HYDROLOGIC AND GEOLOGIC CHARACTERISTICS OF THE COALBED METHANE RESOURCE, RATON BASIN, NEW MEXICO

by

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In memory of my grandmother Marian, who has always given me unquestionable love.

"In the webbed tensions of memory,
No harm
Night lean with hunters.
I wish you well, wish
Tall angels whose rib-freezing
Beauty attend you."

-excerpt from *Wishes for Her* by Dennis Devlin, Irish poet.

ABSTRACT

Coalbed methane is a newly emerging resource for the Raton Basin in New Mexico. Wells are producing methane from coalbeds in the Upper Cretaceous Vermejo Formation and Upper Cretaceous to Paleocene Raton Formation. In recent years a stronger emphasis has been placed on understanding the hydrogeology related to coalbed methane production because of the inextricable relationship of water and gas in such reservoirs. The purpose of this study was to investigate the extent to which hydrological and geological factors contribute to the coalbed methane potential of the basin.

Hydrologic and geologic data was collected, examined, and interpreted. Data from core, well logs, and cross sections suggest coalbeds are relatively thin (1 - 6 ft) with about 1/3-1/2 of the beds lacking lateral continuity on the 1/2 mile well spacing. The average net coalbed thickness of 42 ft is relatively low in comparison to other coal basins in the western United States. Both of these factors limit coalbed methane potential for the basin. Structural contouring of the top surface of the Trinidad Sandstone revealed a connection between subsurface structural features associated with the Vermejo Park dome and increased water production. Increased water production, which limits coalbed methane potential, was noticed in wells near the western basin margin. Wells that contain igneous sills have 24% higher gas and 7% higher water production than wells lacking sills, a definite advantage when producing coalbed methane. Ion ratios of produced waters indicate groundwater flow is generally west to east with younger water usually

associated with increased water production in wells. The low (.02-.07 darcies) matrix permeabilities measured suggest fracture permeability as the primary contributor to water production in wells. Potentiometric surface calculations show that the aquifer system in the basin becomes under pressured with increasing depth. This limits the maximum gas content in coalbeds while at the same time potentially limiting non-coalbed water production for wells. Gas composition analyses show methane on average comprises 97% of the gas being extracted from wells. The high methane content identifies the gas as thermogenic in origin and is almost ideal for production.

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This thesis is accepted on behalf of the
Faculty of the Institute by the following committee:

Advisor

6/22/04

Date

I release this document to the New Mexico Institute of Mining and Technology.

Student's Signature 6/22/04

Date

CHAPTER 1. INTRODUCTION

Coalbed methane is a newly emerging resource for the Raton Basin in New Mexico. In 1981, Pennzoil began exploration and development of coalbed methane in the region. However, it was not until 1999 with completion of an interstate pipeline that commercial production began. Currently the only operator in the New Mexico portion of the basin is El Paso Raton LCC, which in May of 2003 had 256 wells operating. These wells are generating methane from coalbeds in the Upper Cretaceous Vermejo Formation and Upper Cretaceous to Paleocene Raton Formation.

In recent years published work has placed a stronger emphasis on understanding the hydrology related to coalbed methane production (Stevens et al., 1992, Johnson and Finn, 2001). This is because of the inextricable relationship of water and gas in such reservoirs (Close, 1988). To produce coalbed methane, it is necessary to pump water from the coalbed to decrease pressure. This allows gas to desorb from the coal matrix (Levine, 1993). It then must travel from the coal matrix to the wellbore through natural and man-made fracture networks. Understanding how much how a well will produce water can allow for better prediction of how it will produce methane through much of its life (Brister et al., 2004). In turn, the hydrology is tied to the geology. The influence of geology extends beyond hydrology to the potential of the coal to generate and store methane. Therefore, an understanding of both hydrology and geology is essential to accurately predicting coalbed methane potential.

Purpose

The purpose of this study was to investigate how hydrology and geology influence coalbed methane potential of the Raton Basin. Specifically, the intent was to determine how hydrological and geological factors may contribute and/or detract from this potential. Knowing the relationships these factors share with the coalbed methane potential is valuable information in analyzing the potential for the Raton Basin as well as similar coalbed methane basins.

Study Area

The Raton Basin is located in northeastern New Mexico and southeastern Colorado (Figure 1). The Colorado-New Mexico state line serves as the northern border of the study. The western, southern, and eastern borders are defined by the respective basin margins. The outcrop of the Trinidad Sandstone marks the basin margin. West of the study area is the Sangre de Cristo uplift. To the south, the Cimarron arch divides the Raton Basin from the Las Vegas Basin. Eastward from the basin there is a gentle slope to the Sierra Grande arch. The Vermejo Park Ranch covers a substantial portion of the basin and is where El Paso Raton, LCC is currently producing coalbed methane.

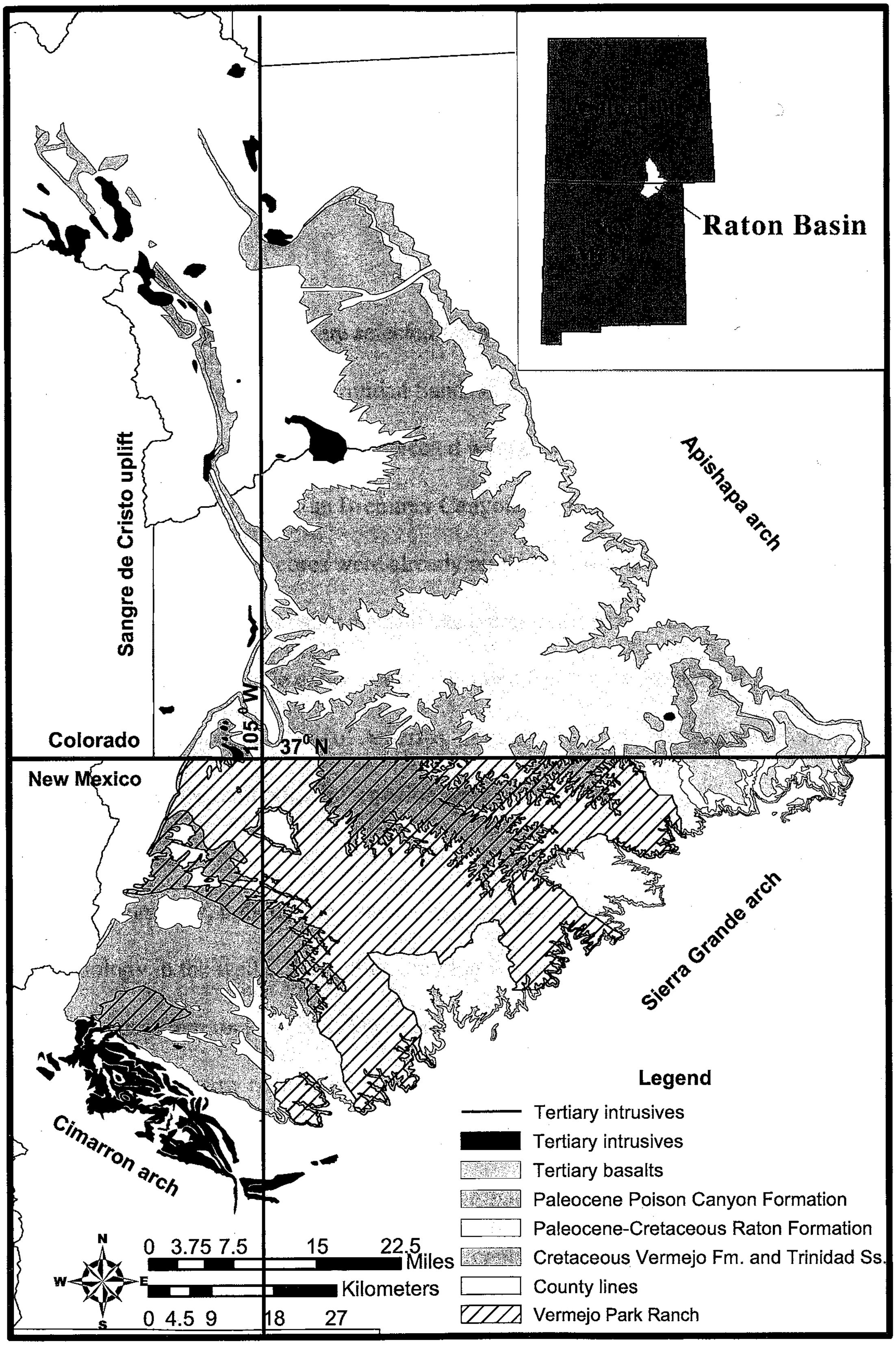

Raton Basin
Apishapa arch
Sangre de Cristo uplift
Colorado
New Mexico
105° W
37° N
Sierra Grande arch
Cimarron arch
Legend
Tertiary intrusives
Tertiary intrusives
Tertiary basalts
Paleocene Poison Canyon Formation
Paleocene-Cretaceous Raton Formation
Cretaceous Vermejo Fm. and Trinidad Ss.
County lines
Vermejo Park Ranch
N
W
E
S
0 3.75 7.5 15 22.5
Miles
Kilometers
0 4.5 9 18 27

Figure 1. Geologic map of the Raton Basin in Colorado and New Mexico. The outcrop of the Trinidad Sandstone serves as the outline for the basin. The Vermejo Park Ranch property in the New Mexico portion basin is illustrated. Geology was derived from New Mexico Bureau of Geology & Mineral Resources (2003).

CHAPTER 2. METHODS

Core description

Four wells with core were selected from the Vermejo Park Ranch to characterize the subsurface lithology of the Trinidad Sandstone, Vermejo Formation, and Raton Formation (Appendix 1). The wells selected were Castle Rock 3117 141G, Castle Rock 3017 021, VPR ST-17, and Van Bremmer Canyon 3019 311G. NMBGMR houses the cores for these wells. The cores were already marked with chalk on 1ft increments. Grain-size was determined using a grain-size comparator based on Wentworth (1922). Colors were assigned while cores were dry using a Geological Society of America rock-color chart (Geological Society of America, 1995). Lithology, bedding structures, fracture occurrence, and other information were also recorded.

Well log analysis

Gamma ray, bulk density, and caliper logs were useful in interpreting stratigraphy and lithology in the wells. The gamma ray log is a measurement of the natural gamma ray emissions from rock. It is useful in estimating lithologies that have predictive values (i.e. sandstone has low radioactivity whereas mudstone has high radioactivity). The bulk density log is a measurement of the combined density of rock and pore space. It also is a useful tool in separating lithologies. However, because the bulk density log is susceptible to borehole washouts (preventing proper tool contact with borehole walls) it should be matched with a caliper log, which records change in the radius of the well bore.

Using these three logs, coalbeds and sandstone beds were picked for a selection of wells (Appendix 2). Coalbeds were picked using the following criteria: a gamma ray reading of less than 100 GAPI (American Petroleum Institute gamma ray units), a bulk density less than or equal to 1.8 gm/cm^3, and a thickness greater than or equal to 1ft. Sandstone beds were picked on the following criteria: a gamma ray reading of less than 100 GAPI, a bulk density greater than 2.6 gm/cm^3, and a thickness greater than or equal to 6 ft. The minimum thickness selected for sandstone beds is larger because almost all sandstone beds are greater than 6 ft in thickness. Criteria were sometimes altered because of differences noticed in the log suites produced by the different companies performing the measurements. Lithologic picks for the Raton-Vermejo and Vermejo-Trinidad Formation contacts were also made using these logs.

Spatial analysis of subsurface data

The following section was adapted from Environmental Systems Research Institute, Inc. (2002) along with Cressie (1993), which is cited where referenced. It is provided to familiarize the reader with the mathematical techniques used to derive surfaces demonstrated later in this study. The method that was used to interpolate values from known to unknown points is known as Kriging. Kriging is a geostatistical method based on autocorrelation. Autocorrelation is the idea that measured points have statistical relationships to one another. There are several steps involved in the Kriging process. First is examination of the spatial distribution of the measured values. Based on this examination, the best-fitting semivariogram is modeled and a surface created. The semivariogram is used as a means of weighting measured values for determining values at other points.

Mathematically a semivariogram is given as:

$\gamma(\mathbf{s}_i, \mathbf{s}_j) = \frac{1}{2}\, \mathbf{var}(Z(\mathbf{s}_i) - Z(\mathbf{s}_j))$ (ESRI, 2002) (1.1)

where

$\mathbf{s}_i$ and $\mathbf{s}_j$ are two points;

$Z(\mathbf{s}_i)$ and $Z(\mathbf{s}_j)$ are values at those points;

var is the variance.

Below is a semivariogram labeled with common terminology. The height at which the curve begins to level off is known as the sill. The distance it takes for the curve to reach the sill is known as the range. The sill can be furthered divided into the nugget and partial sill. The nugget is the effect of a discontinuity at the origin. In turn, the nugget can be separated into measurement error and microscale variation. The partial sill is the portion of the curve where the distance is greater than zero.

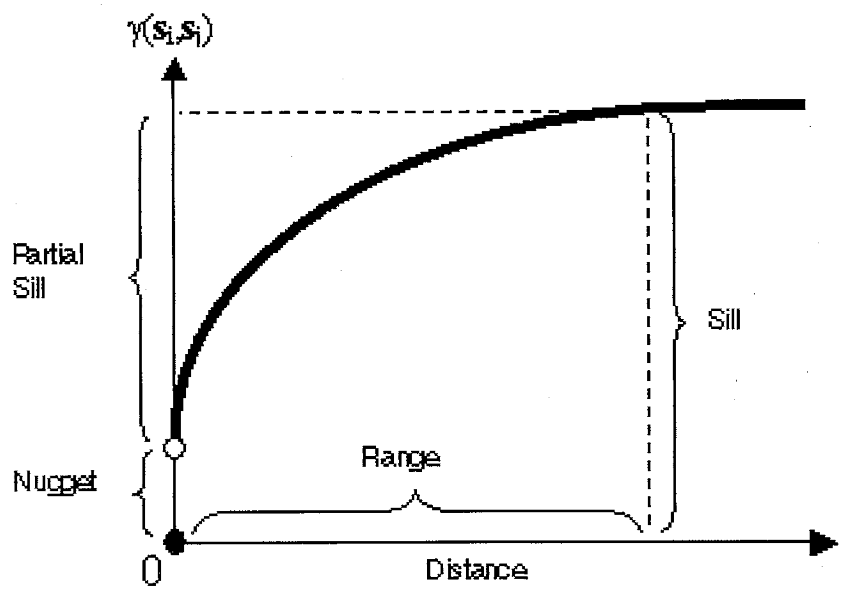


Figure 2. Drawing of a semivariogram labeled with terminology (ESRI, 2002).

As seen above, increase in distance results in an increase in difference between the known and unknown points. Several models are commonly used to describe the nature of this relationship. These are linear, exponential, circular, and spherical. Each model is a description of the behavior of the curve. For instance, the best model for the figure above would be the exponential with a nugget.

The specific type of Kriging used for this study is Ordinary Kriging. It is one of the simplest forms of Kriging (Cressie, 1993). However, it yielded realistic results for surfaces because it fit the data well. Ordinary Kriging assumes the model

$$Z(\mathbf{s}) = \mu + \varepsilon(\mathbf{s}) \qquad \text{(Cressie, 1993)} \qquad (1.2)$$

where

$Z(\mathbf{s})$ is a variable of interest;

μ is an unknown constant;

$\varepsilon(\mathbf{s})$ is the random, autocorrelated error term;

and uses the following formula

$$\hat{Z}(\mathbf{s}_0) = \sum_{i=1}^{N} \lambda_i Z(\mathbf{s}_i) \qquad \text{(Cressie, 1993)} \qquad (1.3)$$

where

$Z(\mathbf{s}_i)$ is a measured value at point i;

λ_i is a weight for the measured value at point i;

$\mathbf{s}_0$ is the point being predicted;

N is the number of measured values.

For the first equation, μ represents the deterministic trend. In the case of Ordinary Kriging this is a constant. $\varepsilon(\mathbf{s})$ is the factor that accounts for the error in the trend being used. In the case of Ordinary Kriging this accounts for the variation seen in the value from the constant. For the second equation, λ_i is determined from the best-fit semivariogram model for the measured values discussed in the previous section. For a more through examination of the derivation of λ_i, refer to Cressie (1993).

Air permeametry measurements

Air permeametry measurements were performed on a selection of core samples from VPR ST-17. The samples were collected from different lithologies of the Raton and Vermejo Formations as well as the Trinidad Sandstone. Equal selections of samples were taken parallel and perpendicular to bedding. An air-minipermeameter device was used to measure permeability of the samples. The specific mechanics of this device are given in Davis (1994). Essentially compressed air travels from tanks through a flow gauge, then a pressure gauge, and finally through a tip seal. When the tip seal is placed against a rock, the flow and pressure gauges are read and a permeability can be calculated. The mathematics used to derive the permeability is explained in Davis (1994).

CHAPTER 3. STRATIGRAPHY

Late Cretaceous-Early Tertiary stratigraphy of the Raton Basin

The following section is a stratigraphic description of the Trinidad Sandstone, Vermejo, Raton, and Poison Canyon Formations based on previous literature as cited.

Trinidad Sandstone

Hills (1899) first described the Trinidad Sandstone (Figure 3). The type locality is from the Trinidad coalfield west of Trinidad, Colorado. The Upper Cretaceous Trinidad Sandstone ranges from 0 to 300 ft (92 m) in thickness (Baltz, 1965). Generally tabular in nature, in some localities it has been noted as irregular or lenticular (Johnson and Wood, 1956). It is 80-100 ft (24-30 m) thick along the eastern limb of the basin and 80-220 ft (24-67 m) along the western margin. Along the axis of the basin the Trinidad Sandstone ranges from 140 ft (43 m) in the south to as thick as 300 ft (91 m) north of the Purgatoire River. In the northern portion of the basin southeast of Huerfano Park, the Poison Canyon Formation truncates the Trinidad Sandstone and unconformably overlies the Pierre Shale (Johnson et al., 1958). The Trinidad Sandstone is also missing in New Mexico between Ute Park and the Vermejo Park dome along the westernmost part of the basin due to an angular unconformity with the Poison Canyon Formation (Baltz, 1965).

Pillmore and Maberry (1976) described the Trinidad Sandstone as very fine grained to medium grained feldspathic sandstone. The contact between the Trinidad Sandstone and Pierre Shale is gradational over several meters. The contact between the

<table>
<tr><th colspan="2">Age</th><th>Formation</th><th>General Description</th><th>Aproximate Thickness (ft)</th></tr>
<tr><td rowspan="2">Tertiary</td><td rowspan="2">Paleocene</td><td>Poison Canyon Formation</td><td>Sandstone-Coarse to conglomeratic beds 13-50 ft thick. Interbeds of soft, yellow-weathering clayey sandstone. Thickens to the west at expense of underlying Raton Formation</td><td>500 +</td></tr>
<tr><td>Raton Formation</td><td>Formation intertongues with Poison Canyon Formation to the west

<u>Upper Coal Zone</u>-Very fine grained sandstone, siltstone, and mudstone with carbonaceous shale and thick coal beds

<u>Barren Series</u>-Mostly very fine to fine-grained sandstone with minor mudstone, siltstone, with carbonaceous shale and thin coal beds

<u>Lower Coal Zone</u>-Same as upper coal zone; coalbeds mostly thin and discontinous. Conglomeratic sandstone at base; locally absent</td><td>0-2100</td></tr>
<tr><td rowspan="3">Mesozoic</td><td rowspan="3">Upper Cretaceous</td><td>Vermejo Formation</td><td>Sandstone-Fine to medium grained with mudstone, carbonaceous shale, and extensive thick coalbeds; local sills</td><td>0-380</td></tr>
<tr><td>Trinidad Sandstone</td><td>Sanstone-Fine to medium grained; contains casts of Ophiomorpha</td><td>0-300</td></tr>
<tr><td>Pierre Shale</td><td>Shale-Silty in upper 300 ft. Grades upward to fine-grained sandstone. Contains limestone concretions</td><td>1800-1900</td></tr>
</table>

Figure 3. Upper Cretaceous and Paleocene stratigraphic column for the Raton Basin (modified from Johnson and Finn (2001)). Note that basal conglomerate of the Raton Formation is grouped with the lower coal zone.

Trinidad Sandstone and the Vermejo Formation, placed at the base of the lowest carbonaceous zone, is generally well defined. However, several authors (Lee, 1917; Johnson and Wood, 1956; Harbour and Dixon, 1956) have described intertonguing of the two. This is evidence that the regression was not continual and that there were temporary periods of transgression. Pillmore and Maberry (1976) concluded deposition took place along an eastward prograding shoreline that accompanied the final regression of the Cretaceous Sea. It was during the transition from marine to terrestrial conditions that the formation was deposited in shallow neritic and beach environments.

Vermejo Formation

Lee (1913) originally proposed the Vermejo Formation to describe the coal-bearing sandstones and mudstone beds immediately above the Trinidad Sandstone (Figure 3). The type locality was in Vermejo Park, New Mexico where the well-exposed formation has a maximum thickness of 375 ft (114 m). Lee interpreted the Cretaceous-Tertiary boundary to be at the unconformable contact between the Vermejo Formation and the basal conglomerate of the Raton Formation. It was recognized later that the boundary was actually within the lower part of the Raton Formation (Brown, 1943) and was more definitively placed above the lower coal zone of the Raton Formation by Pollastro and Pillmore (1987).

The Vermejo Formation ranges from 0-380 ft (116 m) in thickness (Pillmore and Flores, 1987). It reaches its maximum thickness at the western margin of the basin near Vermejo Park, New Mexico. To the east the formation thins and terminates several miles east of Raton, New Mexico. A similar thinning occurs towards the southern margin of the basin. Like the Trinidad Sandstone, the Vermejo Formation is absent from the westernmost part of the basin with the Poison Canyon Formation unconformably deposited over the Pierre Shale (Johnson et al., 1958). The Vermejo Formation is also missing southeast of Huerfano Park, Colorado, where the Poison Canyon Formation unconformably overlies the Pierre Shale. The Vermejo Formation intertongues with the Trinidad Sandstone. The tongues have a general east-northeast orientation (Johnson and Wood, 1956).

Johnson and Wood (1956) described the Vermejo Formation as consisting of buff to gray siltstone and sandstone, black carbonaceous mudstone, and numerous coalbeds. The high fossil content and fine sediment in the lower Vermejo Formation suggests these marginal marine deposits were deposited in coastal swamps, lagoons, estuaries, and tidal flats (Pillmore and Maberry, 1976). At the top of the formation sand-filled stream channels and fining upward sequences indicate lower alluvial plains dissected by meandering streams. Overall, there is a general coarsening upward as depositional environments progress toward more terrestrial settings.

Raton Formation

The Raton Formation was named by Hayden (1869) to describe all coal-bearing rocks in the Raton Mesa. It was later restricted by Lee (1917) to include the rocks between the Vermejo and Poison Canyon Formations (Figure 3). The type locality for the Raton Formation is the high mesa region between Trinidad, Colorado and Raton, New Mexico. Lee (1917) divided the Raton Formation into the basal conglomerate, a lower coal zone, a barren series and an upper coal zone.

The thickness of the Raton Formation is as much as 2100 ft (640 m) in the west central portion of the basin and thins to about 1100 ft (335 m) in the eastern portion

(Pillmore et al., 1999). The general thinning to the east is accompanied by a decrease in grain size laterally among the lithologies. The formation is more continuous than the Vermejo Formation, only suffering local variations in thickness where syndepositional doming created preferential erosion (Lee, 1917). Portions of the Raton Formation have been removed in the west with the Poison Canyon Formation resting unconformably over older Cretaceous rocks (Johnson and Wood, 1956).

Lee (1917) described the basal conglomerate of the Raton Formation as a coarse, massive, and arkosic body in the west that thins and decreases in grain size until it becomes barely distinguishable from sandstone beds overlying it in the east. Pillmore et al. (1999) goes further and argues that in the east the conglomerate disappears along with the unconformity. The conglomerate is as thick as several hundred feet approaching the western margin (Lee, 1917) and absent in the area between Raton, New Mexico and Trinidad, Colorado (Pillmore and Flores, 1987). To the west it is not distinguished from the Poison Canyon Formation (Lee, 1917). Pebbles from the conglomerate have been traced to the Trinidad and Dakota Sandstones. Rapid uplift and erosion to the west of the San Luis highland is responsible for depositing the conglomerate in an upper alluvial plain setting (Pillmore et al., 1999). Eastward depositional settings shift more towards meandering stream deposits associated with the lower coal zone (Ethridge et al., 1981).

The lower coal zone ranges in thickness from 50-250 ft (15-76 m) and experiences the same eastward thinning trend as the basal conglomerate. It is coincident with the meandering streams near the eastern margin. These accumulated mudstone beds and thin coalbeds (Pillmore et al., 1999). The coalbeds are thinner (generally 8-12 inches (20-30 cm) and less continuous than coalbeds of the Vermejo Formation. This is due to swamps and floodplains being better drained and shallow than similar Vermejo Formation environments. These deposits indicate a more stable tectonic environment than seen during the deposition of the basal conglomerate. A general coarsening upwards in this interval preludes the next major tectonic event (Lee, 1917).

The middle barren sequence is sometimes referred to as "the cliffs" because of the interval's prominence in many of the cliffs in the area around Raton, New Mexico (Lee, 1917). "Barren" describes the absence of coalbeds in this section of the Raton Formation. The series ranges from 180-600 ft (55-183 m) in thickness (Pillmore and Flores, 1987). In the north it forms an escarpment approximately 250 ft (76 m) thick. It merges with the Poison Canyon Formation along the western margin. The interval is predominately fine to coarse-grained channel sands. Locally there are thin, discontinuous beds of silt, carbonaceous mudstone, and coal. These were deposited in lower alluvial fans and upper alluvial plains (Etheridge et al., 1981). Uplift to the west is thought responsible for the change from proximal environments in the west to more distal environments to the east.

