.99219	6003	6300	400	1552	1953	Basin	Morrison
MRSN 18	-108.6377	36.96186	5092	5160	780	3359	1960	Chimney Rock	Morrison

TABLE 3. OIL WELL DST PRESSURE DATA CONVERTED TO HEADS BELOW MORRISON GEOLOGICAL GROUP

Well No.	Longitude	Latitude	Salt Water Head (ft.)	Fresh Water Head (ft.)	Shut-in Pressure (psig)	Elevation (ft.)	Date	Field	Formation
BMRSN 1	-108.9477	35.1886	6032	6058	305	5354	1981	Wildcat	San Andres
BMRSN 2	-107.6605	35.44118	5627	5722	100	3182	1954	San Mateo	Glorieta
BMRSN 3	-108.0975	35.52466	7327	7461	537	3911	1980	Wildcat	Glorieta
BMRSN 4	-108.2259	35.54008	6847	6936	29	4560	1980	Wildcat	Glorieta
BMRSN 5	-107.2614	35.73841	6254	6418	890	2053	1978	Wildcat	Todilto
BMRSN 6	-107.3154	35.80389	6261	6584	702	1966	1970	Wildcat	Madera
BMRSN 7	-106.999	35.83559	5905	6029	425	2738	1953	Wildcat	Entrada
BMRSN 8	-107.2618	35.90385	6081	6276	235	1114	1975	Wildcat	Entrada
BMRSN 9	-107.3421	35.84376	6412	6737	726	1868	1977	Wildcat	Hermosa
BMRSN 10	-107.3714	35.94842	6099	6302	337	905	1976	Ojo Encino	Entrada
BMRSN 11	-107.5161	36.07867	6211	6439	625	377	1977	Wildcat	Entrada
BMRSN 12	-107.7353	36.04401	6239	6446	374	963	1977	Wildcat	Entrada
BMRSN 13	-107.4616	36.11869	6378	6631	900	-66	1955	Wildcat	Entrada
BMRSN 14	-107.2673	36.18515	6054	6316	0	-612	1955	NW NW	Todilto
BMRSN 15	-106.923	36.26534	6382	6687	500	1396	1954	Lindrith	Entrada
BMRSN 16	-107.3368	36.3209	6077	6365	300	1256	1953	Blanco South	Entrada
BMRSN 17	-109.001	36.30396	6866	6940	860	4954	1967	Wildcat	McCracken
BMRSN 18	-107.2873	36.37355	5540	5819	200	1571	1953	Wildcat	Entrada
BMRSN 19	-108.0333	36.39918	6484	6761	175	-572	1958	Bisti	Entrada
BMRSN 20	-107.6851	36.50313	6286	6558	117	-641	1967	Tocito Dome	Pennsylvanian
BMRSN 21	-108.8897	36.51971	6360	6613	896	-75	1975	Beautiful Mtn.	Ouray LM
BMRSN 22	-108.659	36.60169	6873	7234	140	2327	1961	Table Mesa	Leadville
BMRSN 23	-108.8611	36.62755	6059	6363	487	1690	1963	Wildcat	Mississippian
BMRSN 24	-108.5622	36.71397	6857	7200	925	1865	1952	Hogback	Mississippian
BMRSN 25	-108.5887	36.7614	6859	7185	725	1418	1959	Hogback	Paradox SH
BMRSN 26	-108.7935	36.76155	5892	6176	250	1330	1958	Rattlesnake Area	Paradox SH
BMRSN 27	-108.5703	36.76899	6748	7096	982	2100	1960	Wildcat	Mississippian
BMRSN 28	-108.7049	36.81922	6042	6340	420	1558	1966	Wildcat	Ismay
BMRSN 29	-108.9342	36.79733	5057	5307	870	1321	1959	Wildcat	Madison
BMRSN 30	-108.9026	36.79398	5836	6100	20	-875	1959	Wildcat	Paradox SH
BMRSN 31	-108.2991	36.91811	6328	6699	250	3116	1958	Ute Dome	Mississippian
BMRSN 32	-108.6802	36.93608	5770	6109	885	2863	1953	Wildcat	Mississippian
BMRSN 33	-108.6134	36.86964	6001	6344	930	2732	1952	Horseshoe	Molas
BMRSN 34	-108.7218	36.90649	5708	6030	685	2480	1963	Wildcat	Paradox SH
BMRSN 35	-108.8146	36.88899	5768	6073	487	1980	1976	Wildcat	Desert Creek
BMRSN 36	-109.0097	36.92996	4575	4777	315	-569	1961	Cambrian	Ismay
BMRSN 37	-108.317	36.98841	5112	5409	400	2443	1945	Barker Creek	Paradox SH
BMRSN 38	-108.4632	36.94008	5740	6096	70	3304	1958	Barker Creek	Mississippian
BMRSN 39	-108.6387	36.96153	5644	5960	620	2400	1960	Wildcat	Desert Creek
BMRSN 40	-108.7706	36.99075	4999	5300	440	2645	1957	Wildcat	Paradox SH
BMRSN 41	-108.7707	36.9472	5518	5827	540	2349	1959	Wildcat	Paradox SH
BMRSN 42	-108.6979	36.93972	5529	5835	500	2248	1952	Chimney Rock	Paradox SH
BMRSN 43	-108.9146	36.94713	4403	4617	450	1041	1962	Wildcat	Ismay Upper

Table 4
Wells Common to Fields
San Juan Basin

BASIN FIELD

Well Number	Formation	Geological Group
TERT 3	Farmington	Tertiary
TERT 4	Farmington	Tertiary
CRET 21	Pictured Cliffs	Upper Cretaceous
CRET 24	Fruitland	Upper Cretaceous
CRET 25	Pictured Cliffs	Upper Cretaceous
CRET 31	Ojo Alamo	Upper Cretaceous
CRET 32	Fruitland	Upper Cretaceous
CRET 34	Kirtland	Upper Cretaceous
CRET 37	Fruitland	Upper Cretaceous
MVRD 26	Cliff House	Mesa Verde
MVRD 28	Mesa Verde	Mesa Verde
MVRD 30	Cliff House	Mesa Verde
GLLP 13	Gallup /SD/SH/	Gallup
GLLP 24	Gallup /SD/SH/	Gallup
GLLP 26	Gallup /SD/SH/	Gallup
GLLP 30	Gallup /SD/SH/	Gallup
GLLP 32	Gallup /SD/SH/	Gallup
DKOT 34	Dakota Group /SD/	Dakota
DKOT 35	Dakota Group /SD/	Dakota
DKOT 36	Dakota Group /SD/	Dakota
DKOT 37	Dakota Group /SD/	Dakota
DKOT 39	Dakota Group /SD/	Dakota
DKOT 40	Dakota Group /SD/	Dakota
DKOT 41	Dakota Group /SD/	Dakota
DKOT 42	Dakota Group /SD/	Dakota
DKOT 43	Dakota Group /SD/	Dakota
DKOT 45	Dakota Group /SD/	Dakota
DKOT 46	Dakota Group /SD/	Dakota
DKOT 48	Dakota Group /SD/	Dakota
DKOT 52	Dakota Group /SD/	Dakota
DKOT 53	Dakota Group /SD/	Dakota
DKOT 58	Dakota Group /SD/	Dakota
DKOT 65	Dakota Group /SD/	Dakota
MRSN 11	Morrison	Morrison
MRSN 14	Morrison	Morrison
MRSN 17	Morrison	Morrison

Table 4 (cont)
Wells Common to Fields
San Juan Basin

BLANCO SOUTH FIELD

Well Number	Formation	Geological Group
TERT 2	Tertiary	Tertiary
CRET 9	Fruitland	Upper Cretaceous
CRET 10	Kirtland	Upper Cretaceous
MVRD 19	Point Lookout	Mesa Verde
DKOT 24	Dakota Group /SD/	Dakota
DKOT 25	Dakota Group /SD/	Dakota
MRSN 9	Morrison	Morrison
MRSN 12	Morrison	Morrison
BMRSN 16	Entrada	Below Morrison

LINDRITH FIELD

Well Number	Formation	Geological Group
CRET 4	Kirtland	Upper Cretaceous
CRET 8	Lewis /SD/	Upper Cretaceous
GLLP 12	Tocito	Gallup
MRSN 7	Morrison	Morrison
MRSN 8	Morrison	Morrison
BMRSN 15	Entrada	Below Morrison

BISTI FIELD

Well Number	Formation	Geological Group
CRET 6	Pictured Cliffs	Upper Cretaceous
CRET 11	Pictured Cliffs	Upper Cretaceous
CRET 12	Pictured Cliffs	Upper Cretaceous
CRET 15	Pictured Cliffs	Upper Cretaceous
MVRD 20	Point Lookout	Mesa Verde
MVRD 21	Point Lookout	Mesa Verde
MVRD 22	Point Lookout	Mesa Verde
MVRD 24	Point Lookout	Mesa Verde
GLLP 14	Gallup /SD/SH/	Gallup
GLLP 15	Gallup /SD/SH/	Gallup
GLLP 16	Gallup /SD/SH/	Gallup
GLLP 20	Gallup /SD/SH/	Gallup
GLLP 21	Gallup Lower	Gallup
DKOT 29	Dakota Group /SD/	Dakota

Table 4 (cont)
Wells Common to Fields
San Juan Basin

BLANCO FIELD

Well Number	Formation	Geological Group
CRET 22	Fruitland	Upper Cretaceous
CRET 30	Pictured Cliffs	Upper Cretaceous
CRET 35	Fruitland	Upper Cretaceous
CRET 36	Fruitland	Upper Cretaceous
CRET 38	Fruitland	Upper Cretaceous
MVRD 27	Mesa Verde	Mesa Verde
MVRD 32	Mesa Verde	Mesa Verde

GALLEGOS FIELD

Well Number	Formation	Geological Group
CRET 20	Pictured Cliffs	Upper Cretaceous
CRET 26	Pictured Cliffs	Upper Cretaceous
MVRD 23	Menefee	Mesa Verde
GLLP 25	Gallup /SD/SH/	Gallup
GLLP 27	Gallup /SD/SH/	Gallup

TABLE 5. SUMMARY OF DATA SCREENING FOR DST AND WATER WELL HEADS

SUMMARY OF DATA POINTS FOR PETROLEUM RESERVOIRS

Reservoir	Orig No. Wells	Removed	Final No.Wells
Quaternary-Tertiary (QT)	5	1	4
Upper Cretaceous (UK)	122	84	38
Mesa Verde Group (MV)	163	131	32
Gallup Formation (GL)	201	169	32
Dakota Formation (DK)	195	129	66
Morrison Formation (MR)	25	7	18
Below Morrison	75	32	43
Total	786	553	233

SUMMARY OF DATA POINTS FOR USDWs

USDW	Orig No Wells	Removed	Final No.Wells
Quaternary-Tertiary (QT)	173	29	144
Upper Cretaceous (UK)	42	3	39
Mesa Verde Group (MV)	140	14	126
Gallup Formation (GL)	45	0	45
Dakota Formation (DK)	33	0	33
Morrison Formation (MR)	55	0	55
Total	488	46	442

TABLE 6

LATITUDE, LONGITUDE AND ELEVATIONS FOR ALL USDW DATA SHOWN IN MAPS 9-26

WELL #	NORTH LATITUDE	WEST LONGITUDE	ELEV
QT- 1	36.0361	106.9589	6863
QT- 2 *	36.0333	106.9786	6795
QT- 3	36.5889	107.0047	7084
QT- 4	36.2445	107.0050	7259
QT- 5	36.8083	107.0075	7136
QT- 6	36.1667	107.0095	7237
QT- 7	36.1833	107.0128	6749
QT- 8	36.1695	107.0128	6927
QT- 9	36.9639	107.0206	7310
QT- 10	36.2472	107.0231	7184
QT- 11	36.2472	107.0275	7183
QT- 12	36.5694	107.0281	7221
QT- 13	36.7000	107.0311	7151
QT- 14 *	36.6139	107.0345	7007
QT- 15	36.2556	107.0347	7171
QT- 16	36.8500	107.0367	7075
QT- 17	36.2694	107.0397	7181
QT- 18	36.4083	107.0428	7142
QT- 19 *	36.9000	107.0450	7441
QT- 20 *	36.3639	107.0547	6723
QT- 21 *	36.8083	107.0575	7370
QT- 22 *	35.9611	107.0606	7090
QT- 23 *	36.3639	107.0617	6829
QT- 24 *	36.3639	107.0672	6843
QT- 25	36.1111	107.0731	6735
QT- 26	36.5167	107.0758	7138
QT- 27	36.9000	107.0806	7390
QT- 28	35.9972	107.0850	6872
QT- 29	37.0278	107.0861	7134
QT- 30	36.6556	107.0911	7030
QT- 31 *	36.2861	107.0970	7208
QT- 32	36.2333	107.0983	7001
QT- 33	36.3417	107.0989	7103
QT- 34	36.5556	107.1120	6872
QT- 35	36.5222	107.1139	7035
QT- 36	36.8667	107.1203	7118
QT- 37	36.6417	107.1220	6962
QT- 38	36.6222	107.1228	6870
QT- 39	36.3722	107.1322	7107
QT- 40	36.9361	107.1333	7060
QT- 41	36.5917	107.1408	6946
QT- 42	37.0445	107.1478	6300
QT- 43	36.7195	107.1533	6870
QT- 44	36.1528	107.1606	9999
QT- 45	36.7000	107.1675	6815
QT- 46	36.0556	107.1678	6464
QT- 47	36.8195	107.1694	6853
QT- 48	36.8833	107.1703	6950
QT- 49 *	36.5750	107.1708	6996
QT- 50	36.1056	107.1719	6496
QT- 51 *	36.5500	107.1731	7024
QT- 52 *	36.5611	107.1733	7026
QT- 53	36.8639	107.1756	6981
QT- 54	36.8000	107.1786	6905
QT- 55 *	36.1083	107.1847	6957
QT- 56	36.0167	107.1856	6441
QT- 57	36.0167	107.1886	6515
QT- 58	36.5583	107.1900	6815
QT- 59	36.3583	107.1911	7140
QT- 60	36.5028	107.1925	6818
QT- 61	36.2917	107.1967	6909
QT- 62	36.2472	107.1972	6904
QT- 63	36.8417	107.1992	6977
QT- 64 *	36.6972	107.2075	6178
QT- 65	36.6972	107.2089	6198
QT- 66	36.3528	107.2136	6783
QT- 67 *	36.8445	107.2181	7116
QT- 68	36.0306	107.2195	6562
QT- 69	36.4833	107.2256	6780
QT- 70	36.4917	107.2311	6910
QT- 71	36.5417	107.2417	6722
QT- 72	36.4111	107.2506	6725
QT- 73	36.2667	107.2533	6847
QT- 74	36.2861	107.2553	6802
QT- 75	36.2722	107.2622	6706
QT- 76	36.4889	107.2661	6678
QT- 77	36.2472	107.2703	6760
QT- 78	36.2694	107.2895	6765
QT- 79	36.0917	107.2897	6438
QT- 80	36.4500	107.2931	6631
QT- 81	36.5889	107.2975	6569
QT- 82	36.0667	107.2975	6526
QT- 83	36.2083	107.3139	6714
QT- 84	36.4056	107.3220	6582
QT- 85	36.5806	107.3247	6541
QT- 86	36.2528	107.3264	6635
QT- 87	36.3889	107.3300	6624
QT- 88	36.5167	107.3314	6531
QT- 89	37.0861	107.3328	6070
QT- 90 *	36.6694	107.3411	6135
QT- 91	36.0500	107.3439	6790
QT- 92	36.5639	107.3461	6519
QT- 93	36.2389	107.3500	6788
QT- 94	36.2417	107.3500	6788

* DENOTES POINT NOT INCLUDED IN CONTOURING.

TABLE 6 (cont)

LATITUDE, LONGITUDE AND ELEVATIONS FOR ALL USDW DATA SHOWN IN MAPS 9-26

WELL #	NORTH LATITUDE	WEST LONGITUDE	ELEV	WELL #	NORTH LATITUDE	WEST LONGITUDE	ELEV
QT- 95 *	36.1833	107.3908	6812	QT- 142 *	36.3944	107.8439	6516
QT- 96	36.3694	107.3928	6258	QT- 143	36.5250	107.8445	6149
QT- 97	36.4167	107.3964	6211	QT- 144	36.9195	107.8467	6024
QT- 98	36.4139	107.3967	6209	QT- 145 *	36.4445	107.8514	6603
QT- 99	36.3917	107.3978	6180	QT- 146	37.0667	107.8742	5960
QT-100	37.0611	107.4053	6120	QT- 147	37.0889	107.8742	6010
QT-101	37.0917	107.4097	9999	QT- 148	36.5250	107.8747	6342
QT-102	37.0917	107.4120	6070	QT- 149	37.0833	107.8795	5947
QT-103	37.0917	107.4122	6110	QT- 150	36.3250	107.8886	6220
QT-104	37.0583	107.4133	9999	QT- 151	36.9306	107.8908	9999
QT-105	37.0528	107.4233	9999	QT- 152	36.3889	107.8936	6310
QT-106	37.0694	107.4286	6140	QT- 153	36.5945	108.0050	6035
QT-107	36.7167	107.4422	6113	QT- 154	37.0722	108.0203	6260
QT-108	36.3000	107.4553	6600	QT- 155	37.0722	108.0206	6250
QT-109	36.6611	107.4936	6125	QT- 156	36.6139	108.0261	6035
QT-110	36.5861	107.4981	6252	QT- 157	36.7861	108.0300	5511
QT-111	36.5778	107.4983	6198	QT- 158	36.9417	108.0422	5866
QT-112	36.6889	107.5011	6118	QT- 159	36.7195	108.0536	5731
QT-113	37.0945	107.5042	6220	QT- 160	36.6806	108.0542	5662
QT-114	36.2750	107.5181	6309	QT- 161	36.5528	108.0628	6070
QT-115	37.0972	107.5208	6280	QT- 162	36.8944	108.0736	5558
QT-116	36.4889	107.5261	6224	QT- 163	36.7222	108.0933	5734
QT-117	36.5861	107.5283	6181	QT- 164	36.4806	108.1547	5975
QT-118	36.4917	107.5558	6101	QT- 165	36.6195	108.1925	5963
QT-119	36.5056	107.5586	6098	QT- 166 *	36.6500	108.2186	6015
QT-120	37.0778	107.5639	6390	QT- 167	36.6889	108.2283	5791
QT-121 *	36.0167	107.5714	6850	QT- 168 *	36.2056	108.8500	8240
QT-122	37.0861	107.5983	6430	QT- 169 *	36.2083	108.9411	8900
QT-123	36.6000	107.6061	6135	QT- 170 *	36.1667	108.9417	7760
QT-124	37.0917	107.6061	6460	QT- 171 *	36.3111	109.0317	7010
QT-125 *	36.1639	107.6103	6820	QT- 172 *	36.4833	109.1028	8470
QT-126	36.5528	107.6617	6227	QT- 173 *	36.4333	109.1058	7900
QT-127	36.8778	107.6831	5911	UK- 1	36.0278	107.3467	6590
QT-128	36.9306	107.6939	5987	UK- 2	36.0333	107.3578	6570
QT-129	36.9778	107.6986	6046	UK- 3	35.9972	107.3695	6591
QT-130 *	36.4778	107.7147	6399	UK- 4	35.9000	107.3783	6590
QT-131	36.7195	107.7161	5801	UK- 5 *	36.0306	107.3786	6602
QT-132	36.3806	107.7464	6374	UK- 6	37.0917	107.4120	6094
QT-133	36.5389	107.7520	6245	UK- 7	36.0250	107.4122	6587
QT-134	36.5722	107.7528	6227	UK- 8	36.0306	107.4125	6641
QT-135	36.5194	107.7531	6243	UK- 9	36.0583	107.4328	6500
QT-136	36.2945	107.7708	6339	UK- 10	36.0111	107.5239	6573
QT-137	36.6250	107.7881	6249	UK- 11 *	36.1111	107.5239	6245
QT-138	36.8278	107.7967	5643	UK- 12	35.6500	107.7892	6753
QT-139	36.4861	107.8383	6184	UK- 13	36.2028	107.8297	6270
QT-140	36.5972	107.8411	6133	UK- 14	36.2667	107.8478	6331
QT-141	36.5056	107.8420	6152	UK- 15	36.2750	107.8742	6208

* DENOTES POINT NOT INCLUDED IN CONTOURING.

TABLE 6 (cont)

LATITUDE, LONGITUDE AND ELEVATIONS FOR ALL USDW DATA
SHOWN IN MAPS 9-26

WELL #	NORTH LATITUDE	WEST LONGITUDE	ELEV	WELL #	NORTH LATITUDE	WEST LONGITUDE	ELEV
UK- 16	35.5861	107.8772	6813	MV- 21	36.0500	107.3467	6622
UK- 17	36.2917	107.8861	6272	MV- 22	35.6250	107.3506	6400
UK- 18	36.1945	107.9108	6174	MV- 23	35.6833	107.3533	6330
UK- 19	36.1889	107.9108	6211	MV- 24	35.6694	107.3711	6340
UK- 20	36.1972	107.9111	6224	MV- 25	35.4250	107.3864	7740
UK- 21	36.1945	107.9378	6145	MV- 26 *	35.8445	107.3969	6612
UK- 22	36.2639	107.9378	6186	MV- 27 *	35.8695	107.4411	6328
UK- 23	36.2695	107.9383	6203	MV- 28	35.2445	107.4467	7814
UK- 24	35.7028	108.0450	6734	MV- 29	36.0445	107.4603	6540
UK- 25	37.0111	108.1325	5899	MV- 30	35.3806	107.4672	7845
UK- 26	36.2528	108.1386	5881	MV- 31 *	36.0056	107.4825	6163
UK- 27	36.3611	108.1436	5885	MV- 32	35.7056	107.4906	6420
UK- 28	36.3611	108.1522	5857	MV- 33	36.0778	107.4925	6580
UK- 29	36.3917	108.1525	5858	MV- 34	35.5000	107.4981	7900
UK- 30	36.3306	108.1583	5860	MV- 35	35.8111	107.5903	6510
UK- 31	35.7167	108.1875	7436	MV- 36	35.9333	107.6278	6600
UK- 32	36.7222	108.2186	5650	MV- 37	36.0611	107.6406	6345
UK- 33	36.4083	108.2942	5624	MV- 38	36.1028	107.6417	6437
UK- 34	36.9250	108.3617	5216	MV- 39 *	35.9028	107.6475	6700
UK- 35	36.9222	108.3631	5358	MV- 40	36.1111	107.6547	6417
UK- 36	36.8111	108.3717	5165	MV- 41	36.0806	107.6547	6430
UK- 37	36.8111	108.3720	5181	MV- 42	36.0833	107.6556	6329
UK- 38 *	36.9056	108.3806	5163	MV- 43	36.0722	107.6703	6395
UK- 39	36.7972	108.3953	5112	MV- 44	35.8861	107.6722	6443
UK- 40	36.8611	108.3953	5284	MV- 45	35.9028	107.6983	6479
UK- 41	36.4944	108.4972	5398	MV- 46	35.9695	107.7083	6327
UK- 42	35.7139	108.7478	6275	MV- 47	35.7639	107.7231	6875
MV- 1	35.9000	107.0578	6466	MV- 48	35.8195	107.7231	6839
MV- 2	35.8750	107.0953	6446	MV- 49	35.7639	107.7231	6863
MV- 3 *	35.1806	107.0961	5584	MV- 50	35.9000	107.7475	6497
MV- 4	35.8778	107.1322	6345	MV- 51	35.8944	107.7520	6475
MV- 5	36.0556	107.1678	6487	MV- 52	36.0361	107.7558	6300
MV- 6	35.6889	107.2367	6029	MV- 53	35.8945	107.7567	6388
MV- 7	35.8000	107.2442	6050	MV- 54	35.9611	107.7567	6416
MV- 8	35.6139	107.2508	7210	MV- 55	35.9778	107.7608	6234
MV- 9	35.8139	107.2508	6310	MV- 56 *	36.2389	107.7742	5869
MV- 10	35.6917	107.2575	6400	MV- 57 *	36.0694	107.7856	6077
MV- 11 *	35.6694	107.2770	6210	MV- 58	36.0306	107.8172	6238
MV- 12	35.7028	107.2911	6311	MV- 59	36.1500	107.8383	6249
MV- 13	35.6889	107.2917	6180	MV- 60	36.1028	107.8545	6305
MV- 14	35.7639	107.3086	6320	MV- 61	35.9611	107.8747	6456
MV- 15	35.8528	107.3114	6263	MV- 62	36.1611	107.9036	6305
MV- 16	35.8583	107.3220	6446	MV- 63	36.0917	107.9647	6210
MV- 17	35.7750	107.3261	6211	MV- 64	35.8944	107.9675	6319
MV- 18	35.7417	107.3261	6360	MV- 65	36.1556	107.9992	6075
MV- 19 *	35.9222	107.3283	6647	MV- 66	35.8583	108.0120	6330
MV- 20 *	35.9222	107.3381	6420	MV- 67	36.0806	108.0144	6103

* DENOTES POINT NOT INCLUDED IN CONTOURING.

TABLE 6 (cont)

LATITUDE, LONGITUDE AND ELEVATIONS FOR ALL USDW DATA
SHOWN IN MAPS 9-26

WELL #	NORTH LATITUDE	WEST LONGITUDE	ELEV
MV- 68	35.8667	108.0375	6503
MV- 69	36.0306	108.0522	6050
MV- 70	36.0556	108.0853	6058
MV- 71	35.7917	108.0939	6551
MV- 72	36.1167	108.0947	5986
MV- 73	36.0445	108.1094	6077
MV- 74	35.9306	108.1097	6247
MV- 75 *	36.3750	108.1308	6155
MV- 76 *	35.9333	108.1542	6416
MV- 77	36.3250	108.1558	5821
MV- 78	36.1361	108.1636	6047
MV- 79	35.9139	108.1645	6291
MV- 80 *	36.0611	108.1814	6037
MV- 81	36.2917	108.1858	5817
MV- 82	35.8611	108.1914	9999
MV- 83	36.0000	108.1983	6064
MV- 84	36.3861	108.2156	5763
MV- 85	36.1278	108.2242	5866
MV- 86	36.0806	108.2733	5662
MV- 87	36.1556	108.3008	5800
MV- 88	36.2111	108.3239	5819
MV- 89	36.0972	108.3250	5828
MV- 90	36.9611	108.3272	5545
MV- 91	36.3917	108.3272	5629
MV- 92	37.0167	108.3370	6095
MV- 93	36.1361	108.3689	9999
MV- 94	36.2667	108.3903	5759
MV- 95	36.3000	108.4167	5595
MV- 96	36.1417	108.4217	5774
MV- 97	36.1167	108.4331	5746
MV- 98	35.9833	108.4464	9999
MV- 99	35.8583	108.4497	9999
MV-100	35.8667	108.4819	6237
MV-101	36.9889	108.4850	5506
MV-102 *	36.3445	108.4947	6407
MV-103	36.9667	108.4989	5492
MV-104	36.3861	108.5053	5448
MV-105	36.0639	108.5092	5828
MV-106	35.9056	108.5139	9999
MV-107	37.0500	108.5231	5513
MV-108	35.6056	108.5464	6757
MV-109	36.2000	108.5467	5637
MV-110	35.9278	108.5495	6199
MV-111	35.9972	108.5700	5765
MV-112	35.9972	108.5700	5765
MV-113	36.1611	108.5897	5635
MV-114	36.1222	108.5908	5618
MV- 115	35.9583	108.6122	9999
MV- 116	36.2333	108.6136	5681
MV- 117	36.0445	108.6186	5827
MV- 118	36.2806	108.6197	5617
MV- 119	36.4945	108.6233	5410
MV- 120	36.0833	108.6339	5731
MV- 121	36.4472	108.6386	5400
MV- 122	35.9195	108.6436	9999
MV- 123	35.9167	108.6461	5910
MV- 124	35.9861	108.6467	5906
MV- 125	36.4028	108.6539	9999
MV- 126	36.1583	108.6875	5983
MV- 127	36.2333	108.7072	5780
MV- 128	36.2083	108.7120	5838
MV- 129	36.2917	108.7272	9999
MV- 130	35.7417	108.7439	6231
MV- 131	35.7195	108.7520	6360
MV- 132	36.2306	108.7608	5883
MV- 133	35.9194	108.7664	6104
MV- 134	35.7306	108.7689	6425
MV- 135	35.7333	108.7750	6219
MV- 136	35.8833	108.7792	6298
MV- 137	35.7195	108.7953	6056
MV- 138	36.2806	108.8022	9999
MV- 139	35.8056	108.8028	6280
MV- 140	35.7667	108.8358	6430
GL- 1	35.2389	107.0958	5589
GL- 2	35.6000	107.1520	5875
GL- 3	35.6472	107.2036	6288
GL- 4	35.7278	107.2228	6497
GL- 5	35.1972	107.5411	6681
GL- 6	35.8500	107.5622	6590
GL- 7	35.5222	107.6633	6481
GL- 8	36.1611	107.9039	6480
GL- 9	35.9139	107.9289	6573
GL- 10	36.0639	107.9397	9999
GL- 11	36.0472	107.9778	6442
GL- 12	35.7250	108.0208	6797
GL- 13	35.8750	108.0667	6398
GL- 14	35.8195	108.1797	6644
GL- 15	35.8111	108.2433	6757
GL- 16	35.6778	108.2836	6939
GL- 17	35.7306	108.2895	6666
GL- 18	35.7889	108.3183	6597
GL- 19	35.7083	108.4778	6705
GL- 20	35.8750	108.5228	6462
GL- 21	35.7750	108.5256	6683

* DENOTES POINT NOT INCLUDED IN CONTOURING.

TABLE 6 (cont)

LATITUDE, LONGITUDE AND ELEVATIONS FOR ALL USDW DATA SHOWN IN MAPS 9-26

WELL #	NORTH LATITUDE	WEST LONGITUDE	ELEV	WELL #	NORTH LATITUDE	WEST LONGITUDE	ELEV
GL- 22	35.7667	108.5945	9999	DK- 24	37.0000	108.7656	5187
GL- 23	35.8445	108.6289	5946	DK- 25	36.8250	108.7983	5337
GL- 24	36.0083	108.6481	6045	DK- 26	37.0945	108.8528	4979
GL- 25	35.9917	108.6483	6042	DK- 27	36.5000	108.8653	6002
GL- 26	36.0778	108.6620	9999	DK- 28	36.3861	108.8964	6283
GL- 27	35.9167	108.6719	9999	DK- 29	36.5361	108.9547	6239
GL- 28	36.5667	108.6861	9999	DK- 30	37.0945	108.9770	4848
GL- 29	35.8306	108.6922	9999	DK- 31	35.7500	109.8911	9999
GL- 30	35.8389	108.6995	6196	DK- 32	35.9111	109.9317	9999
GL- 31	35.5556	108.7589	6310	DK- 33	35.7389	109.9606	9999
GL- 32	35.6778	108.7683	6025	MR- 1	35.7417	106.8864	6700
GL- 33	35.7917	108.7728	9999	MR- 2	35.2833	107.2306	5997
GL- 34	35.6361	108.7883	6228	MR- 3	35.3389	107.2958	5786
GL- 35	36.3472	108.8086	5818	MR- 4	35.3806	107.2969	6028
GL- 36	36.3389	108.8125	9999	MR- 5	35.3083	107.3061	5485
GL- 37	35.6333	108.8292	6300	MR- 6	35.3222	107.3103	5803
GL- 38	35.6778	108.8356	6411	MR- 7	35.2778	107.3108	9999
GL- 39	36.4833	108.8392	5699	MR- 8	35.2722	107.3108	5854
GL- 40	36.6667	108.8514	5542	MR- 9	35.3500	107.3117	5550
GL- 41	35.5889	108.9053	6341	MR- 10	35.2333	107.3158	5859
GL- 42	35.7472	108.9844	6524	MR- 11	35.2306	107.3172	5998
GL- 43	35.7056	109.0536	6489	MR- 12	35.3056	107.3178	5826
GL- 44	35.6611	109.0553	6492	MR- 13	35.3306	107.3189	5931
GL- 45	35.6222	109.0628	6525	MR- 14	35.2639	107.3203	5913
DK- 1	35.7861	106.9070	6660	MR- 15	35.2639	107.3203	5690
DK- 2	35.7750	106.9244	6400	MR- 16	35.2472	107.3244	5804
DK- 3	35.8139	106.9550	6375	MR- 17	35.3889	107.3272	6877
DK- 4	35.7167	107.1839	6184	MR- 18	35.1806	107.3533	5922
DK- 5	35.2306	107.2369	6083	MR- 19	35.4361	107.7825	6750
DK- 6	35.3861	107.2444	5991	MR- 20	35.3972	107.7922	6711
DK- 7	35.3583	107.3192	5897	MR- 21	35.4500	107.8594	6485
DK- 8	35.2639	107.4331	6135	MR- 22	36.0445	107.8981	6400
DK- 9	35.2556	107.4664	6470	MR- 23	35.7639	107.9447	6471
DK- 10	35.1222	107.4800	6197	MR- 24	35.6222	108.0061	6572
DK- 11	35.1667	107.5314	6120	MR- 25	35.7695	108.1220	6452
DK- 12	35.2083	107.5403	6141	MR- 26	35.7639	108.1220	6455
DK- 13	35.1861	107.5489	6138	MR- 27	35.8028	108.1439	6403
DK- 14	35.1722	107.5694	6080	MR- 28	35.8167	108.1439	6413
DK- 15	35.1583	107.7783	6305	MR- 29	35.6972	108.1528	6429
DK- 16	35.6167	107.9442	6544	MR- 30	35.7083	108.2131	6455
DK- 17	35.5667	108.0339	6856	MR- 31	35.7278	108.2272	6426
DK- 18	35.7639	108.1217	6571	MR- 32	35.7333	108.2278	6430
DK- 19	35.8445	108.2161	6635	MR- 33	35.7833	108.2364	6450
DK- 20	35.7972	108.2853	6641	MR- 34	35.7972	108.2853	6446
DK- 21	34.8611	108.6508	9999	MR- 35	36.3278	108.3247	6449
DK- 22	36.8111	108.7008	5310	MR- 36	35.8556	108.3481	6387
DK- 23	36.4833	108.7478	5368	MR- 37	35.7750	108.5256	6428

* DENOTES POINT NOT INCLUDED IN CONTOURING.

TABLE 6 (cont)

LATITUDE, LONGITUDE AND ELEVATIONS FOR ALL USDW DATA
SHOWN IN MAPS 9-26

WELL #	NORTH LATITUDE	WEST LONGITUDE	ELEV
MR- 38	35.7167	108.6439	6631
MR- 39	36.8222	108.6572	9999
MR- 40	36.6556	108.7422	5584
MR- 41	36.5361	108.7714	5716
MR- 42	36.6195	108.7786	5739
MR- 43	36.5472	108.7931	9999
MR- 44	36.6111	108.7995	5872
MR- 45	36.3139	108.8111	9999
MR- 46	36.3389	108.8175	6236
MR- 47	36.4500	108.8192	6042
MR- 48	36.4778	108.8236	6237
MR- 49	36.5250	108.8258	5759
MR- 50	36.4778	108.8753	9999
MR- 51	36.4695	108.8761	9999
MR- 52	36.5778	108.9111	6173
MR- 53	36.7833	109.0036	5598
MR- 54	36.6778	109.0183	5774
MR- 55	36.6750	109.0195	5861

* DENOTES POINT NOT INCLUDED IN CONTOURING.