Early geologic study of the basin focused primarily on the upper coal zone of the Raton Formation. The alternating beds of mudstone and sandstone are home to the principal coalbeds of the Raton Formation (Lee, 1917). Lower beds have been commercially developed near Raton, Trinidad, and many other locations throughout the basin. Its thickness ranges from 180 ft (55 m) near Raton to nearly 1100 ft (335 m) at York Canyon Mine, New Mexico (Pillmore and Flores, 1987). The upper coal zone is subject to diminishing thickness eastward through the basin. The depositional environments are similar to those of the lower coal zone. Swamps and floodplains are more conducive to generating thicker coalbeds, though they are nearly as lenticular as older coalbeds in the formation. One reason hypothesized for these more conducive environments is the abandonment of meandering stream systems that were eventually encroached upon by swamps. These deposits represent another wane in tectonic activity similar to that of the lower coal zone.

Poison Canyon Formation

The Poison Canyon Formation was originally described by Hills (1899) (Figure 3). The thickness of the formation ranges from 2500 ft (762 m) south of the Spanish Peaks to a "thin edge" in Huerfano Park (Johnson and Dixon, 1966). In the Vermejo Park area it averages 500-600 ft (152-183 m) (Pillmore and Flores, 1987). It overlies the Raton Formation in a majority of the basin but to the west and southwest the formations intertongue. In these areas it also unconformably overlies the Vermejo Formation, Trinidad Sandstone, and Pierre Shale. Where the Poison Canyon Formation does not intertongue with the Raton Formation an indefinite gradational contact is observed. The formation thins to the east.

Typically the Poison Canyon Formation is divided into a lower and upper facies. The lower facies bears resemblance to the barren series of the Raton Formation. In some western extents of the basin the two merge, becoming indistinguishable (Johnson et al., 1956). The formation consists of coarse-grained to conglomeratic channel sandstone beds (Pillmore and Flores, 1987). These are usually massively bedded and lenticular, forming ledges in the basin.

The upper facies of the Poison Canyon Formation is a conglomerate containing pebbles to cobbles of igneous and metamorphic material (Johnson and Wood, 1956). The size and lithology change reflects a change in source area. This new source area for deposits is believed to be further north and west than the source area for the lower facies. Facies thickness and increase in grain size led to this conclusion (Johnson and Wood, 1956). The upper facies in the northwest intertongues and cuts into the lower facies. The upper facies also cut into the Raton Formation, Vermejo Formation, Trinidad Sandstone, and Pierre Shale. Coalbeds are absent throughout the formation (Etheridge et al., 1981) due to rapid rise of the source areas.

Detailed stratigraphy of the study area

The Trinidad Sandstone, Vermejo Formation, and Raton Formation were examined in core to gain a better understanding of the subsurface stratigraphy in the study area. A total of four wells were selected for examination of cores (Figure 4). These cores represent the best spatial variability through the central region of the study area. Detailed descriptions and a lithologic overview were performed (Appendix 1).

Corresponding gamma ray, neutron bulk density, and caliper logs for these wells were compared to the core descriptions. This enabled correlation of behaviors in the logs to specific lithologies and formation contacts noted in the core descriptions (Figure 5). Using these fours wells as examples, logs for wells throughout the region were examined and lithologic and formation contacts interpreted (Appendix 2). The lithologic and formation contact information gathered in this study was then combined with another database created by Gretchen Hoffman and Brian Brister at the New Mexico Bureau of Geology and Mineral Resources. The database was used in this study as well as Hoffman and Brister (2003) and Brister et al. (2004). The entire database can be found in Brister et al. (2004). While the figures introduced in the following paragraph are modified from

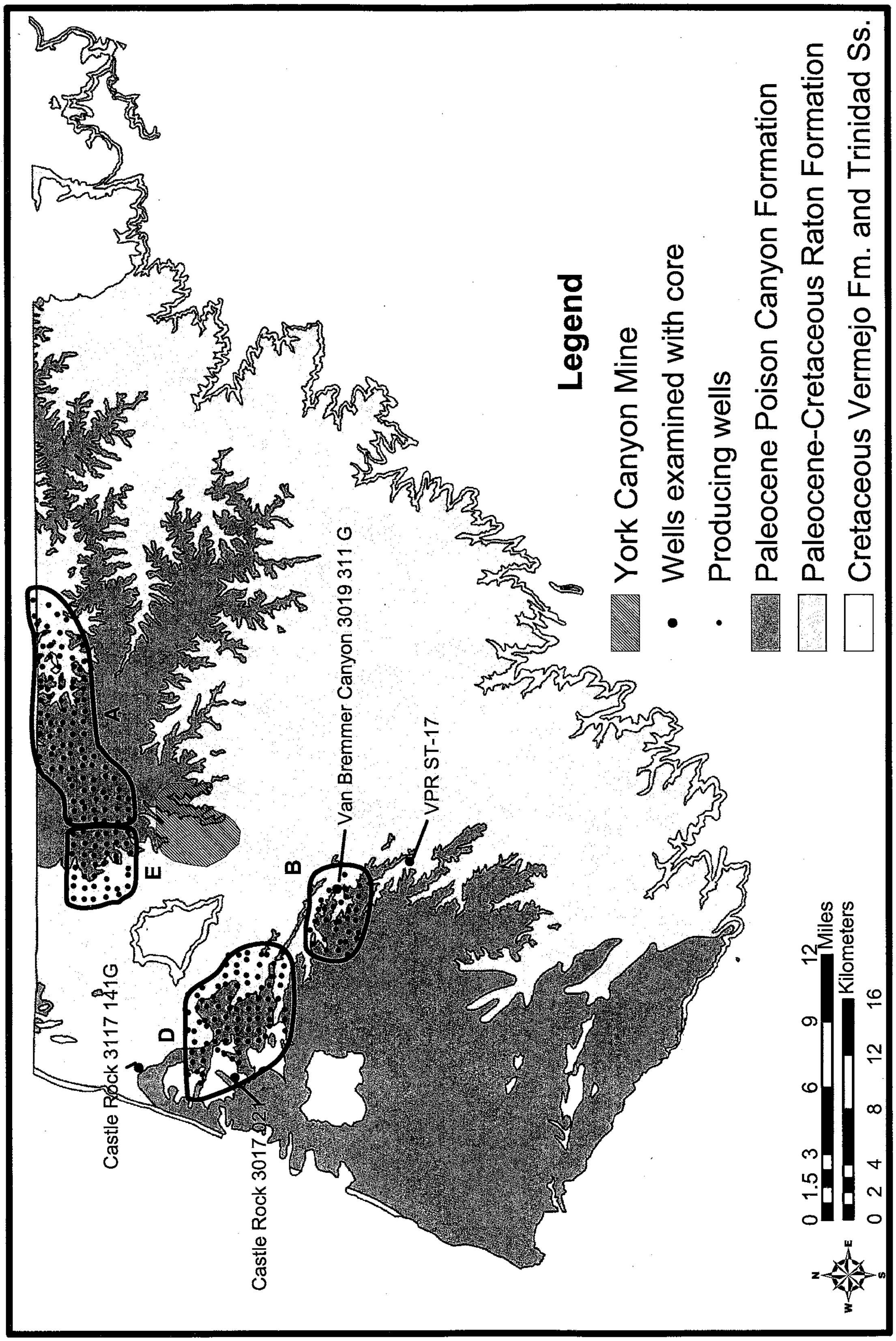

Legend
York Canyon Mine
Wells examined with core
Producing wells
Paleocene Poison Canyon Formation
Paleocene-Cretaceous Raton Formation
Cretaceous Vermejo Fm. and Trinidad Ss.
Castle Rock 3117 141G
Castle Rock 3017 121
Van Bremmer Canyon 3019 311 G
VPR ST-17
A
B
D
E
0 1.5 3 6 9 12 Miles
0 2 4 8 12 16 Kilometers
N
E
S
W

Figure 4. Map of the A, B, D, and E producing areas on Vermejo Park Ranch. The four named wells have core that was examined during this study. The wells were selected to best capture the spatial variability of the stratigraphy in this region of the basin. The York Canyon Mine is outlined. Well and mine location data was obtained from Brister et al. (2004). The core for these wells is housed at the New Mexico Bureau of Geology and Mineral Resources. The geology depicted in this map was generated from New Mexico State Geologic Map (New Mexico Bureau of Geology and Mineral Resources, 2003).

VPR ST 17

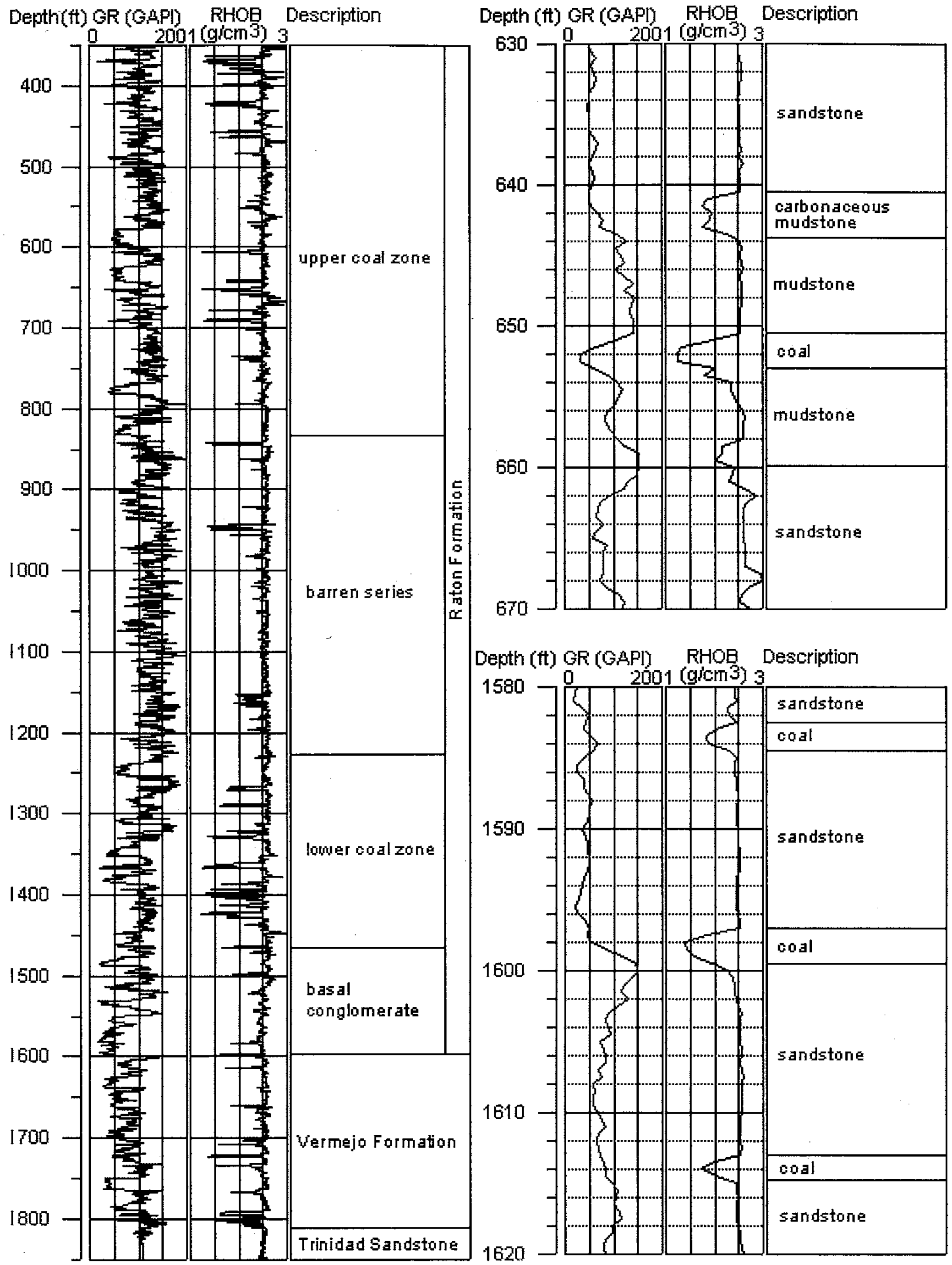

Depth(ft)
GR (GAPI)
0
200
RHOB
(g/cm3)
1
3
Description
400
500
600
700
800
900
1000
1100
1200
1300
1400
1500
1600
1700
1800
upper coal zone
barren series
lower coal zone
basal conglomerate
Raton Formation
Vermejo Formation
Trinidad Sandstone
Depth (ft)
630
640
650
660
670
sandstone
carbonaceous mudstone
mudstone
coal
mudstone
sandstone
1580
1590
1600
1610
1620
sandstone
coal
sandstone
coal
sandstone
coal
sandstone

Figure 5. Well log for VPR ST-17. Curves for gamma ray labeled GR and measure in GAPI (American Petroleum Institute gamma ray units) and neutron density labeled RHOB and measured in gm/cm^3 shown for the cored portion of the well. Formation and zone contacts are indicated. To the right two intervals are expanded to indicate general lithology. Note the behaviors in the curves in response to lithology.

Hoffman and Brister (2003) the interpretations are based on the work conducted during the course of this study.

Coalbed lateral continuity

Two stratigraphic/lithologic cross sections were generated using the aforementioned database and are indicated in Figure 6. Figures 7 and 8 illustrate the east-west oriented A-A' and northwest-southeast oriented B-B' cross sections, respectively. Though a number of observations can be made about these figures, some of which are noted in the captions, the most significant to this study concerns lateral continuity. The lateral continuity of a coalbed is an influential factor in determining the potential volume of coal a well is able to affect by pumping. Laterally continuous coalbeds have a larger volume of coal in contact with the well, increasing the coalbed methane potential.

Approximate well spacing for the A-A' and B-B' cross sections are 1 mile and 3/4 mile, respectively. At either of these spacings coalbeds could not be definitively correlated between wells. A 1/2 mile scale was selected to study lateral continuity of the coalbeds because it corresponded to the spacing of producing wells in the area and would give an idea as to how well coalbeds connected between wells. To better investigate the lateral continuity of coalbeds in the Raton Formation, cross sections from subsurface mining operations at the York Canyon Mine (Figure 4) were examined (Kaiser Coal Corporation, 1986). Figures 9 and 10 illustrate a typical cross section from those analyzed. The cross sections cover an interval of the upper coal zone of the Raton Formation containing the York Canyon coalbed (Figure 10). Spacing for wells in this and other cross sections reviewed ranged from 200-6,000 ft with most ranging between 1,000-2,000 ft. The closer spacing provides a clearer picture of the continuity of

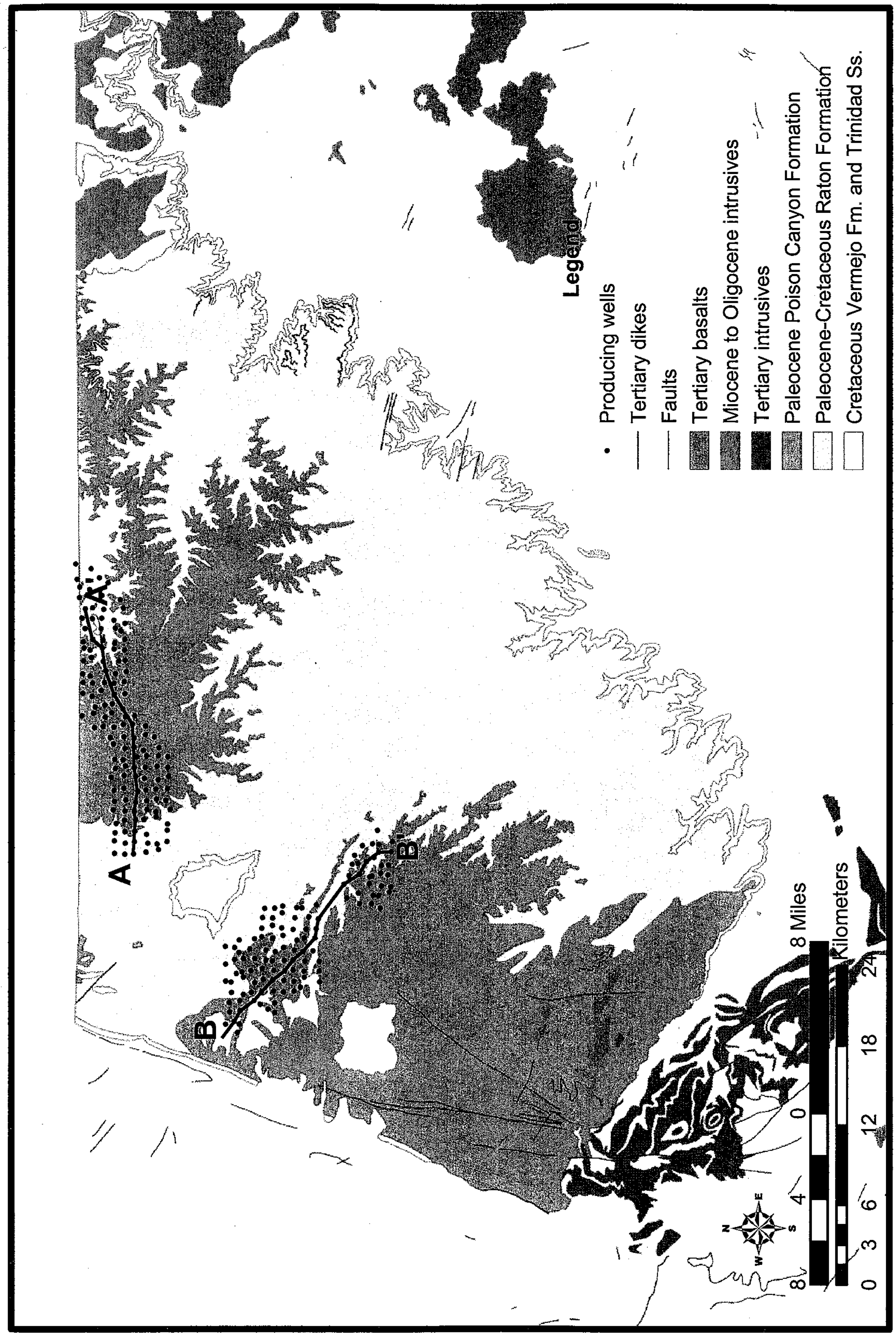

A
A'
B
B'
Legend
Producing wells
Tertiary dikes
Faults
Tertiary basalts
Miocene to Oligocene intrusives
Tertiary intrusives
Paleocene Poison Canyon Formation
Paleocene-Cretaceous Raton Formation
Cretaceous Vermejo Fm. and Trinidad Ss.
8 Miles
Kilometers
8 4 0 8
0 3 6 12 18 24

Figure 6. Map identifying locations of cross sections A-A' and B-B'. The cross sections were created using well logs from coalbed methane producing wells in the north and central portions of the study area. Geology was derived from New Mexico Bureau of Geology & Mineral Resources (2003).

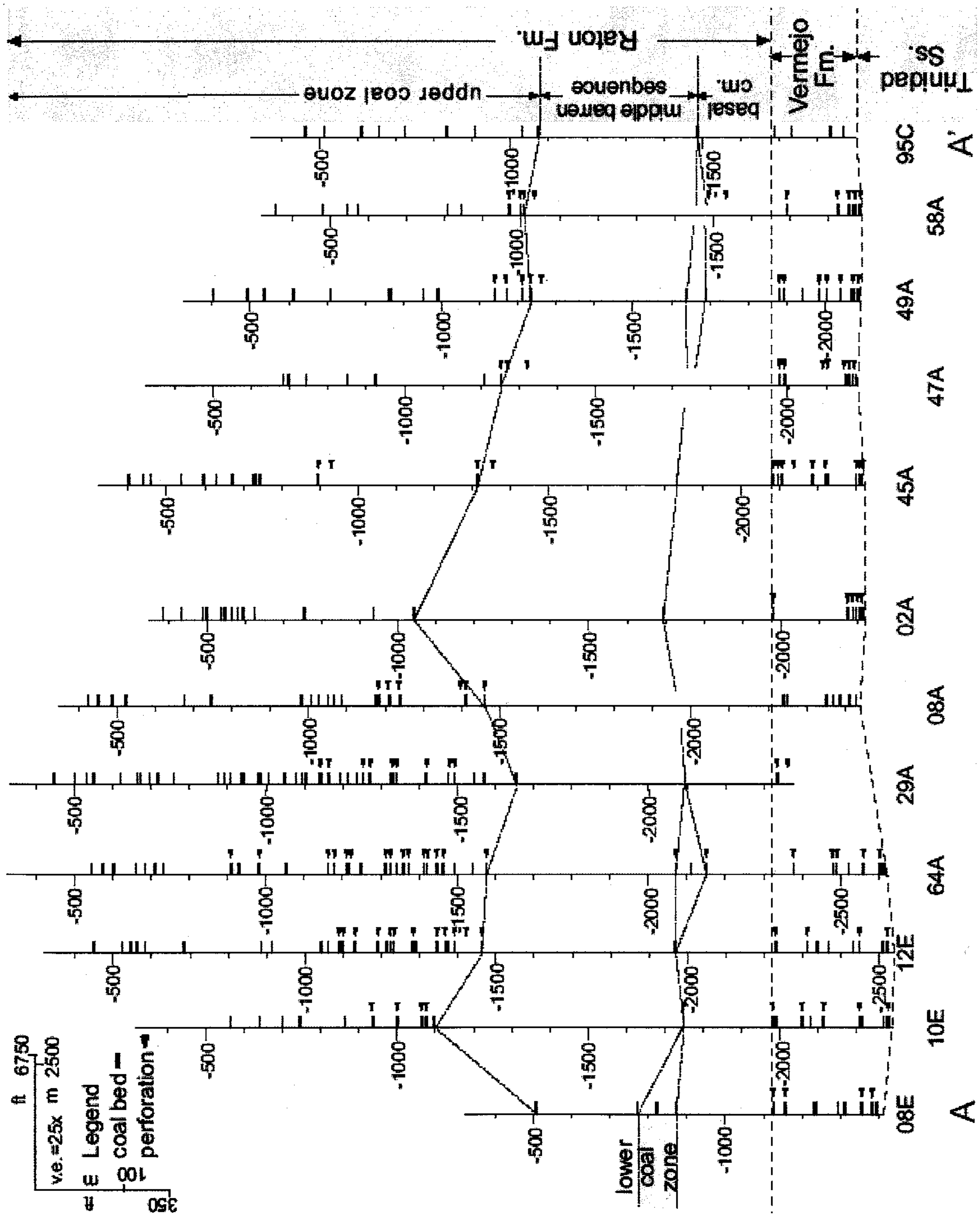

A
A'
08E
10E
12E
64A
29A
08A
02A
45A
47A
49A
58A
95C
v.e.=25x
ft 6750
m 2500
ft 350
m 100
Legend
coal bed
perforation
lower coal zone
upper coal zone
middle barren sequence
basal cm.
Raton Fm.
Vermejo Fm.
Trinidad Ss.

Figure 7. A-A' cross section (modified from Hoffman and Brister (2003). The location of the cross-section is shown in Figure 6. Wells are roughly spaced 1-mile. Coal seams $\geq$ 1 ft in thickness are indicated as well as perforation data obtained from well records. The stratigraphic datum used is the contact between the Raton and Vermejo Formations. The cross-section trends west to east with the eastern half trending slightly northeast. The section is oblique to the depositional strike in this region of the basin. The Vermejo Formation thins from west to east. The basal conglomerate of the Raton Formation tends to thin overall moving from west to east though it fluctuates in thickness several hundred feet between some wells. While the basal conglomerate increases in thickness westward the lower coal zone decreases in thickness. The lower coal zone in some wells is only a single coalbed. The barren series thickens and thins through the section. The thickness of the upper coal zone in the section could not be calculated because it is not fully represented in well logs. Variation in coalbed thickness or number of seams showed no pattern moving from west to east.