Field Names	North Latitude	West Longitude	Maximum Permitted Surface Injection Pressure (psi)	Surf. Elev.	Resv*	Head .433 psi/ft Grad	Head .45 psi/ft Grad
Bisti	36.39063	-108.0143	901	6463	GLLP	8543	8465
Blanco South	36.50689	-107.4709	904	6730	TOCT	8817	8738
Cha Cha	36.63122	-108.1356	908	5156	GLLP	7253	7174
Escrito	36.30436	-107.6096	911	7343	GLLP	9447	9367
Media	35.86998	-107.1326	802	6910	ENRD	8762	8692
Papers Wash	35.87364	-107.3567	720	6629	ENRD	8292	8229
Puerto Chiquito	36.53574	-106.8491	808	7785	MNCS	9651	9580
Red Mountain	35.94374	-107.8100	810	6466	MVRD	8337	8266
Rio Puerco	36.16819	-107.0940	811	6892	PCCF	8765	8694

***RESERVOIRS:** **GLLP = Gallup, TOCT = Tocito, ENRD = Entrada, MNCS = Mancos, MVRD = Mesaverde, PCCF = Pictured Cliffs**

TABLE 7: Injection Well Locations and Heads Converted from Pressures Using .45 and .433 psi/ft Gradients and Using Ground Surface as the Datum

TABLE 8 - NEW MEXICO SAN JUAN BASIN FIELDS BY BASIN SUB AREA

WESTERN AREA		SOUTHERN AREA		INTERIOR I AREA	
FIELD	SEC-TWP-RGE	FIELD	SEC-TWP-RGE	FIELD	SEC-TWP-RGE
Beautiful Mountain	5-T26N-R19W	Blackeye	29-T20N-R 9W	Alamito	31-T23N-R 7W
Big Gap	20-T27N-R19W	**Chaco Wash (†)**	21-T20N-R 9W	Arena Blanca	
Blue Hill *	36-T32N-R18W	**Hospah (†)**	12-T17N-R 9W	Barker Creek *	16-T32N-R14W
Chimney Rock	23-T31N-R17W	**Hospah, S. (†)**	12-T17N-R 9W	Chaco	
Cone	22-T31N-R18W	Leggs	11-T21N-R10W	Eagle Mesa	12-T19N-R 4W
Hogback	19-T29N-R16W	**Lone Pine (†)**	13-T17N-R 9W	Franciscan Lake	7-T20N-R 5W
Horseshoe (†)	4-T30N-R16W	Marcelina	18-T16N-R 9W	Gallup	16T15N-R17W
Jewett Valley	3-T29N-R16W	**Miguel Creek (†)**	29-T16N-R 6W	Harper Hill *	1-T29N-R14W
Many Rocks (†)	27-T32N-R17W	**Red Mountain (†)**	29-T20N-R 9W	La Plata, NW *	35-T32N-R13W
Many Rocks, N. (†)	18-T32N-R17W	Seven Lakes	T18N-R11W	Meadows	33-T30N-R15W
Mesa (†)	24-T32N-R18W	Stoney Butte	1-T21N-R14W	**Media(†)**	14-T19N-R 3W
Pajarito	31-T29N-R17W	Walker Dome	13-T15N-R10W	Media, SW	22-T19N-R 3W
Rattlesnake (†)	1-T29N-R19W			Nageezi	15-T23N-R 8W
Salt Creek	4-T30N-R17W			Ojo *	36-T28N-R15W
Shiprock	17-T29N-R18W			Ojo Encino	21-T20N-R 5W
Shiprock, N.	14-T30N-R18W			**Papers Wash (†)**	15-T19N-R 5W
Slick Rock	36-T30N-R17W			Pot Mesa	3-T20N-R 6W
Straight Canyon	14-T31N-R16W			Rusty	16-T22N-R 7W
Table Mesa	3-T27N-R17W			**San Luis(†)**	21-T18N-R 3W
Tocito Dome	17-T26N-R18W			San Luis, S.	33-T18N-R 3W
Tocito Dome, N. (†)	34-T27N-R18W			San Ysidro	29-T21N-R 3W
				Snake Eyes	20-T21N-R 8W
				Star	16-T19N-R 6W
				Torreon	17-T19N-R 4W
				Twin Mounds *	4-T29N-R14W
				Ute Dome *	36-T32N-R14W
				Verde	14-T31N-R15W
				Waterflow, S.	19-T29N-R15W

(*) denotes gas field
Injection Field (†)

TABLE 8--SAN JUAN BASIN FIELDS BY BASIN SUB AREAS

INTERIOR II AREA		INTERIOR II AREA		INTERIOR II AREA	
FIELD	SEC-TWP-RGE	FIELD	SEC-TWP-RGE	FIELD	SEC-TWP-RGE
Adobe	13-T24N-R 4W	Devils Fork	16-T24N-R 6W	Navajo City *	35-T30N-R 8W
Alamo	4-T30N-R 9W	Dogie Canyon *	15-T26N-R 6W	Nipp *	17-T26N-R12W
Albino *	26-T32N-R 8W	Dufers Point	17-T25N-R 8W	Ojito	18-T25N-R 3W
Angel's Peak	4-T27N-R10W	**Escrito (†)**	27-T24N-R 7W	Ojito, N.E.	23-T26N-R 3W
Armenta	28-T29N-R10W	Five Lakes	25-T22N-R 3W	Oswell	34-T30N-R11W
Aztec	16-T30N-R11W	Flora Vista	10-T30N-R12W	Otero	22-T25N-R 5W
Ballard *	4-T25N-R 7W	Fulcher Kutz *	34-T29N-R11W	Parlay	29-T22N-R 3W
Basin *	4-T27N-R10W	Gallegos	27-T27N-R11W	Pettigrew	9-T26N-R 6W
Bisti(†)	31-T26N-R12W	Gallegos, S. *	2-T26N-R12W	Pinon	13-T28N-R12W
Blanco *	27-T31N-R10W	Gavilan	26-T25N-R 2W	Pinon, N. *	28-T29N-R12W
Blanco, East *	18-T30N-R 4W	Glades *	36-T32N-R12W	Potwin *	15-T24N-R 8W
Blanco, South(†)	15-T26N-R 6W	Gobernador	32-T20N-R 9W	**Puerto Chiquito,E.(†)**	5-T26N-R 1E
Blanco, South(†)	9-T26N-R 6W	Gonzales (Mesa) *	6-T25N-R 5W	**Puerto Chiquito,W. (†)**	13-T25N-R 1W
Bloomfield	14-T29N-R11W	Harris Mesa *	29-T28N-R 9W	Regina	
Boulder	15-T28N-R 1W	Huerfano *	24-T26N-R10W	**Rio Puerco (†)**	31T21N-R 2W
BS Mesa *	5-T26N-R 4W	Knickerbocker Buttes	17-T30N-R10W	Rosa *	20-T32N-R 5W
Buena Suerte	3-T25N-R11W	Kutz	28-T28N-R11W	Schmitz-Torreon *	34-T24N-R 1W
Campanero *	4-T27N-R 5W	Kutz, West *	22-T28N-R12W	Sedro Canyon	23-T31N-R 9W
Campanero, E. *	7-T27N-R 4W	**La Plata (†)**	10-T31N-R12W	Simpson	26-T28N-R12W
Campo *	11-T29N-R 4W	Largo *	3-T27N-R 9W	Sleeper	23-T26N-R 3W
Cedar Hill *	31-T31N-R11W	Lindrith	20-T24N-R 2W	Tapacito	14-T26N-R 4W
Cha Cha (†)	17-T28N-R13W	Lindrith, S.	5-T23N-R 4W	**Totah (†)**	27-T29N-R13W
Chacon	23-T23N-R 3W	Lindrith, W.	3-T24N-R 4W	Trail Canyon	
Choza Mesa *	14-T29N-R 4W	Los Pinos, North *	18-T32N-R 7W	Venado	8-T22N-R 5W
Conner *	1- T30N-R14W	Los Pinos, South *	27-T31N-R 7W	Waw *	32-T27N-R13W
Cottonwood *	35-T32N-R 5W	Lybrook	10-T23N-R 7W	White Wash	2-T24N-R 9W
Counselors	3-T23N-R 6W	Middle Canyon	14-T32N-R15W		
Crouch Mesa *	4-T29N-R12W	Mount Nebo *	28-T28N-R10W		
Cuervo	28-T27N-R 8W	Nenahnezad	10-T29N-R15W		

(*) denotes gas field
Injection Field (†)

TABLE 9
WESTERN AREA FIELDS SUMMARY
DEEP WELLS ONLY

FIELD	LOCATION	DISC YEAR	WELLS DRL	PRODUCING FORMATIONS AND DEPTHS
Beautiful Mntn	5-T26N-R19W	1975	15	Mississippian, 6000; Pennsylvanian, 5500.
Big Gap	20-T27N-R19W	1979	2	Pennsylvanian, 5500.
Blue Hill	26-T32N-R18W	1953	1	Pennsylvanian Paradox, 7650.
Chimney Rock	34-T31N-R17W	NA	5	
Cone	22-T31N-R18W	1964	1	Pennsylvanian Paradox, 6800.
Hogback	19-T29N-R16W	1952	6	Mississippian, 7000; Pennsylvanian, 6350.
Pajarito	31-T29N-R17W	1963	4	Pennsylvanian, 7200.
Rattlesnake (*)	13-T29N-R19W	1929	12	Mississippian, 7000; Pennsylvanian, 6350.
Table Mesa	3-T27N-R17W	1951	7	Mississippian, 7500; Pennsylvanian, 7050.
Tocito Dome	17-T26N-R18W	1963	91	Pennsylvanian, 6350.
Tocito Dome, N. (*)	34-T27N-R18W	1963	5	Mississippian, 6820; Pennsylvanian, 6325.
(*) INJECTION FIELD		Total	149	

TABLE 10
WESTERN AREA FIELDS SUMMARY
SHALLOW WELLS ONLY

FIELD	LOCATION	DISC YEAR	WELLS DRL	PRODUCING FORMATION	AVG. DEPTH
Chimney Rock	34-T31N-R17W	NA	29	Dakota	1200
Hogback	19-T29N-R16W	1922	83	Dakota	800
Horseshoe (*)	4-T30N-R16W	1956	450	Gallup	1500
Jewett Valley	3-T29N-R16W	1961	2	Gallup	3650
Many Rocks (*)	27-T32N-R17W	1962	93	Gallup	1250
Many Rocks, N. (*)	18-T32N-R17W	1963	23	Gallup	1650
Mesa (*)	24-T32N-R18W	1961	26	Gallup	1350
Rattlesnake (*)	1-T29N-R19W	1924	264	Dakota	750
				Gallup	300
Salt Creek	4-T30N-R17W	1958	39	Dakota	1040
Ship Rock	17-T29N-R18W	1959	103	Gallup	100
				Dakota	800
Ship Rock, N.	14-T30N-R18W	1966	2	Dakota	1200
Ship Rock, N.	14-T30N-R18W	1967	2	Gallup	390
Slick Rock	36-T30N-R17W	1967	102	Dakota	660
Straight Canyon	14-T31N-R16W	1975	8	Dakota	2270
Table Mesa	3-T27N-R17W	1951	44	Dakota	
Tocito Dome	17-T26N-R18W	1963	1	None	
		Total	1271		

(*) INJECTION FIELD

TABLE 11 COMBINED WESTERN AREA WELL SUMMARY

(DEEP AND SHALLOW)

Field	Total Number of Abandoned Wells	Total Number of Active Wells	# of Abandoned Wells Examined	# of Active Wells Examined	Total Number of Wells Examined		Total # No Info Wells	Total # No Inter Wells	Total # Abe Runs
Horseshoe (I-act, *)	47	475	2	5	7		0	7	0
Many Rocks (I-act, *)	8	78	2	5	7		0	7	0
Many Rocks, N (I-act, *)	2	18	3	4	7		0	7	0
Mesa (I-act, *)	7	20	4	8	12		0	12	0
Rattlesnake (I-act,†)	90	121	7 (all deep)	5	12		5	0	7
Tocito Dome, N. (I-act)	1	0	4 (all deep)	3 (all deep)	7		0	0	7
Total	155	712	22	30	52		5	33	14

I-act denotes active injection project
(*) Shallow field. No intersections with a USDW. No sample taken.
(†) Field includes both deep and shallow wells. Shallow wells have no intersections with USDWs in the western area.

TABLE 12 ANALYSIS OF WESTERN AREA WELLS

Field	Well Name	Status	No Info	No Inter		BP Abe	TP Abe	# TP Plugs	
Horseshoe	Robby #1	D&A		√					
	Navajo D #1	D&A		√					
	Horseshoe Gal U #119	Oil		√					
	Horseshoe Gal U #46	Oil		√					
	Horseshoe Gal U #254	Oil		√					
	NF Hogback Unit #37	Inj		√					
	Navajo #16	Inj		√					
	Note: Entire field has no intersection!								
	The Horseshoe Field produces only from Gallup, although some wells were								
	drilled to Dakota. Injection is in the Gallup and there is no USDW above the Gallup.								

TABLE 12 ANALYSIS OF WESTERN AREA WELLS

			TABLE 12 (pg 2)						
	Well Name	Status	No Info	No Inter		BP Abe	TP Abe	# TP Plugs	
Field									
Many Rocks	Navajo Ute #1	P&A		√					
	Navajo #9-27	D&A		√					
	Nav Tribe of Ind #209	Oil		√					
	Navajo #4-27	Oil		√					
	Navajo P#3	Oil		√					
	Navajo M#2	Inj/TA		√					Well status uncertain
	Nav Tribe of Ind #219	Inj/Abd		√					
	Note: This field has no intersections.								

TABLE 12 ANALYSIS OF WESTERN AREA WELLS

			TABLE 12 (pg 3)						
	Well Name	Status	No Info	No Inter		BP Abe	TP Abe	# TP Plugs	
Field									
Many Rocks,N	Navajo AA # 26	D&A		√					
	Navajo AA #19-Y	D&A		√					
	Navajo AA #7	Oil		√					
	Navajo AA #9	Oil		√					
	Navajo AA #2	Oil		√					
	Navajo AA #4	Inj ?	√	√					No injection report.
	Navajo Tribal AA #18	Inj/Abd		√					
	Note: This field has no intersections.								

TABLE 12 ANALYSIS OF WESTERN AREA WELLS

TABLE 12 (pg 4)

	Well Name	Status	No Info	No Inter		BP Abe	TP Abe	# TP Plugs	
Field									
Mesa	Navajo Tribal C #7	P&A		√					
	Navajo B #1	P&A		√					
	Navajo #5	P&A		√					
	Navajo #6	P&A		√					
	Horseshoe #1	Oil		√					
	Navajo Tribal C #6	Oil		√					
	Navajo B #3	Oil		√					
	Navajo #11	Inj		√					
	Aztec-Navajo A #5	Inj		√					
	Navajo #3	Inj		√					
	Navajo #5	Inj		√					
	Navajo Tribal C #5	Inj		√					
	Note: This entire field has no intersections with USDWs								

TABLE 12 ANALYSIS OF WESTERN AREA WELLS

			TABLE 12 (pg 5)						
	Well Name	Status	No Info	No Inter		BP Abe	TP Abe	# TP Plugs	
Field									
									Note: Wells with 0 plugs
Rattlesnake	Rattlesnake #147	P&A	√						actually have plugs in the
	Rattlesnake #135	P&A				2	1	0	wellbore, but the plugs are
	Rattlesnake #24	P&A	√						below the Dakota injection
	Kern Co. Navajo #1	P&A				1	1	1	zone and the Gallup USDW
	Rattlesnake #141	P&A				1	1	1	so are not given credit in the
	Rattlesnake #143	P&A				1	0	0	ABE runs between Dakota an
	Rattlesnake #140	P&A	√						Gallup.
	Rattlesnake #50	Oil	√						No csg cement report
	Navajo #148	Oil				1	2	-	
	Rat Nav Ind Res #1	Oil	√						No csg cement report
	Navajo #155	Inj				1	3	-	
	Navajo #151	Inj				1	2	-	Missing conversion report.
									Evaluated on construct data.

TABLE 12 ANALYSIS OF WESTERN AREA WELLS

			TABLE 12 (pg 6)						
	Well Name	Status	No Info	No Inter		BP Abe	TP Abe	# TP Plugs	
Field									
Tocito Dome N	Navajo Tocito #1	P&A				3	5	4	
	Navajo Tocito #4	P&A				3	5	4	
	navajo #5	P&A				3	3	3	
	Navajo Tribal P #4	Oil				1	2	-	
	Navajo Tribal N #11	Oil				1	2	-	
	Navajo Tribal AR #4	Oil				1	1	-	
	Navajo Tocito #4	Inj /ABD				3	5	4	No injection information. Evaluated as an abandoned well.

TABLE 13
SOUTHERN AREA FIELDS SUMMARY

FIELD	LOCATION	DISC YEAR	WELLS DRLD	PRODUCING FORMATION	AVG. DEPTH
Blackeye	29-T20N-R 9W	1972	15	Dakota	3780
				Mesaverde	1050
Chaco Wash (*)	21-T20N-R 9W	1961	79	Mesaverde	340
Hospah (*) & S. Hospah (*)	12-T17N-R 9W	1927	319	Dakota/Hospah	2625
Leggs	11-T21N-R10W	1977	2	Entrada	5400
Lone Pine (*)	13-T17N-R 9W	1970	45	Dakota	2550
Marcelina	18-T- 6N-R 9W	1975	11	Dakota	1820
				Gallup	860
Miguel Creek (*)	29-T16N-R 6W	1973	66	Gallup	740
Red Mountain (*)	29-T20N-R 9W	1934	133	Mesaverde	500
Seven Lakes	18-T 8N-R10W	1911	92	Menefee	400
Stoney Butte	1-T21N-R14W	1950	18	Dakota	3650
				Mesaverde	1000
Walker Dome	13-T15N-R10W	NA	39	Mancos	1000
	Total		819		

(*) INJECTION FIELD

TABLE 14 COMBINED SOUTHERN AREA WELL SUMMARY

Field	Total Number of Abandoned Wells	Total Number of Active Wells	# of Abandoned Wells Examined	# of Active Wells Examined	Total Number of Wells Examined	Total # No Info Wells	Total # No Inter Wells	Total # Abe Runs
Chaco Wash (I-act, *)	31	39	32	7	39	0	39	0
Hospah (I-act, †)	56	152	49	22	71	28	4	39
Hospah, S (I-act)	4	99	4	7	11	1	0	10
Lone Pine (I-act, *)	8	12	12	3	15	1	0	14
Miguel Creek (I-act)	9	51	8	6	14	4	0	10
Red Mountain (I-act)	56	65	9	5	14	0	14	0
Total	164	418	114	50	164	34	57	73

I-act denotes active injection project

(*) Shallow field. No intersections with a USDW. No sample taken.

TABLE 15 ANALYSIS OF SOUTHERN AREA WELLS

			TABLE 15 (pg 1)						
Field	Well Name	Status	No Info	No Inter		BP Abe	TP Abe	# TP Plugs	
Chaco Wash	State K #1883	D&A		√					
	State of NM #2	P&A		√					
	Scanlon #18	P&A		√					
	Scanlon #14	P&A		√					
	Santa Fe RR #6	P&A		√					
	Santa Fe RR #9	P&A		√					
	Santa Fe RR #12	P&A		√					
	Ray #1	D&A		√					
	SFP Mesa #1	P&A		√					
	Santa Fe Pacific RR #8	P&A		√					
	Santa Fe RR #13	D&A		√					
	Santa Fe RR #11	P&A		√					
	Santa Fe Pacific RR #7	P&A		√					
	Santa Fe RR #11	P&A		√					
	Santa Fe Pacific RR #9	P&A		√					
	State #1	P&A		√					
	S. F. Chaco Wash #83-	P&A		√					
	Santa Fe RR #10	D&A		√					
	Santa Fe RR #1	P&A		√					
	Santa Fe RR #2	P&A		√					
	Santa Fe RR #3	P&A		√					
	Santa Fe Pacific RR #1	P&A		√					
	Santa Fe RR #5	D&A		√					
	Scanlon #17	P&A		√					
	State #5	P&A		√					
	Ohwell #9	P&A		√					
	Ohwell #10	P&A		√					
	Ohwell #11	P&A		√					
	Ohwell #6	P&A		√					

TABLE 15 ANALYSIS OF SOUTHERN AREA WELLS

			TABLE 15 (pg 2)						
	Well Name	Status	No Info	No Inter		BP Abe	TP Abe	# TP Plugs	
Chaco Wash	Scanlon-Ray #6	P&A		√					
(cont'd)	Ohwell #7	P&A		√					
	State #4	P&A		√					
	Santa Fe Pacific #116	SUSP	√	√					
	State #34	SUSP	√	√					
	Santa Fe RR #6	Oil		√					
	State #29	Oil		√					
	State #2	Oil		√					
	State #6	Inj		√					
	Ohwell #5	Inj		√					
	Note: This entire field has no intersections with a USDW.								

TABLE 15 ANALYSIS OF SOUTHERN AREA WELLS

			TABLE 15 (pg 3)						
	Well Name	Status	No Info	No Inter		BP Abe	TP Abe	# TP Plugs	
Field									
Hospah	Santa Fe RR B #38	P&A				2	2	1	
	Walker Dome #2	P&A		√					
	Santa Fe A #1	D&A				1	1	1	
	Santa Fe RR #30	P&A				1	3	3	
	Hansen #5	P&A				1	1	1	
	Santa Fe #11	P&A				1	1	1	
	Santa Fe #1	P&A				1	1	1	
	Santa Fe #2	P&A	√						No state P&A rpt.
	Santa Fe #45	P&A	√						No state P&A rpt.
	Santa Fe #24	P&A				2	2	1	
	Hospah SU #11	P&A				3	2	1	
	Hospah SU #4	P&A	√						No state P&A rpt.
	Santa Fe #4	D&A	√						No state P&A rpt.
	Hospah SU #14	P&A				3	3	2	
	Santa Fe #14	D&A	√						No state P&A rpt.
	Santa Fe #20	D&A	√						No state P&A rpt.
	Santa Fe #23	D&A	√						No state P&A rpt.
	Hospah Santa Fe #1	P&A	√						No state P&A rpt.
	(no name) #2	D&A	√	√					State card only.
	GOVT #24	D&A	√						No state P&A rpt.
	Mcmillan-White #1	P&A	√	√					No state P&A rpt.
	McMillan-White #1-X	P&A				2	2	1	
	Santa Fe B #1	P&A				1	1	1	
	Santa Fe D #1	P&A				1	1	1	
	Whigham #2	P&A				1	1	1	
	Hospah #37	P&A				1	1	1	
	CTV Hospah #1	P&A		√					No P&A data.
	CTV Hospah A#5	P&A				1	2	2	

TABLE 15 ANALYSIS OF SOUTHERN AREA WELLS

				TABLE 15 (pg 4)					
	Santa Fe #1	P&A	√						Abd@ comp. Scout card only
	R&S Federal #7	P&A				0	0	0	
	New Mexico 14-3	P&A				0	0	0	
Hospah	Santa Fe #1	D&A	√						Scout card only.
(cont)	Santa Fe C #1	D&A				1	1	1	
	S Fe #1 (Williams)	P&A	√						Scout card only.
	Santa Fe #1 (Fr &Gilbe	P&A	√						Scout card only.
	Pettitt #1	P&A	√						Scout card only.
	Pettitt #2	D&A	√						No state records.
	Tenneco-Santa Fe #1	D&A				1	2	2	
	Santa Fe Tract C #1	D&A				1	1	1	
	Santa Fe #1A	D&A	√						No P&A report.
	SF 88 Buck #1	D&A				1	2	2	
	(no name) #1	D&A	√						No P&A report.
	Hospah SU #103	P&A				1	1	1	
	Hospah SU #30-A	P&A				3	2	1	
	State Wilson #31	D&A	√						Scout reports P&A-no date
	(no name) #26	P&A	√						No state report.
				date					
	State #7	TA	√	Jun-40					
	State #16	TA	√	Aug-41					
	State #15	TA	√	Jul-41					
	State #17	TA	√	Sep-41					
	State #19	TA	√	Feb-42					
	State #25	TA	√	Jan-42					
	State #27	TA	√	Feb-42					
	Hospah #53	Oil	√						No csg cement rpt
	Hospah Sand U #62	Oil?				1	1	-	
	Hospah Sand U #4-Y	Oil				1	1	-	
	Hospah Sand U #56	Oil				1	1	-	
	Hospah Sand U #105	Oil				1	2	-	

TABLE 15 ANALYSIS OF SOUTHERN AREA WELLS

			TABLE 15 (pg 5)						
Hospah (cont)	Hospah Sand U #63	Oil				1	1	-	
	Hospah Sand U#53	Oil				1	1	-	
	Whigham#2	Inj	√						No csg cement report
	Hanson #24	Inj				1	1	-	
	Santa Fe RR #66	Inj				1	1	-	
	Hospah Sand U #61	Inj				1	1	-	
	Hospah Sand U #84	Inj				1	2	-	
	Hospah Sand U #60	Inj				1	1	-	
	Hospah Sand U #68	Inj				1	1	-	
	Hospah Sand U #69	Inj/Abd				1 (*2)	1 (*2)	(*1)	(* Abandoned ABE rating)
	Hospah Sand U #64	Inj/Abd				1 (*2)	1 (*2)	(*1)	(* Abandoned ABE rating)
	Hospah Sand U #70	Inj				1	2	-	
	Hospah Sand U #65	Inj/Abd				1 (*2)	1 (*2)	(*1)	(* Abandoned ABE rating)

TABLE 15 ANALYSIS OF SOUTHERN AREA WELLS

			TABLE 15 (pg 6)						
	Well Name	Status	No Info	No Inter		BP Abe	TP Abe	# TP Plugs	
Field									
Hospah, S.	Santa Fe A #1	D&A				1	1	1	
	Hospah Federal #1	D&A				1	1	1	
	Santa Fe RR A #92	D&A				1	1	1	
	South Hospah U #15	Oil				1	1	-	
	Santa Fe RR A #76	Oil				1	1	-	
	Hanson #26	Oil				1	1	-	
	Hospah #48	Oil				1	1	-	
	Santa Fe RR #33	Oil				1	1	-	
	Santa Fe RR #23	Inj				1	2	-	
	Santa Fe RR B #35	Inj	√						
	Wigham #1	Inj/Abd				1 (*3)	2 (*3)	(*2)	(* Abandoned ABE rating)

TABLE 15 ANALYSIS OF SOUTHERN AREA WELLS

			TABLE 15 (pg 7)						
	Well Name	Status	No Info	No Inter		BP Abe	TP Abe	# TP Plugs	
Field									
	Santa Fe RR #28	D&A				1	1	1	
Lone Pine	Dosh-E-PI-Henio #2X	D&A				1	1	1	
	Dosh-E-PI-Henio #2	P&A				2	2	1	
	LP Dakota Unit #17	P&A				2	3	1	
	LP Dakota Unit #30	P&A				3	3	2	
	Hospah #45	P&A				1	2	2	
	SFP-RR #16	D&A				1	1	1	
	SFPRR #4	P&A	√						
	Lone Pine #1	D&A				2	3	2	
	Lillie #1	D&A				1	1	1	
	SF RR #27	Oil				1	1	-	
	SF RR #9	Oil				1	1	-	
	SF RR #14	Oil/TA				1	1	-	
	Lone Pine Dak U #17	Inj/Abd				1 (*2)	2 (*3)	(*1)	Gas injection
	Hospah #44	Inj/Abd				1 (*2)	2 (*3)	(*1)	(* Abandoned ABE rating)

TABLE 15 ANALYSIS OF SOUTHERN AREA WELLS

			TABLE 15 (pg 8)						
	Well Name	Status	No Info	No Inter		BP Abe	TP Abe	# TP Plugs	
Field									
	Chavez #1	P&A	√						
Miguel Creek	Santa Fe RR #23	P&A				1	2	2	
	Fernandez #1	P&A				1	3	1	
	Santa Fe RR #22	P&A				2	23	21	
	Santa Fe RR #18	P&A				1	2	2	
	Santa Fe RR #17	P&A	√						
	SFP RR #16	P&A	√						
	SFP #28-12	P&A				3	3	1	
	Santa Fe Pacific #42	Oil				1	1	-	
	Santa Fe Pacific #46	Oil				1	2	-	
	SFP RR #21	Oil				1	1	-	
	Santa Fe RR #6-Y	Inj	√						
	SFP RR #79	Inj				1	2	-	
	SFP RR #83	Inj				1	2	-	

TABLE 15 ANALYSIS OF SOUTHERN AREA WELLS

			TABLE 15 (pg 9)						
	Well Name	Status	No Info	No Inter		BP Abe	TP Abe	# TP Plugs	
Field									
Red Mountain	Red Mountain #1	D&A	√						
	Santa Fe #3	D&A	√						
	Santa Fe #5	D&A	√						
	#3 (Newton)	P&A	√						
	#5 (Newton)	P&A	√						
	Red Mountain #6	P&A				1	1	1	
	Hoxsey State #1	D&A	√						
	Santa Fe #1	D&A	√						
	Santa Fe RR D #1	D&A				2	3	2	
	Santa Fe Pacific #47	Oil				1	1	-	
	Naposuta #3	Oil	√						No csg cement report
	Federal A #3	Oil				1	2	-	
	Santa Fe RR #36	Inj ?				1	1	-	Well status uncertain
	Santa Fe Pacific I-#12	Inj ?				1	1	-	Well status uncertain

TABLE 16
INTERIOR I AREA FIELDS SUMMARY *

FIELD	LOCATION	DISC YEAR	WELLS DRLD	PRODUCING FORMATION	AVG. DEPTH
Alamito	31-T23N-R 7W	1971	13	Gallup	4800
Eagle Mesa	12-T19N-R4W	1975		Entrada	5480
Franciscan Lake	7-T20N-R 5W	1975	25	Mesaverde	2100
Gallup	25-T15N-R18W	1923	13	Gallup	1200
Meadows	33-T30N-R15W	1961	21	Gallup	4100
Media (†)	14-T19N-R 3W	1953	18	Entrada	5200
Ojo Encino	21-T20N-R 5W	1976	7	Entrada	5900
Papers Wash (†)	15-T19N-R5W	1976	9	Entrada	5200
San Luis (†)	21-T18N-R 3W	1959	35	Mesaverde	1000
San Luis, S.	33-T18N-R 3W	1959	18	Mesaverde	400
Torreon	17-T19N-R 4W	1953	25	Mesaverde	1700
Verde	14-T31N-R15W	1955	354	Gallup	2400
		Total	538		

* Sampled Oil Fields and Injection Fields Only

(†) Injection Fields

TABLE 17 COMBINED INTERIOR I AREA WELL SUMMARY

Field	Total Number of Abandoned Wells	Total Number of Active Wells	# of Abandoned Wells Examined	# of Active Wells Examined	Total Number of Wells Examined		Total # No Info Wells	Total # No Inter Wells	Total # Abe Runs
Media (I-act)	4	11	6	3	9		2	1	6
Papers Wash (I-act)	2	5	4	3	7		0	0	7
San Luis (I-act, *)	23	5	3	5	8		0	8	0
Total	29	21	13	11	24		2	9	13

I-act denotes active injection project
I-inact denotes inactive or abandoned injection project
na- not applicable, e.g. active wells were not examined in fields with no water injection.

(*) Field has no intersections with USDWs.

TABLE 18 ANALYSES OF INTERIOR I AREA WELLS

			TABLE 18 (pg 1)						
	Well Name	Status	No Info	No Inter		BP Abe	TP Abe	# TP Plugs	
Field									
Media	Federal Media #7	P&A		√					TD above Injection zone.
	Beard #1	P&A				2	4	3	
	Federal Media #5	P&A				2	4	2	
	Fluid Power Pump #5	Oil/Abd	√						
	Fluid Power Pump #1	Oil				1	1	-	
	Boling Federal #6	Oil				1	1	-	
	Boling Federal #22-9	Oil				1	1	-	
	Fluid Power Pump #2	Inj/Abd	√						
	Federal Media #4	Inj/Abd				1 (*2)	2 (*4)	(*3)	(* Abandoned ABE rating)

TABLE 18 ANALYSES OF INTERIOR I AREA WELLS

			TABLE 18 (pg 2)						
	Well Name	Status	No Info	No Inter		BP Abe	TP Abe	# TP Plugs	
Field									
Papers Wash	Federal #22A-2	P&A				0	2	2	Open hole.- Multpl plugs
									0 ABE has no meaning
	Navajo Allotted #16-1	P&A				1	4	2	
	State 2-16-19-5	Oil				1	2	-	
	Federal #15-2	Oil/Abd				1 (*2)	1 (*2)	(*1)	(* Abandoned ABE rating)
	Federal #15-1	Oil/Abd				1 (*2)	1 (*2)	(*1)	(* Abandoned ABE rating)
	Navajo Allotted #15-6	Inj				1	3	-	
	Navajo Allotted #15-3	Inj				1	2	-	

TABLE 18 ANALYSES OF INTERIOR I AREA WELLS

TABLE 18 (pg 3)

Field	Well Name	Status	No Info	No Inter		BP Abe	TP Abe	# TP Plugs	
San Luis	Demas #1	P&A		√					
	Yah-Tah-Hey #1	P&A		√					
	Yah-Tah-Hey #2	P&A		√					
	San Luis Federal #15	Oil		√					
	San Luis Federal #3	Oil	√	√					No Csg Cement Rpt
	San Luis Federal #1	Oil	√	√					No Csg Cement Rpt
	San Luis Federal #4	Inj	√	√					No Csg Cement Rpt
	San Luis Federal #5	Inj		√					
	Note: This field has no intersections with USDWs								
	Note: This field is listed on the September 1992 injection report but has not had active injection since 1982.								

TABLE 19
INTERIOR II AREA FIELDS SUMMARY

FIELD	LOCATION	DISC YEAR	WELLS DRLD	PRODUCING FORMATION	AVG. DEPTH
Alamo	13-T24N-R 3W	1967	3	Farmington	2300
Angel Peak	4-T27N-R10W	1958	52	Gallup	6150
Bisti (*)	16-T25N-R12W	1955	592	Gallup	4750
Blanco, S (*)	9-T26N-R6W	1951	1868 (†)	Tocito	6600
Bloomfield	14-T29N-R11W	1924	141	Farmington	750
Boulder	15-T28N-R 1W	1961	30	Mancos	4400
Cha Cha (*)	17-T28N-R13W	1959	146	Gallup	5500
Chacon	23-T23N-R 3W	1974	150	Dakota	7325
Counselor's	3-T23N-R 6W	1981	60	Gallup	5550
Devil's Fork	24-T24N-R 7W	1958	131	Gallup	5500
Dogie Canyon	10-T26N-R 6W	1052	9	Tocito	6650
Dufer's Point	17-T25N-R 8W	1959	30	Gallup-Dak	6350
Escrito (*)	18-T24N-R6W	1957	88	Gallup	5300
Gallegos	14-T26N-R12W	1954	116	Gallup	5050
Gavilan	26-T25N-R 2W	1982	70	Gallup-Dak	7400
La Plata (*)	5-T31N-R13W	1959	10	Gallup	4500
Lindrith, S.	5-T 3N-R 4W	1958	94	Gallup-Dak	6500
Oswell	34-T30N-R11W	1932	8	Farmington	1450
Otero	23-T25N-R5W	1955	376	Chacra	6000
Pinon	14-T28N-R12W	1966	47	Gallup	5600
Puerto Chiquito, E. (*)	5-T26N-R 1E	1960	85	Mancos	1900
Puerto Chiquito, W. (*)	13- T25N-R 1W	1963	49	Mancos.	5900
Rio Puerco (*)	T20,21N-R2,3W	1925	26	Mancos	2700
Simpson	26- T28N-R12W	1959	7	Gallup	6100
Totah (*)	27-T29N-R13W	1959	74	Gallup	5100
	Total		4262		

(*) INJECTION FIELD

(†) 1868 Blanco S. wells include 1718 shallow gas wells.

TABLE 20 COMBINED INTERIOR II AREA WELL SUMMARY

Field	Total Number of Abandoned Wells	Total Number of Active Wells	# of Abandoned Wells Examined	# of Active Wells Examined	Total Number of Wells Examined	Total # No Info Wells	Total # No Inter Wells	Total # Abe Runs
Bisti (I-act)	52	499	8	4	12	0	0	12
Blanco, S (I-act)	76	15	4	9	13	3	4	6
Cha Cha (I-act)	5	122	3	4	7	1	0	6
Escrito (I-act)	4	84	3	3	6	0	0	6
La Plata (I-act)	4	4	4	5	9	1	3	5
Puerto Chiquito, E (I-act)	10	49	3	6	9	0	2	7
Puerto Chiquito, W (I-act)	4	44	3	6	9	1	0	8
Rio Puerco (I-act)	6	16	7	4	11	2	3	6
Totah (I-act)	2	58	2	4	6	0	0	6
Total	163	891	37	45	82	8	12	62

I-act denotes active injection project
(*) Field has no intersections with USDWs.

TABLE 21 ANALYSES OF INTERIOR II AREA WELLS

			Table 21 (pg 1)						
Field	Well Name	Status	No Info	No Inter		BP Abe	TP Abe	# TP Plugs	
Bisti									
	Navajo #1	D&A				1	4	4	
	Navajo 23 #11	D&A				1	5	5	
	E. Bisti Unit #80	P&A				3	4	4	
	Central Bisti Unit #20	P&A				2	4	4	
	Sullivan B #1	P&A				1	2	1	
	Douthit B #3	P&A				3	3	1	
	Hunter Wash #27	D&A				1	1	1	
	West Bisti Unit #155	Prod				1	1	-	
	Central Bisti Unit #27	Prod				1	1	-	
	Gold Medal #3	Prod				1	2	-	
	CBU WI #7	Inj/Abd				1 (*3)	2 (*4)	(*4)	(* Abandoned ABE rating)
	WBU #125	Inj				1	2	-	

TABLE 21 ANALYSES OF INTERIOR II AREA WELLS

			Table 21 (pg 2)						
Field	Well Name	Status	No Info	No Inter		BP Abe	TP Abe	# TP Plugs	
Blanco, S.									
	#146-9	Gas				3	3	1	Inj. Zone. Abandoned. Both
	MLK #7	Gas				3	4	1	are recompletions.
	Harvard-Federal #1	D&A		√					
	Gilcrease #2	D&A		√					
	L.L.McConnell #1	Oil				1	1	-	
	Breech A #204	Oil				1	1	-	
	T #185	Oil				1	1	-	
	Sunico-Federal #17	Oil		√					
	Axi Apache N #10	Gas				1	2	-	
	Jicarilla F #11	Gas		√					
	Jicarilla B#5	Inj/Gas	√						These wells all appear to be
	Breech E #587	Inj/Gas	√						recompleted in gas zones.
	Breech A #182A	Inj/Gas	√						No injection reports so cannot
									evaluate wells further.

TABLE 21 ANALYSES OF INTERIOR II AREA WELLS

			Table 21 (pg 3)						
Field	Well Name	Status	No Info	No Inter		BP Abe	TP Abe	# TP Plugs	
Cha Cha									
	USA C.J. Holder #1	P&A				1	2	1	
	Cen. Cha Cha U #5	P&A	√						Prev. Glenn H. Callow B#4
	SE Cha Cha #39	Oil				1	1	-	
	Gallegos Can U #84	Oil				1	2	-	
	Kirtland #14-1	Oil				1	1	-	
	NE Cha Cha 26 #12	Inj				1	1	-	
	Glann H. Callow B#2	Inj/Abd				1 (*2)	2 (*4)	(*3)	(* Abandoned ABE rating)

TABLE 21 ANALYSES OF INTERIOR II AREA WELLS

			Table 21 (pg 4)						
Field	Well Name	Status	No Info	No Inter		BP Abe	TP Abe	# TP Plugs	
Escrito									
	Federal #1-7	P&A				3	3	2	
	Dashko #1	D&A				1	2	2	
	USA -Dashko #1	Abd/Oil				2	3	-	No Abd report ordered.
	Escrito Gallup Unit #1	Oil				1	1	-	
	Escrito Gallup Un #21	Oil				1	1	-	
	Judy #1	Inj/Abd				1 (*3)	1(*6)	(*5)	(* Abandoned ABE rating)

TABLE 21 ANALYSES OF INTERIOR II AREA WELLS

			Table 21 (pg 5)						
	Well Name	Status	No Info	No Inter		BP Abe	TP Abe	# TP Plugs	
Field									
La Plata	McCord #1	D&A				2	1	1	
	Patterson #1	D&A		√					
	Pump Canyon B #5	D&A		√					
	Stevens FF McCarthy	D&A		√					
	La Plata Mancos U #7	Oil				1	1	-	
	La Plata Mancos U #1	Oil				1	1	-	
	La Plata #3	Oil				1	1	-	
	La Plata Mancos U #2	Oil				1	1	-	
	La Plata Mancos U #4	Inj/Obs?	√						This appears to be an observation well rather than an injection well.

TABLE 21 ANALYSES OF INTERIOR II AREA WELLS

			Table 21 (pg 6)						
	Well Name	Status	No Info	No Inter		BP Abe	TP Abe	# TP Plugs	
Field									
Puerto Chiquito	Puerto Chiquito 238 #2	P&A		√					
East	CIDO #5	P&A				0	3	3	D&A with multiple cement
	Puerto Chiquito #24	P&A	√	√					plugs in the hole. 0 ABE has
									no meaning.
	EPC Man Unit #1	Oil				2	2	-	
	RD & P #2	Oil				1	1	-	
	Puerto Chiquito #17	Oil				1	1	-	
	Puerto Chiquito U #21	Oil				1	1	-	
	Cido #2	Oil				1	1	-	
	EPC Man Unit #2	Inj				1	1	-	

TABLE 21 ANALYSES OF INTERIOR II AREA WELLS

			Table 21 (pg 7)						
	Well Name	Status	No Info	No Inter		BP Abe	TP Abe	# TP Plugs	
Field									
Puerto Chiquito	Badland Fed #9-1	P&A				3	4	4	
West	Canada Ojitos U #43	D&A	√						
	Har. Federal 28 #1	J&A				0	2	2	D&A with multiple cement
									plugs in the hole. 0 ABE has
	Schmitz Fed 34#3	Oil				1	1	-	no meaning.
	Bolack A #14	Oil				1	1	-	
	Jicarilla 200 #1	Oil				1	1	-	
	Jicarilla #202-1	Oil				1	1	-	
	Canada Ojitos U17#16	Inj				1	2	-	Gas injector
	Canda OjiotsU19#14A	Inj				1	2	-	Gas injector

TABLE 21 ANALYSES OF INTERIOR II AREA WELLS

			Table 21 (pg 8)						
	Well Name	Status	No Info	No Inter		BP Abe	TP Abe	# TP Plugs	
Field									
Rio Puerco	NG McCroden SF #1	P&A		√					
	H. Leonard SF RR #1	P&A		√					
	Santa Fe #1	P&A		√					
	L. Bar Cattle Co. #1	D&A	√						
	San Isidro #24-13	D&A				2	2	1	
	Federal #22-1-2	P&A				3	4	2	
	Federal #24-3-3	P&A				3	4	2	
	Johnson #7-11	Oil				1	1	-	
	San Isidro #12-4	Oil				1	2	-	
	Chijuilla #31-14-1	Oil				1	1	-	
	San Isidro #13-11	Inj	√						

TABLE 21 ANALYSES OF INTERIOR II AREA WELLS

			Table 21 (pg 9)						
	Well Name	Status	No Info	No Inter		BP Abe	TP Abe	# TP Plugs	
Field									
Totah	USA GH Callow #20	P&A				2	4	3	
	NM Federal I #5	P&A				1	3	3	
	USA GH Callow #10	Oil				1	1	-	
	Hagood #6-G	Oil				1	1	-	
	Hagood #27-G	Inj				1	2	-	
	Navajo Tribal H#13	Inj				0	2	-	0 ABE has no meaning.

TABLE 22 SUMMARY RESULTS OF APPLICATION OF AOR VARIANCE CRITERIA TO SAN JUAN BASIN INJECTION FIELDS

Field & Reservoirs	Status	Field has no intersections with a USDW or INJ zone	Field has negative hydraulic potential between USDW & INJ zone	Sink Zone protects USDW	Slough Zone protects USDW	Squeeze Zone protects USDW	Field Development post-dates adequate regulations	Sufficient AORs exist and demonstrate USDW protection	Sampled Wells have adequate barriers or plugs	Perform AOR(s)
Western Area										
Horseshoe	Active	√					√	?	√	
Many Rocks	Active	√					√		√	
Many Rocks, North	Active	√					√		√	
Mesa	Active	√					√	?	√	
Rattlesnake	Active				√	√				√
Tocito Dome, N	Active						√		√	
Southern Area										
Chaco Wash	Active	√					√	?		
Hospah	Active				√	√		?	?	√
Hospah, S	Active				√	√	√	?	?	?
Lone Pine	Active				√	√	√		√	
Miguel Creek	Active				√	√	√	√	√	
Red Mountain	Active	?			?	?				?
Interior I Area										
Media	Active				√	√	√	?	√	
Papers Wash	Active				√	√	√		√	
San Luis	Active	√					√	?	√	
Interior II Area										
Bisti	Active			√	√	√	√	?	√	
Blanco S	Active			√	√	√	√		√	
Cha Cha	Active			√	√	√	√		√	
Escrito	Active			√	√	√	√		√	
La Plata	Active				√	√	√		√	
Puerto Chiquito, East	Active	?			√	√	√		√	
Puerto Chiquito, West	Active				√	√	√		√	
Rio Puerco	Active			√	√	√			√	
Totah	Active			√	√	√	√		√	

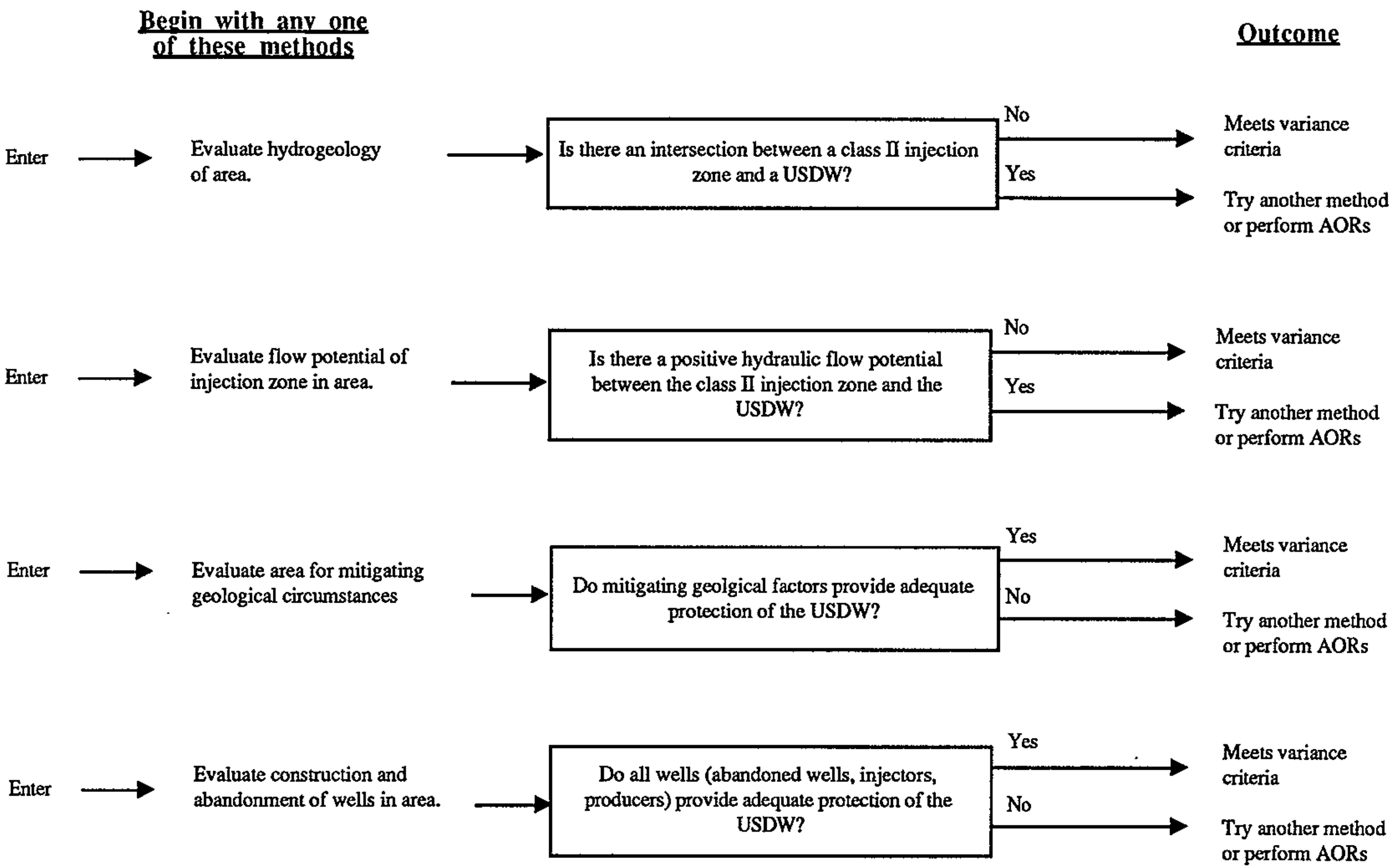


Figure 1. AOR Evaluation Methodology

Four general methods are available for obtaining variance from revised EPA Area of Review requirements. These methods can be used in any order, singly or in combination, to exclude some or all wells from the AOR process. Wells not excluded by variance would be subject to well-by-well AORs.

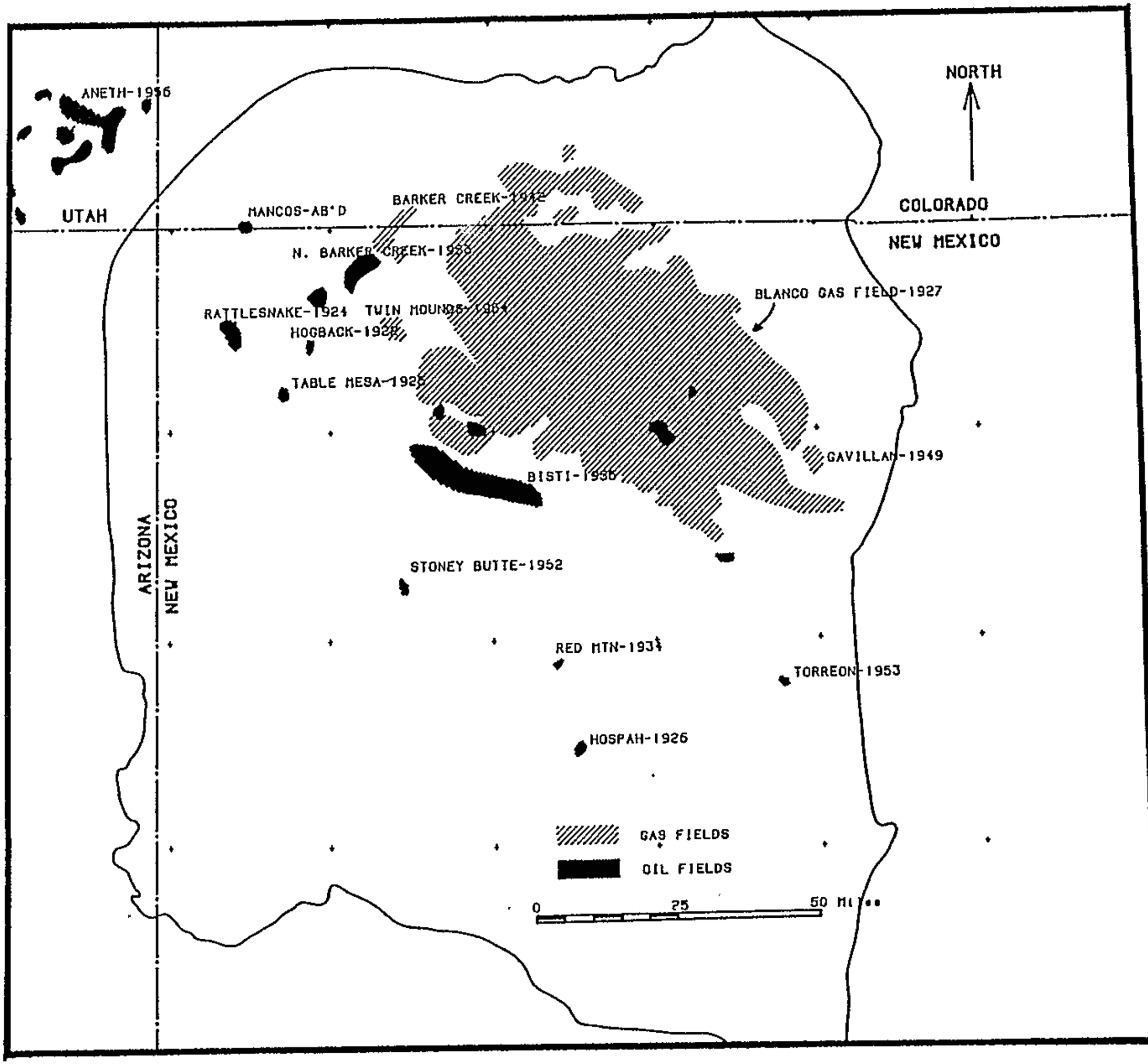


Figure 2: Outline of the San Juan Basin showing major oil and gas field locations and their dates of discovery. Modified from Kuhn (1958)[18] and Fassett et. al. (1978)[19].

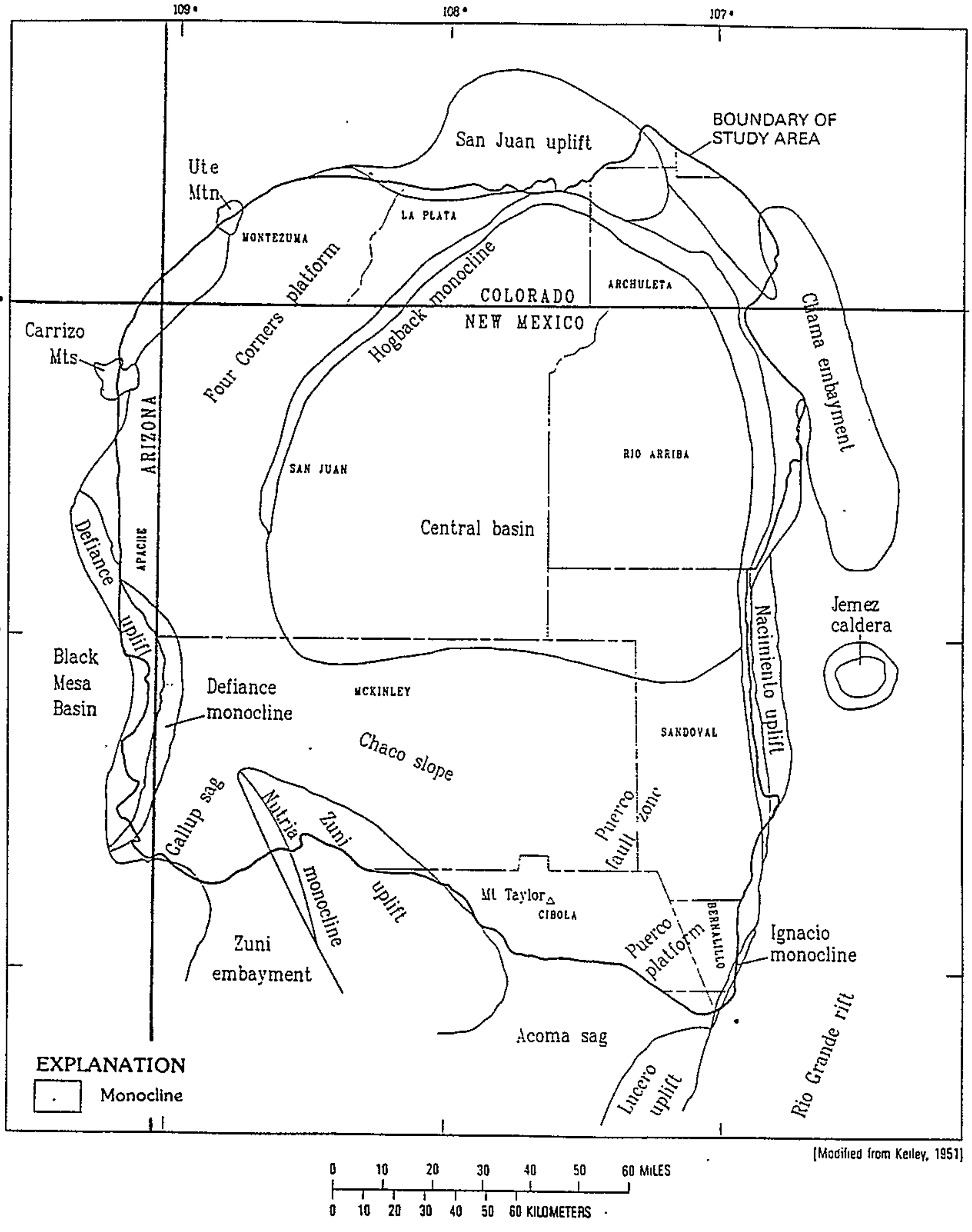


Figure 3: Structural elements of the San Juan Basin and adjacent areas. From Stone et. al. (1983)[3], modified from Kelley, (1951)[20].

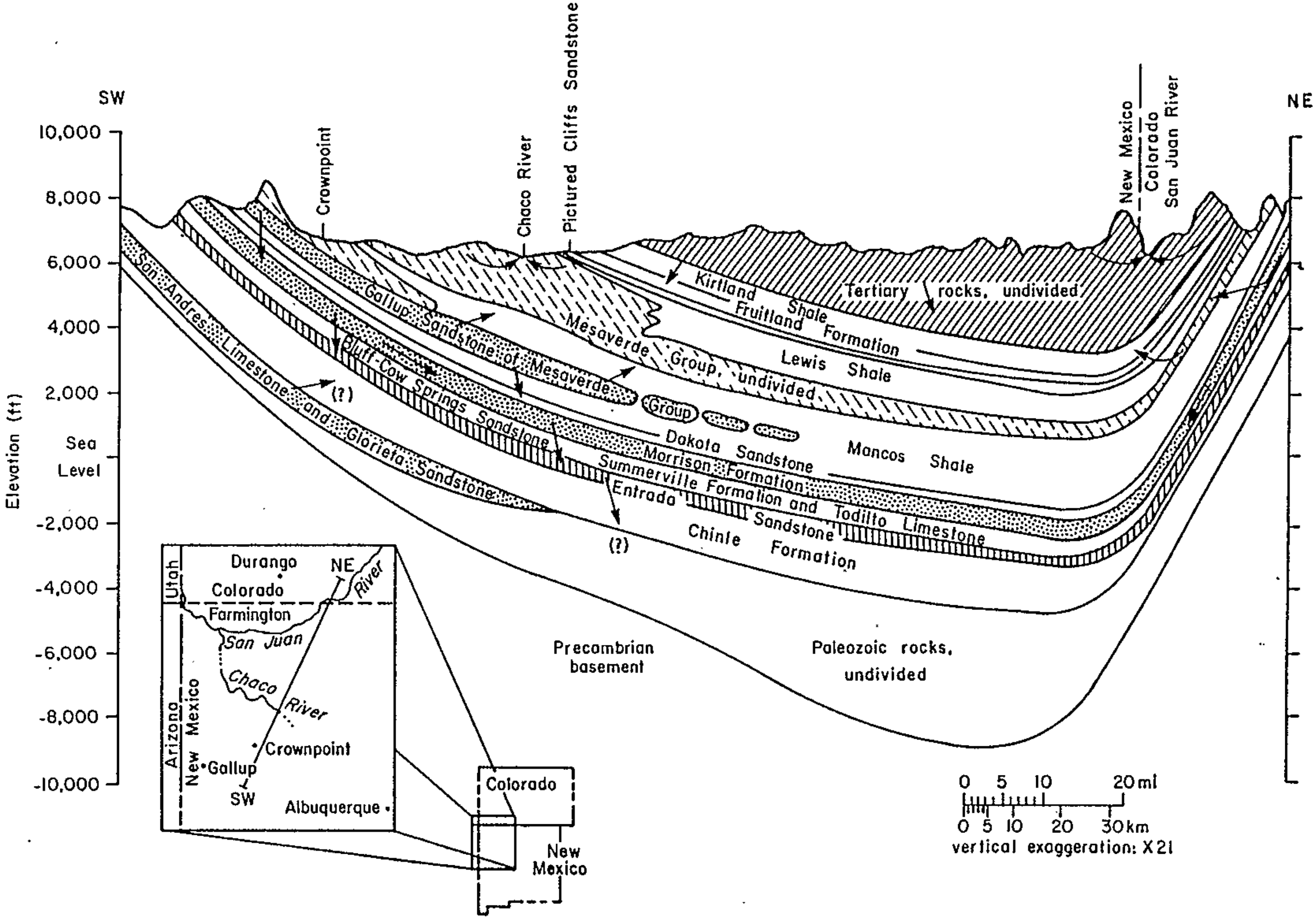


Figure 4: Generalized Hydrogeologic cross section of the San Juan Basin, showing major aquifers, confining beds, and directions of ground-water flow. From Stone <u>et</u>. <u>al</u>. (1983)[3].

	GEOLOGIC TIME UNITS		FORMATIONS	PRODUCTION HORIZONS	USDWs
Cenozoic (to 70 million years)	Quaternary	Recent	Alluvium		★
		Pleistocene	Gravel, sand, clay and volcanic deposits		
	Tertiary	Pliocene	Santa Fe Group; Chuska Sandstone		
		Miocene			
		Oligocene	May be present (?)		
		Eocene	Galisteo Formation (Eocene and questionably Oligocene); Baca Formation (questionably Eocene); San Jose Formation		
		Paleocene	Nacimiento Formation; Animas Formation (Upper Cretaceous and Paleocene)	☼	
Mesozoic (70-225 million years)	Cretaceous		Ojo Alamo Sandstone McDermott Formation Kirtland Shale and Fruitland Formation Pictured Cliffs Sandstone Lewis Shale	☼ ☼	★
			Cliff House Sandstone Menefee Formation Point Lookout Formation Crevasse Canyon Formation (All of the Mesaverde Group)	☼ ● ☼	★
			Mancos Shale with Gallup Sandstone Dakota Sandstone	● ✹	★ ★ ★
	Jurassic		San Rafael Group: Morrison Formation, Bluff Sandstone, Summerville Formation, Todilto Formation, Entrada Sandstone; Zuni Sandstone	●	
	Triassic		Glen Canyon Group Wingate Sandstone Chinle Formation		
Paleozoic (225 to 600 million years)	Permian		San Andres Limestone Glorieta Sandstone		
			Yeso Formation, Abo Formation; Cutler Formation, Rico Formation		
	Carboniferous	Pennsylvanian	Madera Formation, Sandia Formation; Hermosa Formation, Paradox Member, Molas Formation	✹	
		Mississippian	Arroyo Penasco Formation; Present in subsurface (includes the Leadville Limestone)	●	
	Devonian		Present in subsurface; Ouray Limestone (includes the Elbert Formation)		
	Silurian		Absent		
	Ordovician		Absent		
	Cambrian		Present in subsurface (includes the Ignacio Quartzite)		
	Precambrian		Granite, quartzite, pegmatites, etc.		

Figure 5: Generalized stratigraphy of the San Juan Basin showing principal oil and gas production horizons and USGS designated aquifers (USDWs). Modified from Landes (1970)[21].

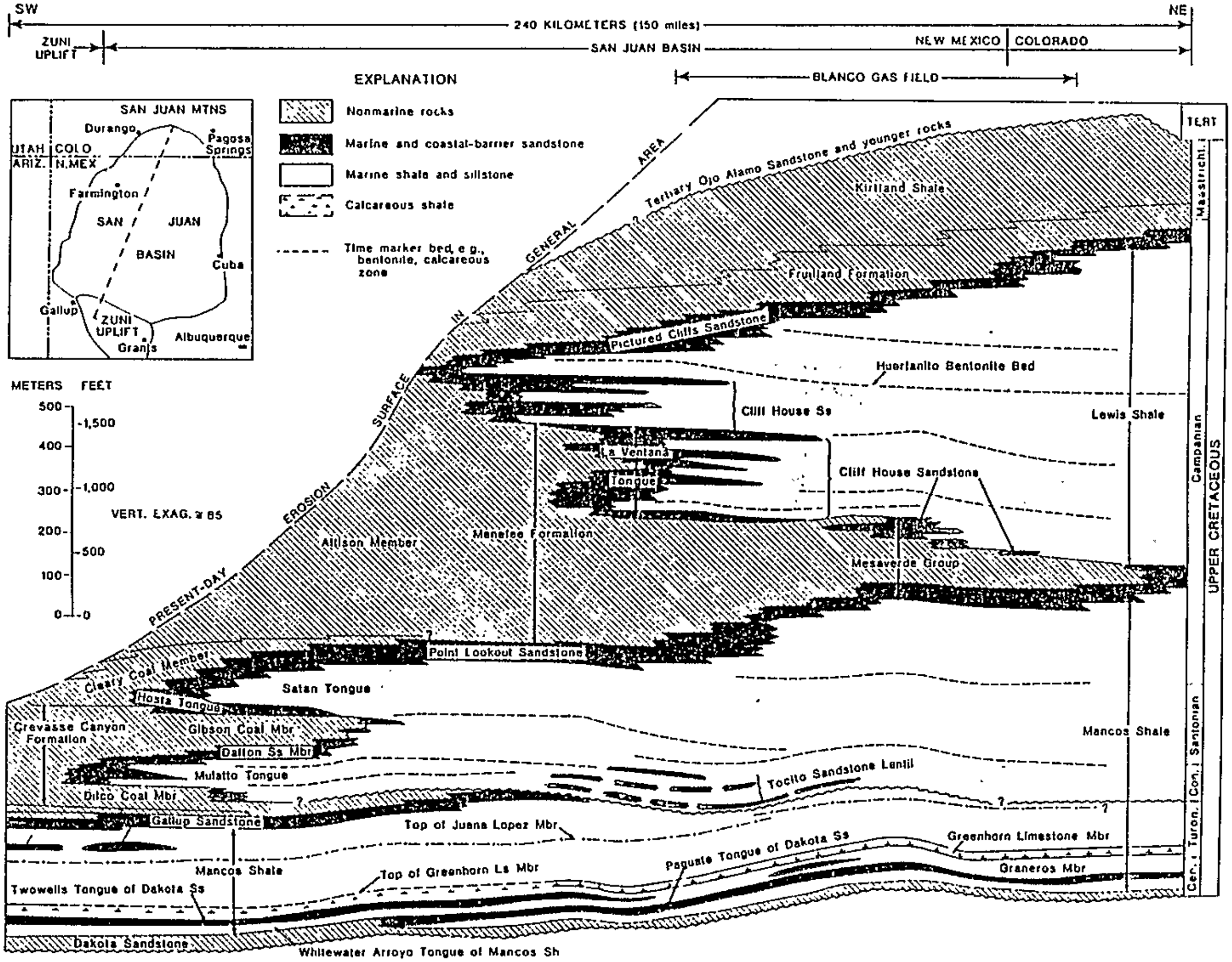
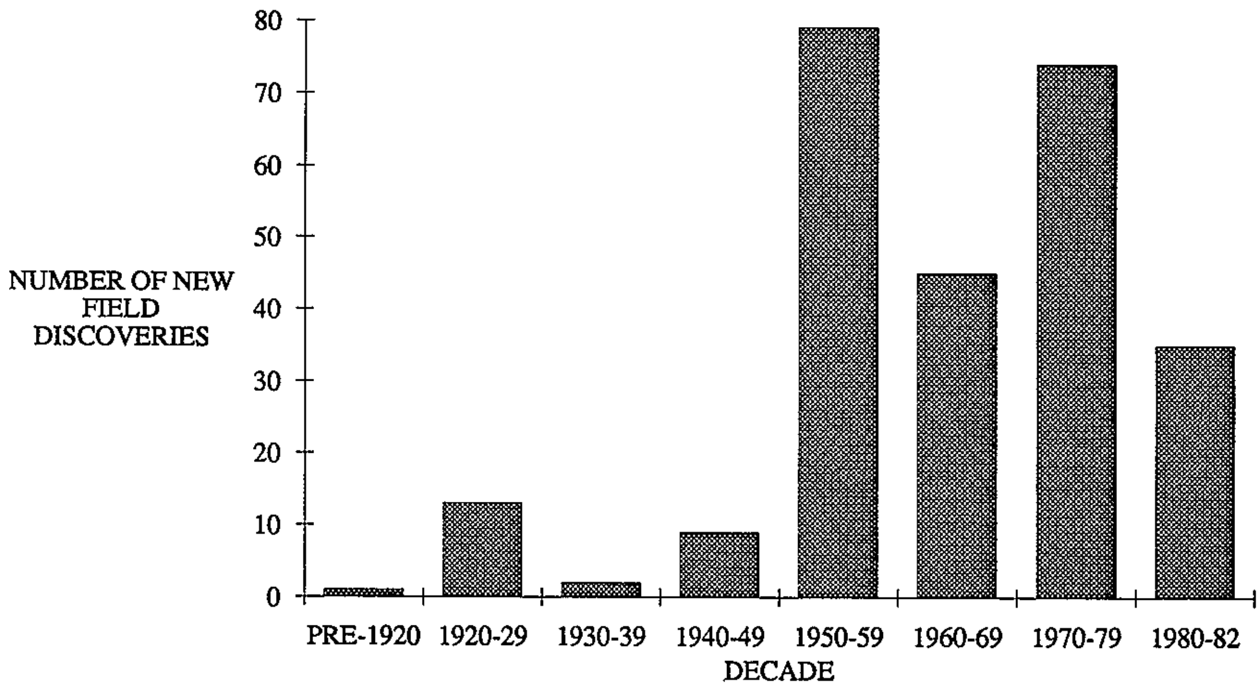
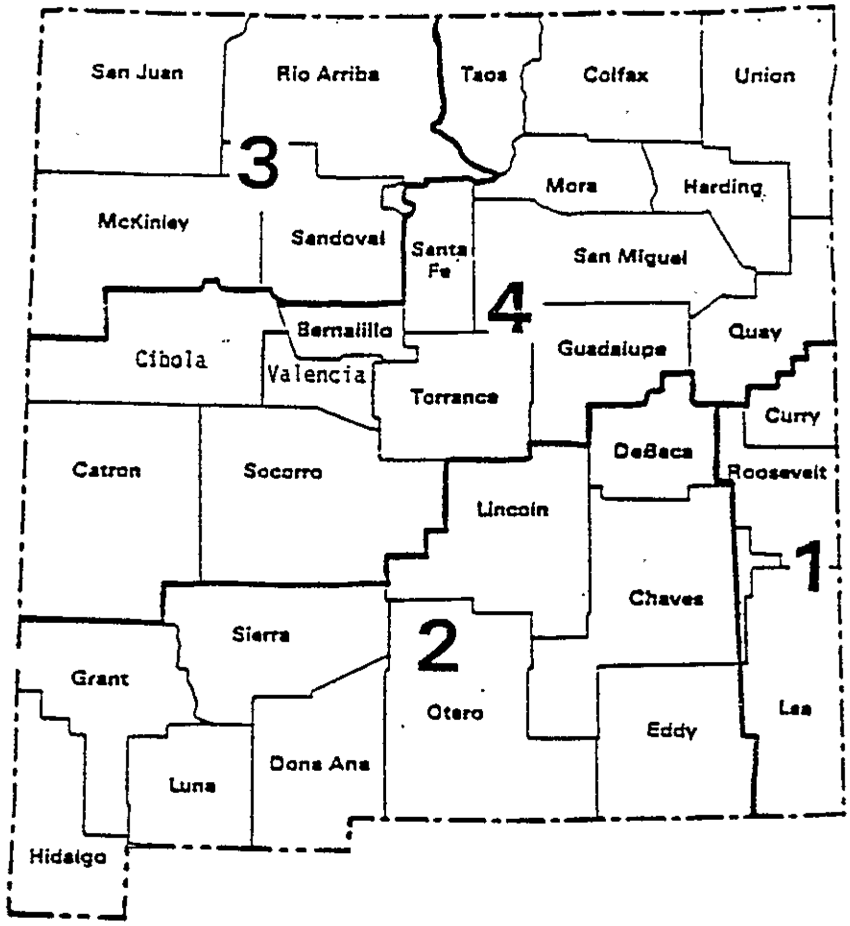


Figure 6: Stratigraphic cross section of Upper Cretaceous rocks of the San Juan basin. From Molenar (1988)[22].

FIGURE 7
NEW FIELD DISCOVERIES IN THE SAN JUAN BASIN BY DECADE





DISTRICT	
1	HOBBS
2	ARTESIA
3	AZTEC
4	SANTA FE

FIGURE 8 . NEW MEXICO OIL CONSERVATION DIVISION DISTRICT OFFICES

FIGURE 9. TIME LINES - SAN JUAN BASIN

BASIN DEVELOPMENT

- 1900 — First well drilled near Farmington just after 1900
- 1910
- 1920
- 1921 - Aztec Farminton
- 1922 - Hobgack Dakota
- 1924 - Bloomfield Farmington
- 1925 - Barker Creek & Table Mesa Dakota
- 1927 - Fulcher Kutz, Pictured Cliffs, Blanco Mesaverde
- 1930
- 1932 - Oswell Farmington
- 1934 - Red Mountain Mesaverde
- 1940
- 1941 - Aztec Pictured Cliffs
- 1943 - Rattlesnake Mississippian
- 1946 Wyper Farmington
- 1947 Basin Dakota
- 1948 - Ute Dome Dakota
- 1950
- 1960
- 1970
- 1980
- 1990

STATUTORY BODIES

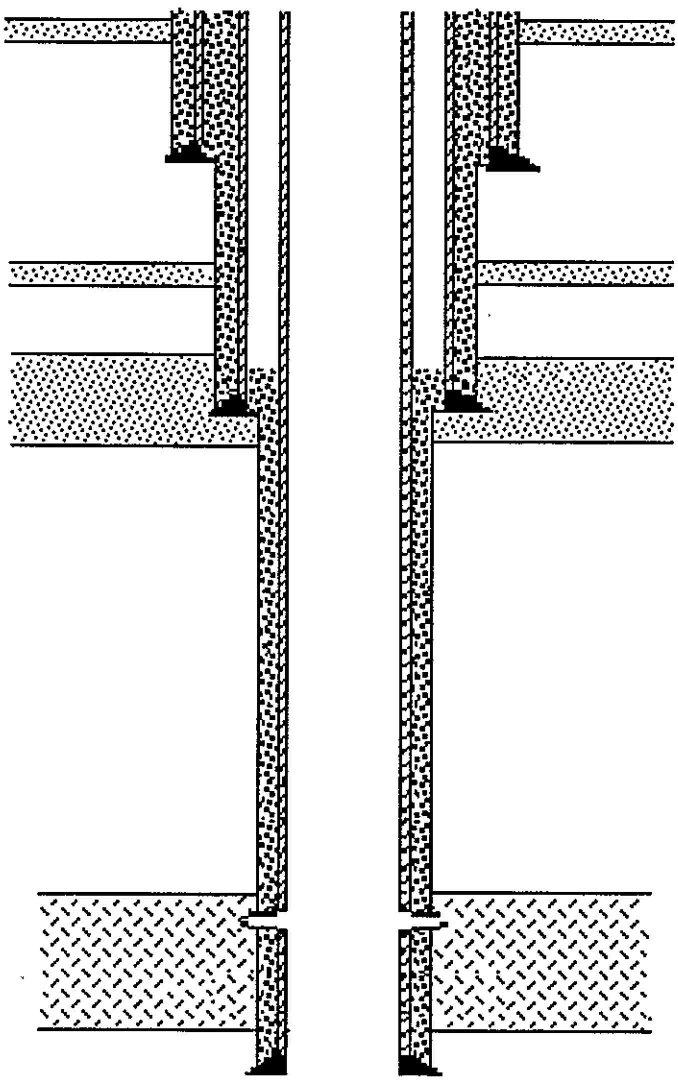
- 1925 Office of State Geologist created to govern oil / gas operations
- 1935 Oil Conservation Commission evolves from Office of State Geologist
- 1940's Four regulatory districts formed - Hobbs, Artesia, Aztec, & Santa Fe
- 1975 Regulatory Agency becomes a Division of the Energy and Minerals Department

WELL CONSTRUCTION / ABANDONMENT REGULATIONS

- 1912 Earliest regulation found. Said oil and gas wells were to be incased. Wells to be abandoned with seasoned wood plugs and covered with sand and sediment
- 1925 First rule book supposedly written. Could not locate this book.
- 1929 State bureau publication shows 1912 rules still in effect.
- 1931 First rulebook found. Casing to be seated in mud (if required by State Geologist). Casing may be cemented but not required. Multiple strings of casing could be used but not required. Wells to be abandoned with mud cement plugs, etc. Outer casing strings pulled to be replaced with mud.
- 1935 Special rules for Hobbs, Jal, Cooper, Eunice and Monument Fields. Required surface casing, a short or long intermediate string of casing, and production casing. All strings to be cemented. Surface location of abandoned holes must be marked.
- 1937 Special rules for all other Lea County Fields. Required conductor pipe or surface casing, a short or long intermediate string of casing, and production casing. All strings except conductor to be cemented.
- 1947 Shut-in time for cementing reduced to 48 hours for intermediate and production casing, 24 hours for surface casing, and 30 hours for all other strings.
- 1949 Special rules for Blanco Mesaverde Gas Field. Required surface casing and production casing to be run and cemented.
- 1950 First "modern" statewide rules instituted. Required surface casing to be cemented top to bottom. Defective casing to be repaired. Required exploratory, seismic, and core holes to be abandoned as per regulations. Does not specifically state number of casing strings or specifics about cement. Does not give specifics about well abandonment either, but allows abandoned wells to be plugged to a certain depth and then turned to the landowner for use as water well. Plugging bond (up to $10000) required. Special Blanco Mesaverde rules continued.
- 1958 Shut-in time for cementing reduced to 18 hours with options for shorter times if cement is pressure tested to a minimum compressive strength.
- 1959 Rule 107 altered to allow for slim hole completions, i.e. tubing acts as casing string. Only wells less than 5000 ft with no corrosion problems.
- 1961 Requirement for some administrative approval of multiple completions. Requirement for 100 feet of cement above the pay interval in multiple slim hole completions.
- 1962 No longer required to notify offset operators of intent to plug a well. Detailed account of P&A required, e.g. information about plugs, fluids, setting depths, etc.
- 1963 Required reports of plugging to be filed within 30 days of abandonment.
- 1964 Rule 107 amended to require the use of surface casing and intermediate casing. Requires these strings to be cemented in a manner which seals off oil, gas and water bearing strata. Requires use of properly cemented production casing in producing wells. Also amended Rule 107 to allow for the use of oil-base casing packing material in lieu of hard-setting cement on intermediate and production casing in special cases. Some cement (300'-int, 500'-prod) was still required above the shoe. Adopted the use of the Oil Compact Commission forms for reporting.
- 1975 Altered time limitations for temporary abandonment of wells. Maximum of 2 years 2 months - 2 1/2 years depending on the type of well being abandoned. No abandonment over 6 months without TA order.
- 1981 Language of many rules revised to be consistent with EPA rules under provision of the Safe Drinking Water Act. Injection wells covered in addition to drilling and production wells. Defined USDWs and New Mexico State Water Engineer. Five year testing for mechanical integrity of injection wells. Isolation of zone within six months of cessation of injection. Permits required for water disposal into formations.
- 1985 Revised Rules 108 and 113 to emphasize the protection of fresh waters as well as hydrocarbon resources when defective casing is found or if damage results from treating a well.
- 1990 Rule 202 amended to require submittal of a wellbore sketch with the application to plug. Altered TA time to 5 years. Other procedural matters about P&A better defined.

FIGURE 10

SAN JUAN BASIN
CURRENT WELL CONSTRUCTION PRACTICES



1. Cement must be circulated around surface pipe. If cement is not circulated, annulus must be filled from surface.

2. All subsequent casing strings shall be cemented a minimum of 100' into the next shallowest string.

   If cement is not circulated, then the top shall be found by temperature survey or CBL.