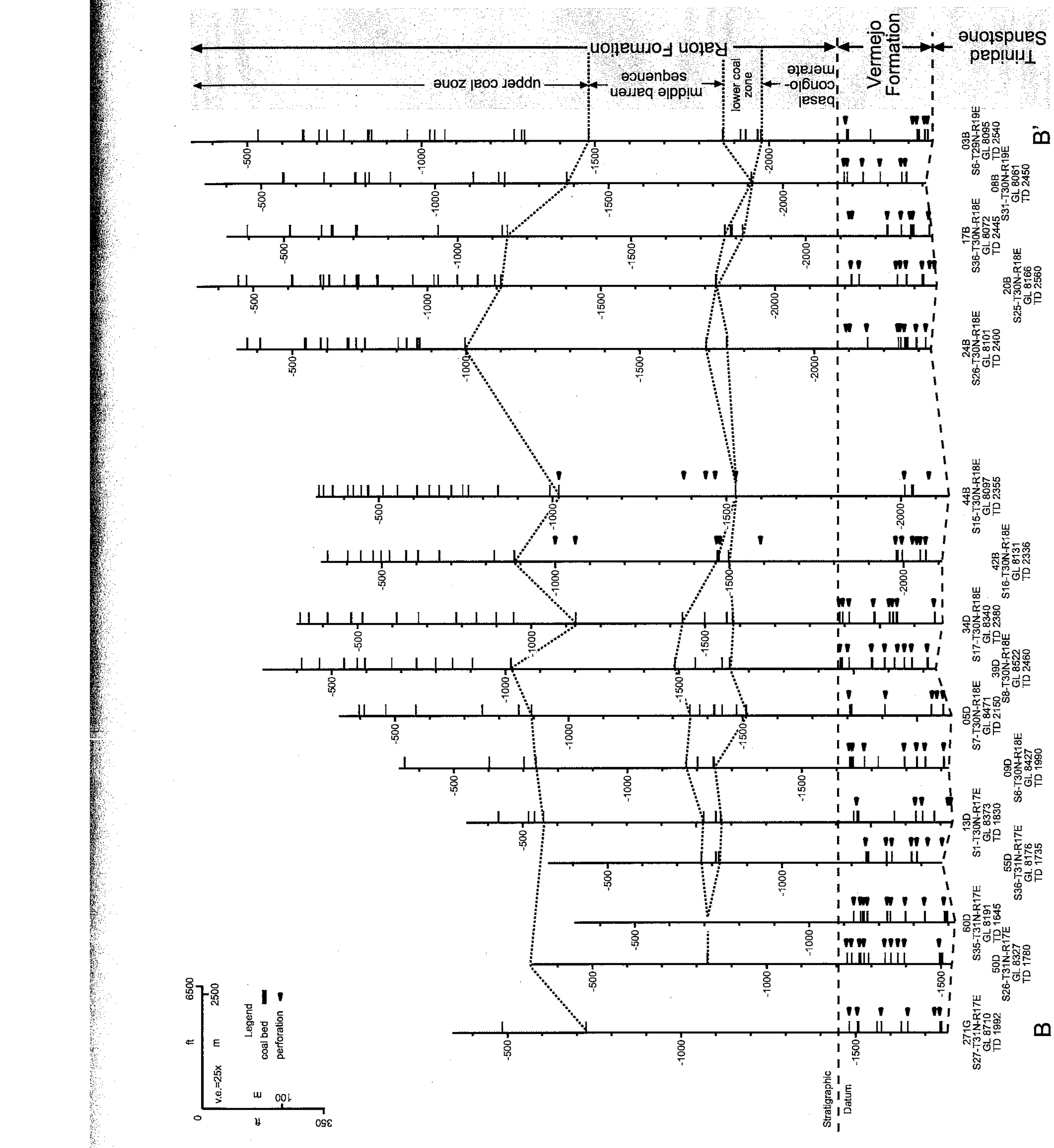

B
B'
Raton Formation
upper coal zone
middle barren sequence
lower coal zone
basal conglo-merate
Vermejo Formation
Trinidad Sandstone
Stratigraphic Datum
271G S27-T31N-R17E GL 8710 TD 1992
50D S26-T31N-R17E GL 8327 TD 1780
60D S35-T31N-R17E GL 8191 TD 1645
55D S36-T31N-R17E GL 8176 TD 1735
13D S1-T30N-R17E GL 8373 TD 1830
09D S6-T30N-R18E GL 8427 TD 1990
05D S7-T30N-R18E GL 8471 TD 2150
39D S8-T30N-R18E GL 8522 TD 2460
34D S17-T30N-R18E GL 8340 TD 2380
42B S16-T30N-R18E GL 8131 TD 2336
44B S15-T30N-R18E GL 8097 TD 2355
24B S26-T30N-R18E GL 8101 TD 2400
20B S25-T30N-R18E GL 8166 TD 2560
17B S36-T30N-R18E GL 8072 TD 2445
08B S31-T30N-R19E GL 8061 TD 2450
03B S6-T29N-R19E GL 8095 TD 2540
Legend
coal bed
perforation
v.e.=25x
ft
m
0
350
100
6500
2500

Figure 8. B-B' cross section (modified from Hoffman and Brister (2003)). Wells are approximately on 1/4 mile spacing. A line of the cross section is shown in Figure 6. See caption for Figure 7 for further information concerning cross-section construction. The cross section trends from the northwest to the southeast. This is nearly perpendicular to the strike of the depositional surface upon which the Vermejo and Raton Formations were deposited purposed by Pillmore et al. (1999). The Vermejo Formation thins from northwest to southeast. The basal conglomerate of the Raton Formation also thins moving from west to east. The lower coal zone is erratic in thickness through the cross section. It pinches out to west. Coalbeds of the lower zone tend to decrease in thickness and number with thinning. The middle barren sequence also has an erratic thickness moving from west to east.

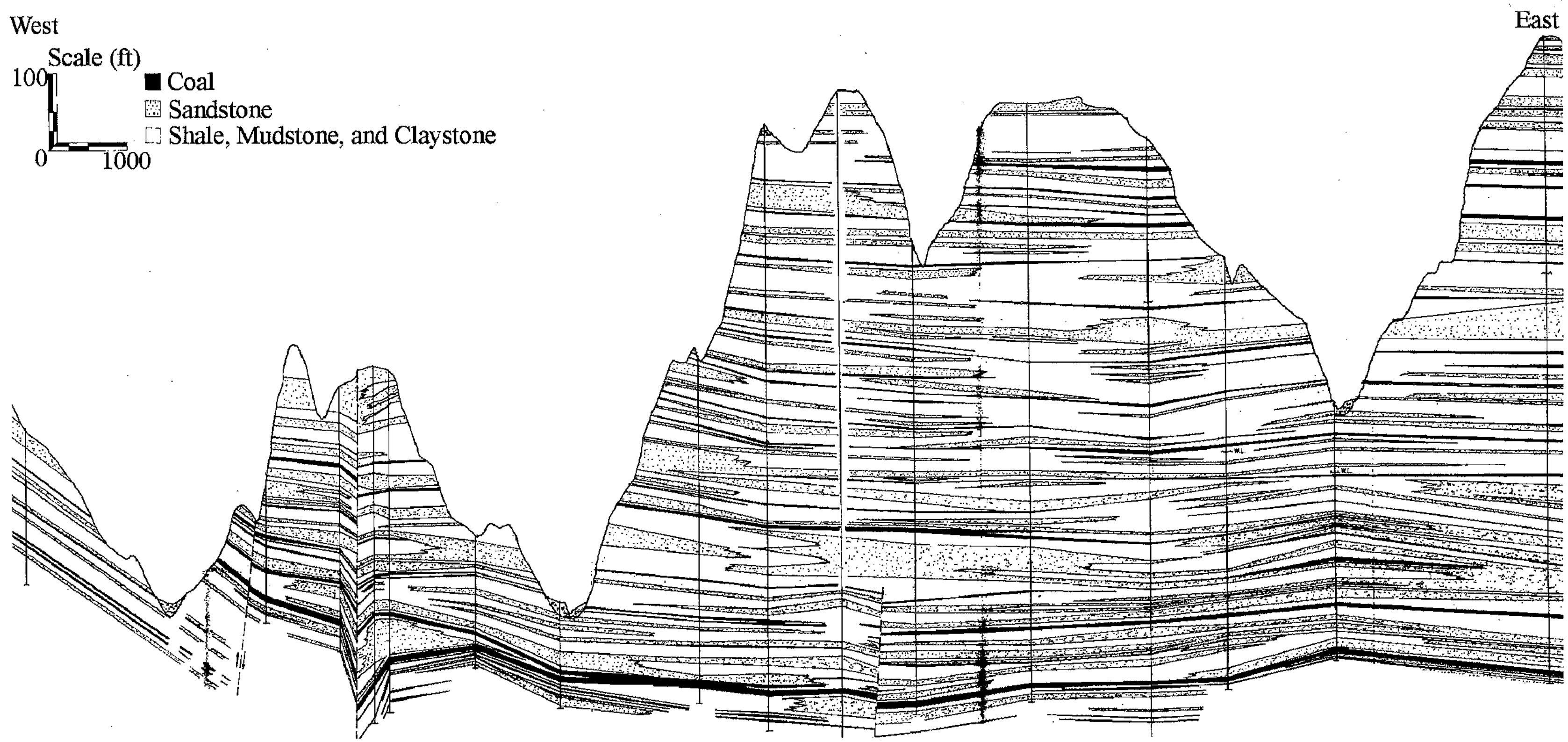

West
East
Scale (ft)
100
0
1000
Coal
Sandstone
Shale, Mudstone, and Claystone

Figure 9. Cross section from York Canyon Mine (modified from Kaiser Coal Corporation, 1986).

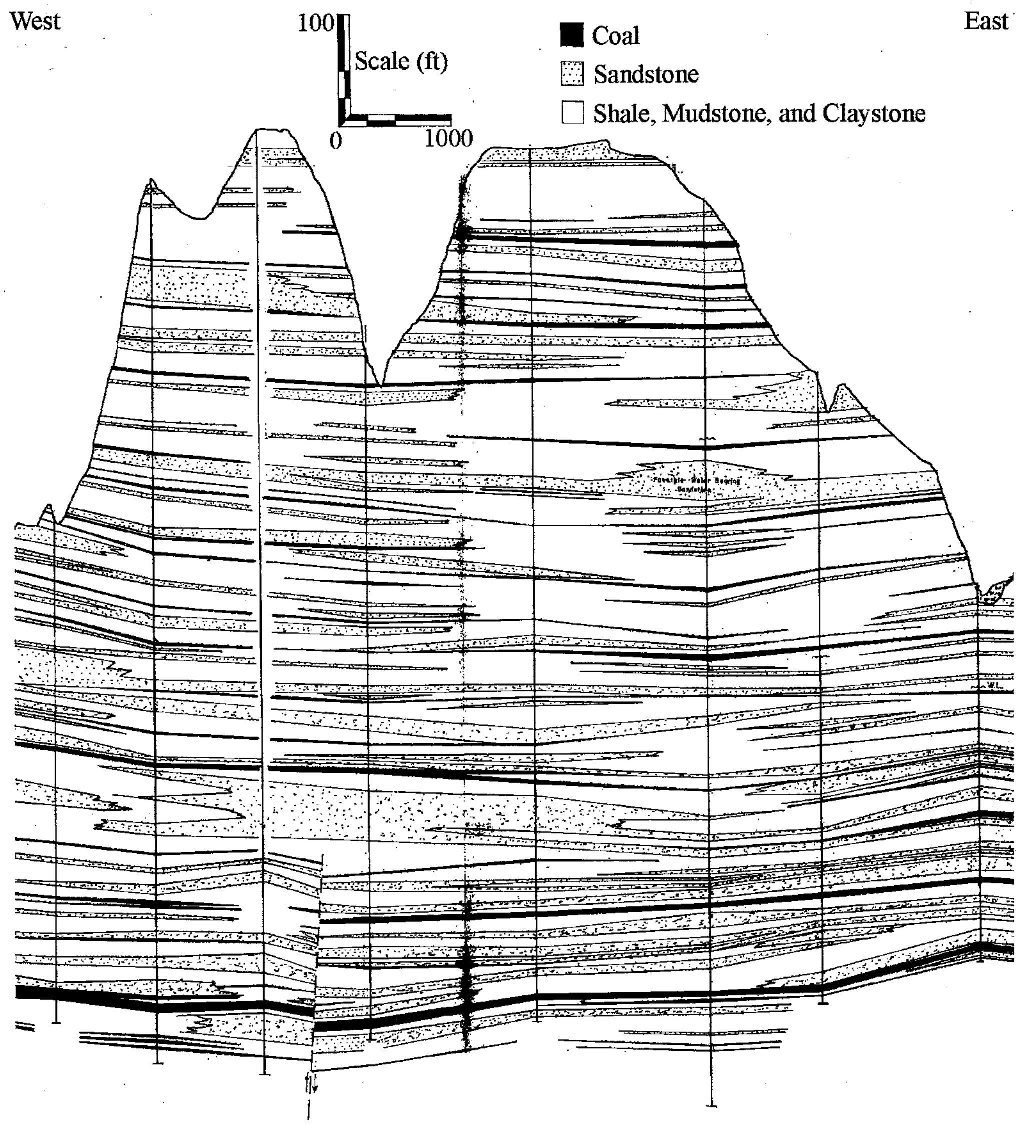

West
East
100
Scale (ft)
0
1000
Coal
Sandstone
Shale, Mudstone, and Claystone

Figure 10. Expanded view of cross section from York Canyon Mine (modified from Kaiser Coal Corporation, 1986). The York Canyon Coalbed is located at the bottom of the section.

coalbeds. From the cross sections examined, lateral extent of the coalbeds ranged from < 300ft feet to > 3 miles. 1/2 mile increments between wells were laid out and well information within the spacings used to examine lateral continuity. At this spacing approximately half of coalbeds terminated between the two end points. Thicker coalbeds were usually more laterally continuous than thinner beds. Cross sections with north-south orientations commonly exhibited a higher percentage of laterally continuous coalbeds than those of an east-west orientation. This is believed to be the result of north-south orientation of depositional environments forming coalbeds in the upper coal zone of the Raton Formation (Pillmore and Flores, 1987).

Further investigation of the lateral continuity of coalbeds in the Vermejo Formation involved examination of cross sections published by Lee (1924). An example of one of the cross sections is given in Figure 11. The cross sections are focused on the Raton coalbed at the base of the Vermejo Formation. Spacing in the cross sections ranges between 1000 ft to 8.5 miles with most averaging 1/4 to 1/2 a mile. The cross sections provide a more comprehensive view of the lateral continuity of the coalbeds of the Vermejo Formation. Still, the spacing on average is nearly twice that of the cross sections examined for the York Canyon Mine. This made correlation of coalbeds more difficult. The lateral extent of the coalbeds examined ranged from < 1/4 mile to > 5 miles. Thicker beds showed increased lateral extent over thinner beds. 1/2 mile increments where again set up and well information between them used to examine laterally continuity. On average almost 2/3 of coalbeds were interpreted to be laterally continuous over the 1/2 mile increments.

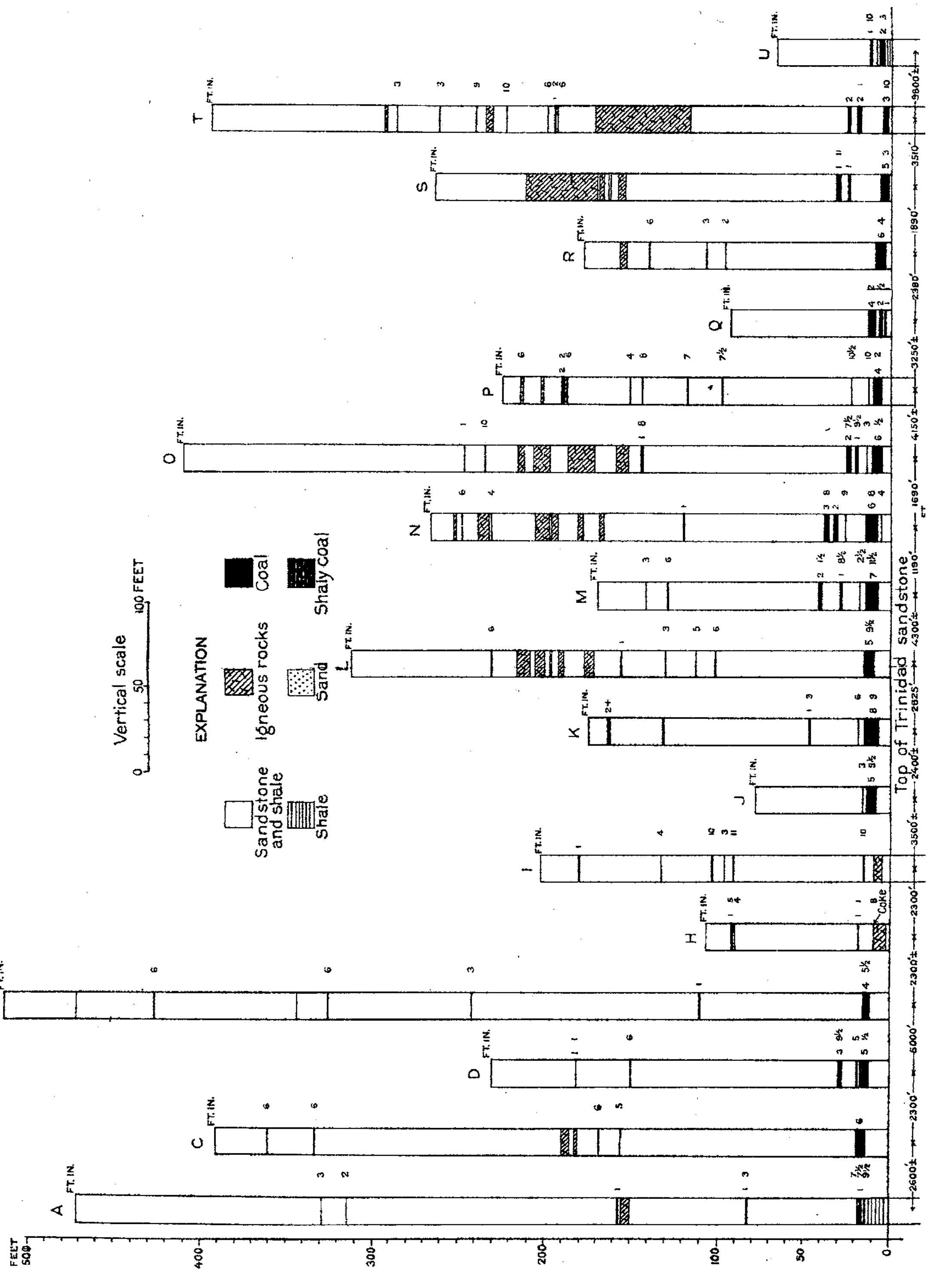

Vertical scale
0
50
100 FEET
EXPLANATION
Sandstone and shale
Shale
Igneous rocks
Sand
Coal
Shaly coal
Top of Trinidad sandstone
FEET
A
C
D
G
H
I
J
K
L
M
N
O
P
Q
R
S
T
U

Figure 11. Cross section including Raton coalbed near Blossburg, New Mexico (modified from Lee, 1924).

Based on the cross sections generated as part of this study and review of cross sections from previous work, both the Raton and Vermejo Formations appear to contain coalbeds of various lateral extents. As shown by the variety of cross sections examined, the notion of lateral continuity of a coalbed is scale dependent. If the scale of importance for coalbed methane production is the spacing between producing wells, then it is reasonable to assume the low degree of lateral continuity some coalbeds are exhibiting in cross section may be adversely influencing coalbed methane production. Brister et al. (2004) demonstrated that adjacent wells on 1/2 mile spacing that perforate coalbeds at a series of similar depths do not show the effects of pumping from one another. This supports the notion of poor lateral continuity preventing interaction between wells for some coalbeds. However, why do coalbeds that appear to be laterally continuous not allow interaction between wells? A possible explanation is that the fracture network created through artificial hydraulic fracturing may not be adequate to interconnect well bores tapping the same coalbeds.

Coalbed statistics

The lithologic/stratigraphic database discussed above was utilized to examine coalbed thickness in wells. Table 1 shows the average, maximum, and minimum values for number of seams, average bed thickness, and total coalbed thickness of the Raton and Vermejo Formations. In an average well there are typically more than 20 beds averaging about 2 ft in thickness. The total coalbed thickness for the Raton Formation was 26 ft and 16 ft for the Vermejo Formation. The average net coalbed thickness of the formations was found to compare relatively well to a previous estimate from Tyler et al. (1995) (Table 2). Compared to other coal basins in the western United States the Raton has the

Table 1. Coalbed data for the Raton and Vermejo Formations

	Coal thickness (ft)		**Number of beds per well**		**Average seam thickness (ft)**		**Net coal thickness (ft)**
Formation	Raton	Vermejo	Raton	Vermejo	Raton	Vermejo	Raton + Vermejo
Average	26	16	14	7	2	2.5	42
Max	64	33	30	13	3.3	5.5	97
Min	8	4	4	2	1.2	1.2	12
Count	59	133					

Table 2. Information for western U.S. coalbed methane basins (modified from Tyler et al. (1995)).

Basin	San Juan	Greater Green River	Piceance	Powder River	Raton
Areas (mi^2)	7500	21000	6700	25800	2200
Thickness of coal-bearing intervals (ft)	300-400	4000	500-1500	1500-2500	500-1500
Coal resource (billion tons)	240	1277	380	1300	1.5-4.8
Coal rank (% Ro)	.65-2.35	.55-.60	.70-1.50	<.50	>2.0
Gas Content (scf/ton)	100-500	50-400	200-450	<100	200-500
Published maximum gas-in-place (Tcf)	88	314	>84	16-103	8.4-12.1
Maximum coal thickness (ft)	25-40	25-35	20-35	100-150	<10
Net coal thickness (ft)	40-60	150-250	100-150	250-350	40-70
Carbon dioxide content	high	Low-high (?)	high	Low-very high	Low

second lowest range of net coalbed thickness (Table 2). Based on this it was concluded that the net thickness of coalbeds in the Raton and Vermejo Formations is relatively low.

CHAPTER 4. STRUCTURE

Structure of the Raton Basin, New Mexico

The following section is a description of the general structure of the Raton Basin derived from previous publications. The Raton Basin is southernmost of the Laramide intracratonic folded basins on the eastern margin of the Rocky Mountains (Baltz, 1965). The Sangre de Cristo Mountains form the western border (Figure 12). A majority of the mountains are composed of Precambrian crystalline rocks and Ordovician to Early Permian sedimentary rocks (Baltz, 1965). During the Laramide orogeny these rocks were uplifted and heaved eastward. The result is the Sangre de Cristo Mountains, which extend from the Arkansas River in Colorado into northern New Mexico (Close, 1988). The mountains have been suspected of undergoing at least three post-Laramide uplifts during Late Oligocene, Late Miocene, and the Quaternary (McCalpin, 1987). The range varies from 10-20 miles in width and is convex to the east (Burbank and Goddard, 1937).

To the south the Cimarron arch separates the Raton Basin from the Las Vegas Basin (Figure 12). It continues southeastward and merges with the Sierra Grande arch. The Sierra Grande arch defines the eastern margin. This feature is thought to have had some expression in the Pennsylvanian (Tweto, 1979). However, it is principally a Laramide feature (Close, 1988).

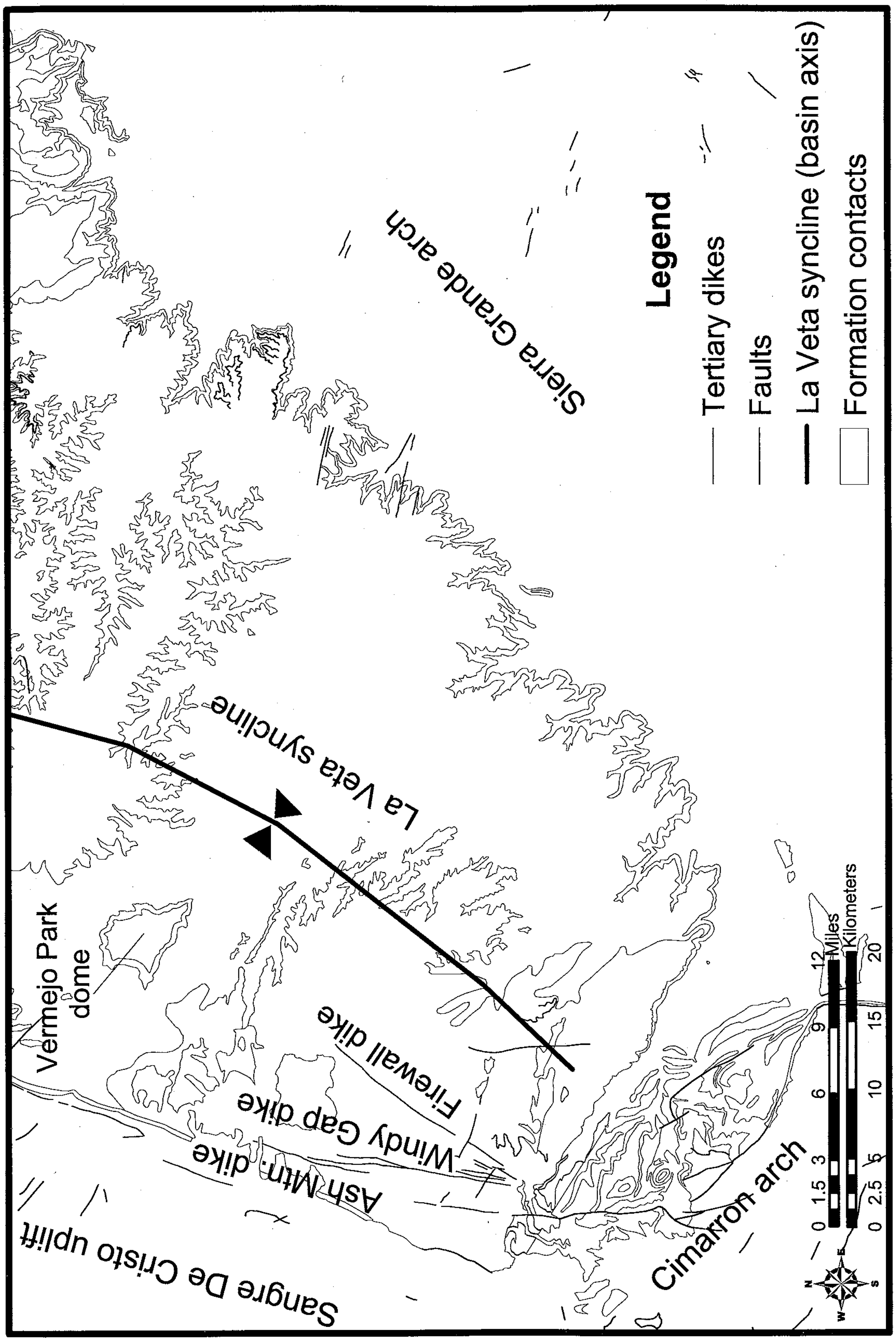

Legend
Tertiary dikes
Faults
La Veta syncline (basin axis)
Formation contacts
Sierra Grande arch
La Veta syncline
Vermejo Park dome
Firewall dike
Windy Gap dike
Ash Mtn. dike
Sangre De Cristo uplift
Cimarron arch
0 1.5 3 6 9 12 Miles
0 2.5 5 10 15 20 Kilometers
N
E
S
W

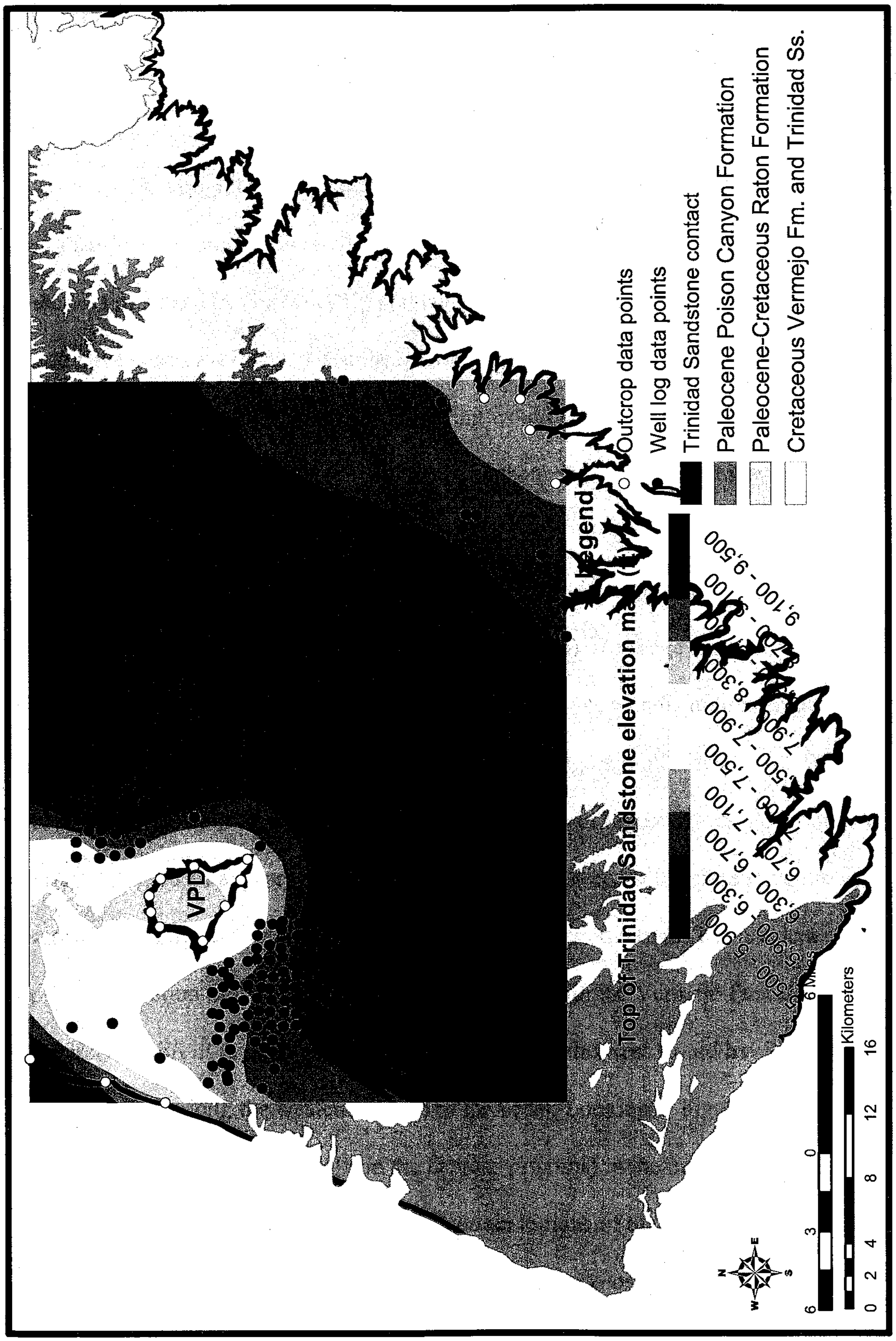
Figure 12. Geologic and general structural feature map of the Raton Basin, New Mexico. Formation contact, dike, and fault information was obtained from the New Mexico State Geologic Map (New Mexico Bureau of Geology and Mineral Resources, 2003).