3. Minimum surface pipe requirements:

Well Depth	Surface Pipe
0-3000'	120'
3-5000'	200'
5-8000	320'
8001'+	call district

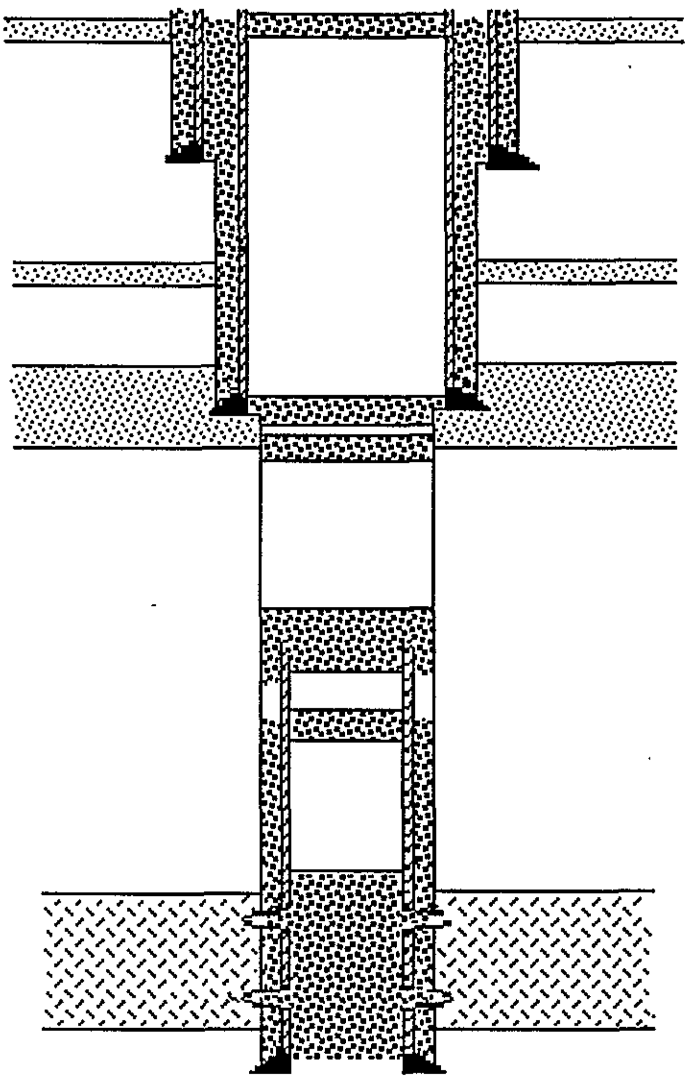
4. Wells drilled in valley fill areas must have surface pipe set at least 50' below the fill.

5. Intermediate casing is optional, but must be cemented according to point #2.

6. Production casing may be set either on top, or through the producing formation.

FIGURE 11

SAN JUAN BASIN
CURRENT WELL ABANDONMENT PRACTICES



1. Minimum 10 sack surface plug should be used.

2. If the surface casing cement was not circulated and the annulus left unfilled, then the annulus should be filled at abandonment.

3. If an intermediate string of casing was run, and cement was not circulated to surface, then a squeeze cement job is required if fresh water or hydrocarbon bearing zones were not originally covered by the primary cement job.

4. In an open hole, cement spacer plugs must be used to cover fresh water and hydrocarbon bearing zone. These plugs should be a minimum of 100' in thickness.

5. In a dry hole with intermediate casing, a cement plug is not routinely required across the shoe of the intermediate string, but may be required depending on formations present at that depth.

6. Cement spacer plugs may be separated by either water or mud. If mud is used then the mud density should be greater than or equal to 9 ppg.

7. Pulling casing is optional, but if it is pulled the casing stub should have a minimum of 50' of cement both inside and outside the stub.

8. If production casing cement does not cover all fresh water and hydrocarbon bearing zones, then the casing must be perforated and squeezed in such a manner as to cover these zones.

9. All productive hydrocarbon bearing formations should be abandoned with a plug across the zone. This may be either a CIBP covered with a minimum of 50' of cement, or a cement plug which covers the entire zone.

Tertiary Group
Tertiary
Farmington
Huerfano
Wasatch

Gallup Group
Upper Gallup
Gallup
Tocito
Lower Gallup
Sanastee
Niobrara
Carlile

Morrison Group
Morrison
Brushy Canyon

Upper Cretaceous Group
Pictured Cliffs
Ojo Alamo
Kirtland
Fruitland
Lewis

Dakota Group
Dakota Silt
Dakota D Sand
Graneros
Greenhorn

Mesa Verde Group
Hospah
Hosta
Mesa Verde
Mancos
Menefee
Point Lookout
Cliff House
Chacra
Hogback
La Ventana

Below Morrison Group
San Andres
Todilto
Yeso
Glorieta
Pennsylvanian
Madera
Colonino
Entrada
Hermosa
Isamy
Masison
Paradox
Lower Ismay
Upper Ismay
Desert Creek
Permian
Poleo
Mack Creek
Mississippian
Akah
Aneth
Precambrian
Devonian
Rico
Leadville
Cambrian
Barker Creek
Paradox
Ouray
De Chelly
Cutler
Elbert
Mississippian LM
Table Mesa
Organ Rock
Shinarump
Molas

FIGURE 12 FORMATION GROUPINGS FOR PETROLEUM RESERVOIR HEAD MAPS

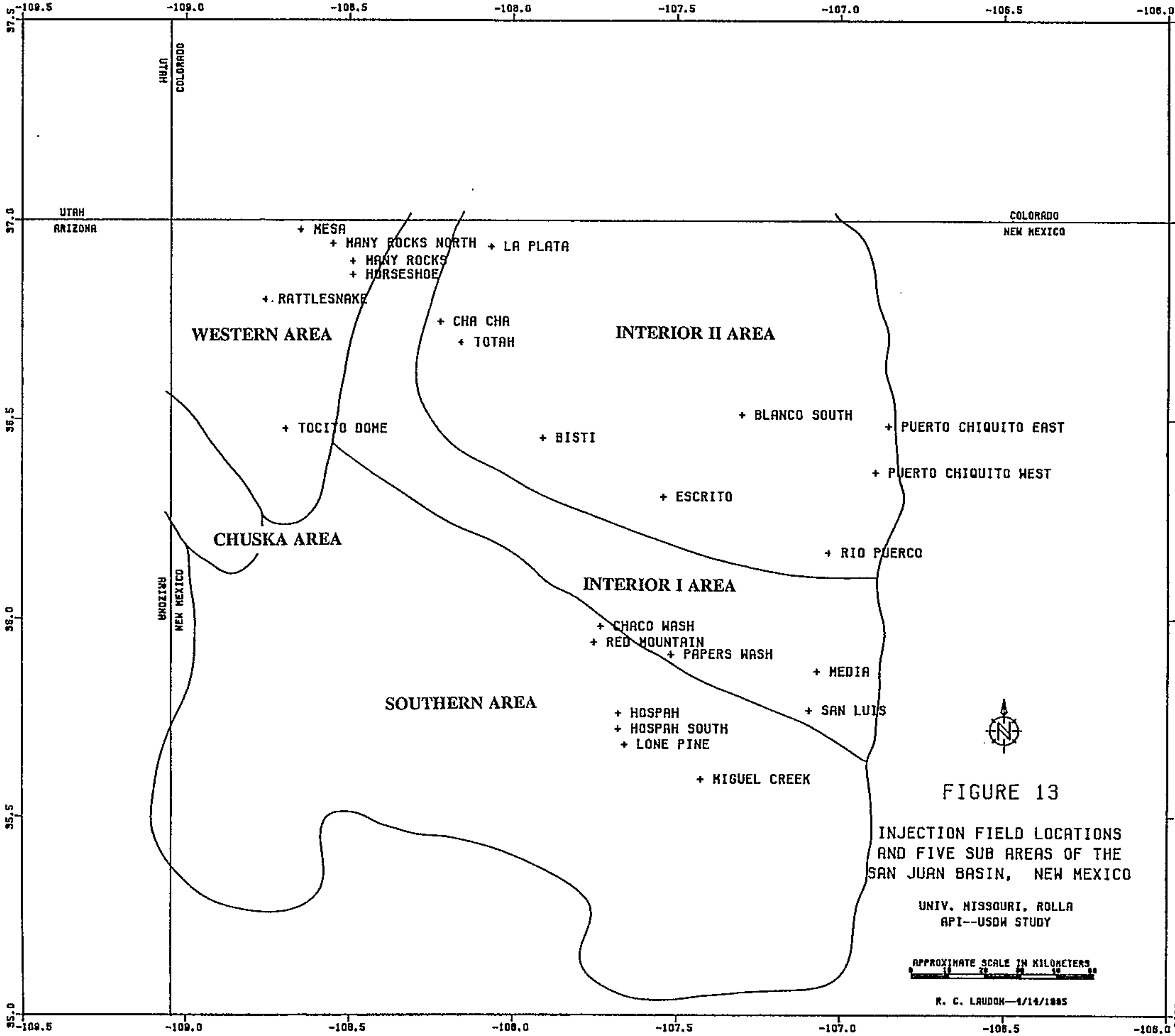


FIGURE 13

INJECTION FIELD LOCATIONS AND FIVE SUB AREAS OF THE SAN JUAN BASIN, NEW MEXICO

UNIV. MISSOURI, ROLLA
API--USDW STUDY

```
Dwights Well Data System CD-ROM                        H# R-957250-0    Original
Copyright 1991    Rocky Mountains                           Run Date: 20-May-91
================================================================================
State : New Mexico        NM Merid  26N - 18W - 21  sw se

County: SAN JUAN                   Oper: PAN AMERICAN PETR CORP

Field : TOCITO DOME PENN D                   Compl: 10/18/1964    D D
================================================================================
Well: NAVAJO TRIBAL U #2                                Last Info: 02/17/1991
Ftg:  600 fsl 1980 fel
Oper Address: P.O. Box 569, Powell WY 82435
Obj:  6500  Pennsylvanian D Permit #:          09/04/1964  API: 30-045-0571500
                                              Elev:  5705RB
================================================================================
Spud: 09/11/1964
TD:  6425                                                              PB:  6229
================================================================================
  Elev:  5705RB     FORMATION TOPS       (Type: L=Log S=Sample V=True Vertical)
                              (Source: H=Scout,T=Govt,S=Shell,G=USGS,N=NDGS)

Formation                Depth  Elev T/S  Formation              Depth  Elev T/S
Todilto                  2010   3695 L S  Pennsylvanian C        5675     30 L S
Entrada                  2030   3675 L S  Barker Creek           6086   -381 L S
Chinle                   2730   2975 L S  lwr Hermosa            6246   -541 L S
De Chelly                3697   2008 L S  Todilto                2010   3695 L T
Cutler                   4303   1402 L S
================================================================================

      << Shell Records >>
Casing: 13 3/8 cmtd @ 92 w/100; 8 5/8 cmtd @ 1480 w/400; 4 1/2 cmtd @ 6425
        w/1050
Journl: 09/02/64        Loc.
        09/07/64        Moving in rotary tools.
        09/16/64  1480 Waiting on cement. Wtr flow while running casing.
        09/23/64  4715 Drlg.
        09/30/64  5902 Drlg.
        10/07/64  6307 Drlg. Core #1 6208-20 ft, recovered 11 ft: 2-1/2 ft sh,
                       rotten; 1 ft sh and limestone; 7-1/2 ft limestone with
                       sh partings.
        10/14/64  6425 Plug 6388 ft. Preparing to squeeze. Perforated 4
                       shots/ft. 6280-84 ft. Swabbed dry. Acidized 6280-84 ft
                       with 250 gallons 15% acid. Flowed 168 barrels salt wtr
                       and 16 barrels load wtr for 2-1/2 hrs on 20/64 in ck,
                       FTP 150 lb, FCP and 1 hr on 10/64 in ck, FTP 350 lb,
                       FCP 1000 lb. Flowed 21 barrels salt wtr for 5 hrs on
                       9/64 in ck, FTP 330 lb, FCP 1050 lb. Recovered 189
                       barrels salt wtr in 8-1/2 hrs total. Set retainer at
                       6276 ft.
        10/21/64  6425 Preparing to abandon. Squeezed 6280-84 ft with 100
                       sacks. Perforated 4 shots/ft. 6253-80 ft, spotted 250
                       gallons mud cut acid, swabbed 22 barrels load oil for
                       10 hrs, swabbed dry. Spotted 250 gallons mud cut acid,
                       swabbed 86 barrels load wtr for 15 hrs, swabbed dry.
                       Swabbed 37 barrels salt wtr for 7-1/2 hrs, no shows oil
Journl:         ----.
                       or gas. Shut in for 7 hrs. Fluid level 3800 ft. Swabbed
                       8 hrs, recovered 69 barrels salt wtr. Set bridge plug
                       6229 ft. Perforated 4 shots/ft. 6138-43 ft, spotted 250
                       gallons mud cut acid. Swabbed 10 hrs, recovered 80
                       barrels load oil & barrel acid wtr. Swabbed dry. 13
                       barrels load oil & 5 barrels acid wtr to recover.

      << State Records >>
Casing: 13 3/8 @ 93 w/100 - 8 5/8 @ 1482 w/400 - 4 1/i @ 6425 w/1100
Logs  : IES GR S C
Perfs :       6138-6284
        w/4 SPF - acid w/1000 gal 15% MA
Journl: /Pan Am Pet Corp.
```

FIGURE 14 EXAMPLE DWIGHT'S WELL REPORT (WITH DATA)

```
Dwights Well Data System CD-ROM                      H# R-972385-0     Original
Copyright 1991    Rocky Mountains                         Run Date: 20-May-91
===============================================================================
State : New Mexico        NM Merid  20N - 9W - 31

County: MCKINLEY                   Oper: RED MOUNTAIN SECURTY OIL

Field : RED MOUNTAIN                        Compl:                  D D    P&A
===============================================================================
Well:  #1                                              Last Info: 05/22/1983
Ftg:
Obj:                      . Permit #:                  API: 30-031-0000000
                                             Elev:
===============================================================================
Spud:
```

Page: 1

FIGURE15. EXAMPLE DWIGHT'S WELL REPORT (WITHOUT DATA)

STATE New Mexico

COUNTY San Juan SEC. 6 [illegible] T. 21 N R. 13 W

FIELD OR AREA LOCATION 250'/S, 300'/W

LEASE Government WELL NO. 1

COMPANY Red Butte Oil SPD. 7-28-37 COMPLETED 10-23-37

ELEV. 6200' (?) T. D. 840' P. B.

CASING 8¼" @ 528' set

SHOT OR ACID

PERF.

I. P.

PRODUCING FORM.

PRODUCTIVE DEPTH OR INTERVAL

REMARKS:

D & A

only record @ State

FIGURE 16 EXAMPLE STATE WELL REPORT (EARLIEST FORM)

Form 9-330 (Rev. 5-63)

Original comp

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

SUBMIT IN DUPLICATE* (See other instructions on reverse side)

Form approved. Budget Bureau No. 42-R

WELL COMPLETION OR RECOMPLETION REPORT AND LOG*

5. LEASE DESIGNATION AND SERIAL NO.: 14-20-603-5035

6. IF INDIAN, ALLOTTEE OR TRIBE NAME: Navajo Tribal

1a. TYPE OF WELL: OIL WELL ☐ GAS WELL ☐ DRY ☒ Other

b. TYPE OF COMPLETION: NEW WELL ☒ WORK OVER ☐ DEEPEN ☐ PLUG BACK ☐ DIFF. RESVR. ☐ Other

7. UNIT AGREEMENT NAME

2. NAME OF OPERATOR: PAN AMERICAN PETROLEUM CORPORATION

8. FARM OR LEASE NAME: Navajo Tribal "N"

3. ADDRESS OF OPERATOR: P. O. Box 480, Farmington, New Mexico

9. WELL NO.: 9

4. LOCATION OF WELL (Report location clearly and in accordance with any State requirements)*
At surface: 600' FNL & 1200' FWL (Unorthodox)
At top prod. interval reported below
At total depth: 631' FNL & 1105' FWL

10. FIELD AND POOL, OR WILDCAT: Tocito Dome-Penn. "D"

11. SEC., T., R., M., OR BLOCK AND SURVEY OR AREA: NW/4 NW/4 Section 20, T-26-N, R-18-W

14. PERMIT NO. | DATE ISSUED

12. COUNTY OR PARISH: San Juan | 13. STATE: New Mexico

15. DATE SPUDDED	16. DATE T.D. REACHED	17. DATE COMPL. (Ready to prod.)	18. ELEVATIONS (DF, RKB, RT, GR, ETC.)*	19. ELEV. CASINGHEAD
3-13-67	4-6-67	4-9-67 (PXA)	5822' GL; 5834' KB	--

20. TOTAL DEPTH, MD & TVD	21. PLUG, BACK T.D., MD & TVD	22. IF MULTIPLE COMPL., HOW MANY*	23. INTERVALS DRILLED BY	ROTARY TOOLS	CABLE TOOLS
6360'	--	--	→	Surf. to 6360'	--

24. PRODUCING INTERVAL(S), OF THIS COMPLETION—TOP, BOTTOM, NAME (MD AND TVD)*

25. WAS DIRECTIONAL SURVEY MADE: Yes

26. TYPE ELECTRIC AND OTHER LOGS RUN: Induction-Electric, Sonic, Gamma Ray

27. WAS WELL CORED: No

28. CASING RECORD (Report all strings set in well)

CASING SIZE	WEIGHT, LB./FT.	DEPTH SET (MD)	HOLE SIZE	CEMENTING RECORD	AMOUNT PULLED
13-3/8"	48#	115'	17-1/4"	100 sacks	None
8-5/8"	24#	1500'	11"	500 sacks	None

29. LINER RECORD

SIZE	TOP (MD)	BOTTOM (MD)	SACKS CEMENT*	SCREEN (MD)

30. TUBING RECORD

SIZE	DEPTH SET (MD)	PACKER SET (MD)

31. PERFORATION RECORD (Interval, size and number)

32. ACID, SHOT, FRACTURE, CEMENT SQUEEZE, ETC.

DEPTH INTERVAL (MD)	AMOUNT AND KIND OF MATERIAL USED

RECEIVED MAY 5 1967 OIL CON. COM. DIST. 3

RECEIVED MAY 4 1967 U. S. GEOLOGICAL SURVEY FARMINGTON, N. M.

33.* PRODUCTION

DATE FIRST PRODUCTION	PRODUCTION METHOD (Flowing, gas lift, pumping—size and type of pump)	WELL STATUS (Producing or shut-in)
		Well PXA 4-9-67

DATE OF TEST	HOURS TESTED	CHOKE SIZE	PROD'N. FOR TEST PERIOD	OIL—BBL.	GAS—MCF.	WATER—BBL.	GAS-OIL RATIO
			→				

FLOW. TUBING PRESS.	CASING PRESSURE	CALCULATED 24-HOUR RATE	OIL—BBL.	GAS—MCF.	WATER—BBL.	OIL GRAVITY-API (CORR.)
		→				

34. DISPOSITION OF GAS (Sold, used for fuel, vented, etc.) | TEST WITNESSED BY

35. LIST OF ATTACHMENTS

36. I hereby certify that the foregoing and attached information is complete and correct as determined from all available records

ORIGINAL SIGNED BY G. W. Eaton, Jr.

SIGNED G. W. Eaton, Jr. TITLE Area Engineer DATE May 3, 1967

*(See Instructions and Spaces for Additional Data on Reverse Side)

FIGURE 17. EXAMPLE FEDERAL WELL COMPLETION REPORT

(Form C-
(Revised 7-

NEW MEXICO OIL CONSERVATION COMMISSION
Santa Fe, New Mexico

MISCELLANEOUS REPORTS ON WELLS

Submit this report in TRIPLICATE to the District Office, Oil Conservation Commission, within 10 days after the work specified is completed. It should be signed and filed as a report on Beginning Drilling Operations, Results of test of casing shut-off, result of plugging of well, result of well repair, and other important operations, even though the work was witnessed by an agent of the Commission. See additional instructions in the Rules and Regulations of the Commission.

Indicate Nature of Report by Checking Below

REPORT ON BEGINNING DRILLING OPERATIONS		REPORT ON RESULT OF TEST OF CASING SHUT-OFF		REPORT ON REPAIRING WELL	
REPORT ON RESULT OF PLUGGING WELL	x	REPORT ON RECOMPLETION OPERATION		REPORT ON (Other)	

September 9, 1955 (Date) Aztec, New Mexico (Place)

Following is a report on the work done and the results obtained under the heading noted above at the

Basin Natural Gas Corporation (Company or Operator) Corscot (Lease)

F. B. Umbarger (Contractor), Well No. 1 in the SW ¼ NE ¼ of Sec. 26

T. 30N, R. 12W, NMPM, Pool, San Juan County

The dates of this work were as follows: September 6, 1955

Notice of intention to do the work (was) (was not) submitted on Form C-102 on July 15 (Cross out incorrect words) 1955

and approval of the proposed plan (was) (was not) obtained.

DETAILED ACCOUNT OF WORK DONE AND RESULTS OBTAINED

Permanently plugged and abandon with 60 foot plug in bottom, using 10 sacks of cement, 3 in formation and 7 in pipe, placing 30 ft. plug in top, using 5 sacks of cement. Leaving pits and location leveled and clean. Placed a 4 inch marker 4 feet above ground level. (Water is shut off)

T. D. 1871 4½" casing

This well is now plugged and abandon, request is hereby made to have the bond released on same.

Witnessed by L. B. V[illegible]t Basin Natural Gas Corp. (Company) Field Supt. (Title)

Approved: OIL CON[illegible] [illegible]N COMMISSION

I hereby certify that the information given above is true and complete to the best of my knowledge.

Name [signature]

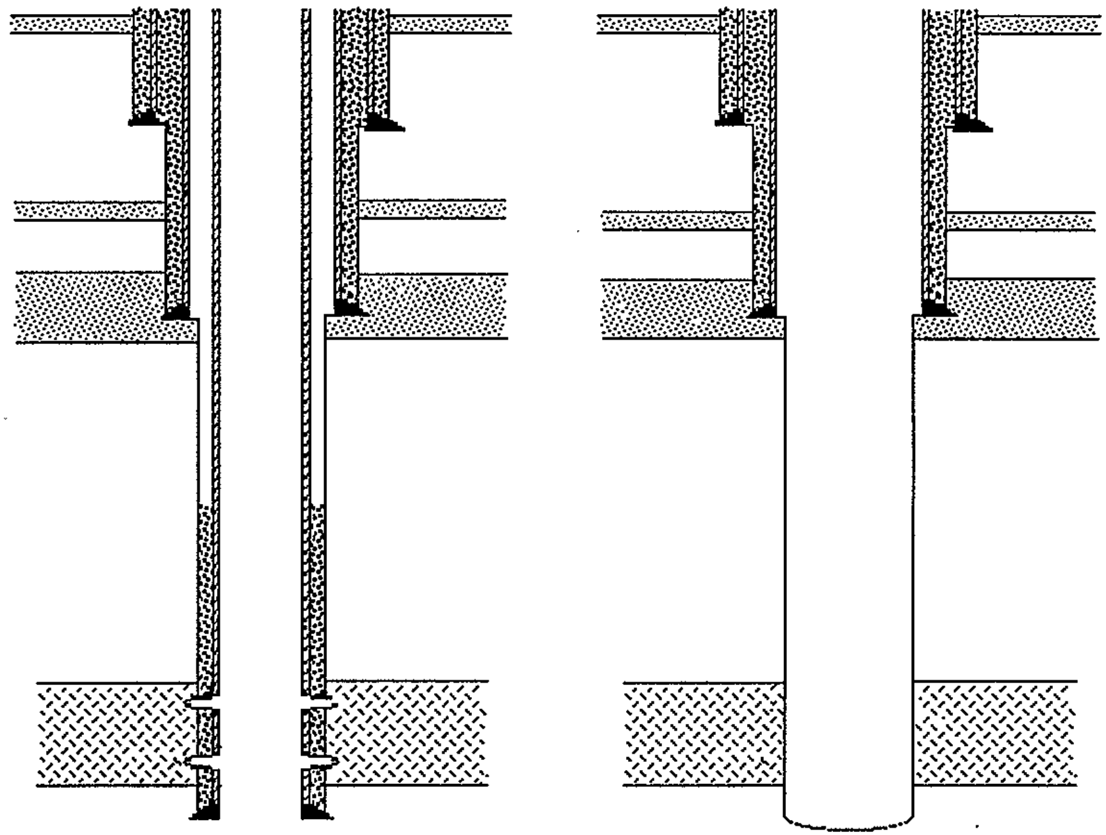
Position Asst. Treas.

Oil and Gas Inspector (Title) (Date)

Representing Basin Natural Gas Corp.

Address 1?0 W. Chaco, Aztec, New Mexico

FIGURE 18. EXAMPLE STATE WELL ABANDONMENT REPORT



PRODUCING WELL
CASING SET THROUGH PRODUCTIVE
ZONE(S)

DRY HOLE
NO PRODUCTION CASING STRING
RUN

FIGURE 19. TYPICAL WELL CONSTRUCTION - WESTERN AREA DEEP WELLS

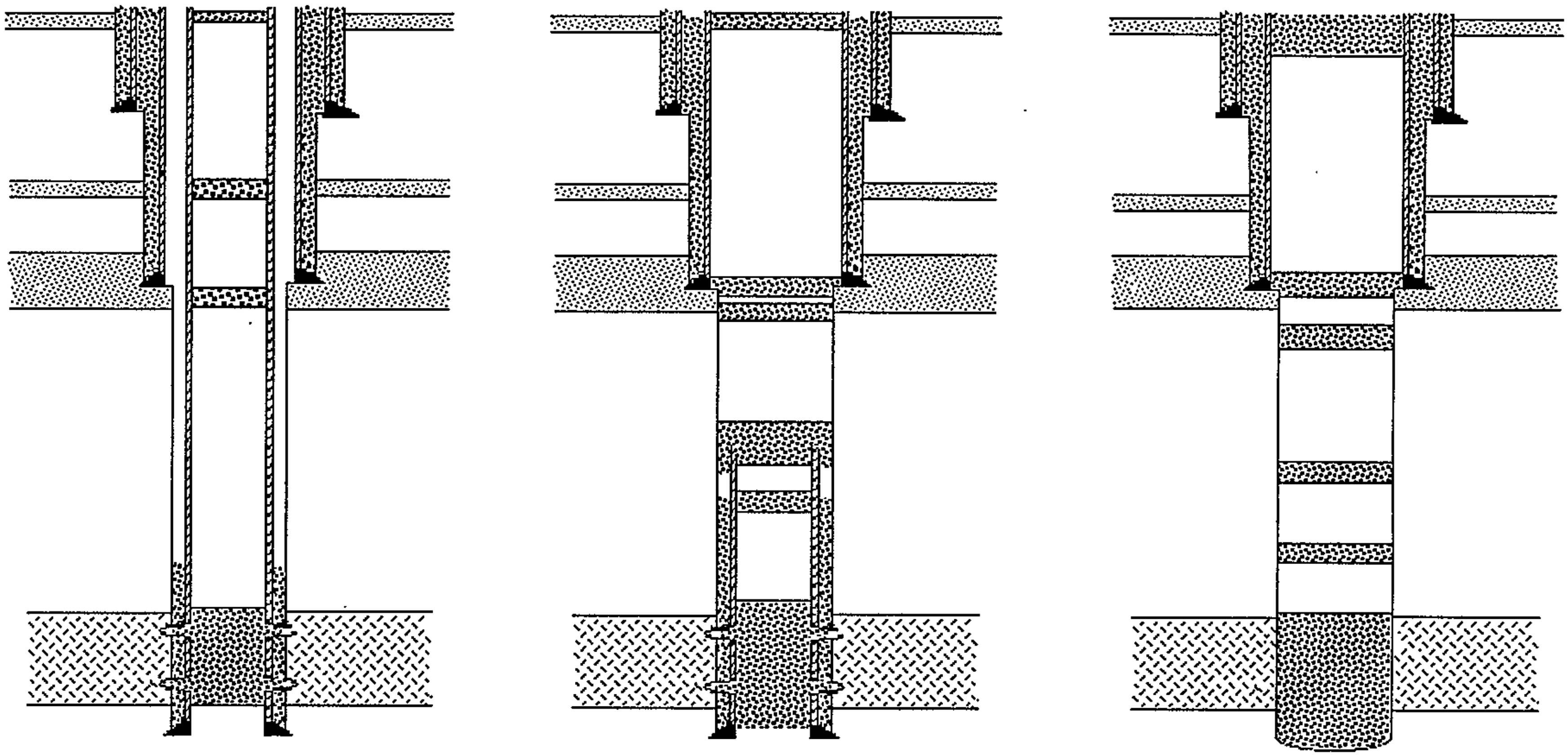
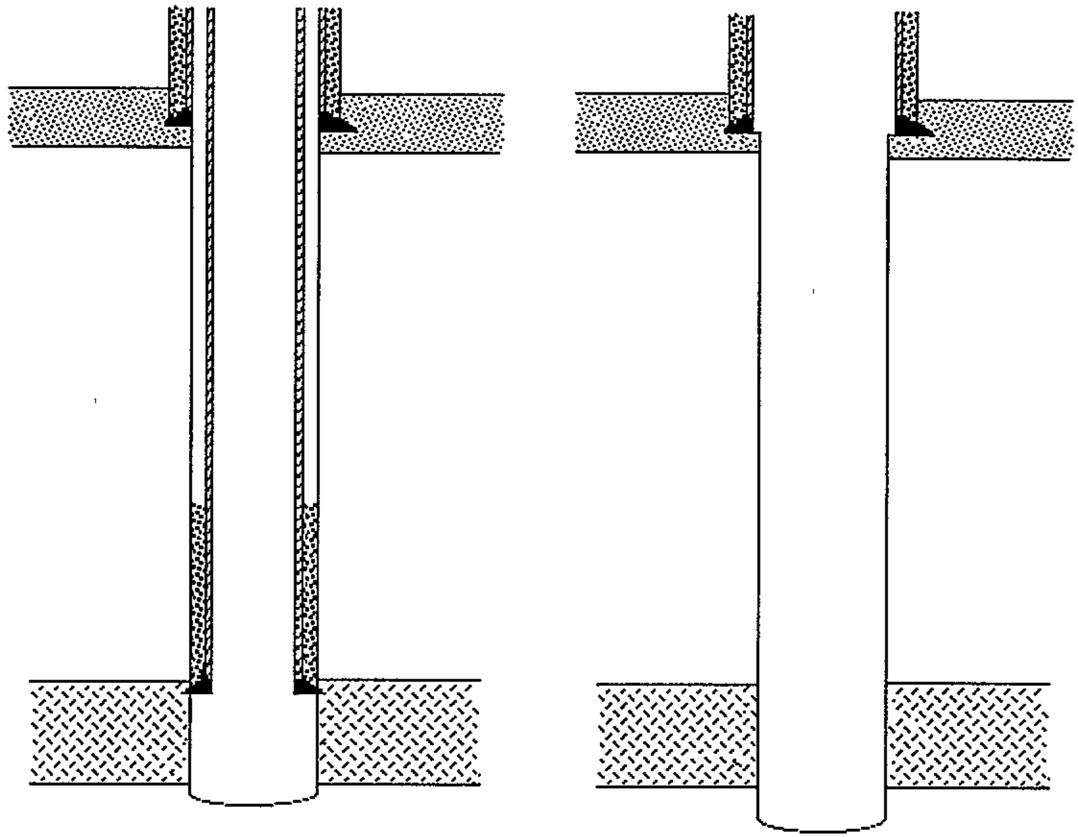


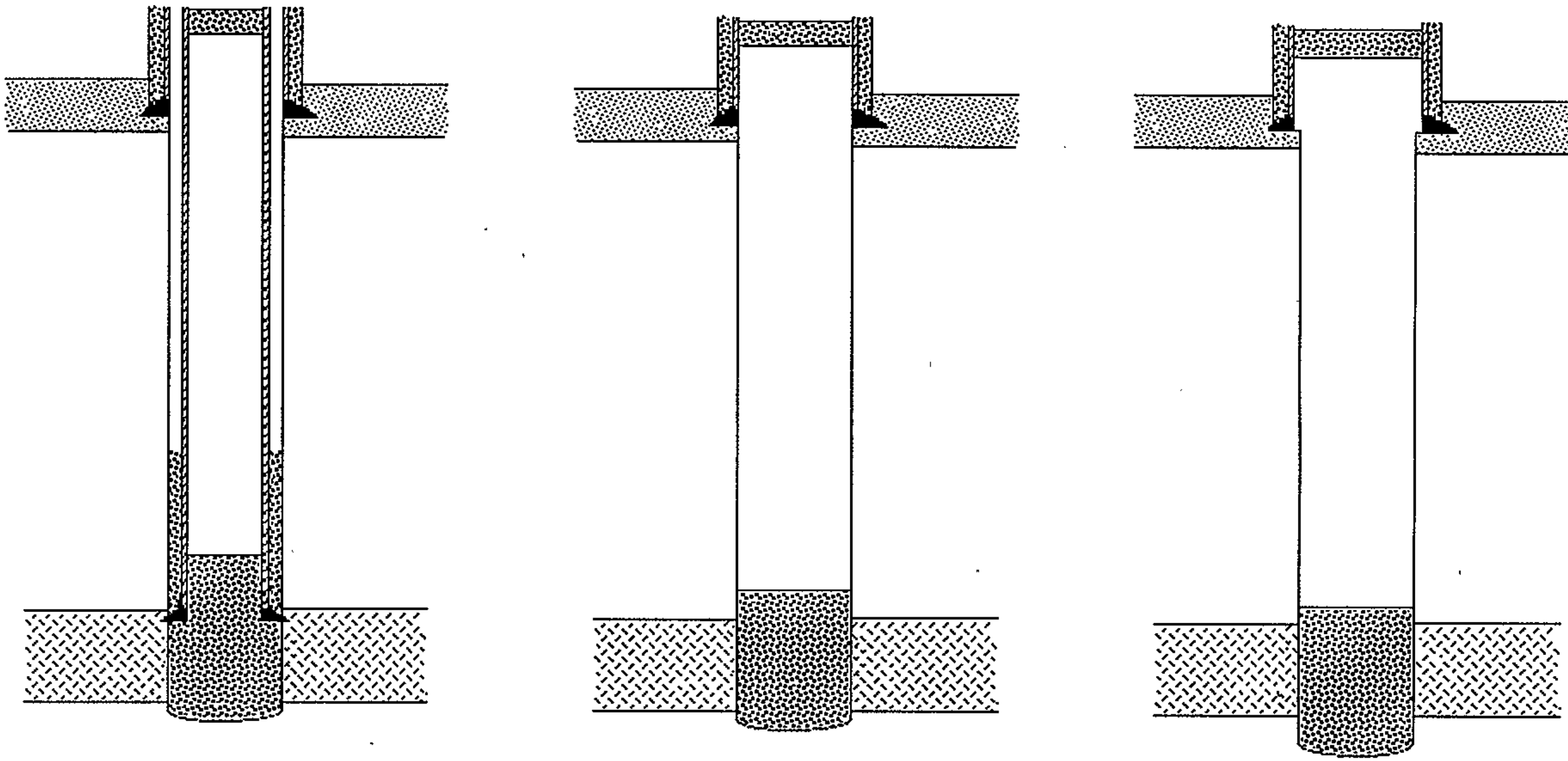
FIGURE 20. TYPICAL WELL ABANDONMENT - WESTERN AREA DEEP WELLS



PRODUCING WELL
CASING SET ON TOP OF PRODUCTIVE
ZONE(S)

DRY HOLE
NO PRODUCTION CASING STRING
RUN

FIGURE 21. TYPICAL WELL CONSTRUCTION - WESTERN AREA SHALLOW WELLS



PRODUCING WELL
CASING NOT PULLED

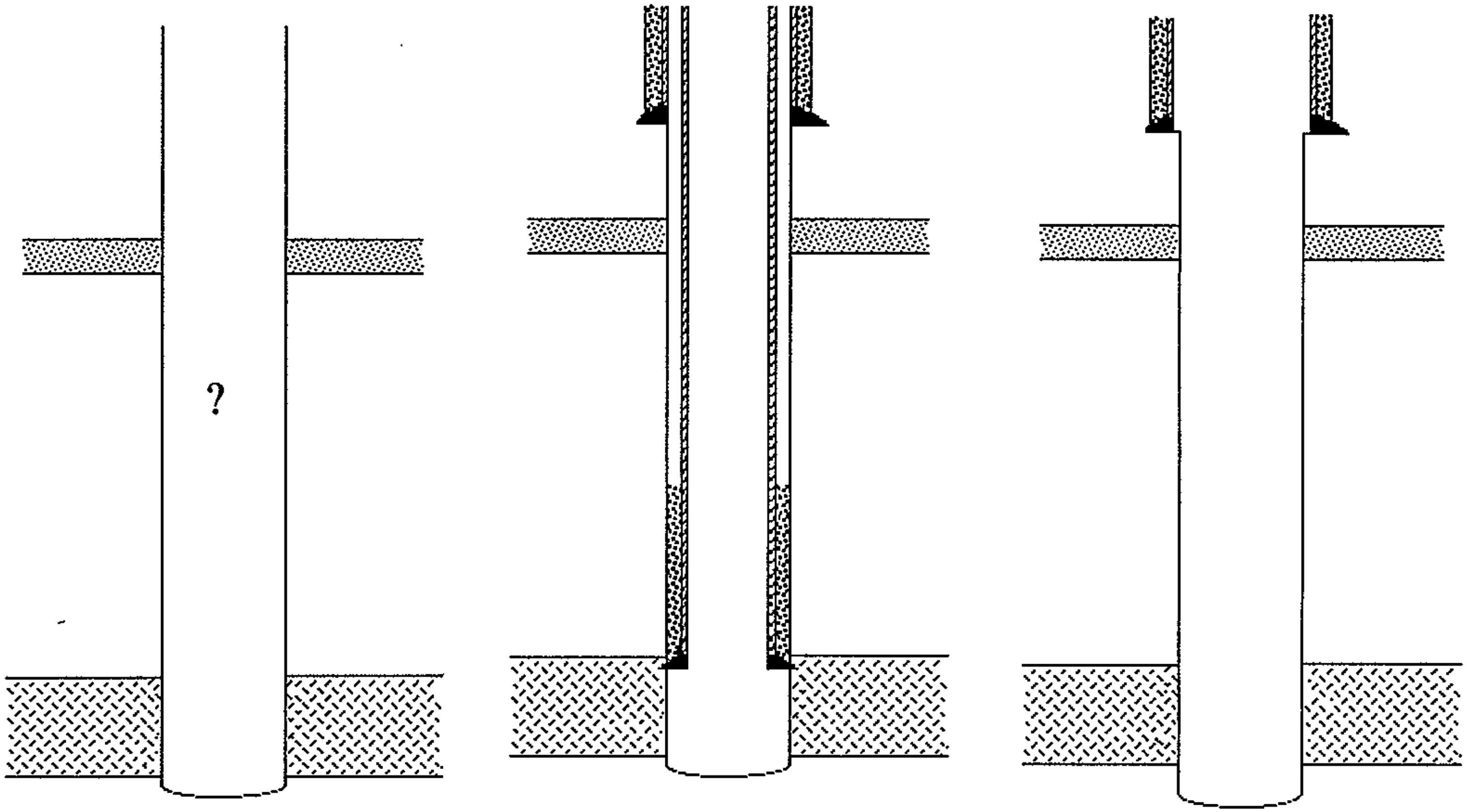
PRODUCING WELL
ALL CASING PULLED

DRY HOLE

NOTE: A NUMBER OF WELLS EXAMINED WERE ALSO CEMENTED FROM TD TO SURFACE

NOTE: IN PRODUCING WELLS WHERE CASING WAS PULLED, THE CASING STRING WAS NOT CEMENTED INITIALLY

FIGURE 22. TYPICAL WELL ABANDONMENT - WESTERN AREA SHALLOW WELLS



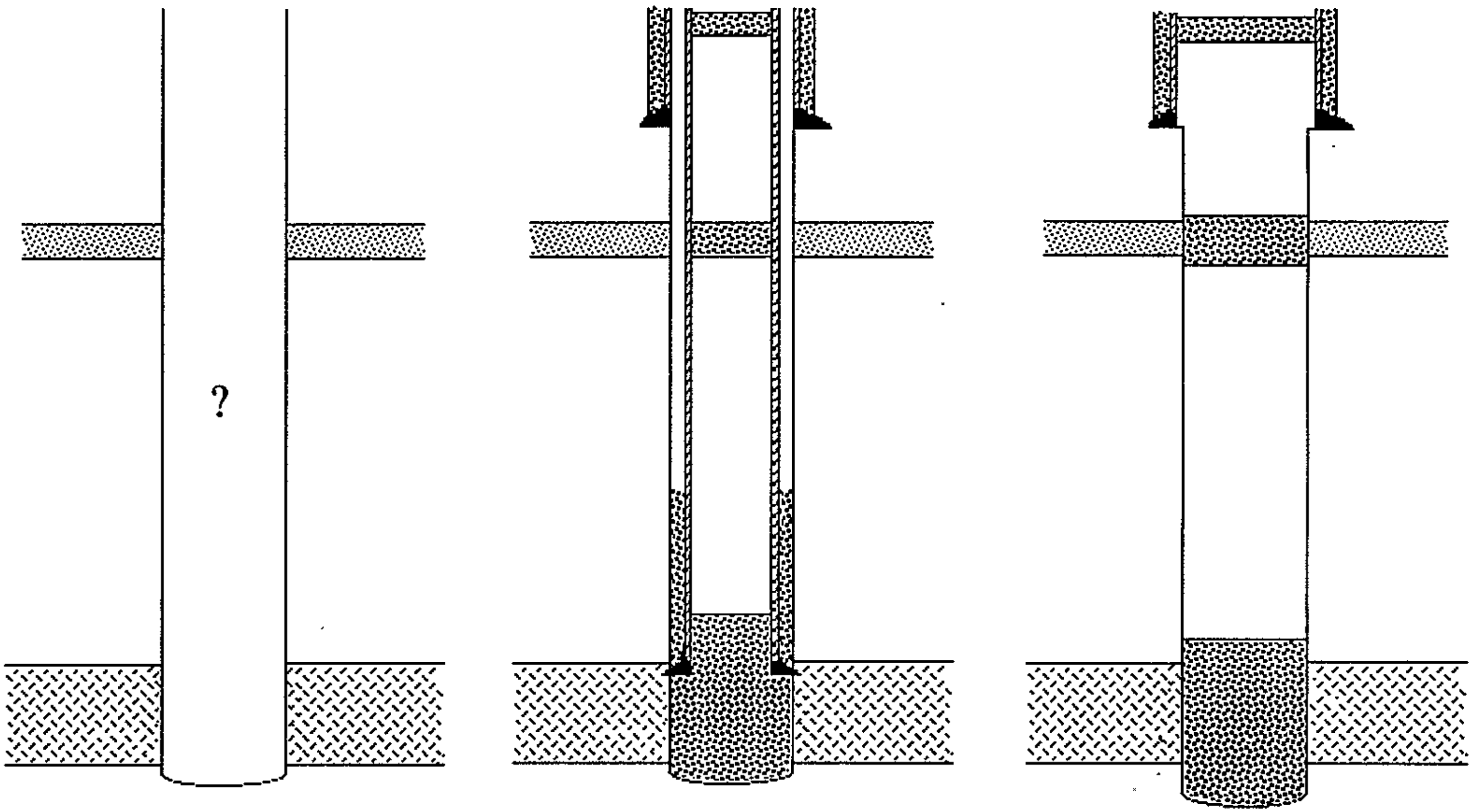
WELLS WITH NO CONSTUCTION DETAILS AVAILABLE