The Raton Basin is an asymmetrical downwarp resulting from the Sangre de Cristo uplift (Baltz, 1965). The structural axis (the La Veta Syncline) lies in the western portion, excluding the area around the Cimarron arch (Figure 12). The western limb of the basin can be vertical to overturned. It is typically dissected by west-dipping high angle reverse faults and thrusts (Northrop et al., 1946). Sills and dikes of Tertiary age occur on the southwestern margin (Baltz, 1965). The eastern limb of the basin gently slopes westward from the Las Animas and Sierra Grande arches.

Fractures in the basin are generally represented by two distinct orientations. The first is an east-west oriented set of fractures associated with the east-west compression during the Laramide (Johnson, 1961). The second is a north-south set of fractures associated with the extensional forces related to the formation of the Rio Grande rift (Close and Dutcher, 1990). Close (1988) did extensive measuring of face cleat orientations for coalbeds in the Vermejo Park Ranch area. The cleats generally trend east-west although there are some which trend north-south. The present day maximum horizontal stress is north-south (Lorenz et al., 2003).

Structural & igneous features of the study area

Subsurface structure of the basin was investigated by creating a structural contour map of the top surface of the Trinidad Sandstone (Figure 13). This was done to determine if structural phenomena in the subsurface correlated to trends in water production of coalbed methane wells. Elevations for the top of the Trinidad Sandstone were interpreted using gamma ray and neutron density logs from wells (Appendix 3). This information was supplemented with outcrop location data for the Trinidad Sandstone derived from the state geologic map (New Mexico Bureau of Geology and



VPD
Legend
Top of Trinidad Sandstone elevation m
9,100 - 9,500
Outcrop data points
Well log data points
Trinidad Sandstone contact
Paleocene Poison Canyon Formation
Paleocene-Cretaceous Raton Formation
Cretaceous Vermejo Fm. and Trinidad Ss.
6 3 0 6 Miles
0 2 4 8 12 16
Kilometers
N
E
S
W

Figure 13. Structural elevation map of the top of the Trinidad Sandstone. The outcrop of the Trinidad Sandstone in the basin is shown in red. Subsurface information for this map was collected from well logs. Surface geology information was obtained from New Mexico Bureau of Geology and Mineral Resources (2003). The following parameters were used in the Ordinary Kriging method of ArcGIS 8.2™ to derive the surface: model = circular, major range = .1496, partial sill = 431010, nugget = 0, lag size = .028748, # of lags = 12, neighbors = 6, minimum neighbors = 3.

Mineral Resources, 2003). ArcMap™ 8.2 was used to extrapolate this point data by applying an Ordinary Kriging method (Figure 13). Further explanation of the techniques employed above is given in Chapter 2.

From the map it appears the Vermejo Park dome has had a significant effect on the subsurface structure in the region. The presence of an intrusive body beneath the dome was proposed by Bates (1942) and later verified by Speer (1976). Such a body would have increased fracturing in the surrounding rock as it was intruded over a period of time (Speer, 1976). The increased fracturing would increase the hydraulic conductivity of the rocks. In wells producing methane from coalbeds this would translate into higher water production.

To investigate if this correlation exists, water production data for wells producing coalbed methane were obtained from Brister et al. (2004). Average monthly water production rates were calculated. Using ArcMap™ 8.2 maps, indicating average monthly production, were generated applying an Ordinary Kriging method (Figure 14). Structural contours derived from the structural contour map shown in Figure 13 were overlain. The overlay in Figure 14 appears to indicate a correlation between subsurface structure associated with the Vermejo Park dome and high water production. This evidence supports the notion of increased fracturing associated with the Vermejo Park dome. Progressive uplift of the Sangre de Cristo Mountains to the west would have created a similar situation along the western margin of the basin. Looking at Figure 14, increased water production is noted for wells in the D areas proximal to the basin margin.

Sills, common in the subsurface for certain regions of the basin, were investigated to determine if their presence showed any correlation to gas or water production trends.

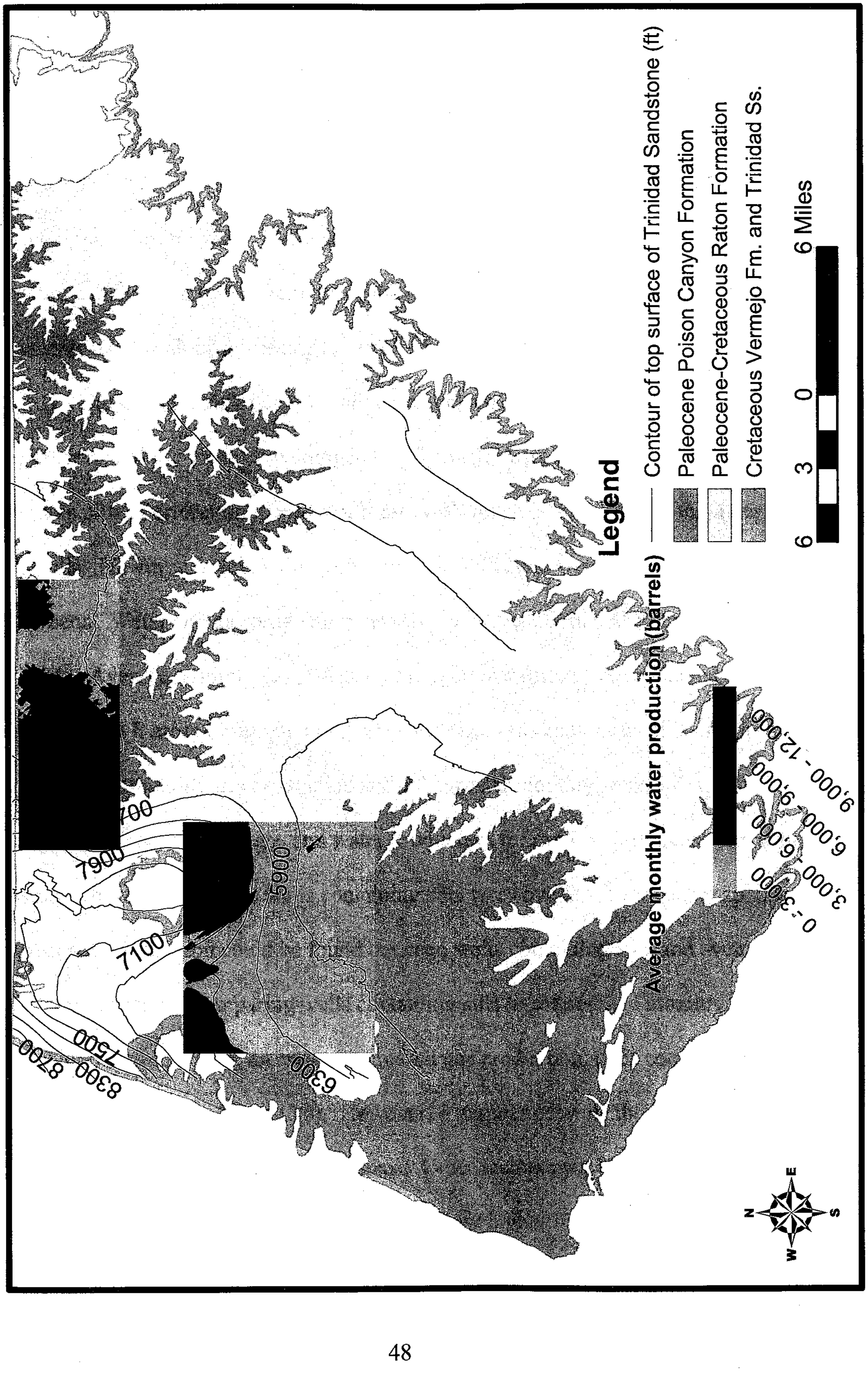

Legend
Contour of top surface of Trinidad Sandstone (ft)
Paleocene Poison Canyon Formation
Paleocene-Cretaceous Raton Formation
Cretaceous Vermejo Fm. and Trinidad Ss.
6 3 0 6 Miles
Average monthly water production (barrels)
0 - 3,000
3,000 - 6,000
6,000 - 9,000
9,000 - 12,000
8700
8300
7500
7100
7900
5900
6300
N
S
E
W

Figure 14. Average monthly water production values for wells overlain by the structural contour map of the Trinidad Sandstone. Raw water production data obtained from Brister et al., (2004). Structural contours derived from map in Figure 12. The following parameters were used in the Ordinary Kriging method of ArcGIS 8.2™ to derive the surface: model = spherical, major range = .07171, partial sill = 5537600, nugget = 2378400, lag size = .014215, # of lags = 12, neighbors = 5, minimum neighbors = 2.

Previous study has noted a correlation between wells with sills and increased gas and water production (Stevens et al., 1992). Igneous sills are known to preferentially intrude coalbeds due to the coal's weaker mechanical properties (Olsson, 2002). The emplacement of such intrusions is thought to increase fracturing in surrounding lithologies (Close, 1988). The intruded coalbed and any nearby coalbeds (typically within a distance half the thickness of the sill) may also experience increased thermal maturity as a result of the heat given off by the sill (Close and Dutcher, 1991).

Gamma ray, bulk density, caliper, and electrical conductivity logs were examined to determine those wells containing sills. Figure 15 displays those wells interpreted to contain sills. Perforation records for these wells revealed that none of them perforated the sills. However, a number of wells contained sills that were proximal to perforated coalbeds. Water and gas production data for wells were obtained from Brister et al. (2004). Average monthly gas and water production values were calculated for the wells in the A and E areas of production (Table 3). The wells containing sills on average had 24% greater monthly gas production and 7 % greater monthly water production. Contour maps of average monthly gas and water production for the A and E areas were generated using ArcMap™ 8.2. The wells containing sills were overlain over each map. No noticeable correlation could be found between wells containing sills and average monthly water production. Comparing wells containing sills to the average monthly gas production contour map, an area of increased gas production, does contain a number of wells containing sills (Figure 16). However, a number of wells thought to contain sills do not fall in the higher gas production areas. Other factors may be influencing gas production in these wells so while they may show higher than average gas production it is

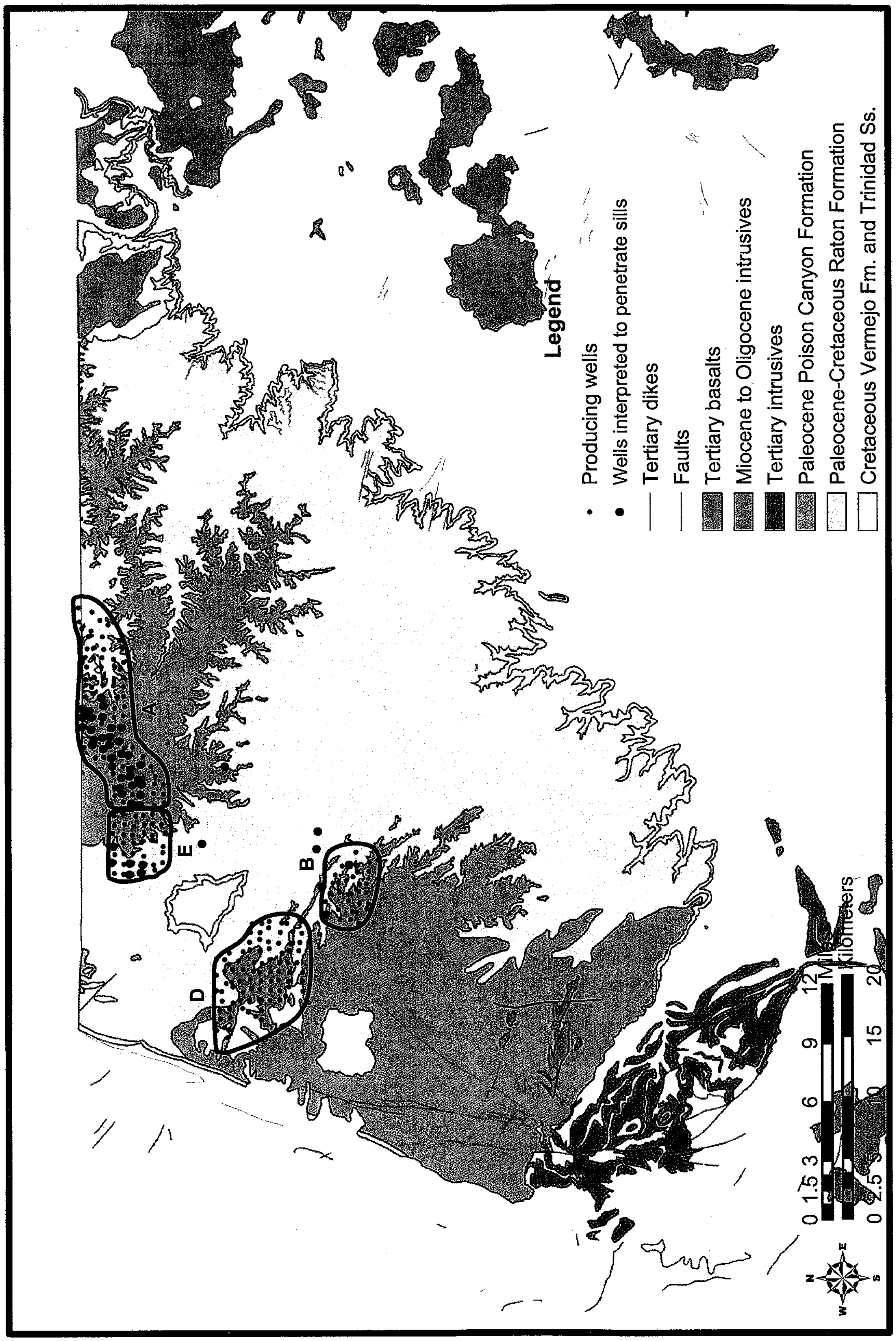

A
B
D
E
Legend
Producing wells
Wells interpreted to penetrate sills
Tertiary dikes
Faults
Tertiary basalts
Miocene to Oligocene intrusives
Tertiary intrusives
Paleocene Poison Canyon Formation
Paleocene-Cretaceous Raton Formation
Cretaceous Vermejo Fm. and Trinidad Ss.
0 1.5 3 6 9 12 Miles
0 2.5 5 10 15 20 Kilometers

Figure 15. Wells in the A, B, and E areas containing igneous sills. The density and frequency of sills in wells decreases moving south. Wells containing sills tend to show higher gas/water production rates compared to surrounding wells.

Table 3. Average monthly gas/water production data for A and E producing areas on the Vermejo Park Ranch.

	Average monthly gas production (mcf)	Average monthly water production (barrels)
Wells without sills	2111	4471
Wells with sills	2607	4802
% increase	24	7

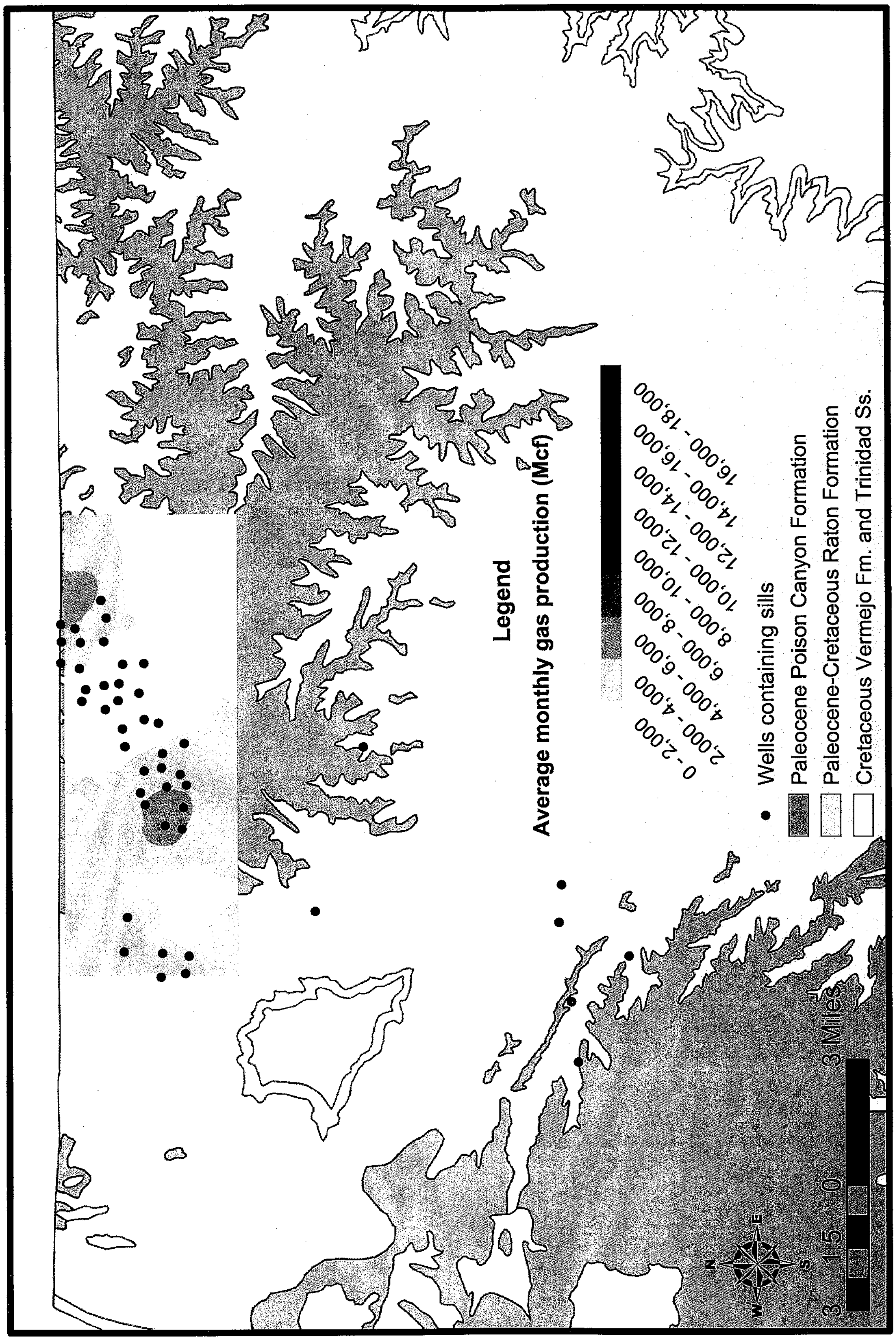

Legend
Average monthly gas production (Mcf)
0 - 2,000
2,000 - 4,000
4,000 - 6,000
6,000 - 8,000
8,000 - 10,000
10,000 - 12,000
12,000 - 14,000
14,000 - 16,000
16,000 - 18,000
Wells containing sills
Paleocene Poison Canyon Formation
Paleocene-Cretaceous Raton Formation
Cretaceous Vermejo Fm. and Trinidad Ss.
3 1.5 0 3 Miles
N
E
S
W

Figure 16. Map comparing average monthly gas production in A/E area to wells containing sills. Several areas of higher gas production have wells believed to contain sills. Other wells thought to contain sills are not found in higher production areas.

not substantial enough to seen in Figure 16. The above findings appear to generally support the idea of increased water and gas production associated with sills in wells.

CHAPTER 5. HYDROLOGY

Produced water chemistry

Produced water data from Vermejo Park Ranch was obtained from the Oil Conservation Division of New Mexico. The data is separated into four areas of production. The A, B, D, and E areas are located within the New Mexico portion of the Vermejo Park Ranch (Figure 4). Complete chemistries for the samples are in Appendix 4. The purpose of this examination was to see if water chemistry could be correlated to gas or water production trends for wells in these areas.

The A area reflects the largest collection of produced water chemistries. Of the four areas it has the greatest variation in chemistry. It is spread over the largest area and has the greatest number of samples through time. The spread of data through space and time contribute to the variation in chemistry. Data from the A area consists of 184 samples from 26 different wells. Figure 17 displays the major ion ratios of the samples. Cations are tightly clustered at the sodium + potassium point of the cation triangle. Moving away from the point the chemistries become more loosely clustered and biased towards calcium. Anions generally fall along a continuum between bicarbonate + carbonate and chloride. There is a slight bias towards to the bicarbonate + carbonate half of the continuum. Chemistries on the diamond reflect these trends. A pattern is seen

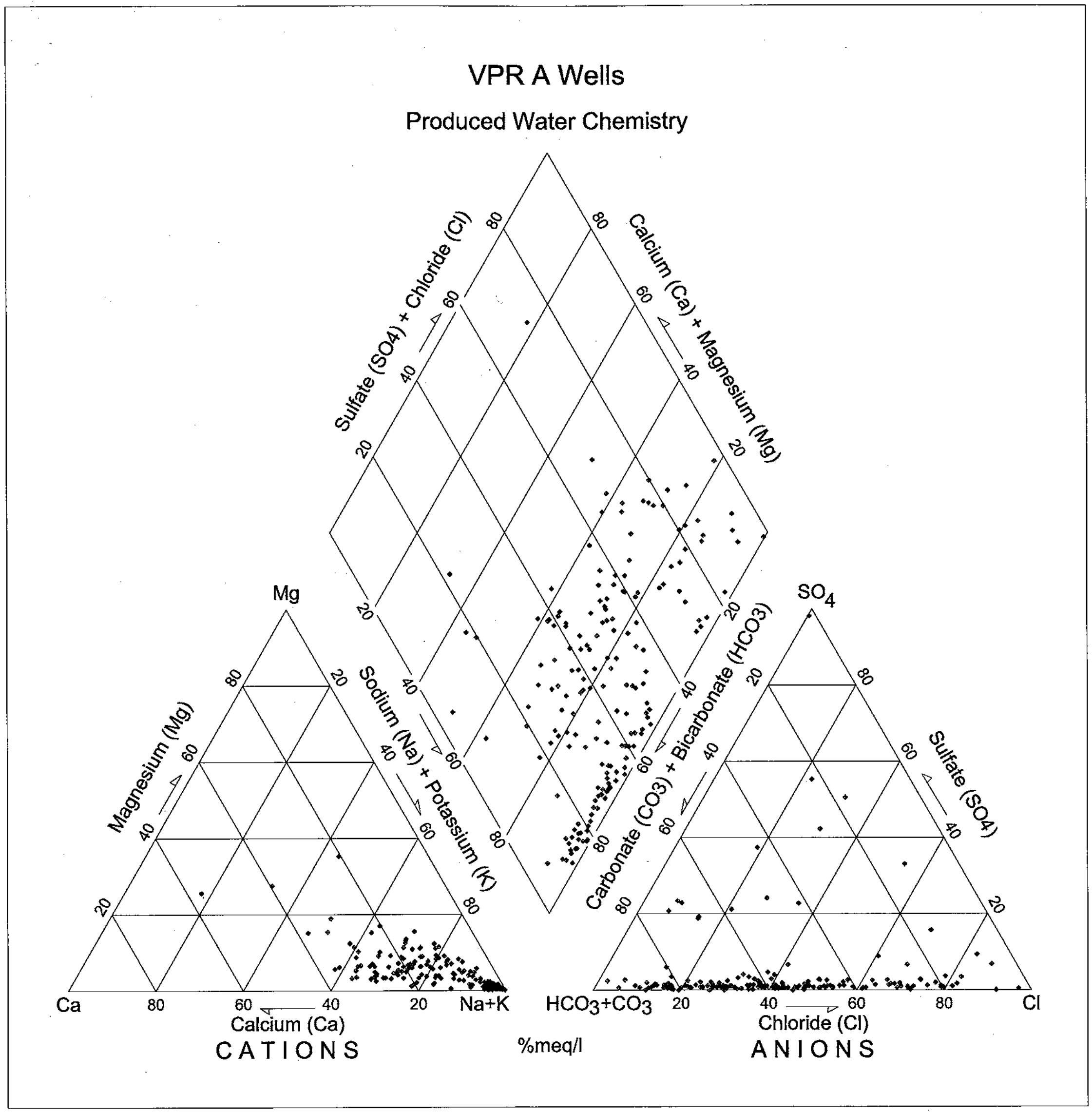

VPR A Wells
Produced Water Chemistry
Sulfate (SO4) + Chloride (Cl)
Calcium (Ca) + Magnesium (Mg)
Sodium (Na) + Potassium (K)
Carbonate (CO3) + Bicarbonate (HCO3)
Magnesium (Mg)
Sulfate (SO4)
Mg
SO4
Ca
Na+K
HCO3+CO3
Cl
Calcium (Ca)
Chloride (Cl)
CATIONS
%meq/l
ANIONS

Figure 17. Piper diagram of A area produced water chemistry. The A area has the largest range in chemistries of the four areas. It is also spread over the largest area and has the most wells with chemistry data.

when comparing location to chemistry. Those wells further west in the pod have higher sodium + potassium and bicarbonate + carbonate ratios than those to the east.

The E area is to the west of the A area. In contrast to the A area, the E area is the smallest and has the fewest wells. A total of 13 samples from different wells were provided. Figure 18 gives the major ion ratios. The chemistries of the E area share the high sodium + potassium and bicarbonate + carbonate ratios of the western portion of the A area. It is seen more clearly in the E area because samples were collected at the same time.

The D area is southwest of the E area. It is the second largest of the areas in size and number of wells. A total of 36 samples were provided from nine wells. Major ion ratios are shown in Figure 19. Cations have a high sodium + potassium ratio. Anions are biased towards bicarbonate + carbonate on a continuum between bicarbonate + carbonate and chloride. The trend of higher sodium + potassium and bicarbonate + carbonate ratios in western wells is again seen.

The B area is to the southeast of the D area. Altogether 29 samples from 14 wells were provided. Major ion chemistry is displayed in Figure 20. Sodium + potassium ratios are high. Anions are biased towards the chloride end of the bicarbonate + carbonate and chloride continuum. A trend is evident that moving east to west there is an increase in the bicarbonate + carbonate ratio.

Figure 21 shows a transect of wells through the B and D areas. Figure 22 indicates major ion ratios for the transect of wells. The transect begins in the northwest section of the D area and continues to the southeast portion of the B area. In the northwest samples have a high bicarbonate + carbonate ratio. Moving to the southeast

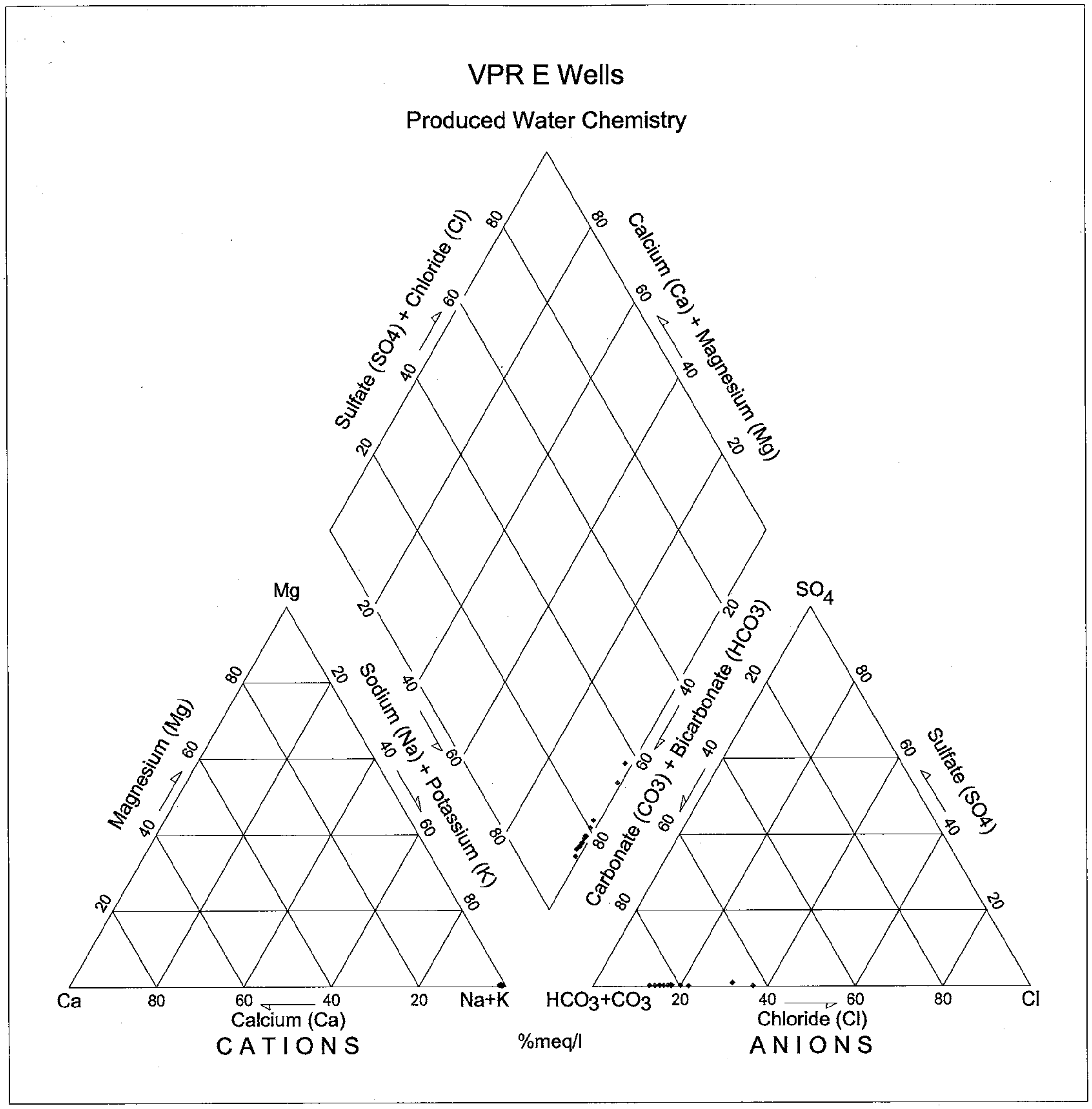

VPR E Wells
Produced Water Chemistry
Sulfate (SO4) + Chloride (Cl)
Calcium (Ca) + Magnesium (Mg)
Mg
Magnesium (Mg)
Sodium (Na) + Potassium (K)
SO4
Carbonate (CO3) + Bicarbonate (HCO3)
Sulfate (SO4)
Ca
Na+K
Calcium (Ca)
CATIONS
%meq/l
HCO3+CO3
Cl
Chloride (Cl)
ANIONS

Figure 18. Piper diagram of E area produced water chemistry. The E area in contrast to the A area has the most limited range of chemistry and covers the smallest area.

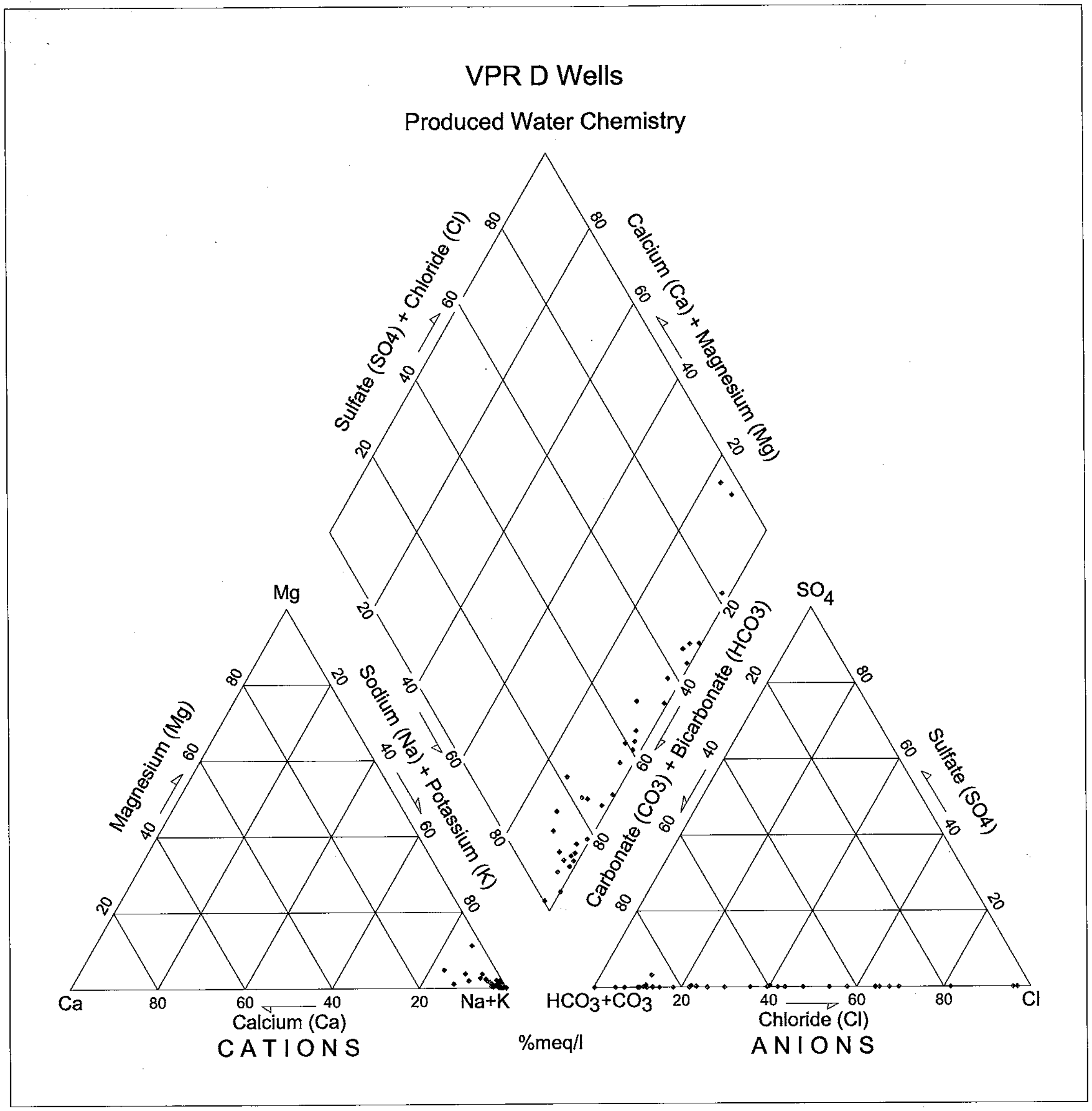

VPR D Wells
Produced Water Chemistry
Sulfate (SO4) + Chloride (Cl)
Calcium (Ca) + Magnesium (Mg)
Sodium (Na) + Potassium (K)
Carbonate (CO3) + Bicarbonate (HCO3)
Mg
Magnesium (Mg)
Ca
Na+K
Calcium (Ca)
CATIONS
%meq/l
SO_4
Sulfate (SO4)
HCO_3+CO_3
Cl
Chloride (Cl)
ANIONS

Figure 19. Piper diagram of D area produced water chemistry. The D area shows an inclination towards the sodium + potassium and carbonate + bicarbonate portion of the Piper diagram.

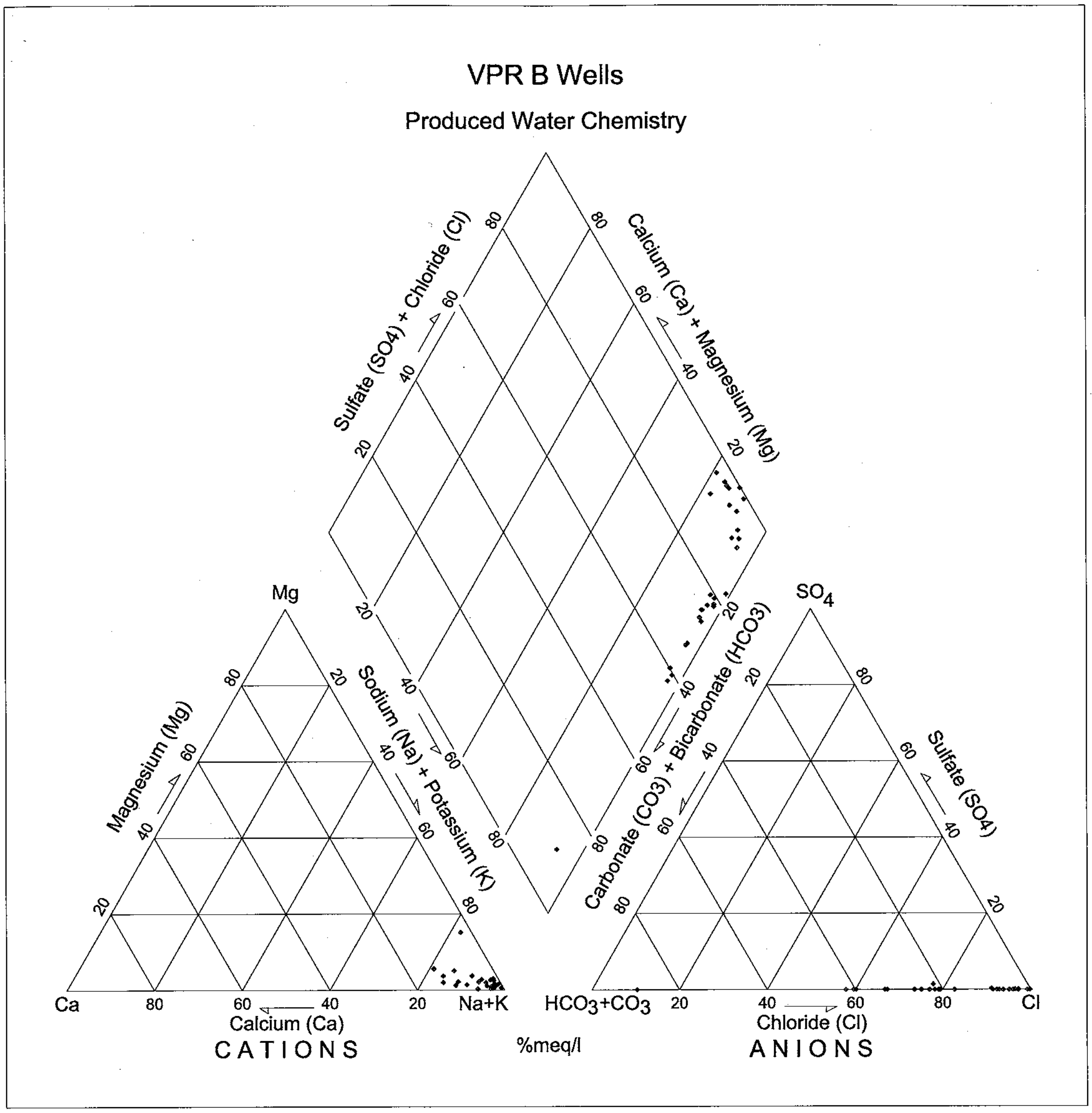

VPR B Wells
Produced Water Chemistry
Sulfate (SO4) + Chloride (Cl)
Calcium (Ca) + Magnesium (Mg)
Sodium (Na) + Potassium (K)
Carbonate (CO3) + Bicarbonate (HCO3)
Mg
Magnesium (Mg)
Ca
Calcium (Ca)
Na+K
CATIONS
%meq/l
SO4
Sulfate (SO4)
HCO3+CO3
Chloride (Cl)
Cl
ANIONS

Figure 20. Piper diagram of B area produced water chemistry. The B area shows an inclination towards the sodium + potassium and chloride portion of the Piper diagram.

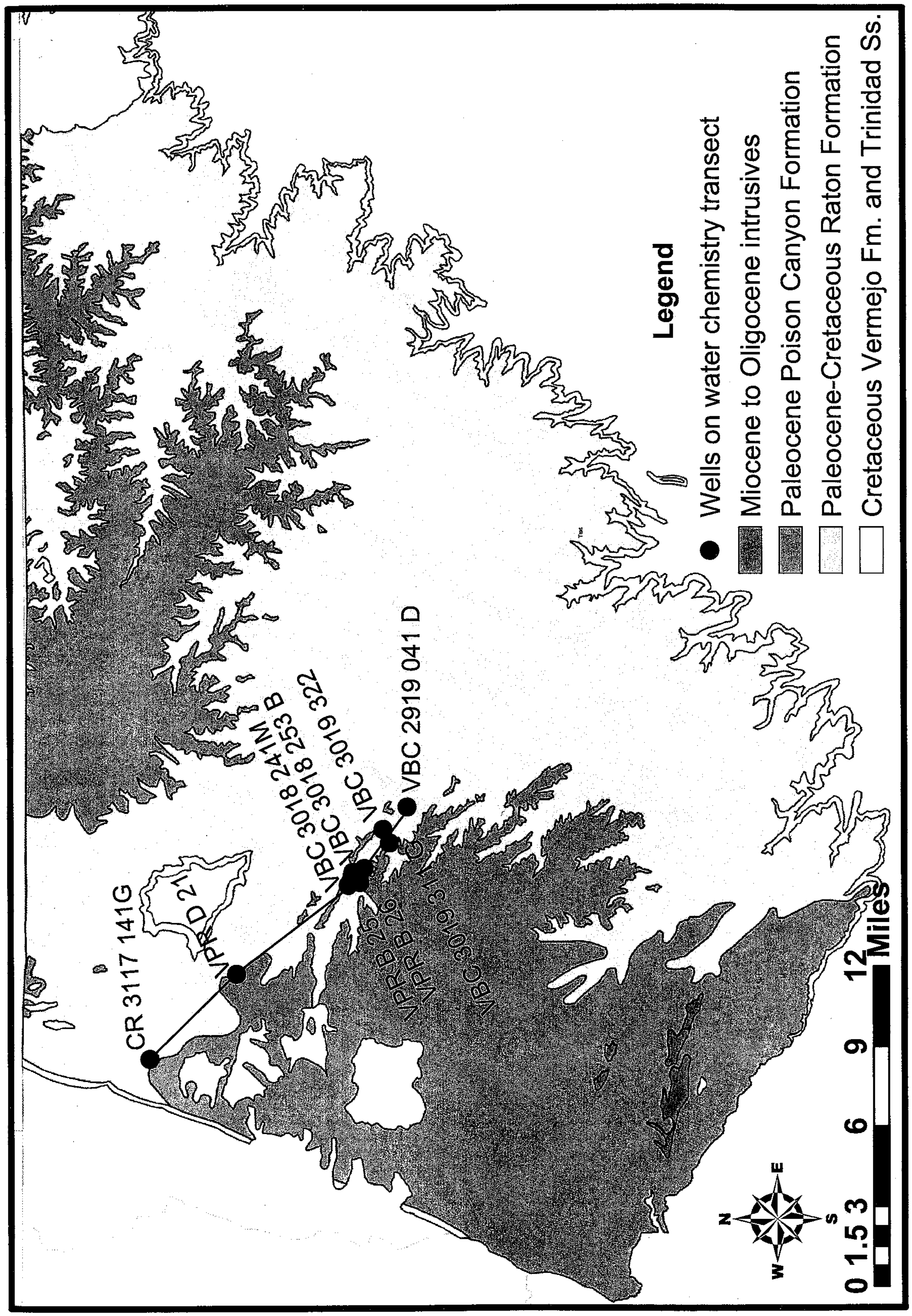

CR 3117 141G
VPR D 21
VBC 3018 241M
VBC 3018 253 B
VBC 3019 322
VBC 2919 041 D
VPR B 25
VPR B 26
Legend
Wells on water chemistry transect
Miocene to Oligocene intrusives
Paleocene Poison Canyon Formation
Paleocene-Cretaceous Raton Formation
Cretaceous Vermejo Fm. and Trinidad Ss.
0 1.5 3 6 9 12
Miles
N
E
S
W

Figure 21. Map view of chemistry transect through the D and B areas. Wells were selected from available chemistry data obtained from the Oil Conservation Division of New Mexico.

Produced Water Chemistry

B and D Well Samples

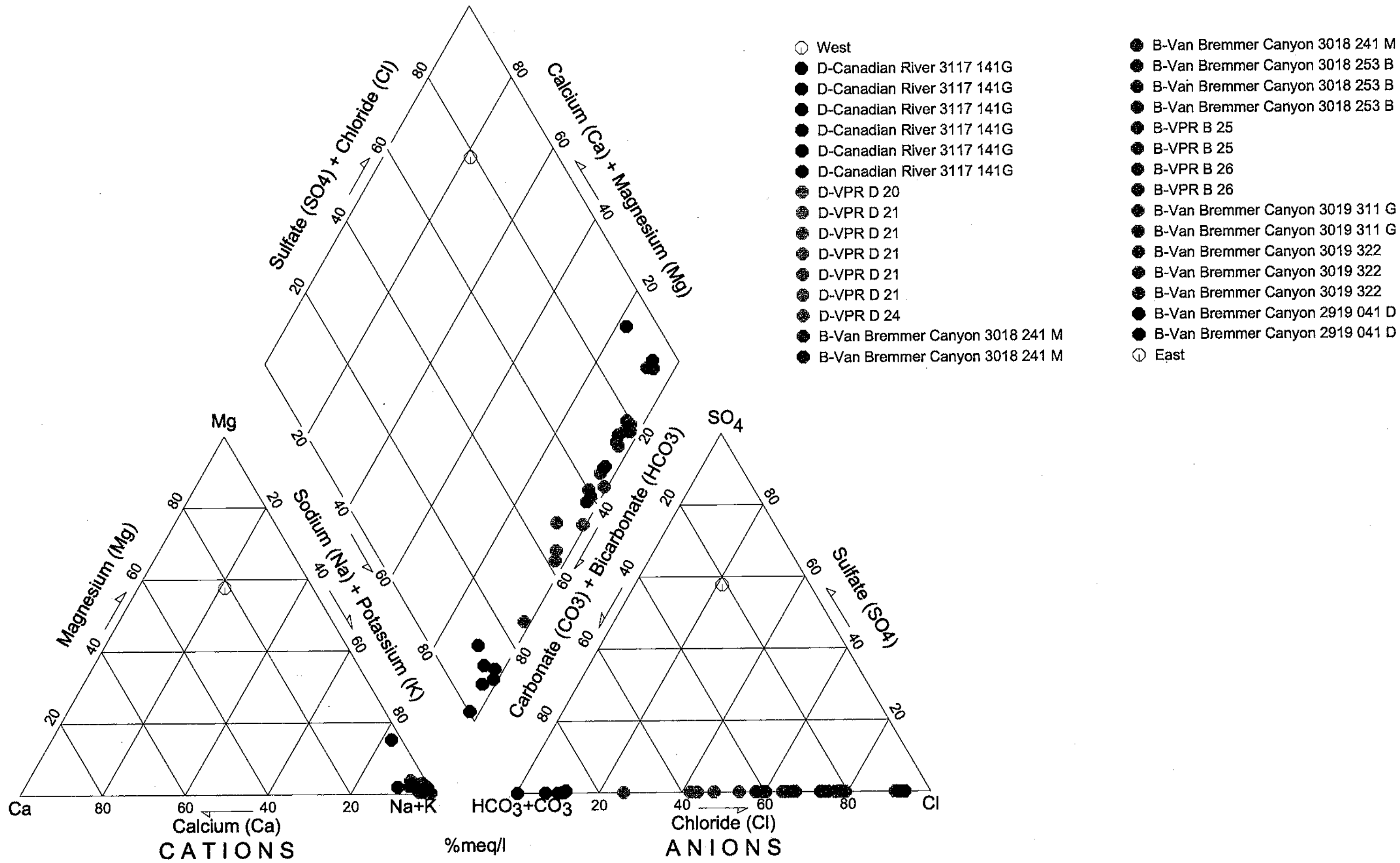


Figure 22. Piper diagram of B-D water chemistry transect. Water chemistry data was selected from wells along a northwest-southeast transect through the D and B areas. Wells in the northwest (blue) have a higher carbonate + bicarbonate to chloride ratio. Wells in the southeast (red) show the exact opposite trend. Wells in between (cyan, green, and yellow) show a continuum between the end members.

samples gradually attain a higher chloride ratio. This progression in chemistry has been known to correlate with the relative age of formation waters, with higher chloride ratios indicating older waters (Freeze and Cherry, 1979). Surface and near surface water examined as part of this study also showed behaviors in chemistry related to their relative ages (Appendix 5). Thus it is interpreted that water in the northwest is younger in age, and water in the southeast is older. Based on these findings, it appears waters become older moving away from the western margin, which supports previous interpretations in the Colorado portion of the basin (Abbott et al., 1983; Geldon, 1989).

Average monthly water production values for wells on the Vermejo Park Ranch are shown in Figure 14. The B/D area shows a general decrease in production moving away from the basin margin. An area of increased production in the northeast portion is believed to be associated with the Vermejo Park dome. The increased water production in wells with younger water may be the result of increased fracture permeability as proposed by Close (1993).