PRODUCING WELL WITH PRODUCTION CASING

DRY HOLE NO PRODUCTION CASING STRING RUN

NOTE: IN A LARGE PERCENTAGE OF THESE WELLS, CASING SETTING DEPTH IS UNKNOWN, AND WE CANNOT DETERMINE WHETHER CASING WAS SET ON TOP OF, OR THROUGH, THE PRODUCING ZONES

FIGURE 23. TYPICAL WELL CONSTRUCTION - SOUTHERN AREA WELLS

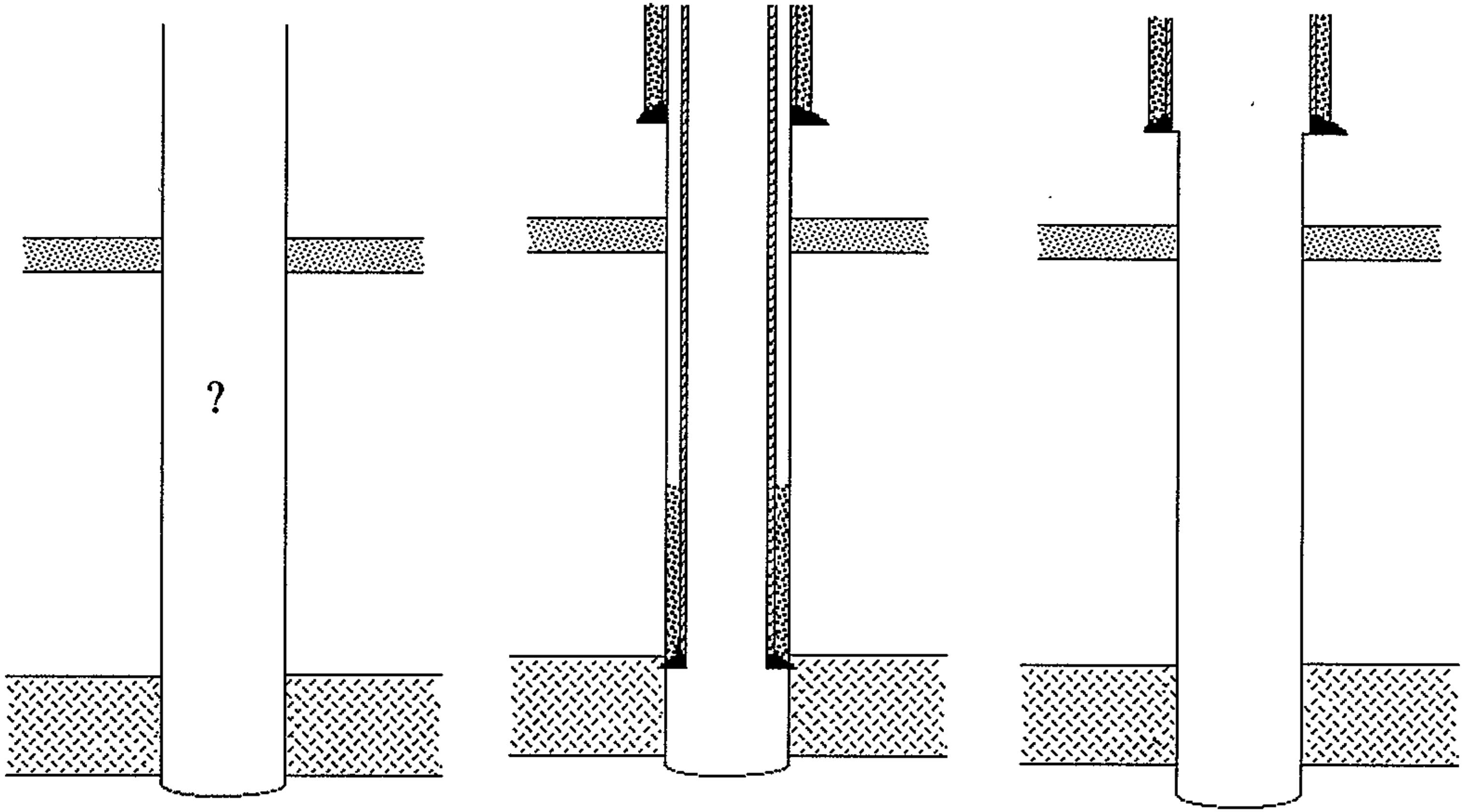


WELLS WITH NO ABANDONMENT DETAILS AVAILABLE

PRODUCING WELL

DRY HOLE

FIGURE 24. TYPICAL WELL ABANDONMENT - SOUTHERN AREA WELLS



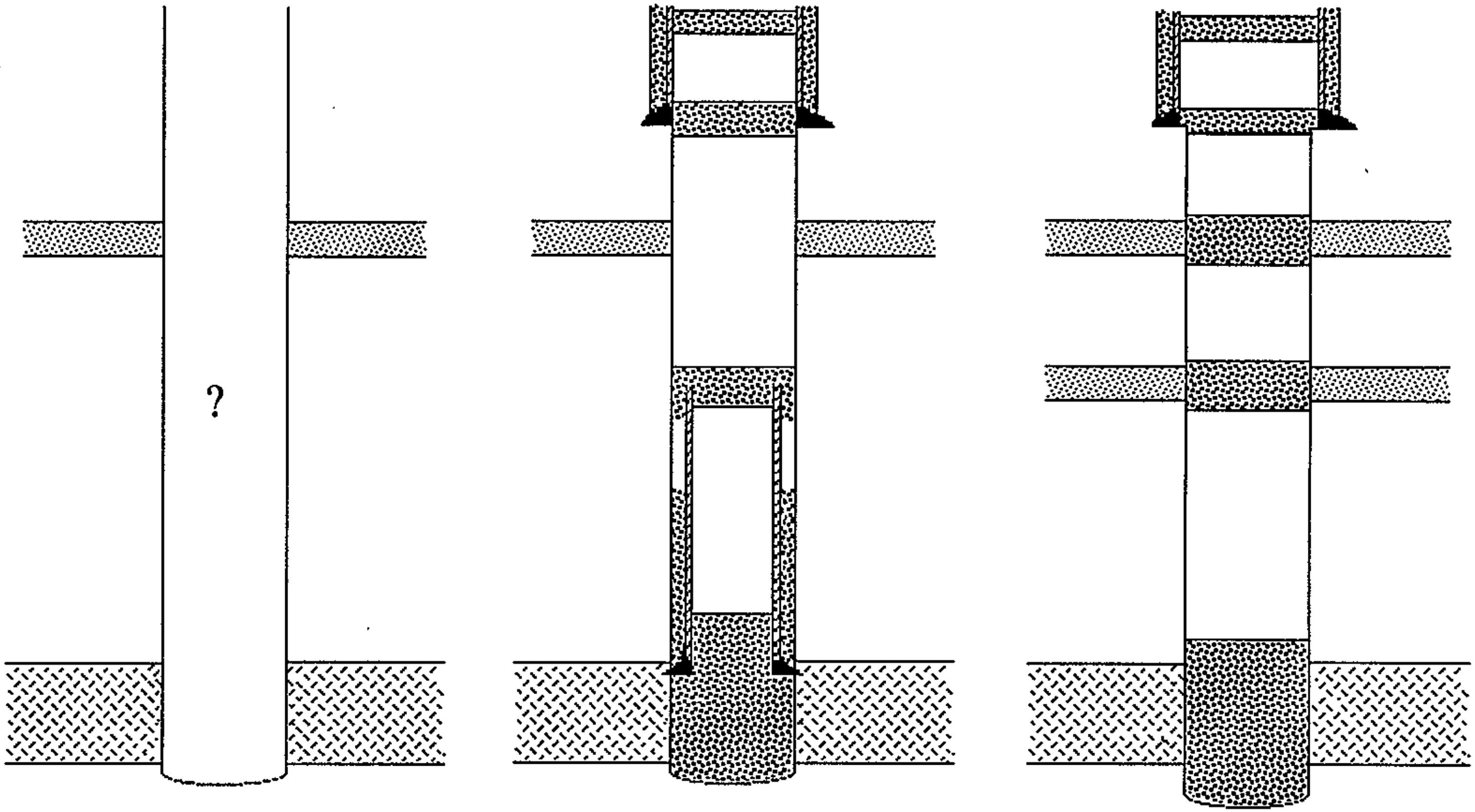
WELLS WITH NO CONSTUCTION
DETAILS AVAILABLE

PRODUCING WELL
WITH PRODUCTION CASING

DRY HOLE
NO PRODUCTION CASING STRING
RUN

NOTE: OPEN HOLE COMPLETIONS DOMINATE IN THE VERDE FIELD WHICH IS ONE OF THE LARGEST FIELDS SAMPLED. OPEN HOLE COMPLETIONS WERE NOT SEEN TO SUCH AN EXTENT IN OTHER SAMPLED FIELDS.

FIGURE 25. TYPICAL WELL CONSTRUCTION - INTERIOR I AREA WELLS

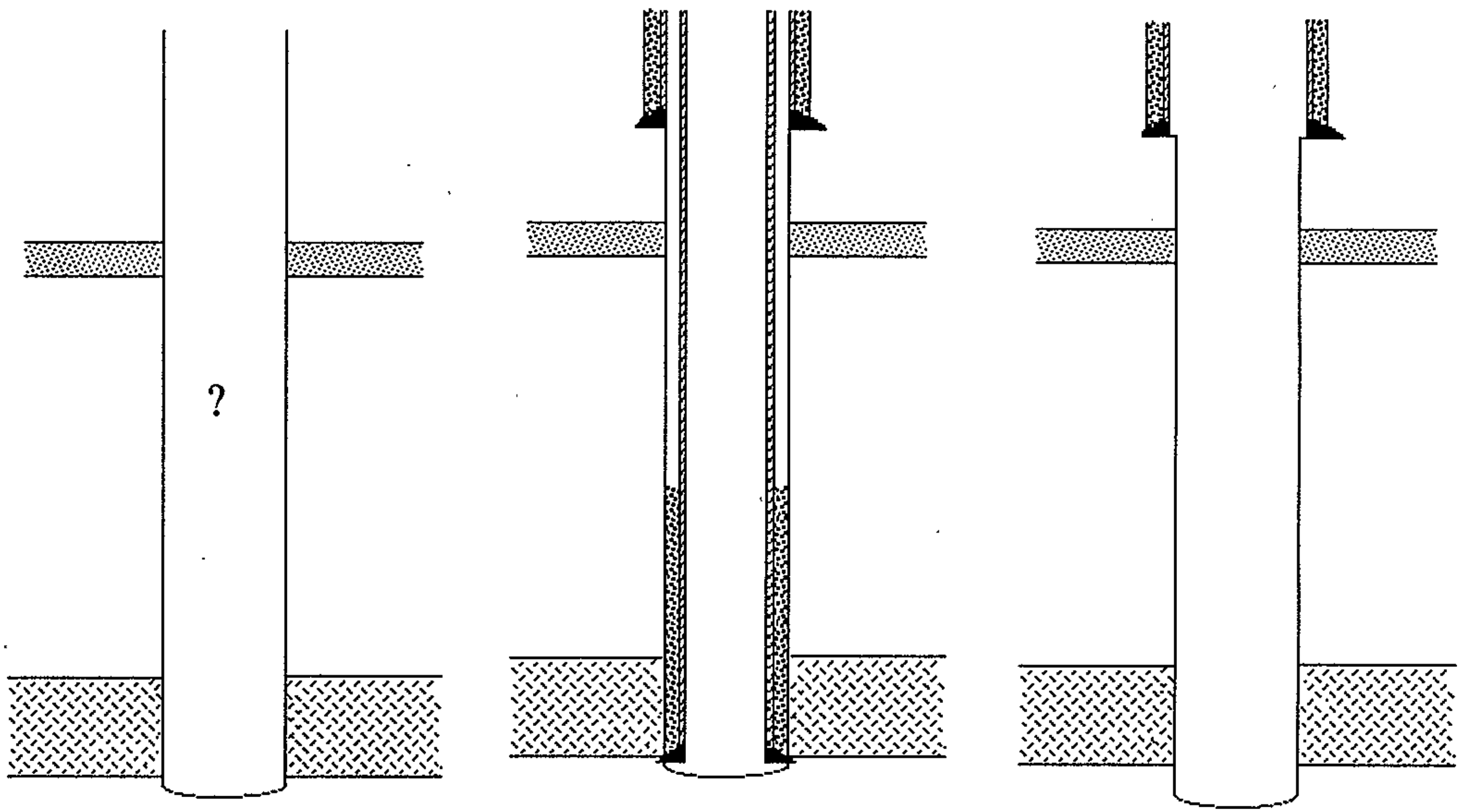


WELLS WITH NO ABANDONMENT DETAILS AVAILABLE

PRODUCING WELL

DRY HOLE

FIGURE 26. TYPICAL WELL ABANDONMENT - INTERIOR I AREA WELLS

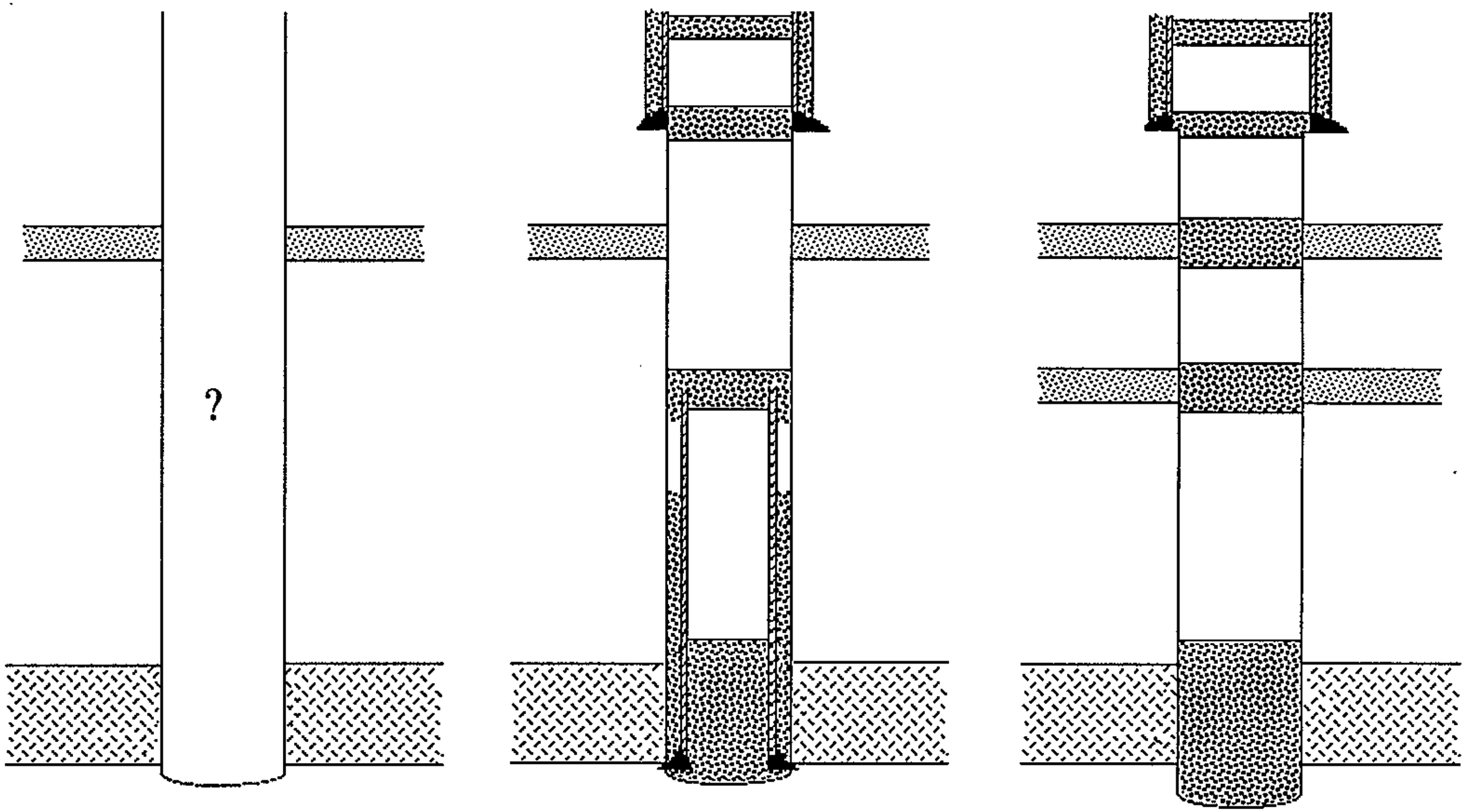


WELLS WITH NO CONSTUCTION
DETAILS AVAILABLE

PRODUCING WELL
WITH PRODUCTION CASING

DRY HOLE
NO PRODUCTION CASING STRING
RUN

FIGURE 27. TYPICAL WELL CONSTRUCTION - INTERIOR II AREA WELLS



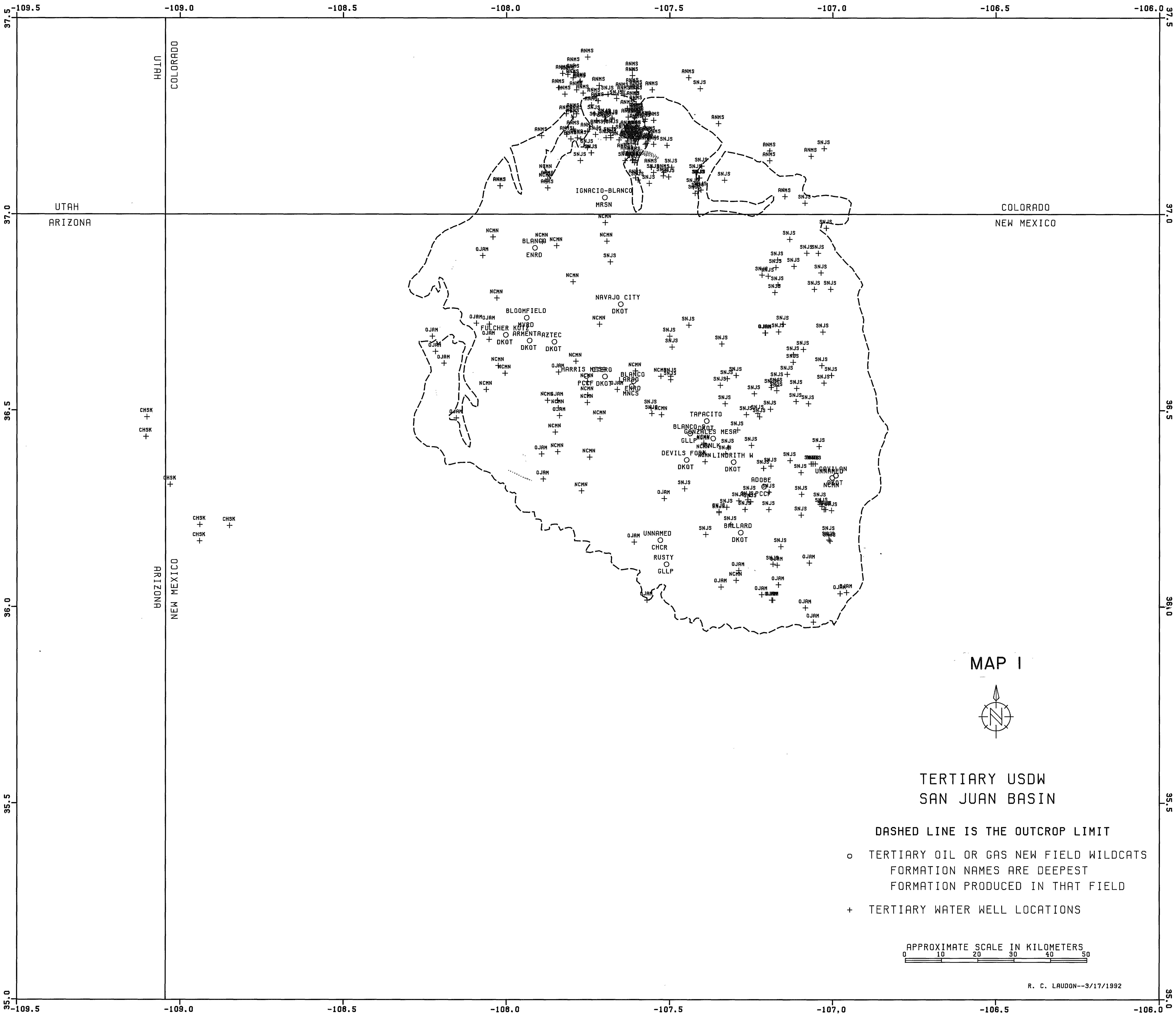
WELLS WITH NO ABANDONMENT DETAILS AVAILABLE

PRODUCING WELL

DRY HOLE

NOTE: APPROXIMATELY 1/2 OF THE WELLS COMPLETED WITH PRODUCTION CASING HAD THE CASING PULLED AT ABANDONMENT. THE REMAINING WELLS WERE ABANDONED WITH THE CASING LEFT IN THE HOLE.

FIGURE 28.TYPICAL WELL ABANDONMENT - INTERIOR II AREA WELLS



KEY TO FORMATION AND MEMBER NAMES--SAN JUAN BASIN
==
(LISTED IN ALPHIBETICAL ORDER BY USDW GROUPING)

TERTIARY
- ANMS = ANIMAS
- CHSK = CHUSKA
- FMNG = FARMINGTON
- NCMN = NACIEMENTO
- OJAM = OJO ALAMO
- SNJS = SAN JOSE

UPPER CRETACEOUS:
- FRLD = FRUITLAND
- KRLD = KIRTLAND
- LWIS = LEWIS
- PCCF = PICTURED CLIFFS

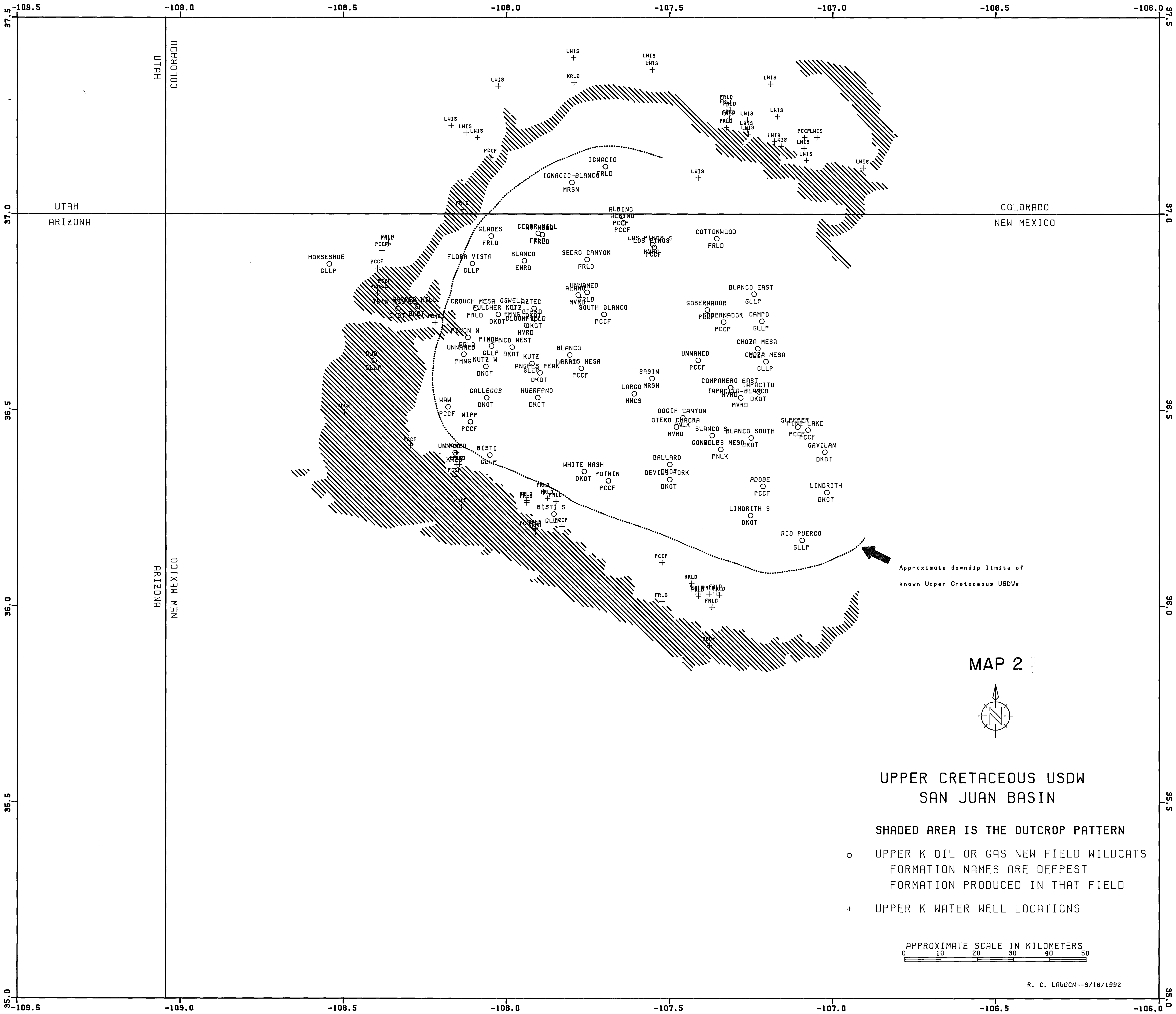
MESA VERDE
- CHCR = CHACRA
- CLFH = CLIFF HOUSE
- CLRY = CLEARY
- CRVC = CREVASSE CANYON
- HOST = HOSTA
- LVNN = LA VENTANA
- MENF = MENEFEE
- MNCS = MANCOS
- MVRD = MESA VERDE
- PNLK = POINT LOOKOUT

GALLUP
- CRLL = CARLILE
- GLLP = GALLUP
- HSPH = HOSPAH
- NBRR = NIOBRARA
- SNST = SANASTEE
- TOCT = TOCITO

DAKOTA
- DKOT = DAKOTA
- GRNR = GREENHORN
- GRRS = GRANEROS

MORRISON
- BRSB = BRUSHY BASIN
- MRSN = MORRISON
- WSRC = WEST WATER CANYON

BELOW MORRISON
- AKAH = AKAH
- BCKC = BARKER CREEK
- CTLR = CUTLER
- DRCK = DRY CREEK
- DVNN = DEVONIAN
- ENRD = ENTRADA
- GRNT = GRANT
- HBCK = HOGBACK
- HRMS = HERMOSA
- ISMY = ISMAY
- MCCK = MACK CREEK
- MSSP = MISSISSIPPIAN
- NOWN = UNKNOWN
- OURY = OURAY
- PCMB = PRECAMBRIAN
- PRDX = PARADOX
- PSLV = PENNSYLVANIAN
- TDLT = TODILTO
- YESO = YESO



KEY TO FORMATION AND MEMBER NAMES--SAN JUAN BASIN
===
(LISTED IN ALPHABETICAL ORDER BY USDW GROUPING)

TERTIARY
ANMS = ANIMAS
CHSK = CHUSKA
FMNG = FARMINGTON
NCMN = NACIEMENTO
OJAM = OJO ALAMO
SNJS = SAN JOSE

UPPER CRETACEOUS
FRLD = FRUITLAND
KRLD = KIRTLAND
LWIS = LEWIS
PCCF = PICTURED CLIFFS

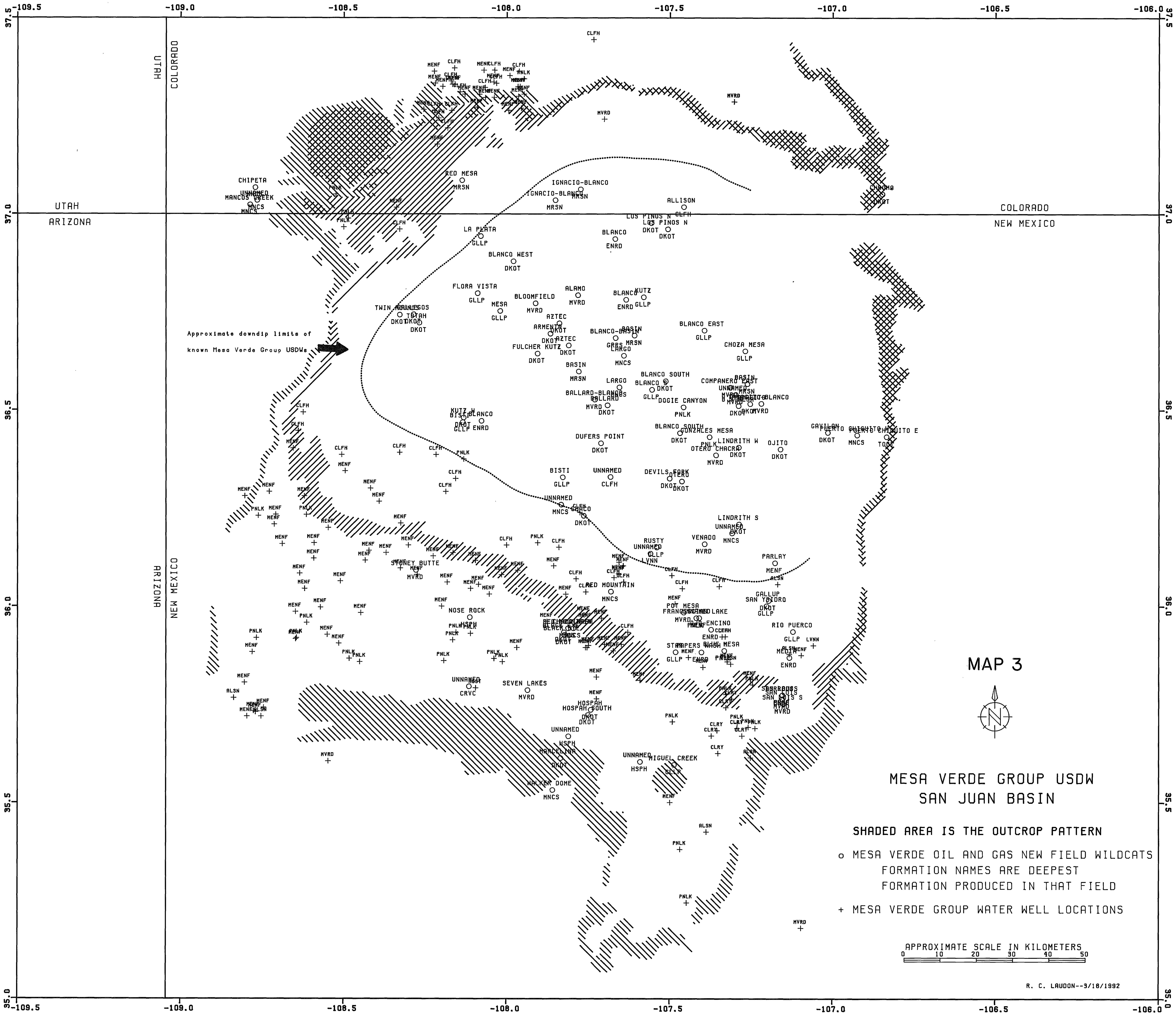
MESA VERDE
CHCR = CHACRA
CLFH = CLIFF HOUSE
CLRY = CLEARY
CRVC = CREVASSE CANYON
HOST = HOSTA
LVNN = LA VENTANA
MENF = MENEFEE
MNCS = MANCOS
MVRD = MESA VERDE
PNLK = POINT LOOKOUT

GALLUP
CRLL = CARLILE
GLLP = GALLUP
HSPH = HOSPAH
NBRR = NIOBRARA
SNST = SANASTEE
TOCT = TOCITO

DAKOTA
DKOT = DAKOTA
GRNR = GREENHORN
GRRS = GRANEROS

MORRISON
BRSB = BRUSHY BASIN
MRSN = MORRISON
WSRC = WEST WATER CANYON

BELOW MORRISON
AKAH = AKAH
BCKC = BARKER CREEK
CTLR = CUTLER
DRCK = DRY CREEK
DVNN = DEVONIAN
ENRD = ENTRADA
GRNT = GRANT
HBCK = HOGBACK
HRMS = HERMOSA
ISMY = ISMAY
MCCK = MACK CREEK
MSSP = MISSISSIPPIAN
NOWN = UNKNOWN
OURY = OURAY
PCMB = PRECAMBRIAN
PRDX = PARADOX
PSLV = PENNSYLVANIAN
TDLT = TODILTO
YESO = YESO



KEY TO FORMATION AND MEMBER NAMES--SAN JUAN BASIN

(LISTED IN ALPHIBETICAL ORDER BY USDW GROUPING)

TERTIARY
ANMS = ANIMAS
CHSK = CHUSKA
FMNG = FARMINGTON
NCMN = NACIEMENTO
OJAM = OJO ALAMO
SNJS = SAN JOSE

UPPER CRETACEOUS
FRLD = FRUITLAND
KRLD = KIRTLAND
LWIS = LEWIS
PCCF = PICTURED CLIFFS

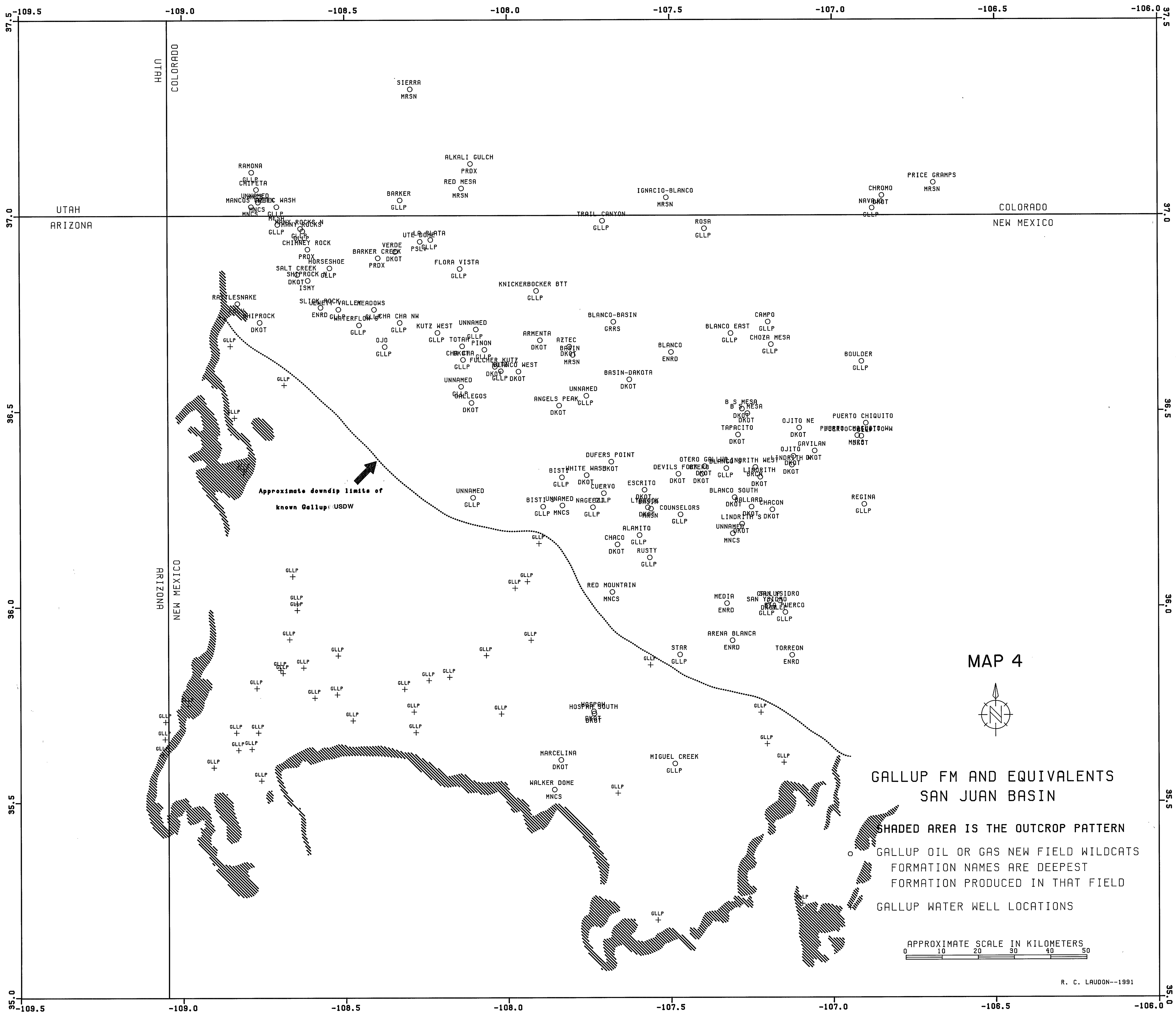
MESA VERDE
CHCR = CHACRA
CLFH = CLIFF HOUSE
CLRY = CLEARY
CRVC = CREVASSE CANYON
HOST = HOSTA
LVNN = LA VENTANA
MENF = MENEFEE
MNCS = MANCOS
MVRD = MESA VERDE
PNLK = POINT LOOKOUT

GALLUP
CRLL = CARLILE
GLLP = GALLUP
HSPH = HOSPAH
NBRR = NIOBRARA
SNST = SANASTEE
TOCT = TOCITO

DAKOTA
DKOT = DAKOTA
GRNR = GREENHORN
GRRS = GRANEROS

MORRISON
BRSB = BRUSHY BASIN
MRSN = MORRISON
WSRC = WEST WATER CANYON

BELOW MORRISON
AKAH = AKAH
BCKC = BARKER CREEK
CTLR = CUTLER
DRCK = DRY CREEK
DVNN = DEVONIAN
ENRD = ENTRADA
GRNT = GRANT
HBCK = HOGBACK
HRMS = HERMOSA
ISMY = ISMAY
MCCK = MACK CREEK
MSSP = MISSISSIPPIAN
NOWN = UNKNOWN
OURY = OURAY
PCMB = PRECAMBRIAN
PRDX = PARADOX
PSLV = PENNSYLVANIAN
TDLT = TODILTO
YESO = YESO



KEY TO FORMATION AND MEMBER NAMES--SAN JUAN BASIN

(LISTED IN ALPHIBETICAL ORDER BY USDW GROUPING)

TERTIARY
- ANMS = ANIMAS
- CHSK = CHUSKA
- FMNG = FARMINGTON
- NCMN = NACIEMENTO
- OJAM = OJO ALAMO
- SNJS = SAN JOSE

UPPER CRETACEOUS
- FRLD = FRUITLAND
- KRLD = KIRTLAND
- LWIS = LEWIS
- PCCF = PICTURED CLIFFS

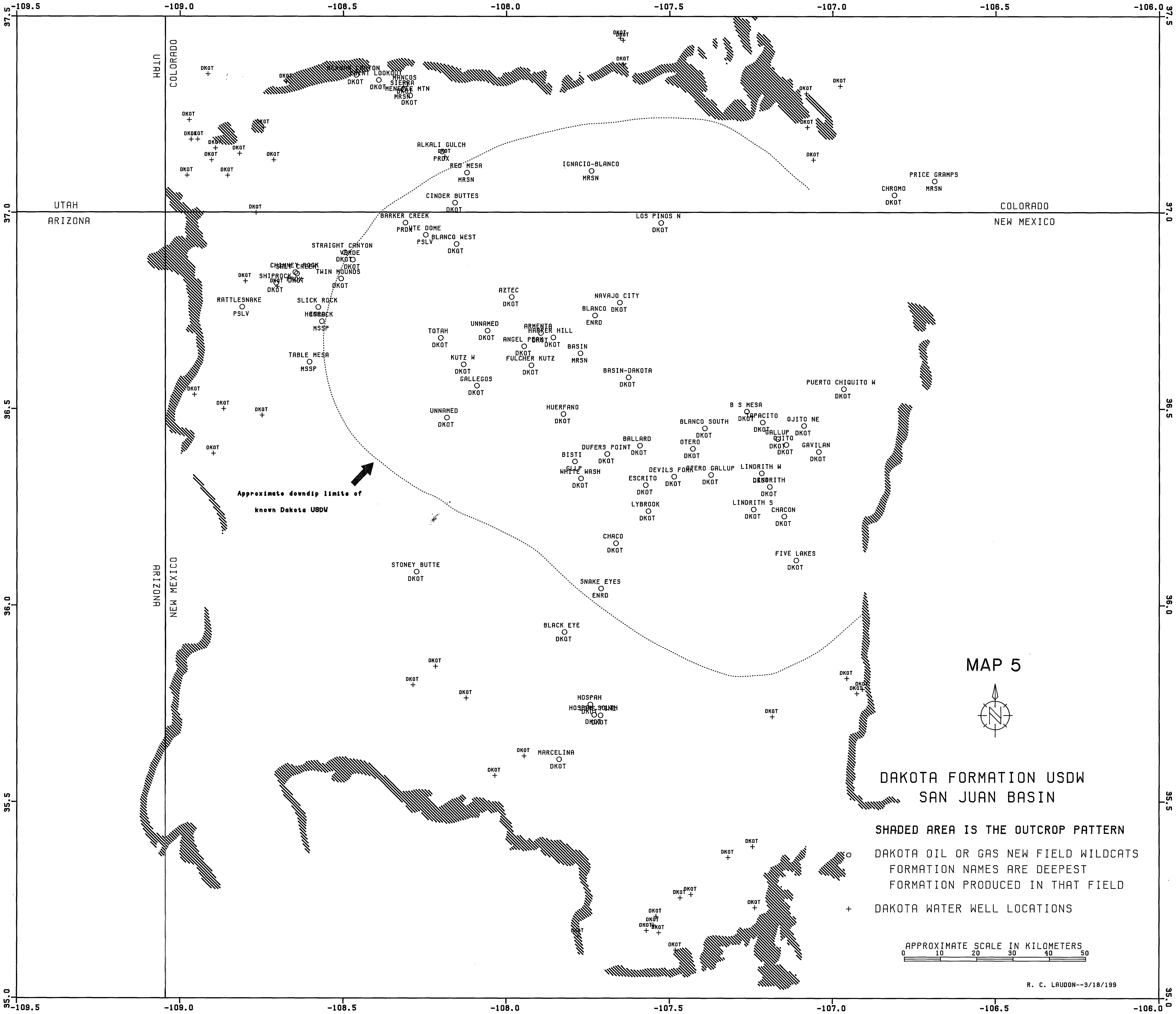
MESA VERDE
- CHCR = CHACRA
- CLFH = CLIFF HOUSE
- CLRY = CLEARY
- CRVC = CREVASSE CANYON
- HOST = HOSTA
- LVNN = LA VENTANA
- MENF = MENEFEE
- MNCS = MANCOS
- MVRD = MESA VERDE
- PNLK = POINT LOOKOUT

GALLUP
- CRLL = CARLILE
- GLLP = GALLUP
- HSPH = HOSPAH
- NBRR = NIOBRARA
- SNST = SANASTEE
- TOCT = TOCITO

DAKOTA
- DKOT = DAKOTA
- GRNR = GREENHORN
- GRRS = GRANEROS

MORRISON
- BRSB = BRUSHY BASIN
- MRSN = MORRISON
- WSRC = WEST WATER CANYON

BELOW MORRISON
- AKAH = AKAH
- BCKC = BARKER CREEK
- CTLR = CUTLER
- DRCK = DRY CREEK
- DVNN = DEVONIAN
- ENRD = ENTRADA
- GRNT = GRANT
- HBCK = HOGBACK
- HRMS = HERMOSA
- ISMY = ISMAY
- MCCK = MACK CREEK
- MSSP = MISSISSIPPIAN
- NOWN = UNKNOWN
- OURY = OURAY
- PCMB = PRECAMBRIAN
- PRDX = PARADOX
- PSLV = PENNSYLVANIAN
- TDLT = TODILTO
- YESO = YESO



KEY TO FORMATION AND MEMBER NAMES--SAN JUAN BASIN

(LISTED IN ALPHIBETICAL ORDER BY USDW GROUPING)

TERTIARY
- ANMS = ANIMAS
- CHSK = CHUSKA
- FMNG = FARMINGTON
- NCMN = NACIEMENTO
- OJAM = OJO ALAMO
- SNJS = SAN JOSE

UPPER CRETACEOUS
- FRLD = FRUITLAND
- KRLD = KIRTLAND
- LWIS = LEWIS
- PCCF = PICTURED CLIFFS

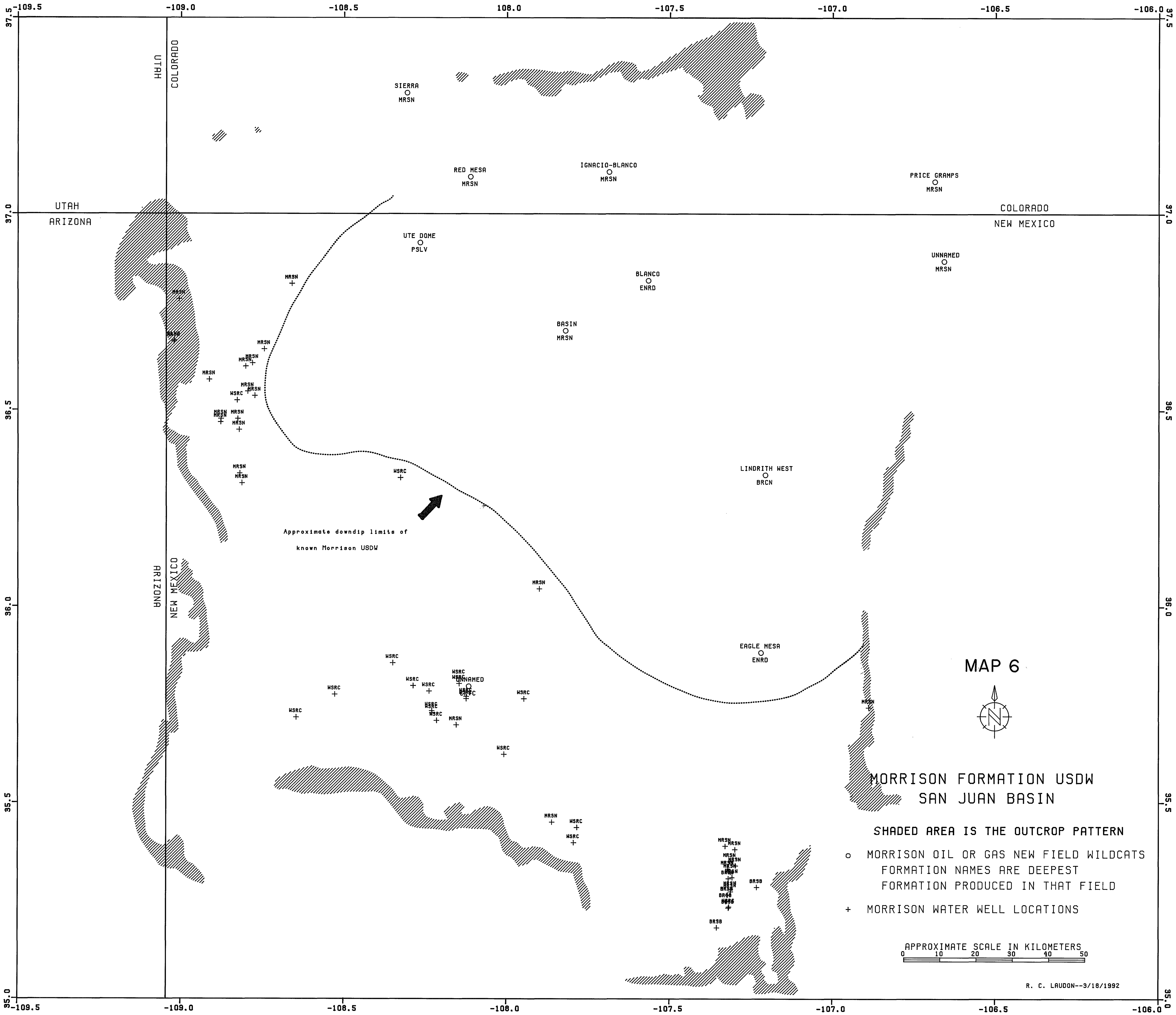
MESA VERDE
- CHCR = CHACRA
- CLFH = CLIFF HOUSE
- CLRY = CLEARY
- CRVC = CREVASSE CANYON
- HOST = HOSTA
- LVNN = LA VENTANA
- MENF = MENEFEE
- MNCS = MANCOS
- MVRD = MESA VERDE
- PNLK = POINT LOOKOUT

GALLUP
- CRLL = CARLILE
- GLLP = GALLUP
- HSPH = HOSPAH
- NBRR = NIOBRARA
- SNST = SANASTEE
- TOCT = TOCITO

DAKOTA
- DKOT = DAKOTA
- GRNR = GREENHORN
- GRRS = GRANEROS

MORRISON
- BRSB = BRUSHY BASIN
- MRSN = MORRISON
- WSRC = WEST WATER CANYON

BELOW MORRISON
- AKAH = AKAH
- BCKC = BARKER CREEK
- CTLR = CUTLER
- DRCK = DRY CREEK
- DVNN = DEVONIAN
- ENRD = ENTRADA
- GRNT = GRANT
- HBCK = HOGBACK
- HRMS = HERMOSA
- ISMY = ISMAY
- MCCK = MACK CREEK
- MSSP = MISSISSIPPIAN
- NOWN = UNKNOWN
- OURY = OURAY
- PCMB = PRECAMBRIAN
- PRDX = PARADOX
- PSLV = PENNSYLVANIAN
- TDLT = TODILTO
- YESO = YESO



KEY TO FORMATION AND MEMBER NAMES--SAN JUAN BASIN

(LISTED IN ALPHIBETICAL ORDER BY USDW GROUPING)

TERTIARY
- ANMS = ANIMAS
- CHSK = CHUSKA
- FMNG = FARMINGTON
- NCMN = NACIEMENTO
- OJAM = OJO ALAMO
- SNJS = SAN JOSE

UPPER CRETACEOUS
- FRLD = FRUITLAND
- KRLD = KIRTLAND
- LWIS = LEWIS
- PCCF = PICTURED CLIFFS

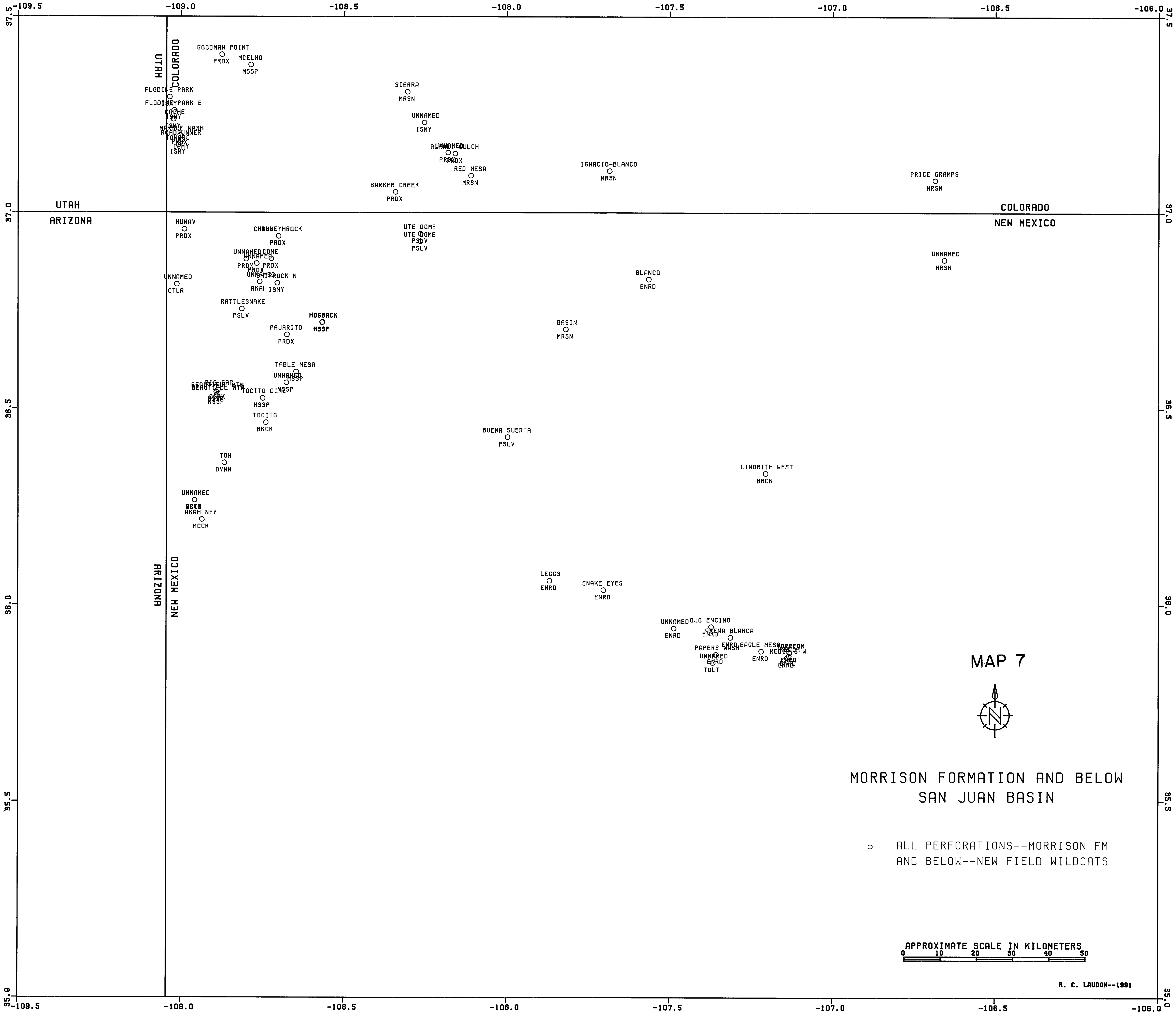
MESA VERDE
- CHCR = CHACRA
- CLFH = CLIFF HOUSE
- CLRY = CLEARY
- CRVC = CREVASSE CANYON
- HOST = HOSTA
- LVNN = LA VENTANA
- MENF = MENEFEE
- MNCS = MANCOS
- MVRD = MESA VERDE
- PNLK = POINT LOOKOUT

GALLUP
- CRLL = CARLILE
- GLLP = GALLUP
- HSPH = HOSPAH
- NBRR = NIOBRARA
- SNST = SANASTEE
- TOCT = TOCITO

DAKOTA
- DKOT = DAKOTA
- GRNR = GREENHORN
- GRRS = GRANEROS

MORRISON
- BRSB = BRUSHY BASIN
- MRSN = MORRISON
- WSRC = WEST WATER CANYON

BELOW MORRISON
- AKAH = AKAH
- BCKC = BARKER CREEK
- CTLR = CUTLER
- DRCK = DRY CREEK
- DVNN = DEVONIAN
- ENRD = ENTRADA
- GRNT = GRANT
- HBCK = HOGBACK
- HRMS = HERMOSA
- ISMY = ISMAY
- MCCK = MACK CREEK
- MSSP = MISSISSIPPIAN
- NOWN = UNKNOWN
- OURY = OURAY
- PCMB = PRECAMBRIAN
- PRDX = PARADOX
- PSLV = PENNSYLVANIAN
- TDLT = TODILTO
- YESO = YESO



KEY TO FORMATION AND MEMBER NAMES--SAN JUAN BASIN

(LISTED IN ALPHIBETICAL ORDER BY USDW GROUPING)

TERTIARY
- ANMS = ANIMAS
- CHSK = CHUSKA
- FMNG = FARMINGTON
- NCMN = NACIEMENTO
- OJAM = OJO ALAMO
- SNJS = SAN JOSE

UPPER CRETACEOUS
- FRLD = FRUITLAND
- KRLD = KIRTLAND
- LWIS = LEWIS
- PCCF = PICTURED CLIFFS

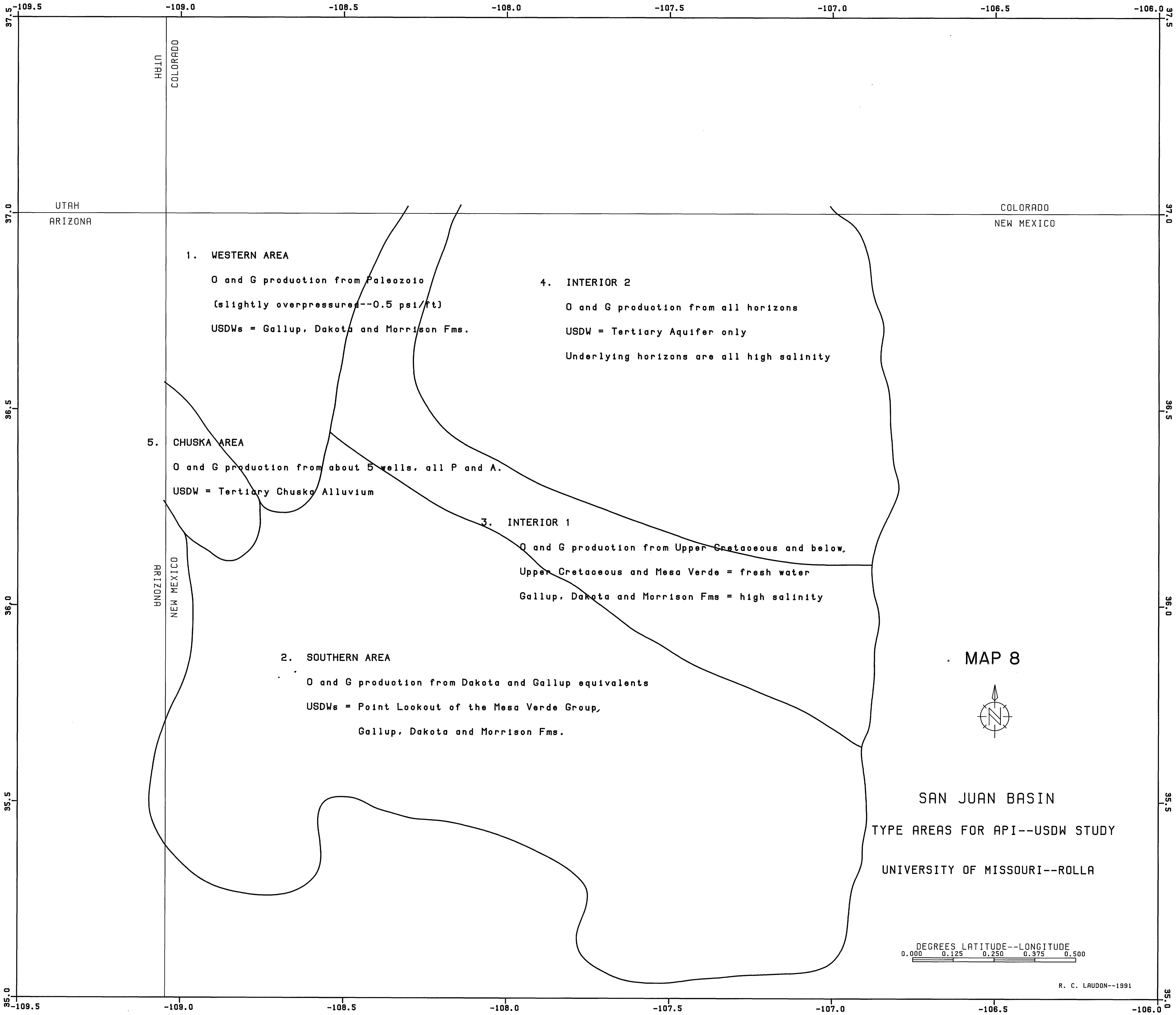
MESA VERDE
- CHCR = CHACRA
- CLFH = CLIFF HOUSE
- CLRY = CLEARY
- CRVC = CREVASSE CANYON
- HOST = HOSTA
- LVNN = LA VENTANA
- MENF = MENEFEE
- MNCS = MANCOS
- MVRD = MESA VERDE
- PNLK = POINT LOOKOUT

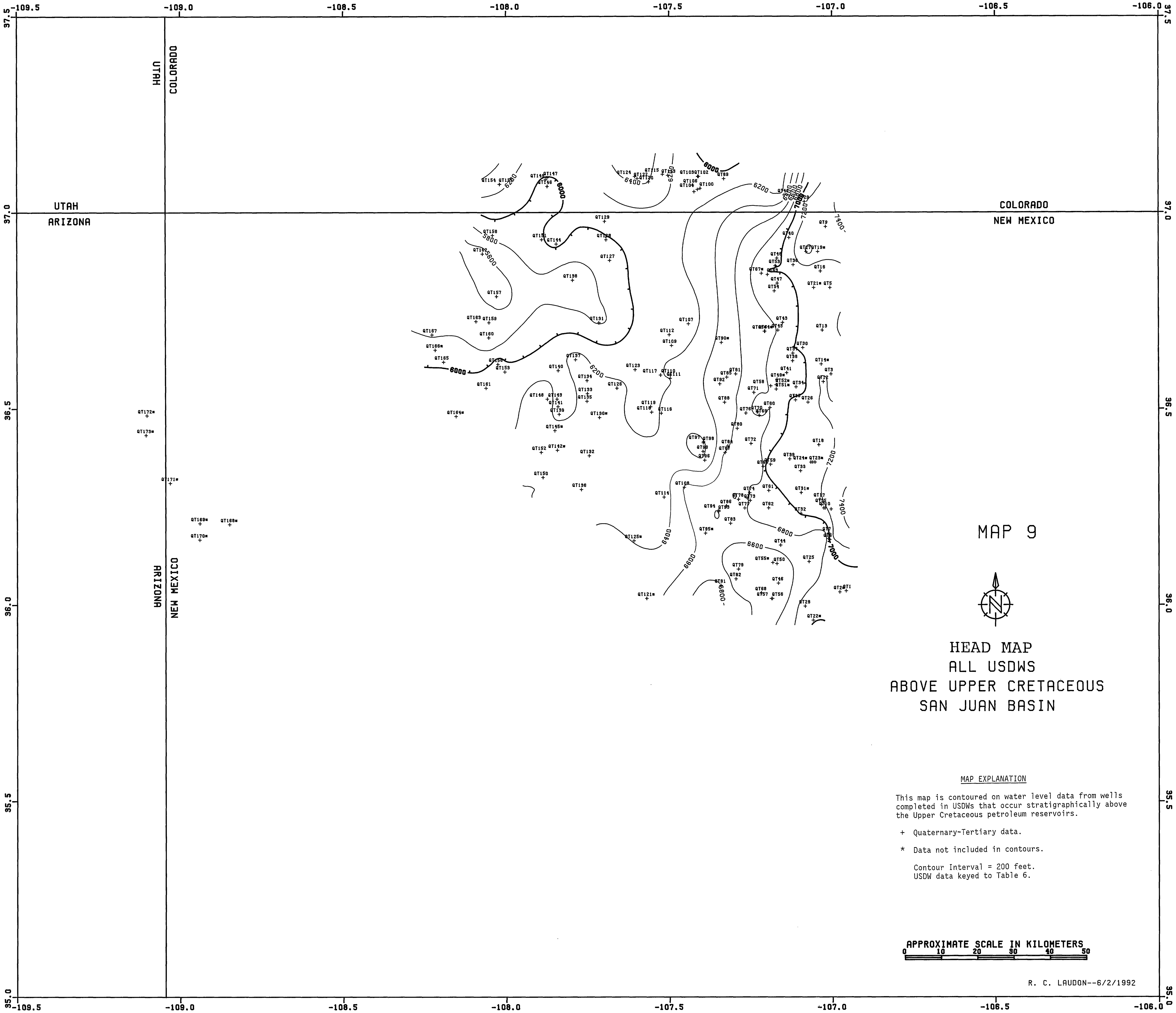
GALLUP
- CRLL = CARLILE
- GLLP = GALLUP
- HSPH = HOSPAH
- NBRR = NIOBRARA
- SNST = SANASTEE
- TOCT = TOCITO

DAKOTA
- DKOT = DAKOTA
- GRNR = GREENHORN
- GRRS = GRANEROS

MORRISON
- BRSB = BRUSHY BASIN
- MRSN = MORRISON
- WSRC = WEST WATER CANYON

BELOW MORRISON
- AKAH = AKAH
- BCKC = BARKER CREEK
- CTLR = CUTLER
- DRCK = DRY CREEK
- DVNN = DEVONIAN
- ENRD = ENTRADA
- GRNT = GRANT
- HBCK = HOGBACK
- HRMS = HERMOSA
- ISMY = ISMAY
- MCCK = MACK CREEK
- MSSP = MISSISSIPPIAN
- NOWN = UNKNOWN
- OURY = OURAY
- PCMB = PRECAMBRIAN
- PRDX = PARADOX
- PSLV = PENNSYLVANIAN
- TDLT = TODILTO
- YESO = YESO


-109.5
-109.0
-108.5
-108.0
-107.5
-107.0
-106.5
-106.0
37.5
37.0
36.5
36.0
35.5
35.0
UTAH
COLORADO
UTAH
ARIZONA
COLORADO
NEW MEXICO
ARIZONA
NEW MEXICO
1. WESTERN AREA
O and G production from Paleozoic
(slightly overpressured--0.5 psi/ft)
USDWs = Gallup, Dakota and Morrison Fms.
4. INTERIOR 2
O and G production from all horizons
USDW = Tertiary Aquifer only
Underlying horizons are all high salinity
5. CHUSKA AREA
O and G production from about 5 wells, all P and A.
USDW = Tertiary Chuska Alluvium
3. INTERIOR 1
O and G production from Upper Cretaceous and below.
Upper Cretaceous and Mesa Verde = fresh water
Gallup, Dakota and Morrison Fms = high salinity
2. SOUTHERN AREA
O and G production from Dakota and Gallup equivalents
USDWs = Point Lookout of the Mesa Verde Group,
Gallup, Dakota and Morrison Fms.
MAP 8
N
SAN JUAN BASIN
TYPE AREAS FOR API--USDW STUDY
UNIVERSITY OF MISSOURI--ROLLA
DEGREES LATITUDE--LONGITUDE
0.000 0.125 0.250 0.375 0.500
R. C. LAUDON--1991



MAP 9

HEAD MAP
ALL USDWS
ABOVE UPPER CRETACEOUS
SAN JUAN BASIN

MAP EXPLANATION

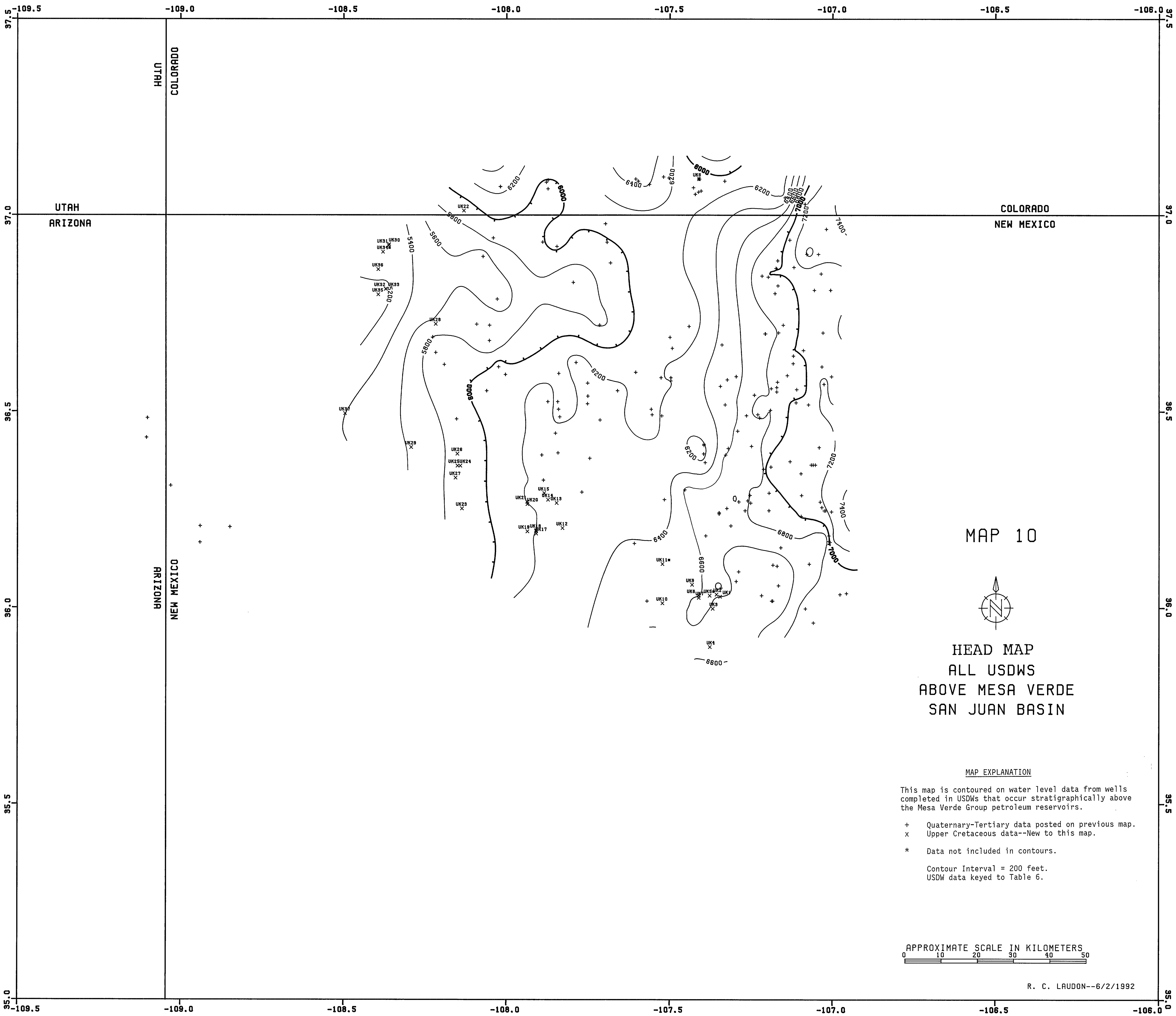
This map is contoured on water level data from wells completed in USDWs that occur stratigraphically above the Upper Cretaceous petroleum reservoirs.

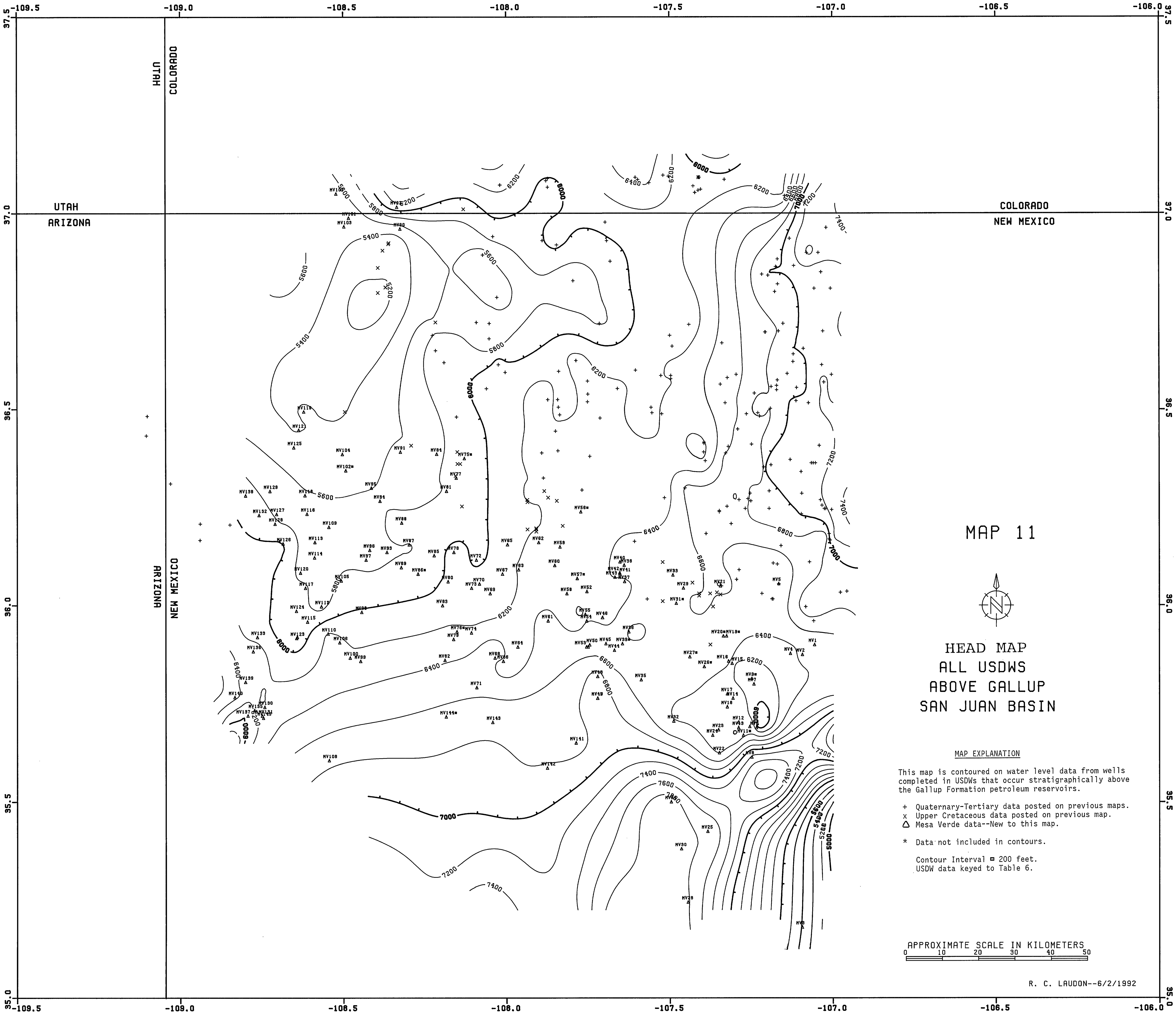
+ Quaternary-Tertiary data.