Aquifer matrix and fracture permeability

Matrix permeability measurements were performed on core samples from the Trinidad Sandstone, Vermejo Formation and Raton Formation. The procedure is outlined in Chapter 2. Table 4 indicates the lithology of the sample, the formation it was derived from, whether the measurement was taken parallel or perpendicular to bedding, and the permeability measured. Measurements were performed on those samples that did not show visible fracturing upon examination with a hand lens. Coal was not tested due to expected changes in matrix and cleat permeability with depth. The results indicate no relationship between permeability and lithology. A relationship was demonstrated

Table 4. Permeability values for rocks of the Raton Formation, Vermejo Formation, and Trinidad Sandstone.

Formation	Sample lithology	Measurement orientation to bedding	Permeability (darcies)
Raton	Sandstone	parallel	0.073
Raton	Sandstone	perpendicular	0.017
Vermejo	Sandstone	perpendicular	0.022
Vermejo	Sandstone	parallel	0.057
Vermejo	Mudstone	perpendicular	0.017
Vermejo	Mudstone	perpendicular	0.017
Vermejo	Mudstone	parallel	0.071
Vermejo	Mudstone	parallel	0.072
Trinidad	Sandstone	perpendicular	0.017
Trinidad	Sandstone	parallel	0.058

between angle to bedding and permeability with permeability higher in measurements made parallel to bedding. On average the ratio between parallel and perpendicular permeability measurements was 3:1.

Overall, permeabilities are low, ranging between .02-.07 darcies. These permeabilities were compared to permeabilities for lithologies in the Raton Formation, Vermejo Formation and Trinidad Sandstone measured by Abbott et al. (1983) (Table 5). The measurements performed by Abbott et al. were inclusive of fracture permeability. The matrix permeabilities measured in this study cannot account for those permeabilities measured by Abbott et al. (1983). Fracture permeability is believed to the other and more substantial contributor.

Fracturing is present in core samples (Appendix 1). Those fractures observed often terminated at lithologic contacts. If interlithologic fracturing is not developed, then a well perforating a coalbed will drain a larger volume of water from the coalbed as opposed to the other lithologies connected to the coalbed by fracturing. It is likely areas of increased structural deformation, like those around the Vermejo Park Dome and western basin margin, have increased interlithologic fracturing responsible for the increased water production. This is an idea that has been discussed by several authors (Close and Dutcher, 1990; Brister et al., 2004)

Potentiometric calculations

Potentiometric surface data for wells on the Vermejo Park Ranch were obtained from the Mining and Minerals Division of New Mexico (Appendix 6) to investigate the pressure conditions in the aquifer. Aquifer pressure was also investigated using a water balance technique given in Appendix 7. Geldon (1989) noted an increasing under

Table 5. Hydraulic conductivities of different lithologies of the Raton Formation, Vermejo Formation, and Trinidad Sandstone (modified from Abbott et al., 1983).

	Hydraulic Conductivity (ft/d)			Permeability (darcies)
Lithology	Tests	Range	Mean	Mean
Shale	12	0-5.66	1.48	70
Sandstone	14	0-5.47	0.76	36
Siltstone and Shale	6	----	----	----

pressured nature in the aquifer with increasing depth in the Colorado portion of the basin. When an aquifer is under pressured, the pressure at a given point is lower then would be expected given the amount of water and rock overlying it. Because of the significant structural and stratigraphic differences between the two halves of the basin, it was deemed important to establish if a similar behavior could be seen in the southern portion.

Potentiometric data was separated into three groups based on the depth at which the wells perforated the aquifer. A number of wells had total depth and/or perforation data available. Wells lacking this information were grouped according to descriptive data indicating whether wells monitored the alluvial or bedrock aquifer and depth to water data. Shallow wells were completed within the alluvial aquifer and typically had depths ranging from 20-50 ft. Mid wells were typically completed within the top of the bedrock aquifer and typically had depths between 80-120 ft. Deep wells were completed lower in the bedrock aquifer, ranging from 160-280 ft in depth. Figure 23 displays these three groupings, plotting surface elevation versus potentiometric surface. Linear regressions applied to each grouping fit very well as shown in Figure 23 by the R^2 values. Based on this figure, wells completed at shallower depth have a higher potentiometric surface than wells completed at greater depths. This would indicate an under pressured nature of the aquifer increasing with depth.

To better quantify the degree to which the aquifer becomes under pressured, the linear regressions derived for each of the groupings above were used to calculate pressure gradients (Table 6). While the shallow regression yields an almost normal pressure gradient, the mid and deep regressions yield noticeably lower pressure gradients. The range of these pressure gradients is similar to the range reported by Stevens et al. (1992).

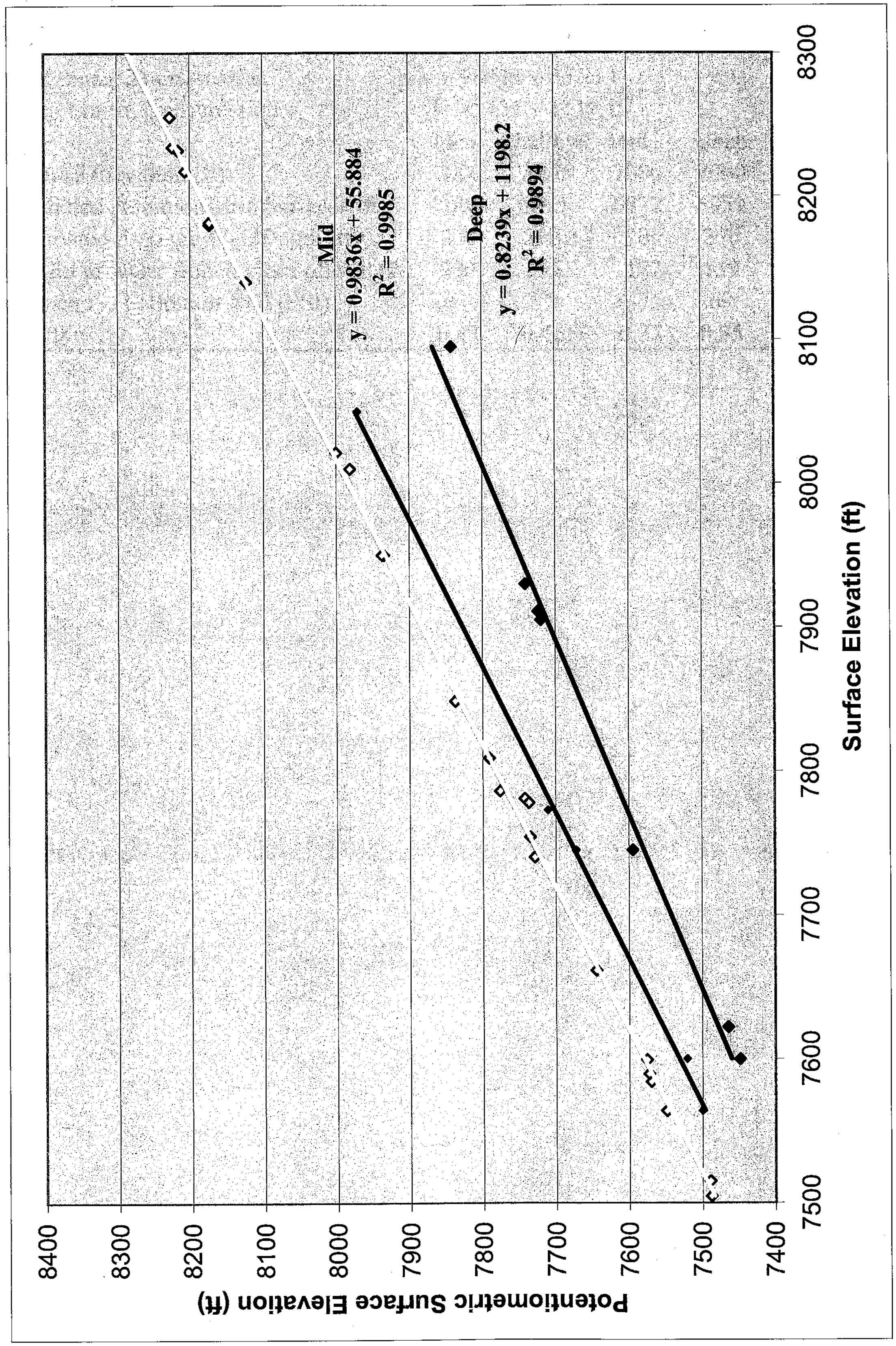

Mid
y = 0.9836x + 55.884
R^2 = 0.9985
Deep
y = 0.8239x + 1198.2
R^2 = 0.9894
Surface Elevation (ft)
Potentiometric Surface Elevation (ft)
7500
7600
7700
7800
7900
8000
8100
8200
8300
7400
8400

Figure 23. Linear trend equations of "Shallow," "Mid," and "Deep" wells. The median potentiometric surface value for each well was used in the graph. The graph illustrates that deeper wells have a lower potentiometric surface elevation than a shallower wells.

Table 6. Pressure gradient (PSI/ft) calculations.

Shallow Linear Transgression	y= 1.0023x -20.178			
Mid Linear Transgression	y= .9834x + 55.214			
Deep Linear Transgression	y= .8343x + 1119.1			
	Ideal	Shallow	Mid	Deep
Surface Elevation (ft)	7000	7000	7000	7000
Predicted Potentiometric Surfaces (ft)	7000	6995	6972	6959
Estimated Average Well Depth (ft)	200	200	200	200
Height of water from bottom of well (ft)	200	195	172	159
Pressure at bottom of well (PSI)	87	85	75	69
PSI/ft	0.43	0.42	0.37	0.35

CHAPTER 6. COAL AND COALBED METHANE

Coal

The following section is provided to the reader as a brief summary of how coal is described and how the description can be used to characterize coalbed methane. Three commonly used criteria for describing coal are *grade*, *type*, and *rank* (Levine, 1993). *Grade* is the proportion of organic material to inorganic material. *Type* describes the nature of constituents that make up the organic material. *Rank* is a measure of the physical and chemical alteration the material has undergone during coalification. *Rank* categories are derived from measurement of a specific physical or chemical property of coal. Vitrinite reflectance, the percentage of vertically incident light reflected from polished coal surface submerged in oil, is the most commonly used property. The *grade* and *type* of the coal will determine how much methane will be produced under optimal conditions. The *rank* and coalification stage will tell whether or not the coal has not produced any methane. If methane has been produced, the *rank* will indicate whether it is entrapped or has been expelled from the coal.

There are five stages to the coalification process, summarized in Table 7 (Levine, 1993). The bituminization stage is the point at which coalbed methane is created and trapped within the coal. Knowing the stage of development of a coal can determine whether it has reached a high enough thermal maturity to have produced methane. Natural fractures associated with the formation of coal are known as cleats. The extent to

Table 7. Major stages of coalification (modified from Levine (1993). The table below outlines the major processes and physical/chemical changes associated with the formation of coal.

Coalification Stage	ASTM Rank Range	Predominant Processes	Physio-Chemical Changes
peatification	peat	maceration, humification, gelification, fermentation, concentration of resistant substances	formation of humic substances, increased aromaticity
dehydration	lignite though subbituminous	dehydration, compaction, loss of O-bearing groups, expulsion of -COOH & H_2O	decreased moisture contents and O/C ratio, increased heating values, cleat growth
bituminization	upper subituminous A through high volatile A bituminous	generation and entrapment of hydrocarbons, depolymerization of matrix, increased hydrogen bonding	increased vitrinite Ro, increased fluorescence, increased extract yields, decrease in density and sorbate accessibility, increased strength
debituminization	uppermost high volatile A through low volatile bituminous	cracking, expulsion of low molecular weight hydrocarbons, especially methane	decreased fluorescence, decreased molecular weight of extract, decreased H/C ratio, decreased strength, cleat growth
graphitization	semi-anthracite to anthracite to meta-anthracite	coalescence and ordering of pre-graphitic aromatic lamellae, loss of hydrogen & nitrogen	decrease in H/C ratio, stronger XRD peaks, increased sorbate accessibility, anisotropy, strength, and ring condensation, cleat healing

which cleats develop during coal formation influence how readily methane moves through the coalbed, either to be expelled or produced.

Coalbed methane

Coalbed methane (CH^4) is a naturally occurring gas that is formed by either biogenic or thermogenic processes. Biogenic methane is formed at shallow depths in coalbeds as a byproduct of microbial digestion of organic matter. Thermogenic methane is derived as a result of the thermal maturation coal undergoes with burial-related heat and pressure. The methane produced in the northern portion of Raton Basin is believed to be of thermogenic origin based gas composition testing (Stevens et al., 1992).

Methane is primarily stored within the coal matrix. It is adsorbed onto internal surfaces of organic matter in coal. Microporosity accounts for about 70% of the total porosity in coal (Schopf, 1952). In terms of methane storage, a volume of coal can store as much gas as an equal volume of sandstone with 20 % porosity that is fully saturated with respect to methane gas. Because most sandstone reservoirs have less than 20% porosity and are not fully saturated with gas, coal usually holds substantially larger volumes of gas than sandstone.

Coalbed methane is unique in that the coal acts as both the source rock and reservoir of methane. Because of this, coal is considered to be an unconventional reservoir. Conventional reservoirs are primarily defined by two factors: relatively good porosity and permeability. Unconventional reservoirs lack one or both these characteristics. Coalbed methane reservoirs are unconventional because they lack matrix permeability. Cleats (fractures in coal) do provide some permeability. However, it is the path the methane must take through the matrix to the cleat fracture that limits methane flow. Coalbed methane wells usually must be stimulated to increase the connectivity of the wellbore to cleat permeability.

The hydrogeology of the coalbeds and surrounding rock is intimately tied to the coalbed methane potential of a well. Water serves an important purpose in coalbed methane production. By pumping water from the well it is possible to reduce the pressure in the coalbed. The reduction in pressure causes the methane gas to desorb from the organic material within the matrix. The gas then moves freely through the cleat (fracture) network. A better understanding of how water flows through a coalbed will yield a better estimate of how much methane will ultimately be produced.

Coal and coalbed methane in the Raton Basin, New Mexico

Thermal maturity of coal

Hoffman (1996) described the coalbeds of the Vermejo and Raton Formations as high-volatile A to B bituminous containing low-sulfur and moderate amounts of ash. Statistics from Hoffman (1996) for the coalbeds of the Raton coalfield are shown in Table 8. The degree of thermal maturity of the coal indicates the potential for it having produced methane through thermogenic activity (Levine, 1993). Hoffman and Brister (2003) utilized unpublished vitrinite reflectance data (used to indicate thermal maturity) to generate an area of probable coalbed methane potential based on thermal maturity (Figure 24).

For this study coal was examined from the Raton and Vermejo Formations in wells Castle Rock 3117 141G, Castle Rock 3017 021, Van Bremmer Canyon 3019 311G, and VPR ST-17 (Appendix 1). The goal was to see if coals in this region of the basin could have produced methane by thermal maturation. The coal described from these

Table 8. Statistics for coal in the Raton and Vermejo Formations (modified from Hoffman (1996)).

Vermejo Formation			
	Average	Standard deviation	Number of samples
Moisture (%)	2.75	0.96	20
Ash (%)	14.49	4.02	20
Volatile Matter (%)	34.83	1.8	20
Fixed carbon (%)	48.24	3.28	20
Sulfur (%)	0.72	0.13	20
Calorific value (Btu/lb)	11,786	1,582	20
Lbs. of sulfur/MMBtu	0.58	0.11	19
			18
Raton Formation			
	Average	Standard deviation	Number of samples
Moisture (%)	4.27	3.19	28
Ash (%)	12.88	5.11	28
Volatile Matter (%)	34.9	3.18	28
Fixed carbon (%)	47.72	5.86	28
Sulfur (%)	0.57	0.14	28
Calorific value (Btu/lb)	11,921	1,764	27
Lbs. of sulfur/MMBtu	0.47	0.13	27

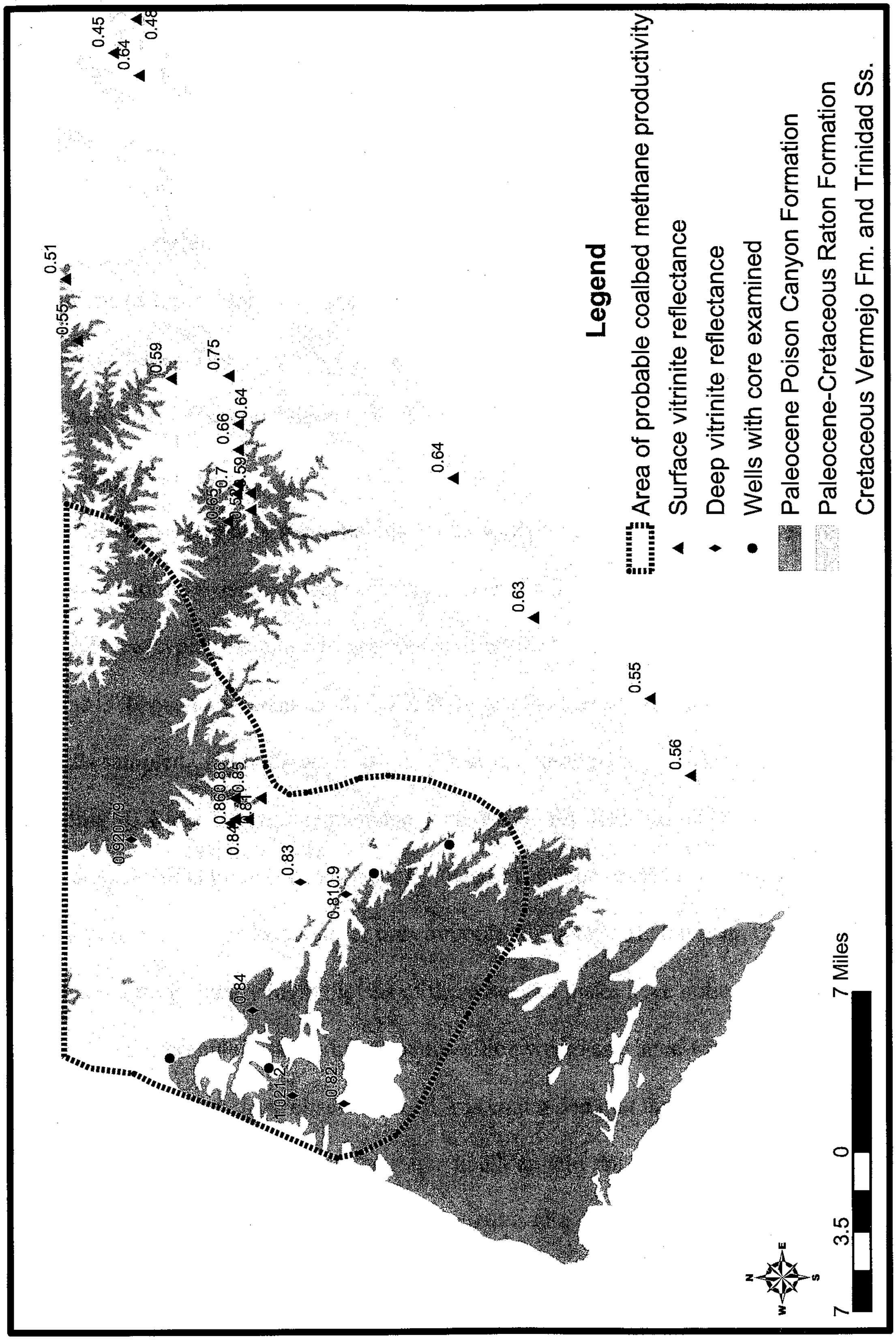

Legend
Area of probable coalbed methane productivity
Surface vitrinite reflectance
Deep vitrinite reflectance
Wells with core examined
Paleocene Poison Canyon Formation
Paleocene-Cretaceous Raton Formation
Cretaceous Vermejo Fm. and Trinidad Ss.
7 3.5 0 7 Miles
N
E
S
W

Figure 24. Map indicating area of coalbed methane potential as defined by thermal maturity data by Hoffman and Brister (2003).

wells fit the descriptions given by Hoffman (1996). No samples from these wells were tested for vitrinite reflectance. However, the unpublished vitrinite reflectance data discussed by Hoffman and Brister (2003) was collected from coalbeds near wells examined in this study (Figure 24). Based on previous work and coal description performed during this study, it was concluded the coalbeds of the Raton and Vermejo Formations examined in this region are of sufficient thermal maturity to have produced coalbed methane. This supports the idea of the methane having a thermogenic origin as opposed to a biogenic one, which typically has a higher carbon dioxide content.

Gas composition

Gas chemistry data was obtained for 23 wells in the A, B, and D areas from the Oil Conservation Division of New Mexico (Appendix 8). Table 9 gives chemistries for four wells that typify the range in gas composition for the dataset. In all four wells methane is the primary component. VPR D-18 has the lowest methane content of any of the wells sampled. All other wells sampled had gas compositions with methane exceeding 90% and the average methane composition for the wells examined was 97%. Nitrogen is the next highest component followed by carbon dioxide. Significantly smaller percentages of heavier gases are common. Samples like that from Castle Rock 161 H containing slightly higher levels of these heavier gases have noticeably higher Btu values. No discernable patterns in gas composition were associated with well location or gas production. From these observations it was concluded that the gas being generated from wells harnessing coalbeds in the Raton and Vermejo Formations is almost entirely composed of methane. The high methane content is also consistent for thermogenically-derived gases (Levine, 1993).

Table 9. Gas composition data for wells in the B and D areas. The gas generally has high methane content, though cases do exist where there are significant amounts of nitrogen.

Well	VPR D 18	Castle Rock 3017 161H	Castle Rock 3117 141G	VPR B 26
Date	5/8/1991	5/2/1991	9/24/1990	1/30/1990
Component (% Mol)				
Nitrogen	40.28	0.78	4.04	0.06
Carbon Dioxide	0.01	1.01	0.16	0.7
Methane	43.43	92.29	95.66	99.14
Ethane	5.98	0.08	0.05	0.1
Propane	4.96	0.01	0.03	0
I-Butane	1.26	0	0.01	0
N-Butane	1.71	0	0.02	0
I-Pentane	0.74	0	0.01	0
N-Pentane	0.69	0	0.01	0
Hexanes	0.71	5.83	0.01	0
Gasoline Content (GPM)				
Pentanes	0.23	2.576	0.012	0
Butanes	0.862	2.576	0.022	0
Propanes	1.842	2.579	0.03	0
Ethane	3.228	2.6	0.043	0.027
26 Gasoline	4.832	0	0.018	0
Heating (Btu/ft^{3})				
Water Saturated	858	1250	952	984
Dry Gas	878	1272	969	1002
Specific Gravity				
Water Saturated	0.893	0.74	0.576	0.564
Dry Gas	0.898	0.742	0.575	0.563

CHAPTER 7. DISCUSSION

Stratigraphy

The lateral continuity of coalbeds was examined in Chapter 3. Lateral continuity relates to the volume of coal a well will affect during pumping. This is known as the effective volume. The larger the effective volume, the higher the maximum gas potential for the well, assuming all other characteristics are constant. As mentioned earlier, the issue of lateral continuity is dependent on scale. In Chapter 3, the 1/2 mile spacing of wells on the Vermejo Park Ranch was adopted as the scale on which to examine lateral continuity. On this spacing about half of coalbeds in the upper coal zone of the Raton Formation and a third of the coalbeds in the Vermejo Formation were interpreted to be laterally discontinuous. This interpretation of lateral continuity is a less than ideal scenario for coalbed methane production. The presence of laterally discontinuous beds in the wells means that a lower total volume is available, and therefore a lower effective volume. This in turn limits the maximum amount of coalbed methane that can be extracted from a well.

The net coalbed thickness in wells was examined. From the analysis of logs for coalbed methane producing wells on the Vermejo Park Ranch it was determined that net coalbed thickness in wells ranged between 12 - 97 ft with an average of 42 ft. When compared to other coalbed methane producing basins in the western United States, the Raton Basin had the second lowest net coalbed thickness (Table 2). The relatively low net coalbed thickness of the wells is less than ideal for coalbed methane production. Similar to lateral continuity, it limits the effective volume from which the well can produce methane. The average bed thickness is also not conducive to coalbed methane production (Table 1). With coalbeds averaging between 2-2.5 ft, a number of beds are not perforated because they are simply too thin to be accurately perforated using conventional techniques. The lateral continuity, net coalbed thickness, and average seam thickness are all less than ideal but adequate for coalbed methane production.

Structure

Earlier in Chapter 4, a connection between subsurface structure and water production was demonstrated using subsurface structural contours and average monthly water production statistics (Figure 14). The subsurface structural features created by the intrusion beneath the Vermejo Park dome and uplift of the Sangre de Cristo Mountains are thought to have increased fracture permeability in the region of the aquifer containing the coalbeds. The increased permeability would better connect perforated coalbeds in wells to the rest of the aquifer, increasing water production. Wells proximal to these features were shown to have increased water production. An increase in water production limits the ability of a well to effectively drain the coalbed. The resultant pressure drop from pumping would be mitigated, allowing less methane to desorb from the coal. Based on this line of reasoning the subsurface features associated with the margin and the dome are considered as less than ideal for coalbed methane potential. Combined their regional influence is extensive over the Vermejo Park Ranch (Figure 14).

Also noted in Chapter 4 was a relation between wells containing sills and increased gas and water production. Using well logs, sills were identified in a number of wells (Figure 15). Average monthly gas and production rates were compared between wells containing sills and those that do not. Wells with sills had 24% greater monthly gas production and 7 % greater monthly water production (Table 3). The reasoning behind why the wells containing sills showed increased gas and water production is thought to relate to the fracturing and thermal maturation associated with the emplacement of the sills. The emplacement of a sill is likely to increase fracturing in lithologies proximal to the intrusion. Sills are also known to preferentially intrude into coalbeds (Olsson, 2003) and many of the sills interpreted from well logs were surrounded by perforated coalbeds. These perforated coalbeds are believed to have increased fracture permeability resulting in higher effective volumes for the coalbeds. While this fracturing may also increase connectivity of the coalbed the adjacent lithologies, it is thought fracturing associated with sill emplacement is limited. Because of their proximity to the sill, it is possible the coalbeds are more thermally mature and contain higher amounts of gas. Regardless of the exact mechanisms, from the information reviewed in this study it appears sills are beneficial to coalbed methane potential.

Hydrology

Produced water chemistry from wells on the Vermejo Park Ranch was examined to determine relative groundwater ages. It was concluded that formation water increases in age moving west to east in the basin based on ratios of particular cations and anions as well as total dissolved solids (Figure 22). Some of the youngest formation waters were associated with wells having increased water production believed to be associated with subsurface structural features related to the Vermejo Park dome and western basin margin (Figure 14). This was expected as the proposed increased fracture permeability associated with these features would allow better connection to shallower waters that are younger in age. These younger water waters have distinct chemistries (Figure 22). Using this information initial produced waters could be tested to determine if a well is producing younger water. If so, this would mean it may have increased fracturing and would therefore have the potential for higher water production.

Matrix permeabilities were determined for a selection of lithologies from the Raton, Vermejo, and Trinidad Formations (Table 4). Permeabilities were low (.02-.07 darcies) and showed no correlation between lithologies. Comparison of hydraulic conductivities measured in this study to previous work (Abbott et al., 1983) led to the conclusion that fracture permeability was the primary contributor to water production in wells. Examination of core for wells in the region revealed minimal interlithologic fracturing. A near absence of interlithologic fracturing would be beneficial to coalbed methane potential because it limits coalbed connectivity with the surrounding aquifer. This means less water production from non-coal lithologies, resulting in a greater pressure drop in the coalbed with resultant increase in methane desorption. For those wells showing higher than average water production associated with the western margin and Vermejo Park dome, it is believed fracturing is increasing the perforated coalbed's connection to the aquifer.

Potentiometric surface data were investigated to examine the behavior of the aquifer. Wells were grouped according to where they perforated the aquifer. The results of the analysis concluded that wells completed in shallower portions of the aquifer had higher potentiometric surfaces than those completed at deeper portions. Further examination revealed that shallower wells had almost normal pressure gradients, whereas deeper wells showed subnormal pressure gradients. The results show that the aquifer becomes more under pressured with increasing depth, which has been shown in the northern portion of the basin (Geldon, 1989). This under pressured nature has an influence on coalbed methane potential. Because the amount of methane stored in the coalbed is a function of the pressure the coalbed is under, a lower pressure means the coalbed has a lower maximum amount of methane it can store. In this respect the under pressured nature is not advantageous to coalbed methane production.

However, the under pressured nature of the aquifer may also be thought of as an advantage. The rock in the aquifer is well cemented and matrix supported, meaning that the lithostatic pressure does not affect water in the pore spaces. Only hydrostatic pressure, which is the pressure resulting from overlying water connected by pore spaces and fractures, is being felt. The reason why the aquifer is under pressured at depth is believed to be the result of poor vertical/lateral connectivity. The poor vertical/lateral connectivity is most easily explained by the lithologic complexity demonstrated in the stratigraphic/lithologic interpretations from Chapter 3. As a result of this complexity, at any given point in the deeper aquifer the pressure from the water lying above cannot fully be exerted on that point. Essentially, the point can't "feel" the full force of the water overlying it. This can be seen as beneficial to coalbed methane potential because it means that on a regional scale as water is drained from the sections of the Raton and Vermejo Formations containing coalbeds, it will not be replaced readily with more water. This implies that once the coalbeds are drained it should take minimum pumping to keep them drained, lowering pumping costs and allowing for maximum desorption of methane.

Coal and Coalbed Methane

Based on previous work and coal description performed during this study, it was concluded the coalbeds of the Raton and Vermejo Formations examined are of sufficient thermal maturity to produce and store coalbed methane. Although this is not definitive proof that the methane in the coalbeds is of thermogenic origin, combined with evidence of known thermogenic methane to the north (Stevens et al., 1992), it makes for a strong argument. The high methane content of gas for wells in Vermejo Park is characteristic of thermogenic methane. If indeed the methane is thermogenic in origin, then the same high methane concentrations should be expected in most wells for the basin. This high methane content is beneficial to production because it requires less effort to refine the gas for commercial use.

8. CONCLUSIONS

The purpose of this study was to examine hydrologic and geologic characteristics of the Raton Basin, New Mexico. These factors were analyzed with a specific focus on their connection to coalbed methane potential in the basin.

The lateral continuity of coalbeds was examined on the 1/2 mile scale on which wells on the Vermejo Park Ranch are spaced. At this spacing as many as half the coalbeds of the Raton Formation and a third of the coalbeds of the Vermejo Formation lack continuity. The lack of continuity in these beds means a lower effective volume for the wells than if they were continuous. The lower effective volume translates into lower coalbed methane production potential for the wells. Net coalbed thickness is relatively low in comparison to other western coal basins. A low net thickness will result in a low effective volume, limiting the potential of a well to produce methane. It is important to note that while these factors are less than ideal, coalbed methane is being economically produced on the Vermejo Park Ranch.

Subsurface structural features associated with the intrusion underlying the Vermejo Park dome and the uplift of the Sangre de Cristo Mountains appear to increase water production in wells. The increased water production is believed to be the result of increased fracture permeability of rocks deformed during the creation of these subsurface features. The increased water production suggests larger volumes of water in the reservoir increasing the expense of retrieving methane from coal. Wells in the area found to contain sills show 24% higher average monthly gas production and 7% higher water production than wells in similar regions lacking sills. An increased in fracture permeability and thermal maturation of nearby coalbeds are thought potential mechanisms for the increased gas/water production observed.

Examination of produced water chemistries provided a means of determining relative ages of formation waters. Younger formation water to the west was found to roughly coincide with higher water production whereas older waters to the east usually have lower water production. The increased fracture connectivity associated earlier with subsurface structural features is believed to introduce younger water into deeper portions of the aquifer, lowering the age and providing a readily available supply of water that increases water production. Matrix permeability values measured compared to previous hydraulic conductivity measurements confirm the dominance of fracture permeability in the aquifer. An under pressured nature with increasing depth in the aquifer was supported by investigation of potentiometric surface data. The under pressured nature of the aquifer is believed to caused by the complex intermixing of lithologies both horizontally and vertically in the aquifer, as demonstrated by core description, well log, and cross section analysis. The under pressured nature of the aquifer limits the methane storage capacity of coals. The lithologic complexity is thought to isolate coalbeds from aquifer waters, allowing for more effective pumping and greater methane desorption.

Gas composition data indicates on average a 97% methane composition for producing wells. High methane content is characteristic of thermogenically-produced gas. The high methane content of gas is beneficial to production because it requires less effort to refine the gas for commercial use.

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APPENDIX 1. CORE DESCRIPTIONS FOR THE VERMEJO PARK RANCH

The following core descriptions are for wells Castle Rock 3117 141G, Van Bremmer Canyon 3019 311, Castle Rock 3017 021, and VPR ST-17. Cores for these wells reside at the New Mexico Bureau of Geology and Mineral Resources. A general lithologic description is provided below.

Lithologic description

Trinidad Sandstone

The Trinidad Sandstone is not entirely represented in well logs or cores (Figures 6 and 7). This is because it marks the lower boundary of interest for coalbed methane production. While logs may record as much as 100 ft (30 m) of the Trinidad Sandstone, corresponding cores usually contain a fraction of that, further limiting the amount of information that can be collected. The lowest portion of Trinidad Sandstone that is preserved in core is light gray sandstone. Grain size ranges from very fine sand to medium sand. Intermixing of grain sizes is seen in the stated range. Fairly homogenous throughout, it is sometimes accompanied by thin (< 2mm) beds of darker grains of similar size to the surrounding material. Occasional beds of coal with a similar thickness are also observed. Cross bedding is seen consistently in the core. Moving upward through the Trinidad Sandstone there is a decrease in grain size and increase in occurrence of mudstone beds and accompanying soft sediment deformation. The light gray sands begin to intermix with dark gray to grayish black carbonaceous mudstone beds. Thin coalbeds are still intercalated with both the sandstone and mudstone beds. The series of lithologies represented are consistent with the Trinidad Sandstone in other portions of the basin. The beach dune depositional setting proposed by Pillmore and Maberry (1976) is appropriate for the Trinidad Sandstone described above.

Vermejo Formation

The contact between the Trinidad Sandstone and Vermejo Formation has been placed at the base of the lowest carbonaceous zone (Pillmore and Maberry, 1976) (Figures 6 and 7). The contact in literature has been qualitatively described as well defined. Well logs indicate the contact by a sudden increase in density. A decrease on the gamma ray log is observed in well logs with measurements continuing into the sandstone. The gamma ray shows a less dramatic shift because of the intermixing of organic material with the upper portion of the Trinidad Sandstone. As noted earlier, the contact demonstrated in core is more gradational, usually over a zone of several feet.

The Vermejo Formation is the best represented of the three formations in the available core. The base of the Vermejo Formation represented in the selected cores consists primarily of mudstone beds and coalbeds. The mudstone beds are typically medium gray to grayish black. The darker mudstone beds are commonly carbonaceous, containing fragments of coalified plant fossils. The lighter mudstone beds sometimes contain fossils but not nearly the same abundance. The mudstone beds are thinly (< 2 inches (5 cm)) interbedded with the siltstones, forming only a small portion (5-10%) of the total rock. Coalbeds are generally black with one exception having a more brownish color. Cleating ranged from well developed to hardly noticeable. The core was not oriented so cleating orientations could not be obtained. Where cleating was noticeable there were commonly two directions orthogonal to one another and perpendicular to the horizontal. One direction (presumed the face cleat) was usually better developed than the other. Secondary mineralization (calcite) was noted in cleat surfaces, often only on the well-developed cleating surfaces.

In each well at least one significant coalbed (> 3 ft (.9 m)) is found within the lower 20 ft (6 m) of the Vermejo Formation. The beds range between 3-11 ft (.9-3.4 m) in thickness. This bed is believed to be the locally named Raton coalbed. The Raton coalbed was reported by Lee (1924) to be the thickest and most extensive coalbed in the Vermejo Formation. It is located near the base of the Vermejo Formation. The lateral continuity of the Raton coalbed in this area is questionable. The number, thickness, and exact location of these coalbeds indicate a Raton coal zone rather than a single coalbed.

Higher in the Vermejo Formation the same lithologies are represented sometimes with the addition of fine-grained sandstone. The sandstone makes up a more substantial component higher in the formation. The grain size ranges from very fine sand to coarse sand with an average grain size of fine sand. Unconformities are recorded in the sandstone. The number and thickness of coalbeds decrease upward and appear to be randomly distributed. In the three wells that contain the top of the Vermejo Formation a 1-2 ft (.3-.6 m) thick coalbed is observed below the Raton/Vermejo contact.

The Vermejo Formation represented in these cores appears to follow the basin scale depositional trends. The lower portion has high coal content and mostly finer sediments, suggesting depositional settings like those proposed by Pillmore and Flores (1987), including coastal swamps, tidal flats, and lagoons. The upper portion has a generally coarser grain content and lesser coal. Pillmore and Maberry (1976) suggested depositional settings in the lower alluvial plains being dissected by meandering streams. The lithologies represented in the cores for the upper portion of the Vermejo do reflect a change to a more proximal set of depositional environments. The degree of this change does not appear to be as severe as in other portions of the basin. While sandstone beds do appear and increase upward, through the Vermejo, their average grain size is medium sand that is often intermixed with a sizable portion of finer sediments.

Raton Formation

The entire Raton Formation is usually not represented in logs for wells on the Vermejo Park Ranch (Figures 6 and 7). While the basal conglomerate, lower coal zone, and barren series are intact, a substantial portion of the upper coal zone cannot be analyzed because it is above the base of well casing behind pipe.

Available core for the basin does not typically include core for the rocks representing the Raton-Vermejo contact. Immediately below the contact is the uppermost coalbed of the Vermejo Formation. When core is available, most of this coalbed has been removed. In the few instances where a portion of the coalbed remains, the basal conglomerate of the Raton Formation overlies the coalbed in apparent unconformity.

The basal conglomerate, referring to the name of this particular zone and not the lithology, of the Raton Formation has at its base a coarse to fine grain sandstone in VPR ST-17. Wells Castle Rock 3117 141G and Castle Rock 3017 021 did not contain core from this interval. Another well examined nearby (VPR ST-7) did contain the basal conglomerate. It is clast-supported conglomerate with clasts ranging between ¼-½ inches (.6-1.3 cm) in diameter. Coarse-grained sandstone beds were found intermingling with the conglomerate. The basal conglomeratic unit has a thickness of approximately 20 ft (6 m). Pillmore and Flores (1987) observed that the conglomerate eventually fines and pinches out moving from west to east. The cores examined supports their observation.

The basal conglomerate is approximately 172 ft (52 m) thick in VPR ST-17. The contact between the conglomerate and the lower coal zone of the Raton Formation is placed at the bottom of the first cluster of coalbeds above the Raton/Vermejo contact. The interval consists of sandstone beds, interbedded sandstone and mudstone beds, mudstone beds, and coalbeds with total percentages decreasing in the same order. The sandstone beds range from very fine sand to medium sand. The coarser grain sands are very light gray in color while the finer grain sands are light gray to medium gray. Mudstone beds are typically darker gray to black. Their grain size ranges from very fine sand to clay. Coalbeds are found interbedded with mudstone or unconformably overlain by sandstone. Cleating was not obvious in Raton Formation coalbeds examined in core and no evidence of secondary mineralization was observed. Many coal seams in Raton

Formation are less than 1 ft (.9 m) in thickness and probably not of interest to coalbed methane production.

Pillmore and Flores (1987) interpreted the basal conglomerate as being deposited in a progression of channel environments. In the west, the deposits are thought to be the result of braided streams of distal alluvial fans. This coincides with the pebble conglomerate that was noted in well VPR ST-7 in the west of the study area. Moving to the east meandering streams and interchannel areas are thought to have been the depositional environments. The basal "conglomerate" seen in VPR ST-17 is made up of channel sands with mudstone beds and coalbeds likely deposited in the interchannel environments.

The lower coal zone of the Raton Formation is approximately 100 ft (30 m) in thickness in VPR ST-17. The upper boundary was chosen as the uppermost significant coalbed (>1ft (.9 m)) at the top of the first cluster of coalbeds above the Raton/Vermejo contact. The interval consists of mudstone beds, interbedded mudstone and sandstone beds, sandstone beds, and coalbeds with percentages decreasing respectively. The lithologies correspond to those described above for the basal conglomerate with only several mentionable exceptions. There are not as many erosional surfaces present between sandstone beds and other lithologies. Mudstone beds are more carbonaceous than those described for the basal unit. The coalbeds range in thickness from several inches to 2 ft (.6 m).

Pillmore and Flores (1987) suggested that the lower coal zone of the Raton Formation represents overbank-floodplain and meandering channel deposits. The rocks seen in core examined from VPR ST-17 are likely to have been deposited in such environments. The mudstone beds and coalbeds represent the low energy overbank and floodplain deposits. The sands were deposited in the meandering channels that overlie mudstone beds and coalbeds in the core. Core was not available for this interval in the western portion of the study area. However, well logs collaborate previous work (Lee, 1917; Pillmore and Flores, 1987) suggesting an eventual pinch out of this zone westward. This is related to the intertonguing of the Raton and Poison Canyon Formations in the western part of the basin. The middle barren sequence overlying the lower coal zone is believed to be an extensive tongue of the Poison Canyon Formation, as it is known to merge with that formation in the west (Lee, 1917).

The middle barren sequence is roughly 480 ft (146 m) thick in VPR ST-17. It is measured from the uppermost coalbed of the lower coal zone to the base of the lowest significant coalbed (> 1 ft (.3 m)) in the upper coal zone. As the name suggests, the interval is nearly void of coalbeds, with several seams reaching a maximum thickness of only a few inches. The zone is predominately composed of sandstone beds ranging in grain size from very fine to coarse sand. Interbedded sandstone and mudstone beds are the next most abundant, followed by mudstone beds, and coalbeds. The lithologies are similar to those described for the basal conglomerate. Erosional unconformities are as prevalent as in the basal conglomerate though the spacing is a little farther apart and the lithologies thicker. Pillmore and Flores (1987) described the sequence as composed of channel sand deposits that laterally grade into floodplain deposits. In the cross-sections that will be described below the sequence is found to thicken east-to-west, fitting with the general pattern of sedimentation observed in the basin.

The entire upper coal zone of the Raton Formation is generally not logged or cored for the Vermejo Park Ranch wells due to construction of wells that place surface water protection casing as deep as 380 ft (116 m). In VPR ST-17 the surface protection casing ends at 340 ft (104 m) below the surface. Wells throughout the ranch are cased down to similar depths to prevent groundwater-surface water interaction. Well logs are not acquired and core not kept for the cased interval.

The portion of the upper coal zone that is in VPR ST-17 consists of sandstone beds, interbedded sandstone and mudstone beds, mudstone beds, and coalbeds. The zone is approximately 500 ft (152 m) in thickness. This is less than half the maximum thickness given by Pillmore and Flores (1987). The upper coal zone shares much of the same lithology as that of the lower coal zone. Coalbeds are further apart in comparison to the lower coal zone. The beds are generally thicker in the upper zone. Pillmore and Flores (1987) have proposed similar depositional environments for the lower and upper coal zones, which are supported by the examination of core from VPR ST-17.

Poison Canyon

Core for the Poison Canyon Formation was not available. Information obtained from previous work conducted in the northern portion of the study area (Pillmore and

Flores, 1987) was used clarify the stratigraphy of this formation. The Poison Canyon Formation in the central portion of the study area is approximately 500-650 ft (152-198 m) thick. An indefinite boundary between the Poison Canyon and Raton Formations lies within a roughly 150 ft (46 m) gradational zone. The Poison Canyon Formation thickens in the western portion of the study, intertonguing with the Raton Formation. It thins to the east and is eventually completely eroded away leaving the Raton Formation exposed. The Poison Canyon Formation consists of thick to massive coarse-grained channel sandstone beds and overbank mudstone beds. It is completely barren of coal is of no interest to coal mining or coalbed methane production.

Abreviations	
<silt	silt and smaller grain sizes
10yr 4/2	dark yellowish brown
1CD	1 cleavage direction pronounced
2CD	two cleavage directions
5pb 3/2	dusky blue
5y 7/2	yellowish gray
CAR	carbonaceous
cl	coal
CLP	coal pieces (<1/4 inches diameter)
CLS	coal seams (<1/4 inches thickness)
cs	coarse sand
CU	grainsize coarsening upward
ECB	erosional unconformity bottom contact
fs	fine sand
FU	grainsize fining upward
ms	mudstone
ms	medium sand
MUS	muscovite present
N	no fracturing
n1	black
n2	grayish black
n3	dark gray
n4	medium dark gray
n5	medium gray
n6	medium light gray
n7	light gray
n8	very light gray
NCD	no visible cleavage
SHF	high fracturing (fractures < 2 in apart)
SLF	low fracturing (fractures > 6 inches apart)
SLK	slicken slides
SMF	moderate fracturing (fractures 2-6 inches apart)
ss	sandstone
SSD	soft sediment deformation
vfs	very fine sand

Castle Rock 3117 141G

Top (ft)	Bottom (ft)	Grainsize	Color	Lithology	Notes
718	719.85	< silt	n1	cl	dirty to touch, cleating (nearly orthogonal/vertical), grayish to white material found in cleats but only in one direction, lenticular portions of more shiny material, contact not visible
719.85	722.25	< silt	n4	ms	bagged at top (broken up), dull luster along some portions of new breaks, pieces (<1mm-10mm) of coalified plant material, secondary mineralization along some fractures (white material); becomes less broken moving downward into shale below
722.25	723.5	< silt	n2	ms	mudstone become more fractured and broken up, more fossils, dull luster
723.5	726	< silt	n4	ms	dull luster along fractures, coalified fossils, slickenslides
727	728.75	< silt	n4	ms	alternating bands of mudstone, coalified fossils, slickenslides, fracturing
728.5	730.1	< silt	n4	ms	absence of mud, slickenslides, fracturing, fewer coalified fossils
730.1	733	< silt	n2	ms	presence of clay beds, pieces of coal (.2-.4 inches in diameter), coalbeds (<.25 inches) erratic about 731 and 732.5 ft, coal shows cleating and white material in one direction of cleating
733	734.25	< silt	n4	ms	lenticular thin (<. 25 inches) coalbeds with coalified fossils
734.25	735	< silt	n2	ms	rich in coal, containing many wavy beds of interbedding mudstone (.1-.2 inches) possible soft sediment deformation
735	738.25	< silt	n5	ms	broken up, fossils, slickenslides, dull luster
738.25	741	< silt	n7	ms	low fossil content, no luster or slickenslides
741	742.5	< silt	n4	ms	fossils increasing downwards, coalified fossil fragments
742.5	743.15	< silt	n4	ms	mudstone interbedded, soft sediment deformation, no fossils, coarsens downwards
743.15	750	fs	n8	ss	becomes lighter moving down, mudstone inclusions and few mudstone beds, bedding not parallel to core cut
964.25	965.6	fs	n7/n4	ss	alternating layers of light and dark grain sands with darker layers increasing downward, beds not quite flat laying
965.6	967.25	fs	n7/n4	ss	beds thinning and still alternating, soft sediment deformation, darker pebbles (shale)
967.25	969.1	vfs	n7/n4	ss	top marked by unconformity, light and dark layer alternate and increase in angle from horizontal becoming nearly vertical, bottom marked by unconformity
969.1	971.3	fs	n7/n4	ss	shale pebbles present at top and decrease downward, bed structures 45 degrees to horizontal, few clay layers
971.3	973	vfs	n7/n4	ss	clay pebbles present, clay layers thicken downwards
973	976	< silt	n4/n7	ms	coal pieces present, soft sediment deformation, some coal layers (.1-.2 inches) have iron staining around coal, similar staining in joints

Castle Rock 3117 141G (continued)

Top (ft)	Bottom (ft)	Grainsize	Color	Lithology	Notes
976	978.5	< silt	n4	ms	clean, few coal pieces, no coalbeds
979	980.8	< silt	n1	cl	little mudstone at top grading into coal, not heavily broken up no strong cleating, secondary mineralization
980.8	984				no core
984	986.25	< silt	n4	ms	not broken up, iron staining with preference to one set of surfaces
968.75	982.9	< silt	n6	ms	bagged, gray with black beds, increasing downward grainsize, soft sediment deformation
982.9	992	< silt	n5	ms	interbedding layers of silt and < silt sized grains, iron staining, soft sediment deformation, fossil material
992	993.5	< silt	n5	ms	larger pieces of fossils, iron staining
993.5	995.6	< silt	n5	ms	abundant coal fragments, iron staining
995.6	1004	< silt	n1	cl	bulky, chunky, cores whole pieces, secondary mineralization
1004	1004.75	< silt	n1	cl	same coal described above
1004.75	1006	fs	n7	ss	some interbedding with mudstone
1006	1007	< silt	n1	cl	flaky brittle lusterous, plastic look
1007	1008	< silt	n4	ms	broken up, brachiopod intact fossils, some lusterous surfaces
1008	1010	vfs	n7	ss	interbedding with mudstone, soft sediment deformation, fracturing in finer grained layers
1010	1011.45	fs	n7	ss	clean sandstone, almost no interbedding
1011.45	1018.9	fs	n7	ss	fairly clean with some dark mud layers (<.25 inches), fracturing near/on finer grained areas
1018.9	1022	fs	n7	ss	same as described on previous page
1022	1022.6	fs	n7	ss	interbedding with dark mudstones, soft sediment deformation
1022.6	1025	fs	n7	ss	vertical fracture at 1024 to 1025, several mud pebbles

Castle Rock 3017 021

Top (ft)	Bottom (ft)	Grainsize	Color	Lithology	Notes
1472	1474	< silt	n3	ms	fairly broken up increasing with depth, also becoming more coal rich, slickenslides
1474	1478.9	< silt	n2	cl	more broken up at top, no apparent cleating, no secondary mineralization
1478.9	1480	< silt	n2	ms	coal rich with fractures at coal/mudstone contacts, plant fossils
1480	148.28	< silt	n3	ms	broken up, mud layers, decreasing coal content downwards
148.28	1485	vfs	n6	ss	little coal, fairly sorted coal found in few breaks
1485	1487	silt-< silt	n5	ms	silty mudstone, soft sediment deformation, mudstone beds decreasing downwards
1487	1490.8	silt-< silt	n5	ms	same as above
1490.8	1491.6	< silt	n2	ms	transitioning to coal below, rich in coal but not broken up
1491.6	1495	< silt	n1	cl	bagged, broken up, no 2nd mineralization, cleating noticed,
1693.8	1700.9	< silt	n4	ms	no secondary mineralization, few possible fractures
1700.9	1703.9	< silt	n4	ms	same as above
1703.9	1708.3	< silt	n3	ms	black mudstone with few breaks, breaks have coal, more coal rich downwards
1708.3	1709.2	< silt	n2	ms	very coal rich
1709.2	1715.2	< silt	n1	cl	many samples missing, no secondary mineralization, cleating noticed
1715.2	1720.6	< silt	n1	cl	same as above
1720.6	1721	< silt	n1	ms	interbedding of coal and mudstone with increasing mudstone downwards

Van Bremmer Canyon 3019 311

Top (ft)	Bottom (ft)	Grainsize	Color	Lithology	Notes
2016	2020.6	fs	n2	ms	mud pieces at top fading down, several fractures with 2nd mineralization, abrupt change in facies but no core to show boundary
2020.6	2023.7	< silt	n1	cl	becomes more brittle downwards, some secondary mineralization
2023.7	2027.5	< silt	n1	cl	same as above
2027.5	2031	vfs	n5	ss	soft sediment deformation, mudstone beds present
2031	2031.3	fs	n6	ss	clean, well sorted
2031.3	2038.4	fs	n6	ss	same as above, few thin (>.25 inches) coalbeds
2038.4	2043	fs	n6	ss	same as above