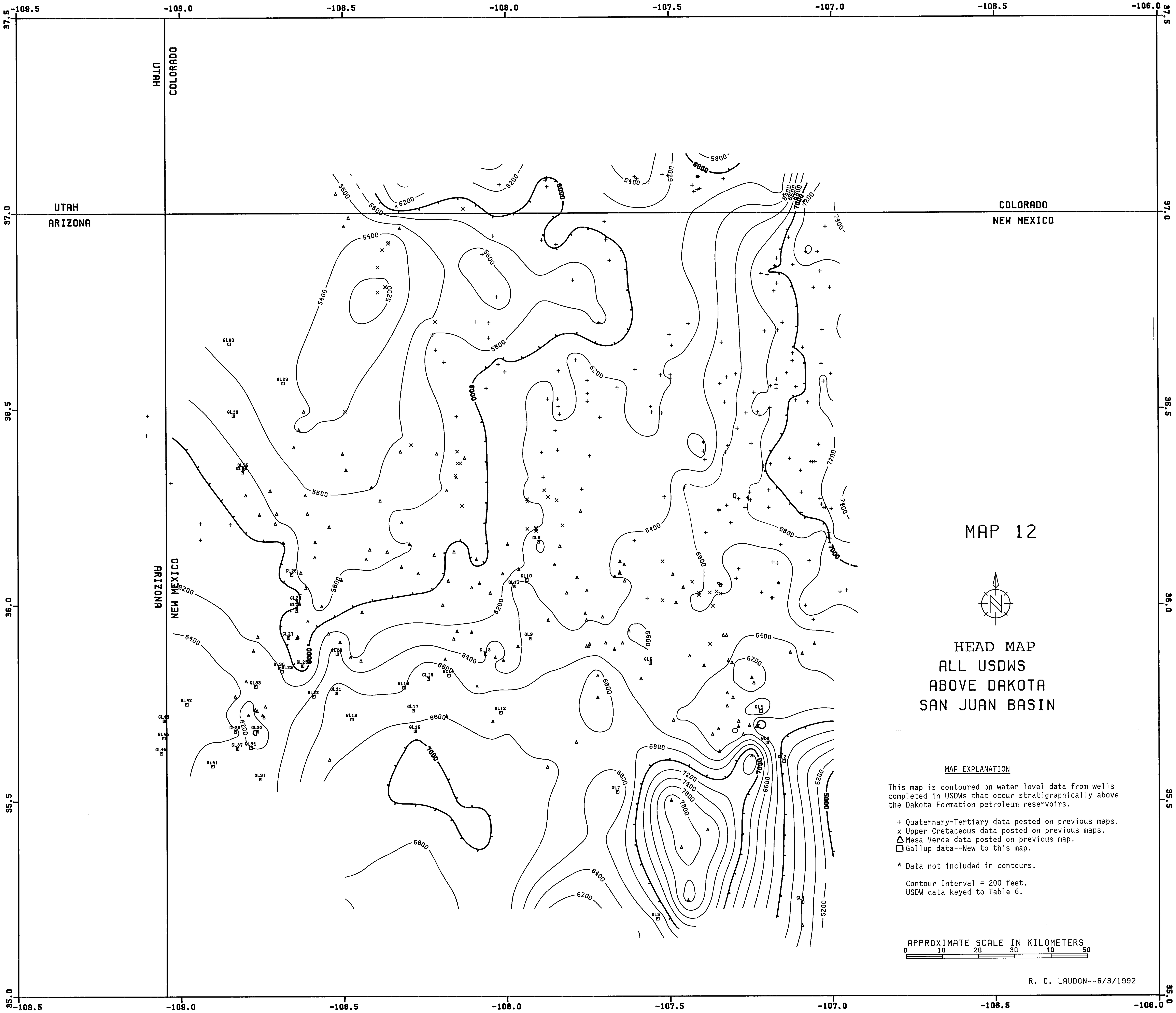
* Data not included in contours.

Contour Interval = 200 feet.
USDW data keyed to Table 6.

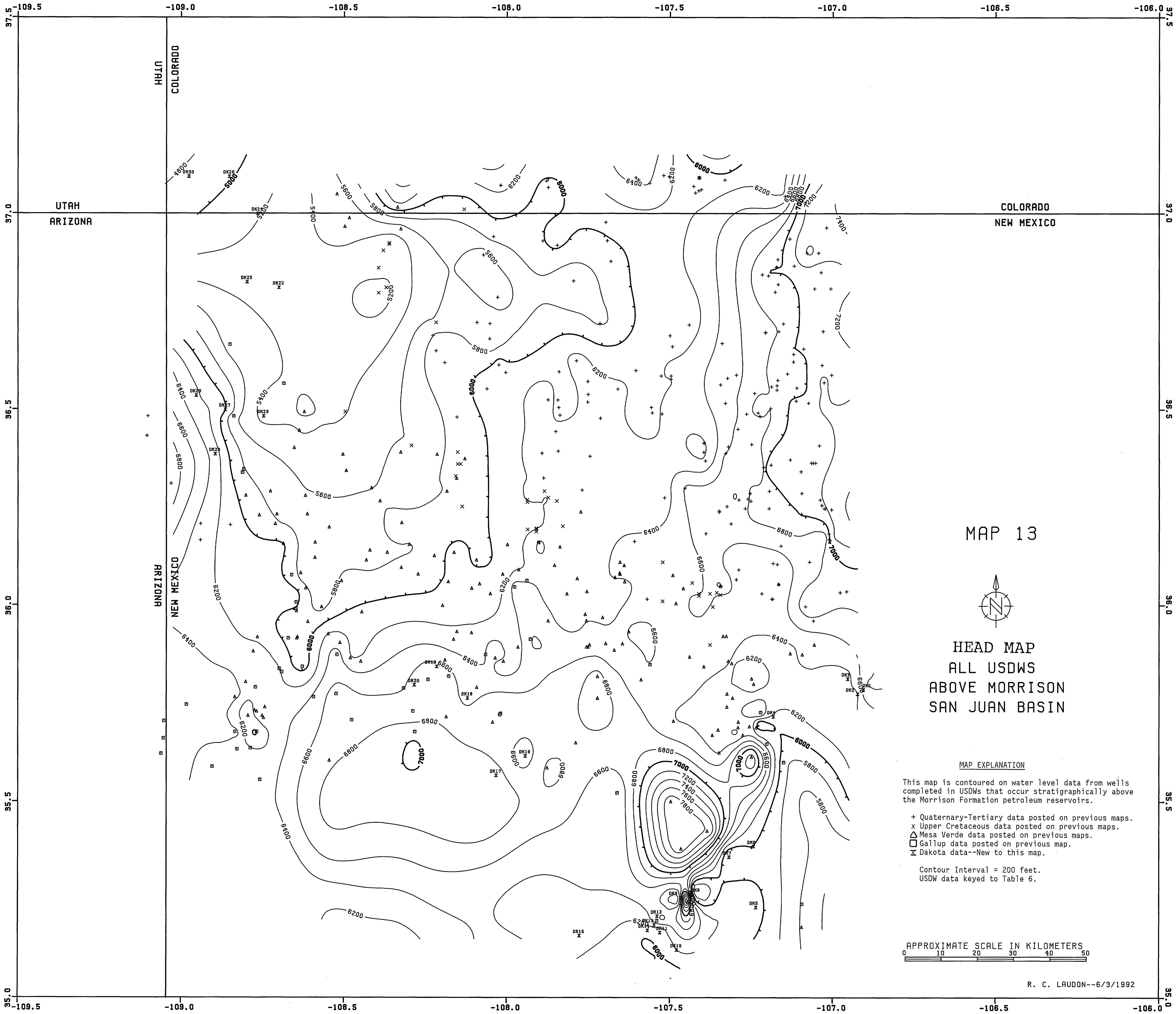
R. C. LAUDON--6/2/1992


MAP 10
HEAD MAP
ALL USDWS
ABOVE MESA VERDE
SAN JUAN BASIN
MAP EXPLANATION
This map is contoured on water level data from wells completed in USDWs that occur stratigraphically above the Mesa Verde Group petroleum reservoirs.
+ Quaternary-Tertiary data posted on previous map.
x Upper Cretaceous data--New to this map.
* Data not included in contours.
Contour Interval = 200 feet.
USDW data keyed to Table 6.
APPROXIMATE SCALE IN KILOMETERS
0 10 20 30 40 50
R. C. LAUDON--6/2/1992
UTAH
ARIZONA
COLORADO
NEW MEXICO
-109.5
-109.0
-108.5
-108.0
-107.5
-107.0
-106.5
-106.0
37.5
37.0
36.5
36.0
35.5
35.0

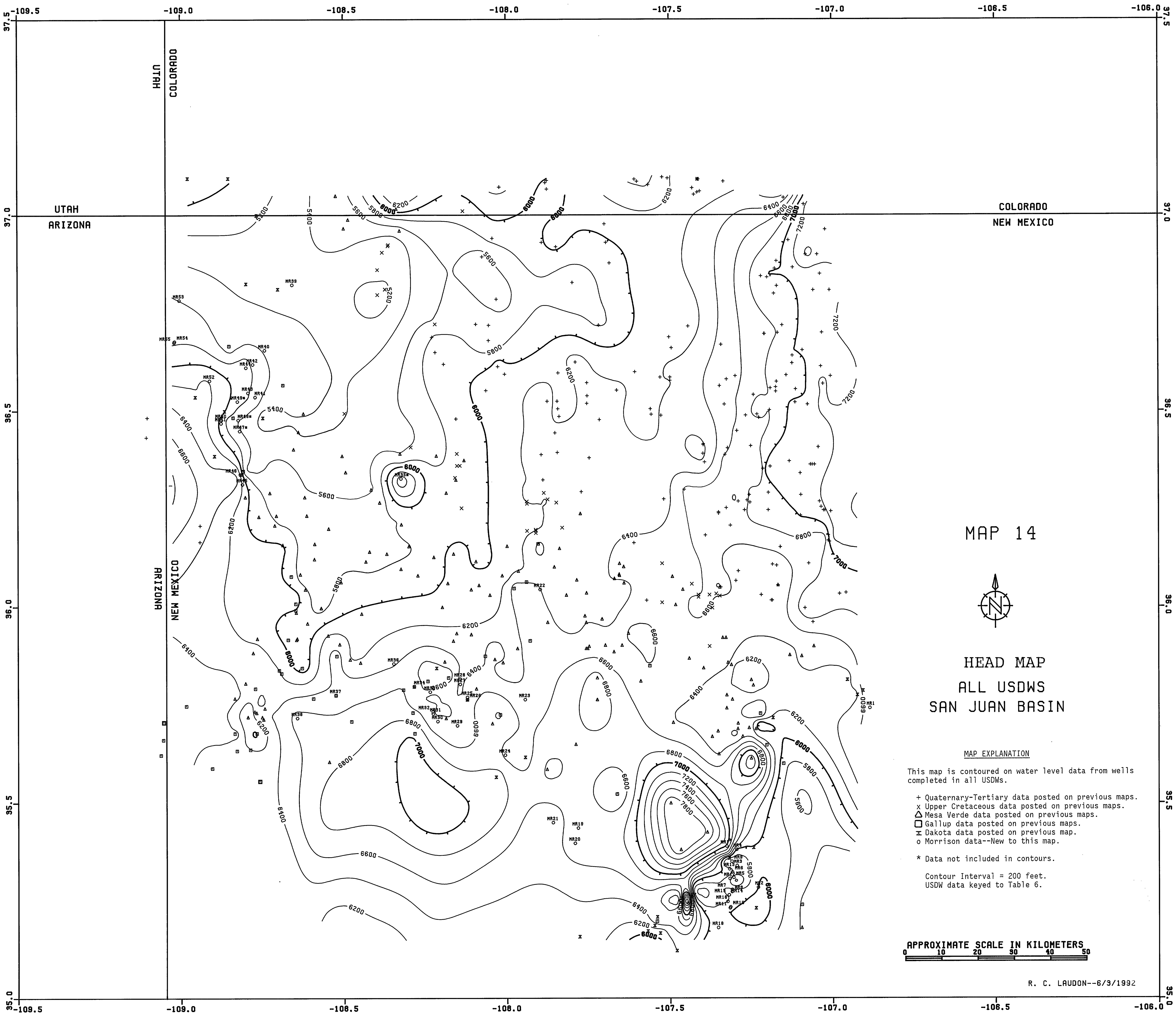

UTAH
COLORADO
ARIZONA
NEW MEXICO
-109.5
-109.0
-108.5
-108.0
-107.5
-107.0
-106.5
-106.0
37.5
37.0
36.5
36.0
35.5
35.0
MAP 11
HEAD MAP
ALL USDWS
ABOVE GALLUP
SAN JUAN BASIN
MAP EXPLANATION
This map is contoured on water level data from wells completed in USDWs that occur stratigraphically above the Gallup Formation petroleum reservoirs.
+ Quaternary-Tertiary data posted on previous maps.
x Upper Cretaceous data posted on previous map.
△ Mesa Verde data--New to this map.
* Data not included in contours.
Contour Interval = 200 feet.
USDW data keyed to Table 6.
APPROXIMATE SCALE IN KILOMETERS
0 10 20 30 40 50
R. C. LAUDON--6/2/1992

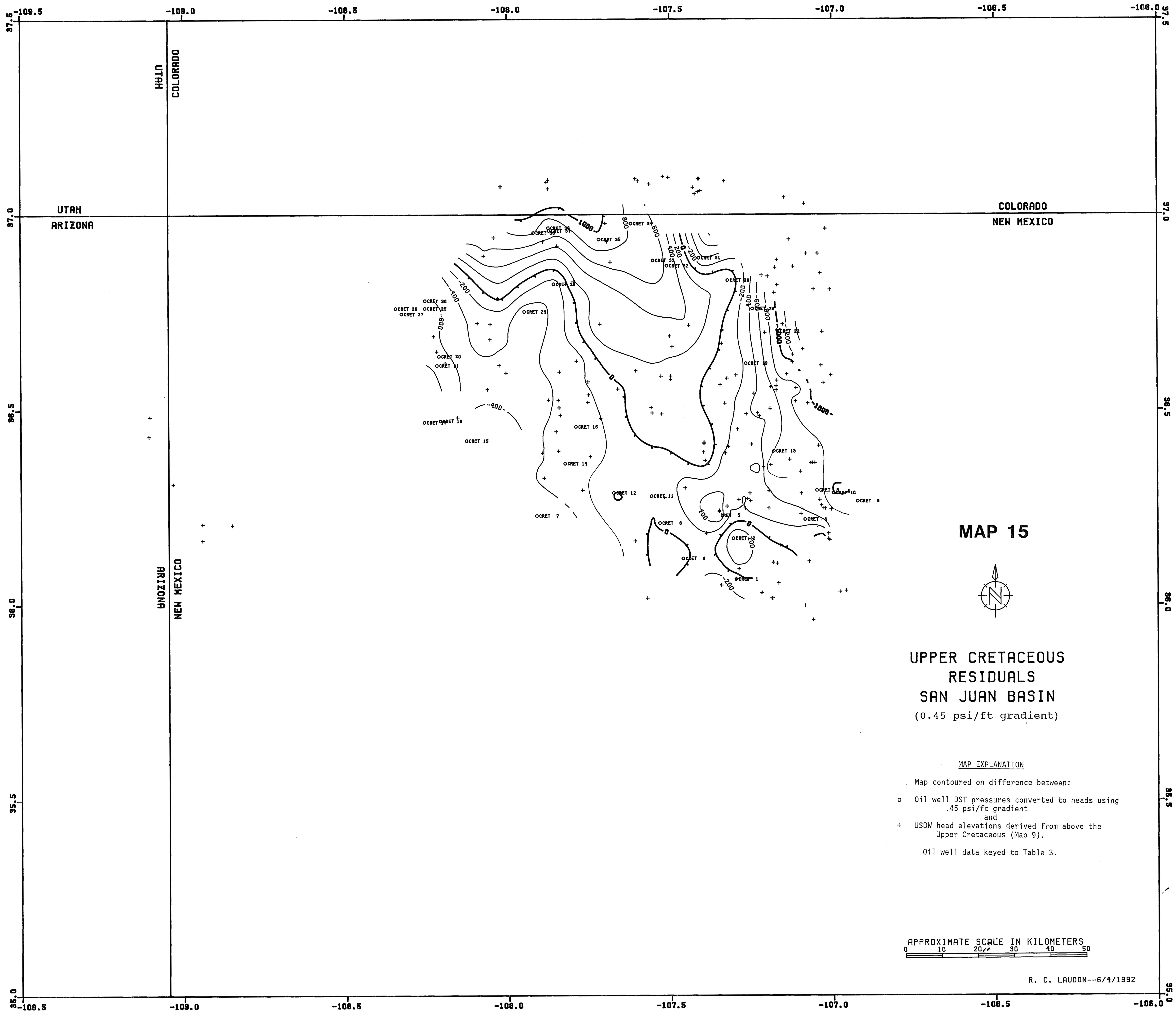


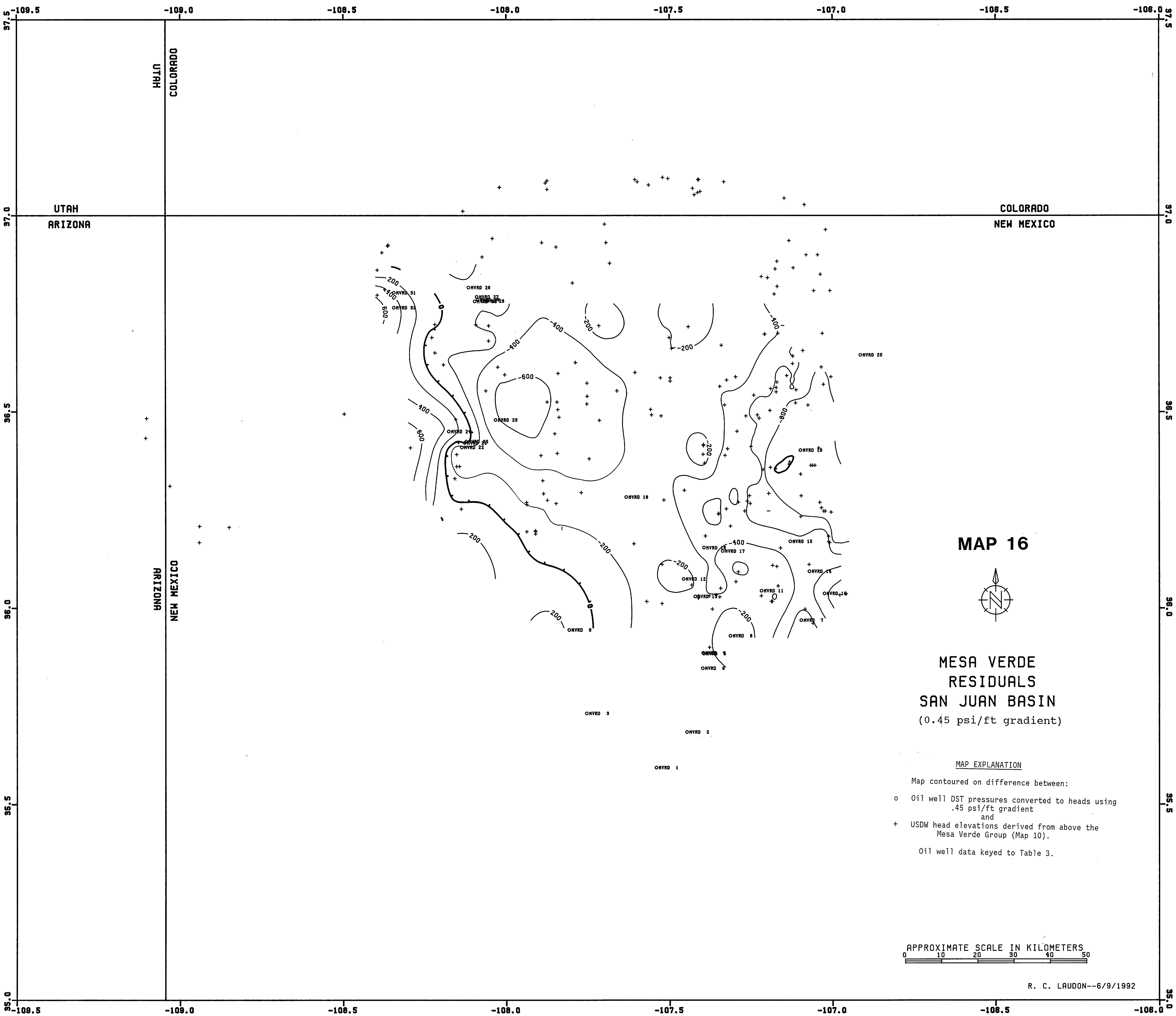
MAP 12
HEAD MAP
ALL USDWS
ABOVE DAKOTA
SAN JUAN BASIN
UTAH
COLORADO
ARIZONA
NEW MEXICO
MAP EXPLANATION
This map is contoured on water level data from wells completed in USDWs that occur stratigraphically above the Dakota Formation petroleum reservoirs.
+ Quaternary-Tertiary data posted on previous maps.
x Upper Cretaceous data posted on previous maps.
△ Mesa Verde data posted on previous map.
□ Gallup data--New to this map.
* Data not included in contours.
Contour Interval = 200 feet.
USDW data keyed to Table 6.
APPROXIMATE SCALE IN KILOMETERS
0 10 20 30 40 50
R. C. LAUDON--6/3/1992
-109.5 -109.0 -108.5 -108.0 -107.5 -107.0 -106.5 -106.0
37.5 37.0 36.5 36.0 35.5 35.0

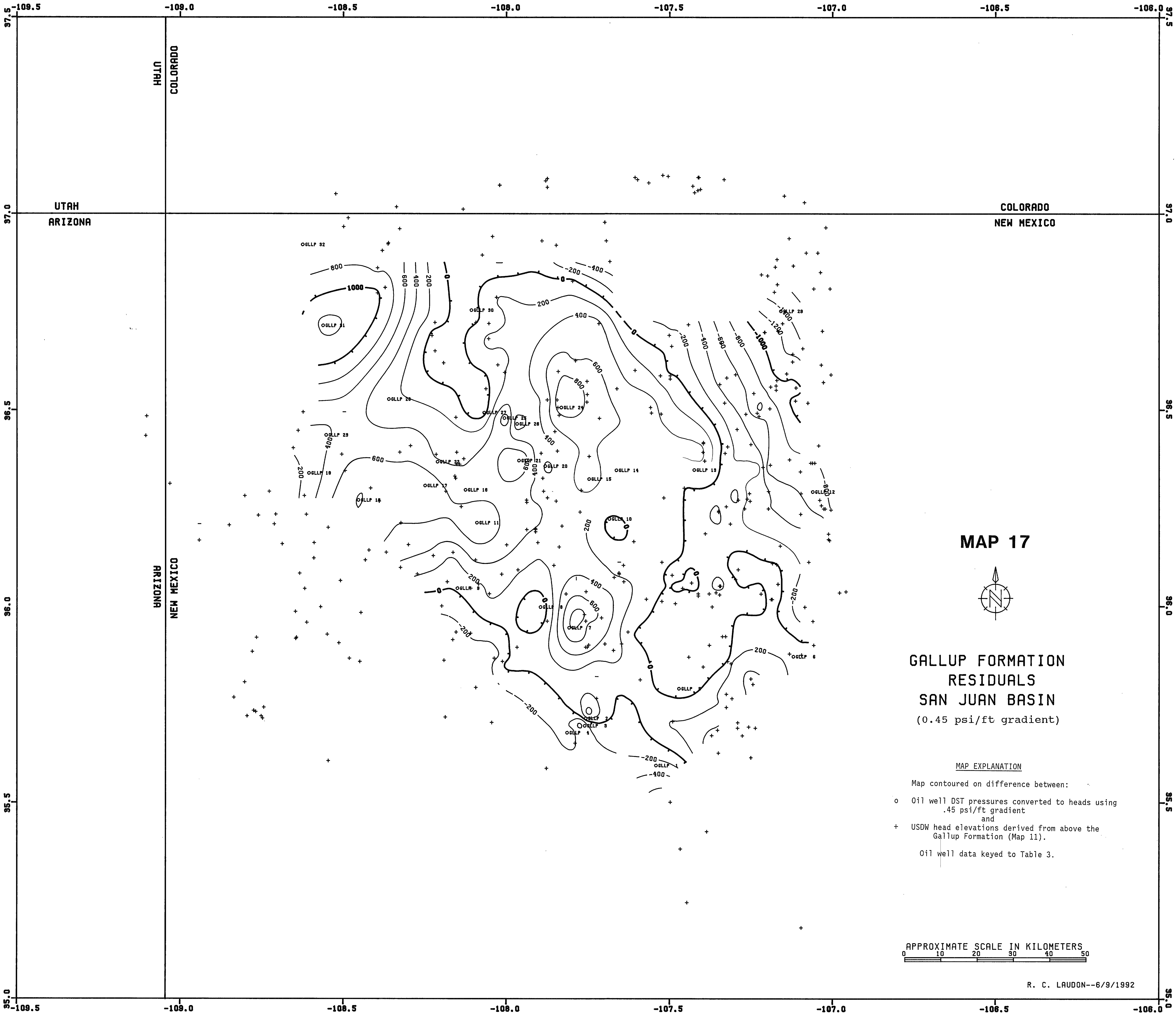


MAP 13
HEAD MAP
ALL USDWS
ABOVE MORRISON
SAN JUAN BASIN
MAP EXPLANATION
This map is contoured on water level data from wells completed in USDWs that occur stratigraphically above the Morrison Formation petroleum reservoirs.
+ Quaternary-Tertiary data posted on previous maps.
x Upper Cretaceous data posted on previous maps.
△ Mesa Verde data posted on previous maps.
□ Gallup data posted on previous map.
Dakota data--New to this map.
Contour Interval = 200 feet.
USDW data keyed to Table 6.
APPROXIMATE SCALE IN KILOMETERS
0 10 20 30 40 50
R. C. LAUDON--6/3/1992
UTAH
COLORADO
ARIZONA
NEW MEXICO
-109.5
-109.0
-108.5
-108.0
-107.5
-107.0
-106.5
-106.0
37.5
37.0
36.5
36.0
35.5
35.0

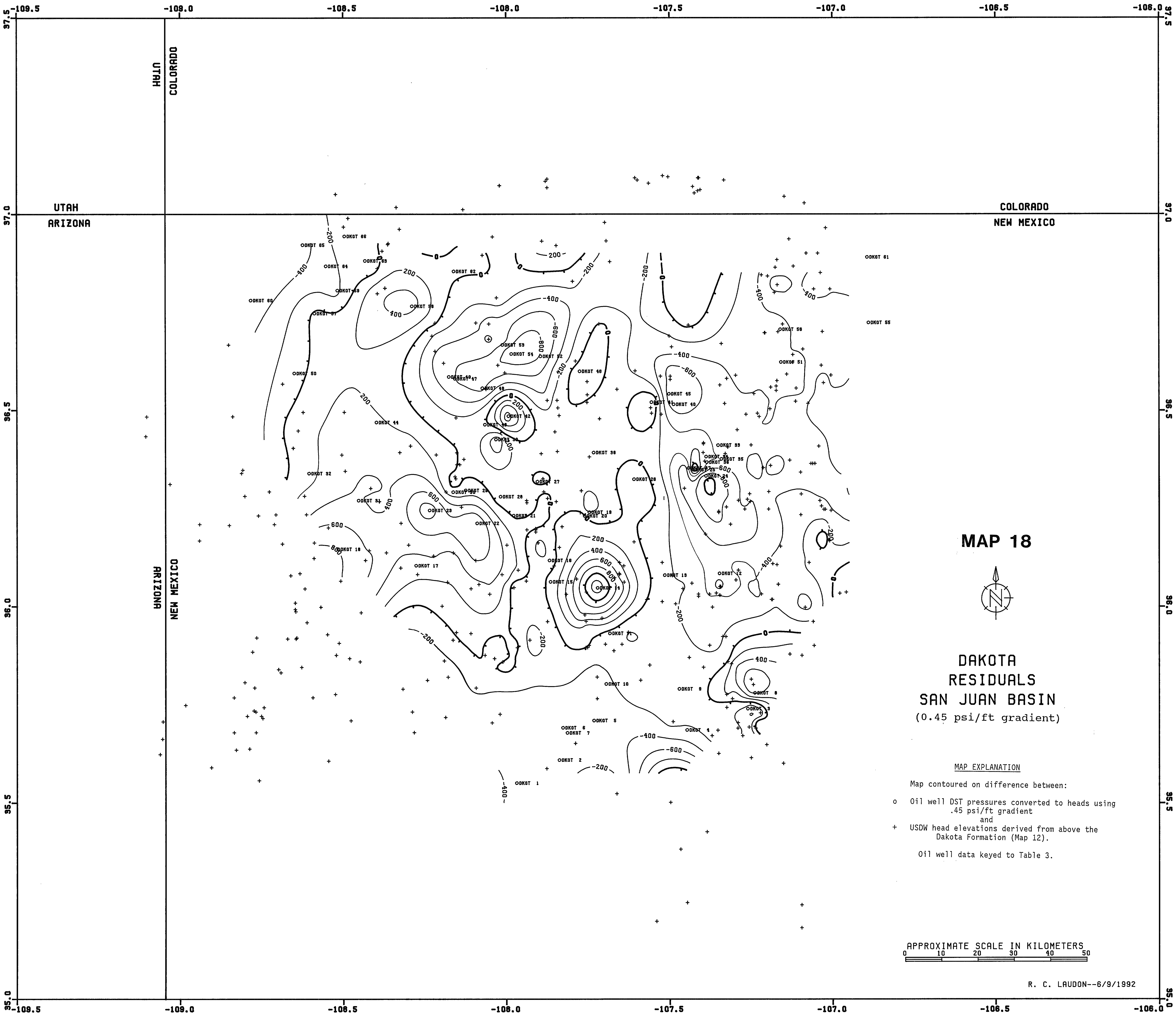

MAP 14
HEAD MAP
ALL USDWS
SAN JUAN BASIN
MAP EXPLANATION
This map is contoured on water level data from wells completed in all USDWs.
+ Quaternary-Tertiary data posted on previous maps.
x Upper Cretaceous data posted on previous maps.
△ Mesa Verde data posted on previous maps.
□ Gallup data posted on previous maps.
ẋ Dakota data posted on previous map.
o Morrison data--New to this map.
* Data not included in contours.
Contour Interval = 200 feet.
USDW data keyed to Table 6.
APPROXIMATE SCALE IN KILOMETERS
0 10 20 30 40 50
R. C. LAUDON--6/3/1992
UTAH
COLORADO
ARIZONA
NEW MEXICO
-109.5 -109.0 -108.5 -108.0 -107.5 -107.0 -106.5 -106.0
37.5 37.0 36.5 36.0 35.5 35.0

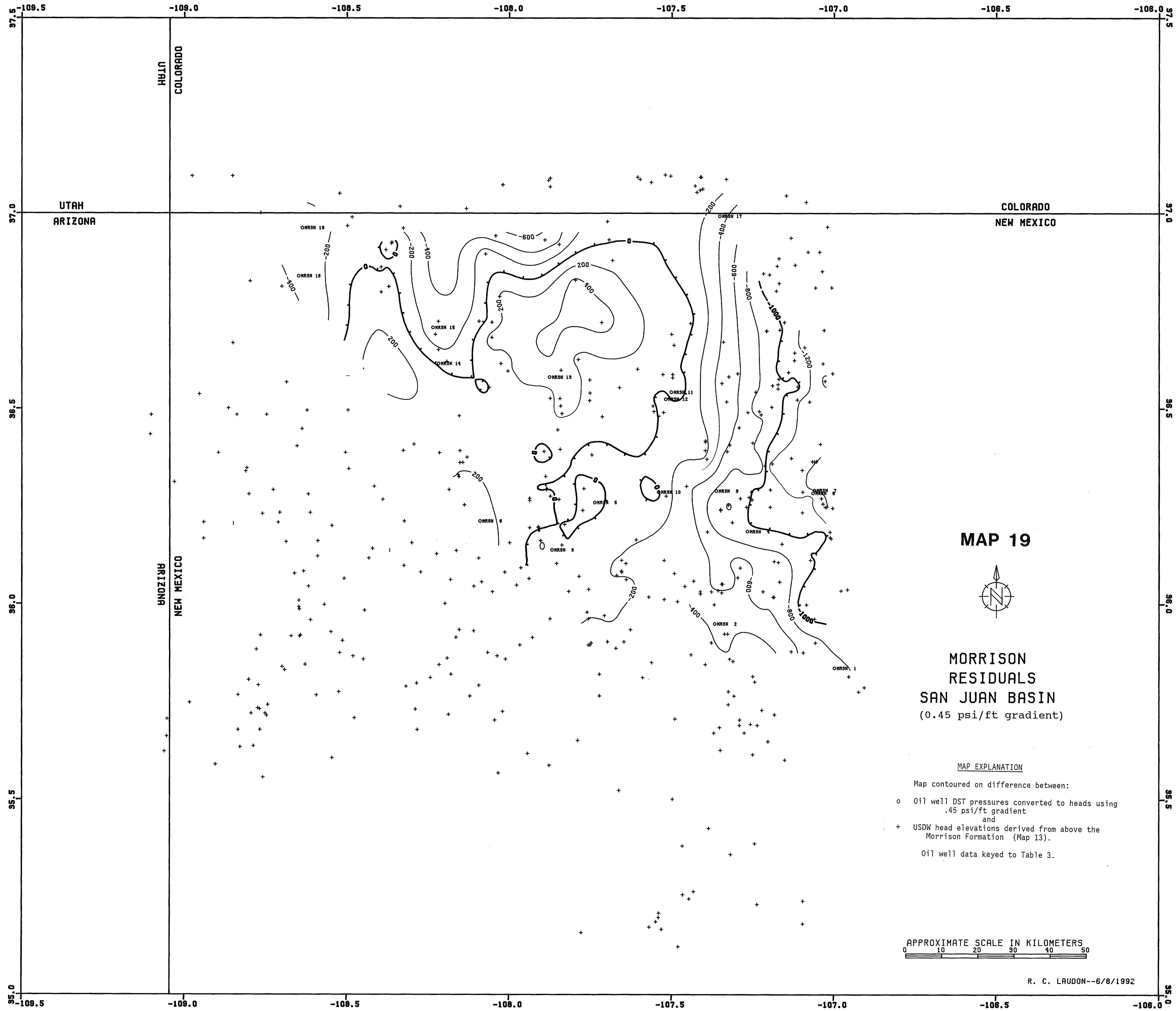

-109.5
-109.0
-108.5
-108.0
-107.5
-107.0
-106.5
-106.0
37.5
37.0
36.5
36.0
35.5
35.0
UTAH
COLORADO
ARIZONA
NEW MEXICO
MAP 15
UPPER CRETACEOUS
RESIDUALS
SAN JUAN BASIN
(0.45 psi/ft gradient)
MAP EXPLANATION
Map contoured on difference between:
o Oil well DST pressures converted to heads using .45 psi/ft gradient
and
+ USDW head elevations derived from above the Upper Cretaceous (Map 9).
Oil well data keyed to Table 3.
APPROXIMATE SCALE IN KILOMETERS
0 10 20 30 40 50
R. C. LAUDON--6/4/1992


MAP 16
MESA VERDE
RESIDUALS
SAN JUAN BASIN
(0.45 psi/ft gradient)
MAP EXPLANATION
Map contoured on difference between:
o Oil well DST pressures converted to heads using .45 psi/ft gradient
and
+ USDW head elevations derived from above the Mesa Verde Group (Map 10).
Oil well data keyed to Table 3.
APPROXIMATE SCALE IN KILOMETERS
0 10 20 30 40 50
R. C. LAUDON--6/9/1992
UTAH
COLORADO
ARIZONA
NEW MEXICO
-109.5
-109.0
-108.5
-108.0
-107.5
-107.0
-106.5
-106.0
37.5
37.0
36.5
36.0
35.5
35.0



-109.5
-109.0
-108.5
-108.0
-107.5
-107.0
-106.5
-106.0
37.5
37.0
36.5
36.0
35.5
35.0
UTAH
COLORADO
ARIZONA
NEW MEXICO
MAP 17
GALLUP FORMATION
RESIDUALS
SAN JUAN BASIN
(0.45 psi/ft gradient)
MAP EXPLANATION
Map contoured on difference between:
o Oil well DST pressures converted to heads using .45 psi/ft gradient
and
+ USDW head elevations derived from above the Gallup Formation (Map 11).
Oil well data keyed to Table 3.
APPROXIMATE SCALE IN KILOMETERS
0 10 20 30 40 50
R. C. LAUDON--6/9/1992


MAP 18
DAKOTA
RESIDUALS
SAN JUAN BASIN
(0.45 psi/ft gradient)
MAP EXPLANATION
Map contoured on difference between:
o Oil well DST pressures converted to heads using .45 psi/ft gradient
and
+ USDW head elevations derived from above the Dakota Formation (Map 12).
Oil well data keyed to Table 3.
APPROXIMATE SCALE IN KILOMETERS
0 10 20 30 40 50
R. C. LAUDON--6/9/1992
UTAH
COLORADO
ARIZONA
NEW MEXICO
-109.5
-109.0
-108.5
-108.0
-107.5
-107.0
-106.5
-106.0
37.5
37.0
36.5
36.0
35.5
35.0



MAP 19

MORRISON RESIDUALS SAN JUAN BASIN

(0.45 psi/ft gradient)

MAP EXPLANATION

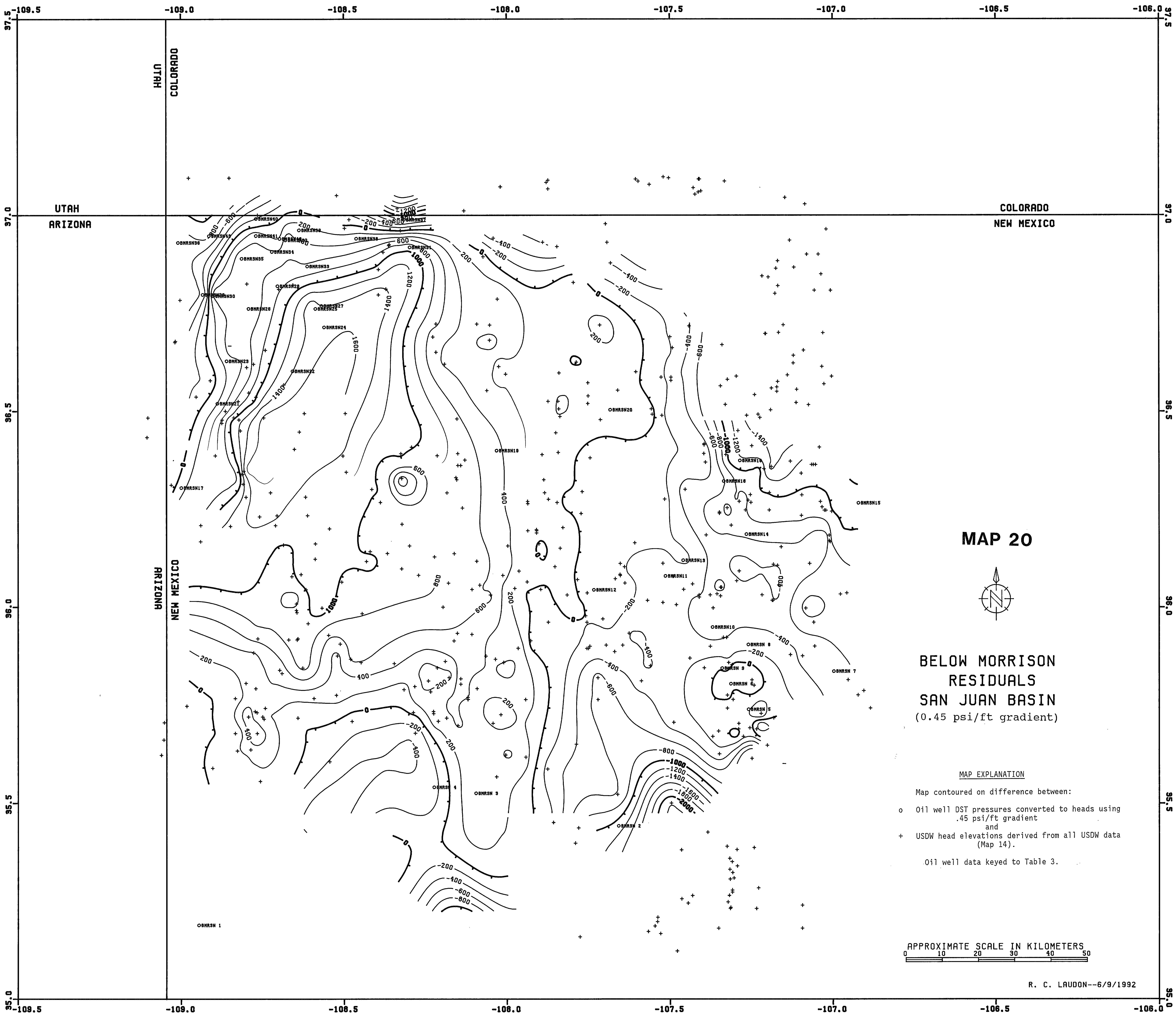
Map contoured on difference between:

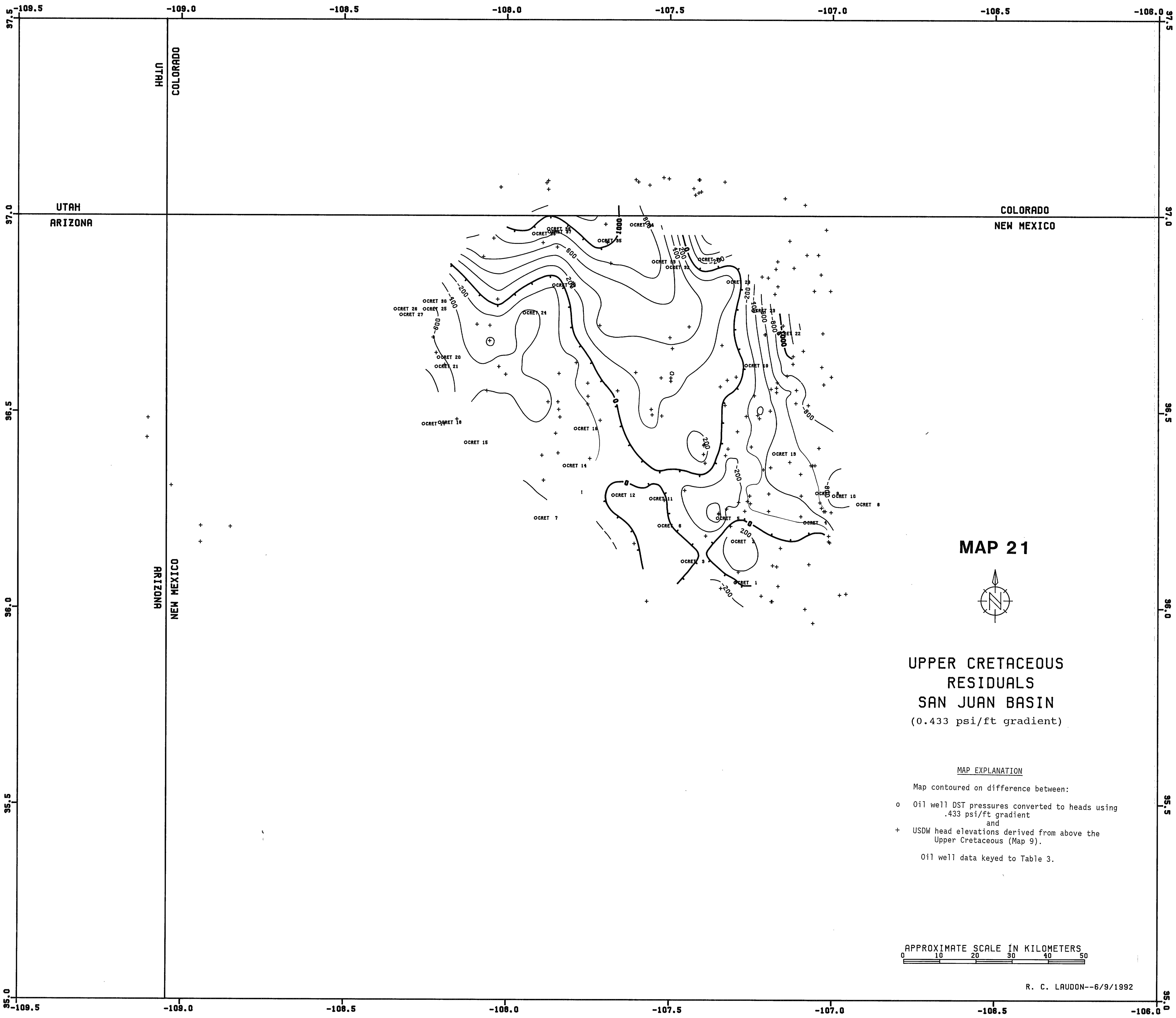
o Oil well DST pressures converted to heads using .45 psi/ft gradient

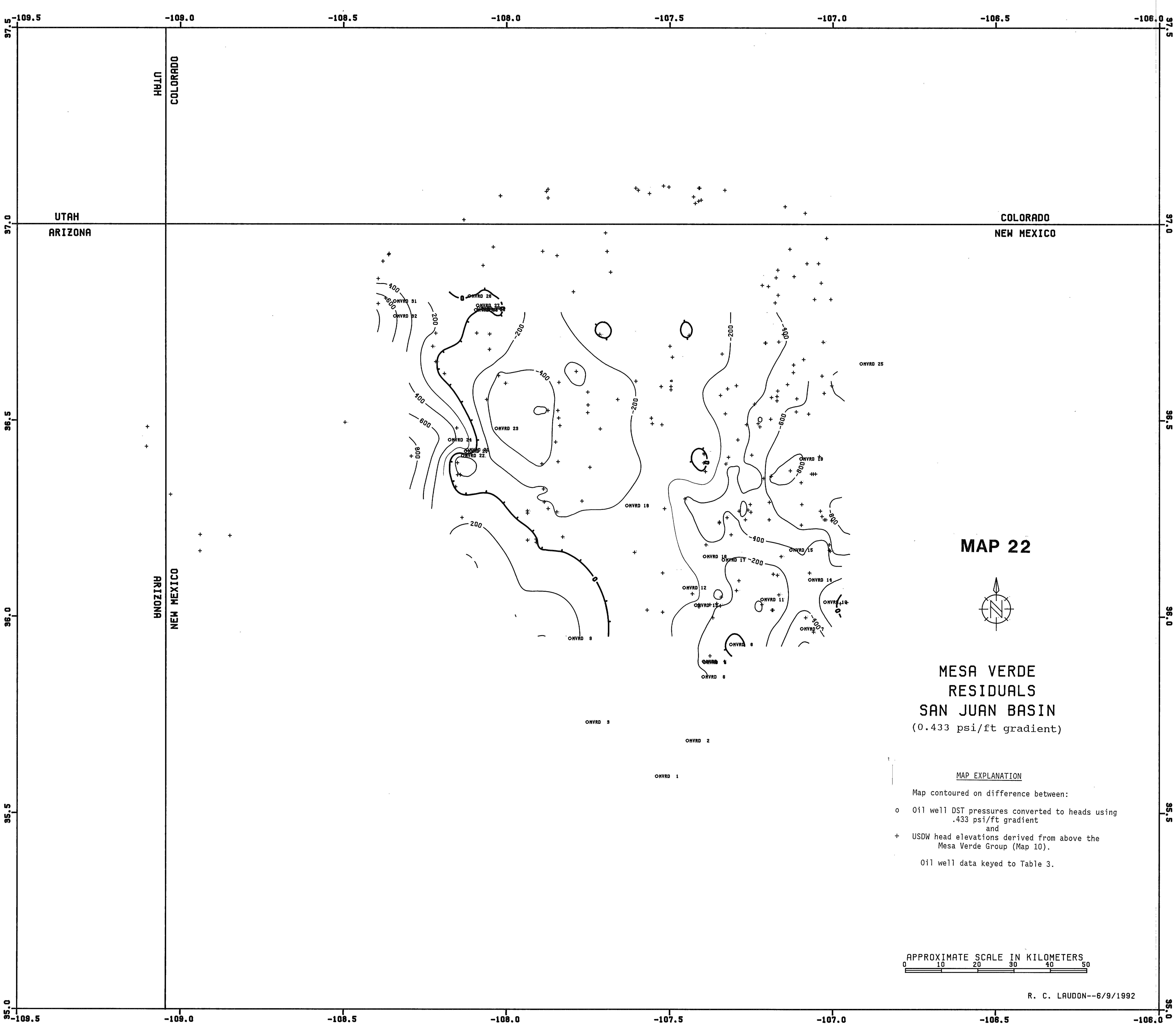
and

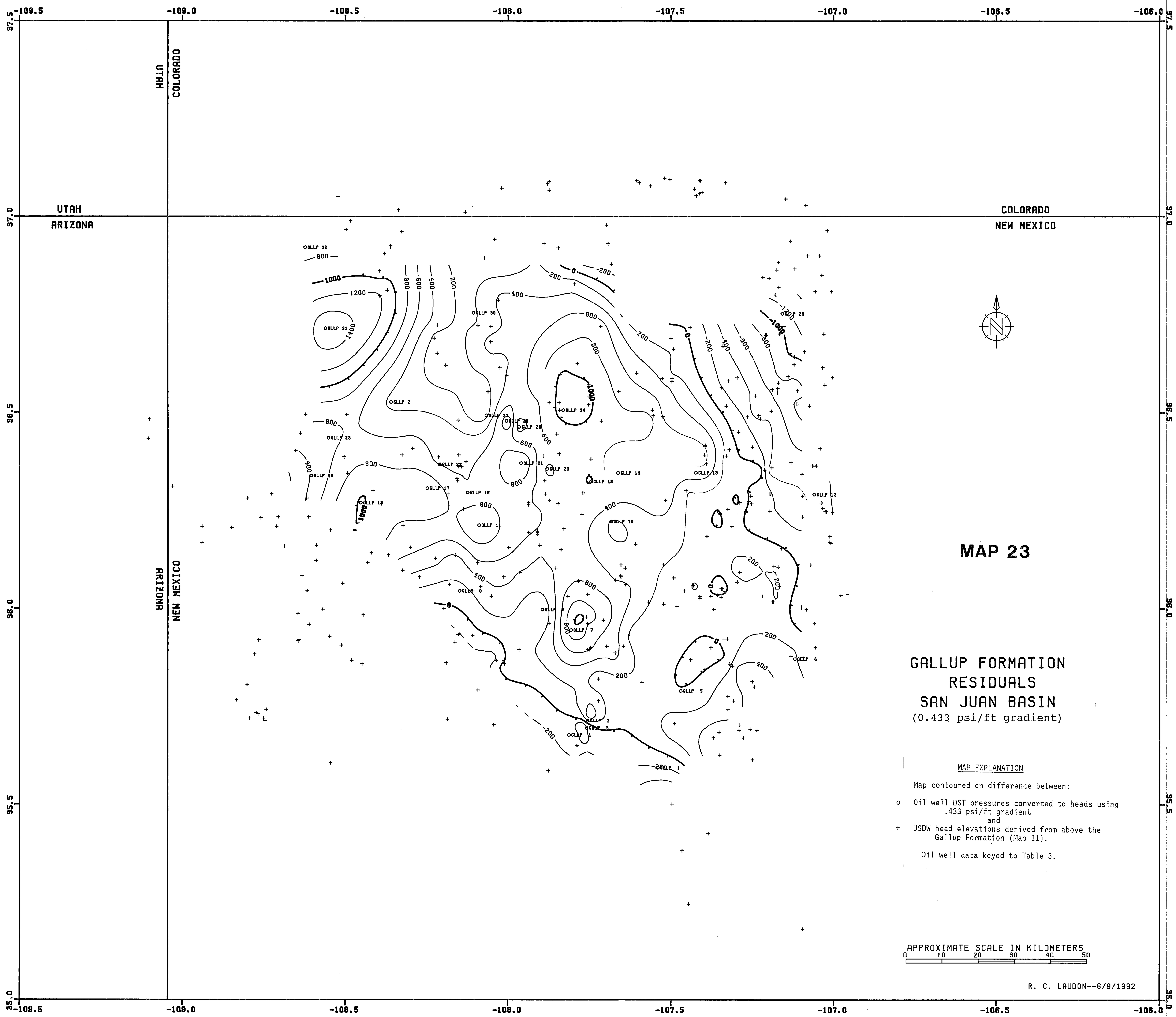
\+ USDW head elevations derived from above the Morrison Formation (Map 13).

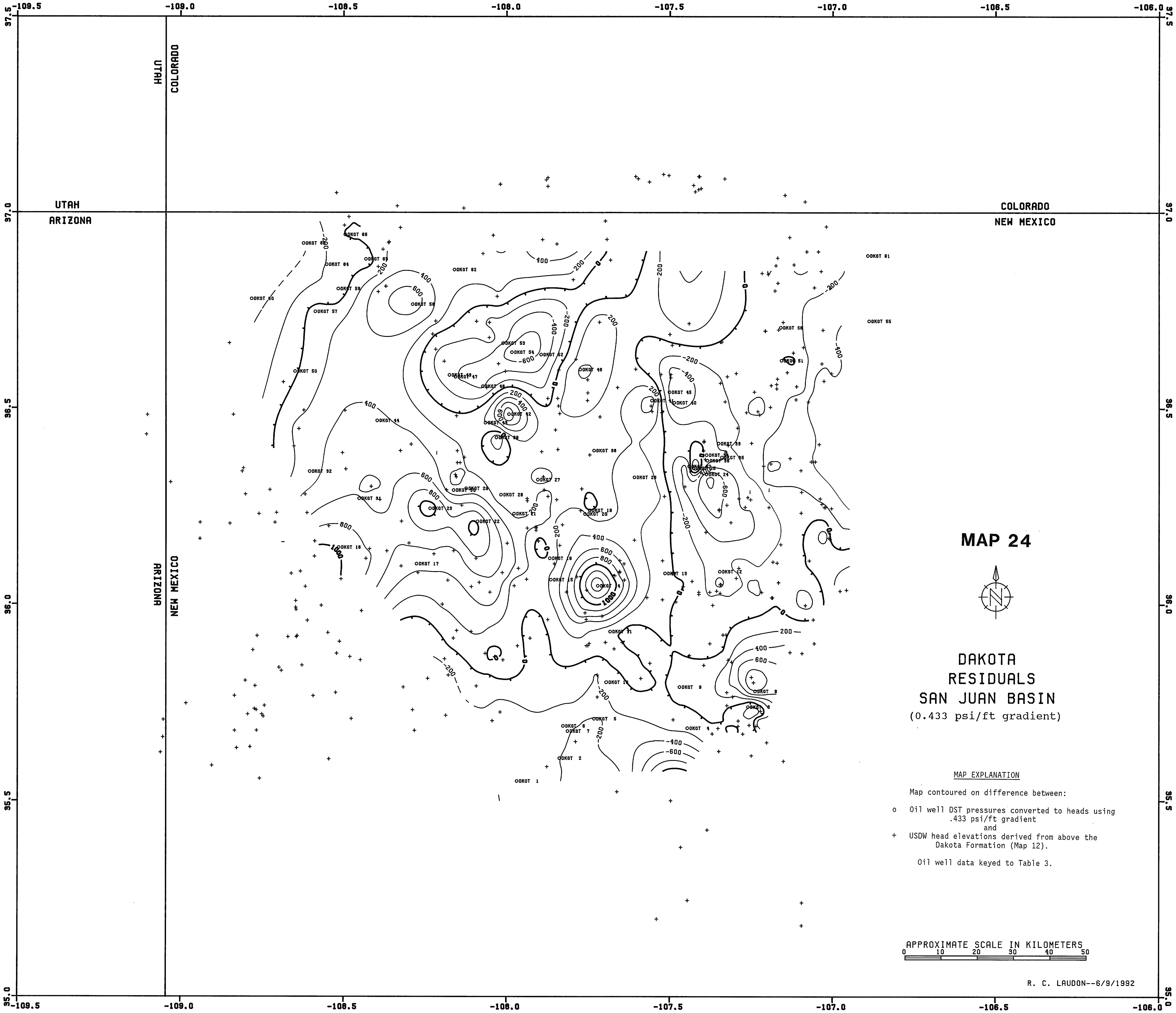
Oil well data keyed to Table 3.


MAP 20
BELOW MORRISON
RESIDUALS
SAN JUAN BASIN
(0.45 psi/ft gradient)
MAP EXPLANATION
Map contoured on difference between:
o Oil well DST pressures converted to heads using .45 psi/ft gradient
and
+ USDW head elevations derived from all USDW data (Map 14).
Oil well data keyed to Table 3.
APPROXIMATE SCALE IN KILOMETERS
0 10 20 30 40 50
R. C. LAUDON--6/9/1992
UTAH
COLORADO
ARIZONA
NEW MEXICO
-109.5
-109.0
-108.5
-108.0
-107.5
-107.0
-106.5
-106.0
37.5
37.0
36.5
36.0
35.5
35.0

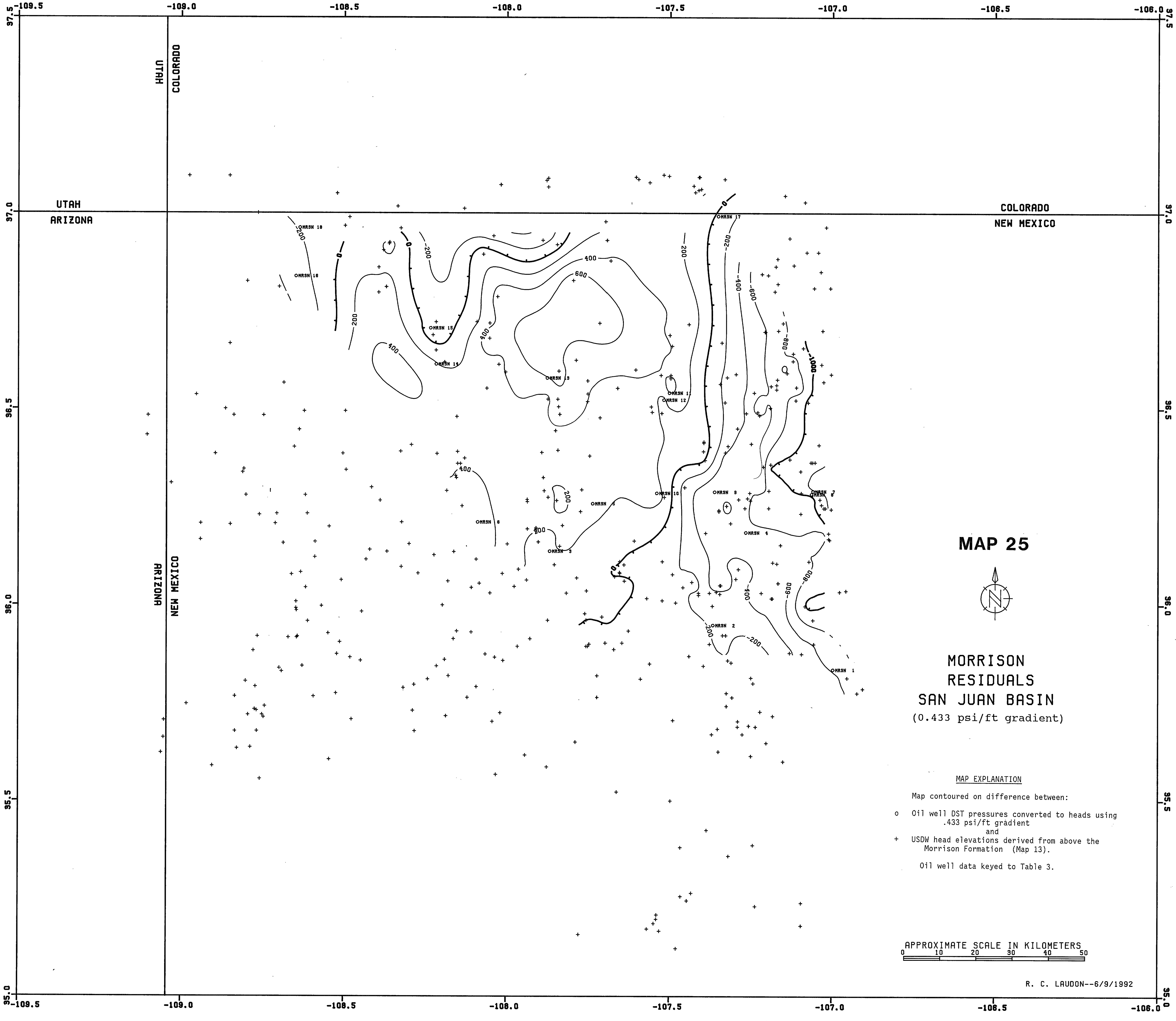

-109.5
-109.0
-108.5
-108.0
-107.5
-107.0
-106.5
-106.0
37.5
37.0
36.5
36.0
35.5
35.0
UTAH
COLORADO
ARIZONA
NEW MEXICO
MAP 21
UPPER CRETACEOUS
RESIDUALS
SAN JUAN BASIN
(0.433 psi/ft gradient)
MAP EXPLANATION
Map contoured on difference between:
o Oil well DST pressures converted to heads using .433 psi/ft gradient
and
+ USDW head elevations derived from above the Upper Cretaceous (Map 9).
Oil well data keyed to Table 3.
APPROXIMATE SCALE IN KILOMETERS
0 10 20 30 40 50
R. C. LAUDON--6/9/1992


MAP 22
MESA VERDE
RESIDUALS
SAN JUAN BASIN
(0.433 psi/ft gradient)
MAP EXPLANATION
Map contoured on difference between:
o Oil well DST pressures converted to heads using .433 psi/ft gradient
and
+ USDW head elevations derived from above the Mesa Verde Group (Map 10).
Oil well data keyed to Table 3.
APPROXIMATE SCALE IN KILOMETERS
0 10 20 30 40 50
R. C. LAUDON--6/9/1992
UTAH
COLORADO
ARIZONA
NEW MEXICO
-109.5
-109.0
-108.5
-108.0
-107.5
-107.0
-106.5
-106.0
37.5
37.0
36.5
36.0
35.5
35.0

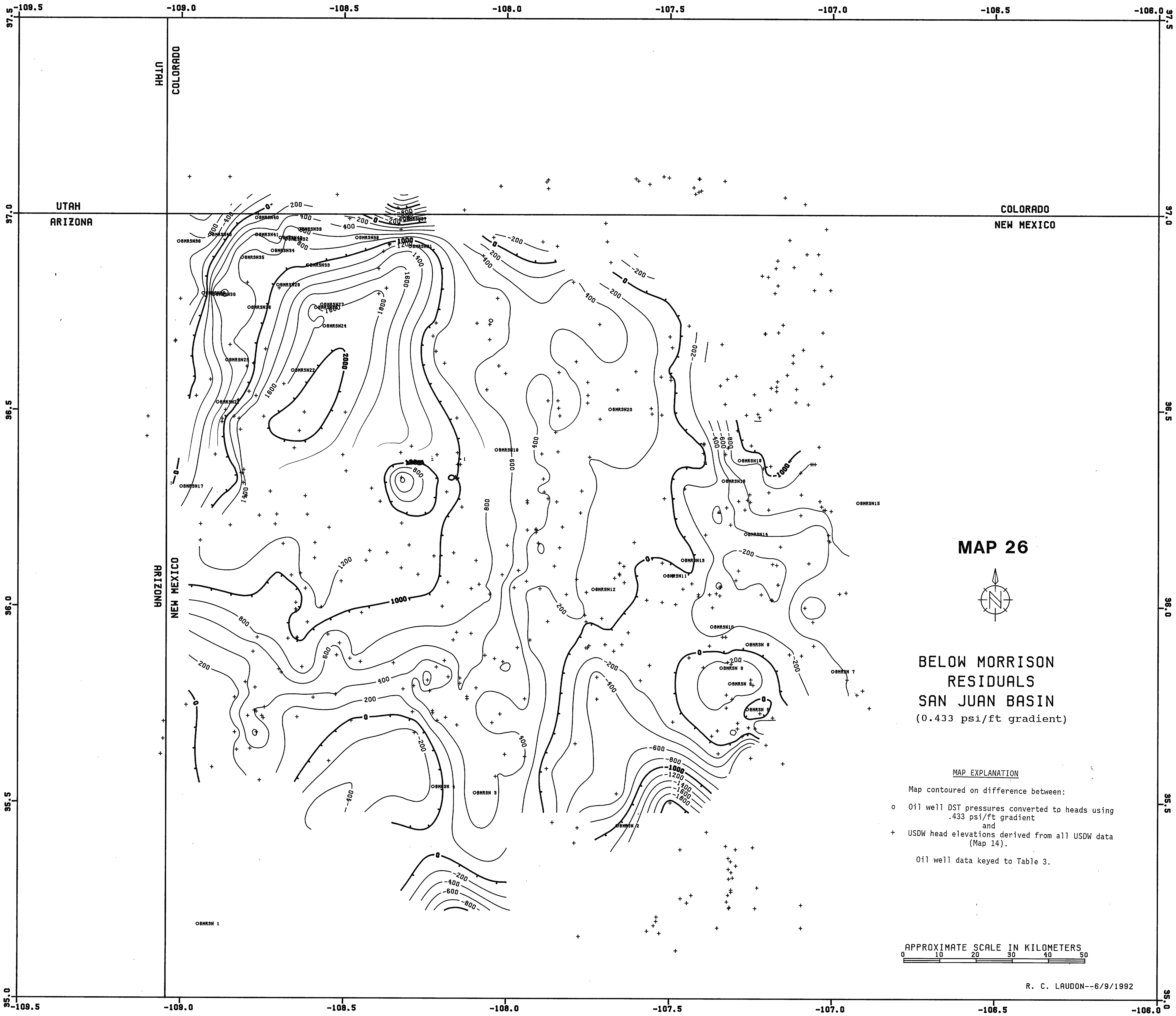

MAP 23
GALLUP FORMATION
RESIDUALS
SAN JUAN BASIN
(0.433 psi/ft gradient)
MAP EXPLANATION
Map contoured on difference between:
o Oil well DST pressures converted to heads using .433 psi/ft gradient
and
+ USDW head elevations derived from above the Gallup Formation (Map 11).
Oil well data keyed to Table 3.
APPROXIMATE SCALE IN KILOMETERS
0 10 20 30 40 50
R. C. LAUDON--6/9/1992
UTAH
COLORADO
ARIZONA
NEW MEXICO
-109.5
-109.0
-108.5
-108.0
-107.5
-107.0
-106.5
-106.0
37.5
37.0
36.5
36.0
35.5
35.0

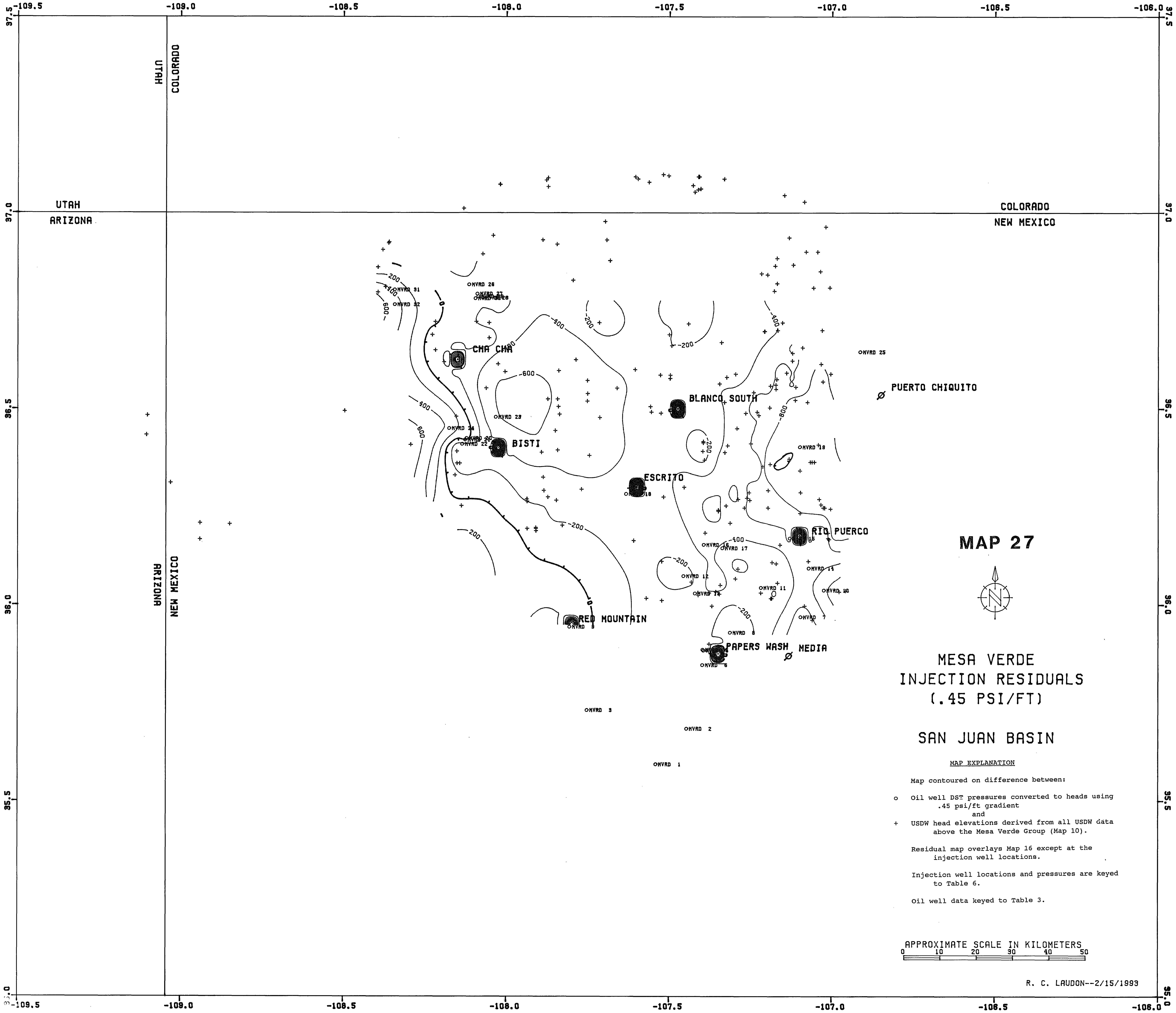


MAP 24
DAKOTA
RESIDUALS
SAN JUAN BASIN
(0.433 psi/ft gradient)
MAP EXPLANATION
Map contoured on difference between:
o Oil well DST pressures converted to heads using .433 psi/ft gradient
and
+ USDW head elevations derived from above the Dakota Formation (Map 12).
Oil well data keyed to Table 3.
APPROXIMATE SCALE IN KILOMETERS
0 10 20 30 40 50
R. C. LAUDON--6/9/1992
UTAH
COLORADO
ARIZONA
NEW MEXICO
-109.5
-109.0
-108.5
-108.0
-107.5
-107.0
-106.5
-106.0
37.5
37.0
36.5
36.0
35.5
35.0



MAP 25
MORRISON
RESIDUALS
SAN JUAN BASIN
(0.433 psi/ft gradient)
MAP EXPLANATION
Map contoured on difference between:
o Oil well DST pressures converted to heads using .433 psi/ft gradient
and
+ USDW head elevations derived from above the Morrison Formation (Map 13).
Oil well data keyed to Table 3.
APPROXIMATE SCALE IN KILOMETERS
0 10 20 30 40 50
R. C. LAUDON--6/9/1992
UTAH
COLORADO
ARIZONA
NEW MEXICO
-109.5
-109.0
-108.5
-108.0
-107.5
-107.0
-106.5
-106.0
37.5
37.0
36.5
36.0
35.5
35.0


MAP 26
BELOW MORRISON
RESIDUALS
SAN JUAN BASIN
(0.433 psi/ft gradient)
MAP EXPLANATION
Map contoured on difference between:
o Oil well DST pressures converted to heads using .433 psi/ft gradient
and
+ USDW head elevations derived from all USDW data (Map 14).
Oil well data keyed to Table 3.
APPROXIMATE SCALE IN KILOMETERS
0 10 20 30 40 50
R. C. LAUDON--6/9/1992
UTAH
ARIZONA
COLORADO
NEW MEXICO
-109.5
-109.0
-108.5
-108.0
-107.5
-107.0
-106.5
-106.0
37.5
37.0
36.5
36.0
35.5
35.0



MAP 27

MESA VERDE INJECTION RESIDUALS (.45 PSI/FT)

SAN JUAN BASIN

MAP EXPLANATION

Map contoured on difference between:

o Oil well DST pressures converted to heads using .45 psi/ft gradient

and

\+ USDW head elevations derived from all USDW data above the Mesa Verde Group (Map 10).

Residual map overlays Map 16 except at the injection well locations.

Injection well locations and pressures are keyed to Table 6.

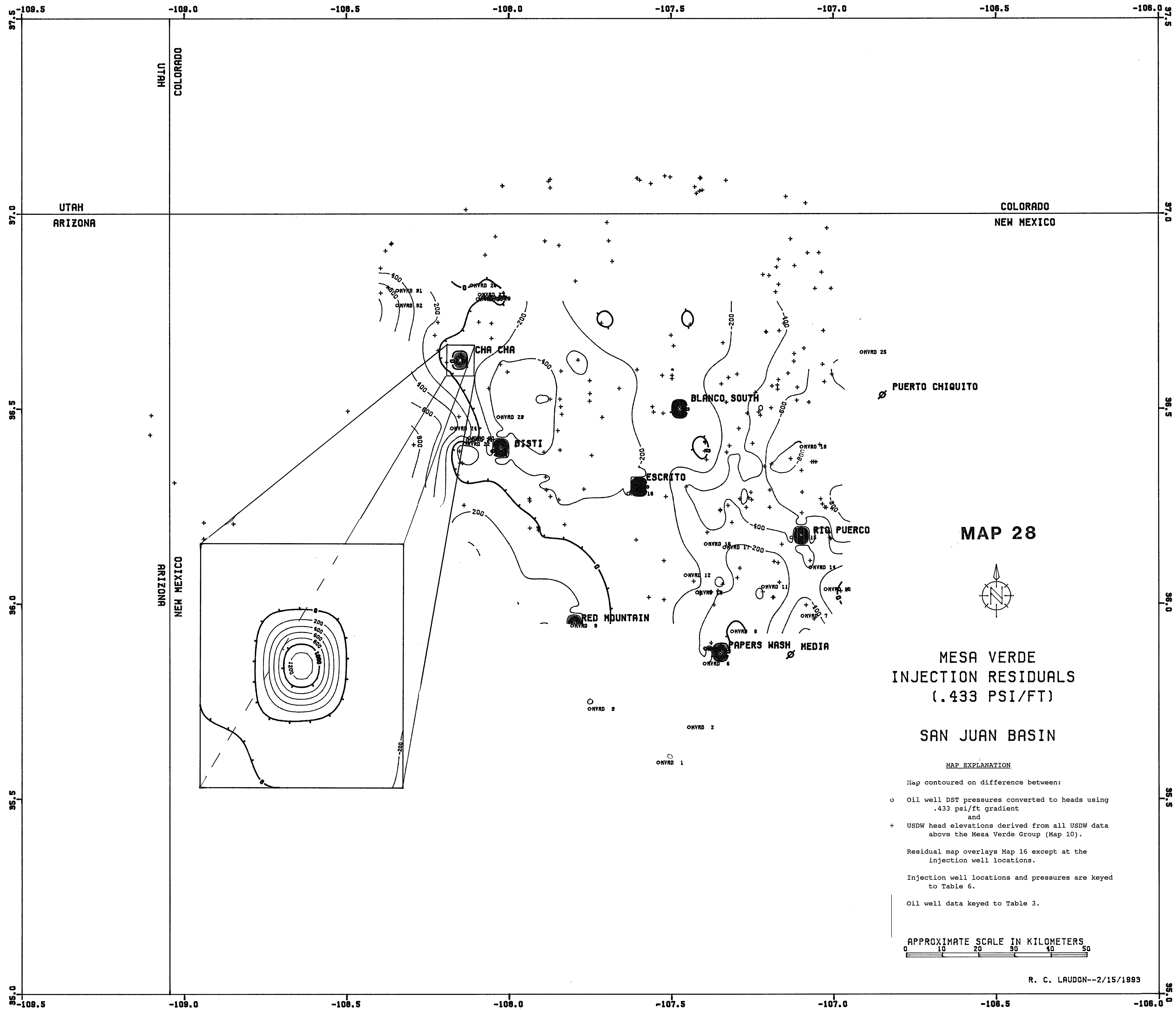
Oil well data keyed to Table 3.

APPROXIMATE SCALE IN KILOMETERS

0 10 20 30 40 50

R. C. LAUDON--2/15/1993

MESA VERDE RESIDUALS--SAN JUAN BASIN--N=242--.45 GRADIENT INJFLDS


MAP 28
MESA VERDE
INJECTION RESIDUALS
(.433 PSI/FT)
SAN JUAN BASIN
MAP EXPLANATION
Map contoured on difference between:
o Oil well DST pressures converted to heads using .433 psi/ft gradient
and
+ USDW head elevations derived from all USDW data above the Mesa Verde Group (Map 10).
Residual map overlays Map 16 except at the injection well locations.
Injection well locations and pressures are keyed to Table 6.
Oil well data keyed to Table 3.
APPROXIMATE SCALE IN KILOMETERS
0 10 20 30 40 50
R. C. LAUDON--2/15/1993
UTAH
COLORADO
ARIZONA
NEW MEXICO
CHA CHA
BISTI
BLANCO, SOUTH
ESCRITO
RIO PUERCO
PUERTO CHIQUITO
RED MOUNTAIN
PAPERS WASH
MEDIA
-109.5
-109.0
-108.5
-108.0
-107.5
-107.0
-106.5
-106.0
37.5
37.0
36.5
36.0
35.5
35.0