VPR ST-17

Top (ft)	Bottom (ft)	Lithology	Color	Grainsize	Fracturing	Description
351.5	353	ms	n4	< silt	SMF	SLK, CLP
353	357.5	ms/ss	n5/n7	< silt-vfs	SMF	SSD, CLS
357.5	363.5	ss	5y 7/2	fs-< silt	SLF	MUS
363.5	368.3	ms	n4	< silt	SMF	SLK, CLP, CU
368.3	370.1	cl	n1	< silt	SLF	2CD
370.1	371.8	ms	n2	< silt	SMF	CAR
371.8	377.1	ms	n3	< silt	SMF	SLK, CLS
377.1	380	ms/cl	n2/n1	< silt	SMF	SSD
380	384.3	ms	n2	< silt	SHF	SLK
384.3	385.9	cl/ms	n1/n2	< silt	SMF	SSD
385.9	392.4	ss/ms	n7	fs-< silt	SLF	SSD, CLS, INT
392.4	396	ms	n3	< silt	SMF	CLP
396	397.2	ss	n8	cs-fs	SLF	CLP, ECB
397.2	398.5	cl	n1	< silt	SLF	1CD
398.5	420	ss/ms	n6/n4	vfs-< silt	SLF	SSD, ECB
420	422.5	cl	n1	< silt	SLF	1CD
422.5	424	ms	n3	< silt	SMF	SLK
424	424.9	cl	n1	< silt	SLF	1CD
424.9	430.2	ms	n3	< silt	SMF	CLP, SLK, FU
430.2	442	ss	n5	fs-< silt	N	SSD, CLP, FU
442	448.5	ms	n4	< silt	SMF	SLK, CLS, FU
448.5	453	ss	n7	fs-< silt	SLF	FU
453	456.1	ms	n4	< silt	SLF	FU
456.1	457.5	cl/ms	n1/n2	< silt	SMF	SLK
457.5	460.6	ss	n8	cs-fs	N	SSD
460.6	464.1	ms	n4	< silt	SLF	SLK
464.1	477.8	ss	n7	fs-< silt	SLF	CLS, CLP, SSD
477.8	480	ms	n6	fs-< silt	SLF	CU
480	486.1	ms	n4	< silt	SMF	CAR
486.1	493.4	ss	n8	ms-vfs	N	FU
493.4	494	ms	n5	fs-< silt	SLF	SLK
494	498.7	ss	n7	fs-< silt	SLF	CU
498.7	500.4	ms	n3	< silt	SMF	CU, SSD
500.4	528.6	ss	n6	fs-< silt	SLF	SSD, ECB
528.6	534	ms	n4	< silt	SLF	CU
534	537.9	ms	n2	< silt	SMF	CLP CLS
537.9	541.3	ss	n6	fs-< silt	N	CLS, CLP, SSD
541.3	542.2	ms	n4	< silt	N	CLP
542.2	548	ss	n5	fs-< silt	SLF	FU
548	559.7	ms	n2	< silt	SMF	SSD, CLP, FU
559.7	567.5	ss	n6	fs-< silt	N	FU, CLS
567.5	569.8	ms/cl	n2	< silt	SMF	CAR
569.8	572.3	ss	n6	fs-< silt	N	FU
572.3	577.9	ss/ms	n6/n4	fs-< silt	SLF	SSD
577.9	603	ss	n8	ms-fs	SLF	FU, ECB
603	605.4	ms	n4	< silt	N	CLS, CLP, SSD
605.4	607.5	ms/cl	n3/n1	< silt	SLF	CLP
607.5	610.2	ss	n6	fs-< silt	N	FU, CLS
610.2	622	ms	n5	vfs-< silt	N	SSD
622	640.1	ss	n6	fs-< silt	N	FU, CLS, ECB

VPR ST-17 (continued)

Top (ft)	Bottom (ft)	Lithology	Color	Grainsize	Fracturing	Description
640.1	643.8	cl/ms	n1	< silt	SMF	CAR
643.8	650.3	ms	n3	< silt	SLF	CAR
650.3	653	cl	n1	< silt	SLF	1CD
653	658.8	ms	n5	vfs-< silt	SLF	FU, CLP
658.8	671.9	ss	n7	fs-< silt	SLF	FU
671.9	677.8	ms	n5	fs-< silt	SLF	CU, CLS
677.8	679.2	cl	n2	< silt	N	1CD
679.2	680.4	ss	n6	fs-< silt	N	FU, CLP
680.4	689.5	ms/ss	n4/n6	fs-< silt	SLF	SSD
689.5	692	cl	n1	< silt	SLF	1CD
692	735.7	ms/ss	n5/n6	fs-< silt	SLF	SSD
735.7	741	ms	n5	fs-< silt	SLF	CU
741	788.4	ss	n6	fs-< silt	SLF	FU
788.4	792.1	ms	n4	< silt	SLF	CU, CLP, SSD
792.1	794.6	ms/cl	n2	< silt	SMF	CLP,CLS
794.6	822	ss/ms	n6/n4	fs-< silt	SLF	SSD
822	826.4	ss	n8	cs-fs	N	FU, ECB
826.4	831.8	ss/cl	n6/n1	fs-< silt	N	CLS
831.8	841.3	ss	n6	fs-< silt	N	CLP, ECB
841.3	844.7	cl	n1	< silt	SLF	1CD
844.7	862	ss	n6	fs-< silt	N	FU
862	862.8	cl	n1	< silt	N	1CD
862.8	875.3	ss	n6	fs-< silt	SLF	FU, CLS
875.3	876.1	cl	n1	< silt	N	1CD
876.1	919.4	ss	n6	fs-< silt	N	FU, CLS, ECB
919.4	921.5	ms	n2	< silt	SLF	CAR
921.5	922	cl	n1	< silt	SLF	1CD
922	939.1	ss	n6	fs-< silt	SLF	SSD, FU, ECB
939.1	956.7	ms	n3	< silt	SLF	SLK, CAR
956.7	974	ss	n5	vfs-< silt	N	SSD, FU
974	976.2	ms	n4	vfs-< silt	SLF	SSD, FU
976.2	979.8	ss	n6	fs-< silt	SLF	FU
979.8	984.5	ms	n4	< silt	N	CU, SSD
984.5	998.5	ss	n6	fs-< silt	SLF	FU, ECB
998.5	1001.6	ms	n3	< silt	SMF	CU, SLK
1002	1013	ss	n6	fs-< silt	N	FU
1013	1015.2	ms	n4	< silt	SLF	CU
1015	1018.3	ms	n6	fs-< silt	SLF	FU
1018	1021	ms	n4	< silt	SLF	CU,SLK
1021	1027.9	ms	n6	fs-< silt	SLF	FU
1028	1030.2	ms	n4	< silt	SLF	CU, SLK
1030	1033.2	ss	n6	fs-< silt	SLF	CLS, FU, ECB
1033	1037.8	ms	n3	< silt	SLF	CAR
1038	1050	ss	n6	fs-< silt	SLF	CLP, FU
1050	1052.2	ms	n4	< silt	SLF	CU
1052	1074.3	ss	n6	fs-< silt	SLF	SSD
1074	1079	ms	10yr 4/2	< silt	SMF	SSD
1079	1084	ss	n6	fs-< silt	SLF	FU
1084	1088.4	ms	n4	< silt	SLF	CU
1088	1094.2	ms/ss	n5/n7	fs-< silt	SLF	SSD

VPR ST-17 (continued)

Top (ft)	Bottom (ft)	Lithology	Color	Grainsize	Fracturing	Description
1094	1097.7	ms	n4	< silt	SLF	SSD, CAR
1098	1111.9	ms/ss	n5/n7	fs-< silt	SLF	SSD
1112	1130.1	ss	n7	fs-< silt	SLF	FU, ECB
1130	1132.8	ms	n4	< silt	SLF	CAR
1133	1134.6	ms	n6	fs-< silt	SLF	SSD, SLK
1135	1150	ss	n6	fs-< silt	SLF	SSD
1150	1169.5	ms	n4	vfs-< silt	SHF	SLK,SSD
1170	1182.5	ss	n6	fs-< silt	SLF	FU
1183	1183.2	cl	n1	< silt	SLF	2CD
1183	1195.2	ss	n7	fs-< silt	SLF	CLP, FU
1195	1196	ms	n3	< silt	SLF	CAR
1196	1228.3	ss	n6	fs-< silt	N	CLS, FU
1228	1231.8	ms	n3	< silt	SLF	CU
1232	1242	ms	n5	fs-< silt	N	SSD, FU
1242	1259.6	ss	n8	fs-< silt	N	CLS, FU, ECB
1260	1263.7	ms	n4	< silt	SLF	CU,
1264	1272.9	ms	n2	< silt	SMF	CAR
1273	1289.4	ss/ms	n6/n4	fs-< silt	SLF	SSD
1289	1290.3	ms/cl	n2/n1	< silt	SMF	CAR
1290	1303.5	ss	n5	fs-< silt	SLF	SSD
1304	1305	ms	n2	< silt	SMF	CAR
1305	1313.4	ss	n8	fs-< silt	N	CLS, FU, ECB
1313	1315.7	ms	n2	< silt	SMF	CAR, SLK
1316	1321.2	ms	n3	< silt	SMF	CAR
1321	1322.1	cl	n1	< silt	N	2CD
1322	1327.6	ss	n6	fs-< silt	N	SSD, CLS
1328	1328.1	ms	n3	< silt	SMF	CAR, SLK
1328	1329.8	cl	n1	< silt	N	2CD
1330	1332	ms	n3	< silt	SMF	CAR
1332	1352.3	ss	n6	fs-< silt	N	SSD, CLS, ECB
1352	1361.6	ms	n4	< silt	SLF	SSD, CLP
1362	1367.9	cl	n1	< silt	SLF	1CD
1368	1373.7	ss	n5	fs-< silt	SLF	SSD, FU
1374	1386	ss	n8	ms-vfs	N	CLS, FU, ECB
1386	1386.7	cl	n1	< silt	N	2CD
1387	1391.4	ms	n4	< silt	SLF	SSD, FU
1391	1393.4	ms	n2	vfs-< silt	SMF	CAR
1393	1394.6	cl	n1	< silt	SLF	1CD
1395	1397.5	ms	n2	< silt	SMF	CAR
1398	1399.1	cl	n1	< silt	SLF	2CD
1399	1402	ms	n2	vfs-< silt	SLF	CAR
1402	1403.8	cl	n1	< silt	SLF	2CD
1404	1406.1	ms	n2	< silt	SMF	CAR, SLK
1406	1418	ms	n4	< silt	SLF	SSD
1418	1429.9	ms	n2	< silt	SLF	CAR, SLK
1430	1444.2	ms	n4	vfs-< silt	N	SSD, CLS
1444	1459.9	ss	n6	fs-< silt	N	SSD
1460	1463.6	ss	n8	cs-fs	N	CLS, ECB
1464	1472.7	ms	n2	< silt	SLF	CAR
1473	1497.5	ss	n7	fs-< silt	SLF	CLS, FU

VPR ST-17 (continued)

Top (ft)	Bottom (ft)	Lithology	Color	Grainsize	Fracturing	Description
1498	1498.3	ms	n4	< silt	SLF	CU
1498	1516	ss	n6	fs-< silt	N	SSD, CLS
1516	1518	ss	n8	ms-vfs	SLF	FU, ECB
1518	1521.4	ms	n2	< silt	SMF	CAR
1521	1522.1	cl	n1	< silt	SLF	2CD
1522	1524.4	ms	n2	< silt	SMF	CAR, SLK
1524	1528.5	ms	n4	< silt	SLF	SSD, SLK
1529	1531.6	ss	n8	ms-vfs	N	CLS, FU, ECB
1532	1542.3	ss/ms	n6/n4	fs-< silt	SLF	SSD, CLS
1542	1545	ms	n4	< silt	SLF	CLS, CU
1545	1583.1	ss	n8	ms-vfs	N	CLS, FU, ECB
1583	1584.6	cl	n1	< silt	SLF	2CD, ECB
1585	1597.2	ss	n8	ms-fs	N	CLP
1597	1599.8	cl	n1	< silt	SLF	2CD
1600	1613.7	ss	n6	fs-< silt	N	FU, CLP
1614	1614.3	cl	n1	< silt	SLF	2CD
1614	1622	ss	n5	fs-< silt	N	SSD, FU
1622	1623.6	ms	n3	< silt	SMF	FU, CLP
1624	1638	ss	n5	fs-< silt	N	FU
1638	1642.4	ms	n3	< silt	SMF	SSD
1642	1660.8	ss	n7	fs-< silt	N	CLS, FU, ECB
1661	1661.5	cl	n1	< silt	SLF	1CD
1662	1664.3	ss	n5	fs-< silt	N	CLS, FU
1664	1667.8	ms	n3	< silt	SLF	CAR
1668	1670.4	ss	n5	fs-< silt	SLF	FU
1670	1675.5	ss	n8	cs-fs	N	FU, CLS
1676	1688.3	ss	n5	fs-< silt	N	CU, ECB
1688	1690.3	ms	n2	< silt	SLF	SSD, CAR, ECB
1690	1702	ss	n8	ms-vfs	N	FU, CLS, ECB
1702	1703.2	cl	n1	< silt	N	1CD, ECB
1703	1708.1	ms	n3	< silt	SLF	CAR
1708	1709.5	cl	n1	< silt	SLF	1CD
1710	1719.9	ss/ms	n5/n3	fs-< silt	SLF	FU, CLP
1720	1722.1	ms	n3	< silt	SMF	FU, CLP
1722	1723.8	cl	n1	< silt	N	2CD
1724	1734.2	ss	n7	fs-< silt	SLF	FU
1734	1736	cl	n1	< silt	SMF	NCD
1736	1748.1	ms	n2	< silt	SMF	SSD
1748	1750.2	ss	n5	fs-< silt	SLF	FU
1750	1764.5	ss	n8	ms-fs	N	FU, ECB
1765	1767	ms	n2	< silt	SLF	SSD
1767	1767.8	cl	n1	< silt	SLF	NCD
1768	1791.7	ss/ms	n6/n4	fs-< silt	SLF	FU
1792	1794	ms	5pb 3/2	< silt	SLF	CU
1794	1810.2	cl/ms	n1/n2	< silt	SLF	NCD
1810	1812	ss/ms	n7/n6	fs-< silt	SLF	SSD
1812	1847.3	ss	n8	cs-fs	N	FU

APPENDIX 2. LITHOLOGIC AND STRATIGRAPHIC WELL LOG ANALYSIS DATA

The following information was collected by examination of well logs stored at the New Mexico Bureau of Geology and Mineral Resources. The depth to the top (DDT) (ft) and depth to bottom (DTB) (ft) were recorded for selected lithologies. The method for selection is outlined in the Methods chapter. Description of the lithologic type is provided. Formation contacts were also recorded.

VPR ST 18			
DTT (ft)	DTB (ft)	Description	Th (ft)
349	352	Coal	3
363	364	Coal	1
381	383	Coal	2
386	389	Coal	3
485	486	Coal	1
692	694	Coal	2
875	876	Coal	1
966	975	Sandstone	9
989	990	Coal	1
1001	1004	Coal	3
1021	1022	Coal	1
1035	1054	Sandstone	19
1084	1085	Coal	1
1122	1124	Coal	2
1142	1145	Coal	3
1192	1203	Sandstone	11
1207	1215	Sandstone	8
1238	1244	Sandstone	6
1250	1256	Sandstone	6
1270	1282	Sandstone	12
1295	1318	Sandstone	23
1331	1370	Sandstone	39
1370	1370	R-V Contact	
1408	1418	Sandstone	10
1462	1463	Coal	1
1476	1491	Sandstone	15
1502	1503	Coal	1
1520	1527	Sandstone	7
1585	1594	Sandstone	9
1606	1608	Coal	2
1608	1608	V-T Contact	

Castle Rock 3118 021			
DTT (ft)	DTB (ft)	Description	Th (ft)
520	526	Sandstone	6
536	542	Sandstone	6
623	632	Sandstone	9
658	696	Sandstone	38
734	787	Sandstone	53
806	815	Sandstone	9
828	864	Sandstone	36
1032	1033	Coal	1
1050	1059	Sandstone	9
1058	1070	Sandstone	12
1093	1102	Sandstone	9
1143	1162	Sandstone	19
1202	1210	Sandstone	8
1262	1270	Sandstone	8
1282	1290	Sandstone	8
1292	1298	Sandstone	6
1314	1320	Sandstone	6
1340	1357	Sandstone	17
1368	1376	Sandstone	8
1380	1428	Sandstone	48
1454	1466	Sandstone	12
1467	1467	R-V Contact	
1472	1475	Coal	3
1480	1488	Sandstone	8
1488	1492	Coal	4
1528	1534	Sandstone	6
1540	1542	Coal	2
1552	1553	Coal	1
1579	1590	Sandstone	11
1594	1604	Sandstone	10
1605	1606	Coal	1
1614	1626	Sandstone	12
1636	1652	Sandstone	16
1658	1660	Coal	2
1681	1688	Sandstone	7
1706	1717	Coal	11
1717	1717	V-T Contact	

VPR D 21			
DTT (ft)	DTB (ft)	Description	Th (ft)
394	396	Coal	2
427	429	Coal	2
430	432	Coal	2
433	435	Coal	2
450	452	Coal	2
454	458	Coal	4
469	471	Coal	2
506	508	Coal	2
525	552	Sanstone	27
578	580	Coal	2
610	634	Sandstone	24
661	693	Sandstone	32
810	822	Sandstone	12
841	858	Sandstone	17
874	924	Sandstone	50
952	975	Sandstone	23
1164	1166	Sandstone	2
1196	1203	Sandstone	7
1262	1273	Sandstone	11
1281	1299	Sandstone	18
1312	1322	Sandstone	10
1340	1352	Sandstone	12
1408	1410	Coal	2
1484	1496	Sandstone	12
1506	1528	Sandstone	22
1596	1612	Sandstone	16
1628	1640	Sandstone	12
1644	1652	Sandstone	8
1656	1739	Sandstone	83
1746	1746	R-V Contact	
1746	1752	Coal	6
1764	1782	Sandstone	18
1798	1810	Sandstone	12
1811	1813	Coal	2
1837	1840	Coal	3
1870	1896	Sandstone	26
1906	1926	Sandstone	20
1926	1928	Coal	2
1936	1939	Coal	3
1963	1966	Coal	3
1970	1970	V-T Contact	

Castle Rock 3117 141			
DTT (ft)	DTB (ft)	Description	Th (ft)
364	372	Sandstone	8
405	429	Sandstone	24
478	490	Sandstone	12
556	571	Sandstone	15
579	638	Sandstone	59
665	685	Sandstone	20
714	714	R-V Contact	
688	714	Sandstone	26
718	722	Coal	4
743	762	Sandstone	19
769	785	Sandstone	16
790	836	Sandstone	46
893	895	Coal	2
907	908	Coal	1
927	929	Coal	2
943	956	Sandstone	13
995	1004	Coal	9
1004	1004	V-T Contact	

Valdez Canyon 012			
DTT (ft)	DTB (ft)	Description	Th (ft)
488	495	Sandstone	7
553	554	Coal	1
584	608	Sandstone	24
663	666	Coal	3
776	811	Sandstone	35
831	872	Sandstone	41
976	989	Sandstone	13
1110	1112	Sandstone	2
1134	1153	Sandstone	19
1191	1192	Coal	1
1226	1234	Sandstone	8
1310	1330	Sandstone	20
1374	1376	Coal	2
1484	1512	Sandstone	28
1610	1614	Coal	4
1616	1618	Coal	2
1706	1721	Sandstone	15
1750	1752	Coal	2
1760	1789	Sandstone	29
1776	1801	Sandstone	25
1808	1810	Coal	2
1820	1822	Coal	2
1844	1855	Coal	11
1850	1860	Sandstone	10
1865	1868	Coal	3
1875	1878	Coal	3
1887	1890	Coal	3
1948	1994	Sandstone	46
2004	2103	Sandstone	99
2115	2115	R-V Contact	
2120	2122	Coal	2
2125	2131	Coal	6
2144	2180	Sandstone	36
2188	2216	Sandstone	28
2236	2240	Coal	4
2243	2247	Coal	4
2252	2254	Coal	2
2254	2265	Sandstone	11
2284	2298	Sandstone	14
2298	2300	Coal	2
2318	2329	Sandstone	11
2333	2335	Coal	2
2345	2347	Coal	2
2350	2350	V-T Contact	

VPR B 23			
DTT (ft)	DTB (ft)	Description	Th (ft)
344	345	Coal	1
369	370	Coal	1
386	388	Coal	2
430	434	Coal	4
442	444	Coal	2
459	460	Coal	1
531	532	Coal	1
548	569	Sandstone	21
572	581	Sandstone	9
601	624	Sandstone	23
631	644	Sandstone	13
703	777	Sandstone	74
798	800	Coal	2
854	856	Coal	2
879	880	Coal	1
899	912	Sandstone	13
938	950	Sandstone	12
961	988	Sandstone	27
1000	1012	Sandstone	12
1108	1112	Sandstone	4
1120	1121	Coal	1
1139	1148	Sandstone	9
1151	1161	Sandstone	10
1171	1197	Sandstone	26
1326	1336	Sandstone	10
1350	1394	Sandstone	44
1413	1439	Sandstone	26
1481	1500	Sandstone	19
1531	1532	Coal	1
1582	1583	Coal	1
1594	1596	Coal	2
1600	1626	Sandstone	26
1694	1710	Sandstone	16
1732	1761	Sandstone	29
1765	1808	Sandstone	43
1824	1839	Sandstone	15
1848	1877	Sandstone	29
1881	1881	R-V Contact	
1879	1881	Coal	2
1894	1924	Sandstone	30
1938	1948	Sandstone	10
1954	1955	Coal	1
1979	1980	Coal	1
2012	2045	Sandstone	33
2045	2047	Coal	2
2052	2058	Coal	6
2075	2079	Coal	4
2085	2085	V-T Contact	

W.S. Ranch 5

DTT (ft)	DTB (ft)	Description	Th (ft)
468	472	Coal	4
518	589	Sandstone	71
658	691	Sandstone	33
870	902	Sandstone	32
928	954	Sandstone	26
1064	1100	Sandstone	36
1154	1163	Sandstone	9
1197	1220	Sandstone	23
1258	1309	Sandstone	51
1332	1350	Sandstone	18
1392	1394	Coal	2
1398	1440	Sandstone	42
1496	1499	Coal	3
1500	1504	Coal	4
1604	1622	Sandstone	18
1644	1656	Sandstone	12
1683	1712	Sandstone	29
1748	1748	R-V Contact	
1728	1748	Sandstone	20
1752	1770	Sandstone	18
1804	1822	Sandstone	18
1830	1844	Sandstone	14
1880	1896	Sandstone	16
1945	1947	Coal	2
1954	1960	Coal	6
1970	1972	Coal	2
1978	1978	V-T Contact	

Gachupin Canyon 3019 201

DTT (ft)	DTB (ft)	Description	Th (ft)
409	411	Coal	2
436	446	Sandstone	10
500	501	Coal	1
682	722	Sandstone	40
760	774	Sandstone	14
841	849	Sandstone	8
959	972	Sandstone	13
1092	1109	Sandstone	17
1187	1190	Coal	3
1228	1236	Sandstone	8
1261	1275	Sandstone	14
1318	1326	Sandstone	8
1331	1344	Sandstone	13
1346	1382	Sandstone	36
1419	1419	R-V Contact	
1393	1419	Sandstone	26
1428	1453	Sandstone	25
1582	1584	Coal	2
1654	1656	Coal	2
1656	1656	V-T Contact	

VPR B 38			
DTT (ft)	DTB (ft)	Description	Th (ft)
463	464	Coal	1
466	468	Coal	2
552	554	Coal	2
563	565	Coal	2
708	723	Sandstone	15
770	778	Sandstone	8
816	830	Sandstone	14
858	860	Coal	2
914	916	Coal	2
659	661	Coal	2
680	682	Coal	2
986	1014	Sandstone	28
1168	1169	Coal	1
1252	1280	Sandstone	28
1412	1470	Sandstone	58
1482	1484	Coal	2
1524	1526	Coal	2
1582	1584	Coal	2
1631	1632	Coal	1
1654	1664	Sandstone	10
1710	1718	Sandstone	8
1730	1754	Sandstone	24
1766	1781	Sandstone	15
1798	1813	Sandstone	15
1820	1870	Sandstone	50
1870	1870	R-V Contact	
1880	1896	Sandstone	16
1925	1930	Coal	5
1930	1962	Sandstone	32
1981	1992	Sandstone	11
2008	2010	Coal	2
2020	2023	Coal	3
2055	2056	Coal	1
2065	2080	Sandstone	15
2092	2093	Coal	1
2097	2110	Sandstone	13
2120	2142	Sandstone	22
2152	2154	Coal	2
2192	2194	Coal	2
2216	2216	V-T Contact	

VPR D 32			
DTT (ft)	DTB (ft)	Description	Th (ft)
367	369	Coal	2
388	390	Coal	2
459	461	Coal	2
518	531	Sandstone	13
541	542	Coal	1
598	600	Coal	2
652	678	Sandstone	26
731	733	Coal	2
837	840	Coal	3
870	872	Coal	2
1000	1054	Sandstone	54
1196	1222	Sandstone	26
1300	1314	Sandstone	14
1345	1346	Coal	1
1398	1401	Coal	3
1420	1422	Coal	2
1463	1465	Coal	2
1486	1488	Coal	2
1522	1543	Sandstone	21
1554	1566	Sandstone	12
1574	1582	Sandstone	8
1588	1619	Sandstone	31
1655	1670	Sandstone	15
1684	1760	Sandstone	76
1760	1760	R-V Contact	
1784	1785	Coal	1
1813	1815	Coal	2
1824	1826	Coal	2
1872	1874	Coal	2
1878	1882	Coal	4
1894	1898	Coal	4
1926	1927	Coal	1
1935	1937	Coal	2
1944	1946	Coal	2
1969	1971	Coal	2
2034	2034	V-T Contact	

VPR D 53			
DTT (ft)	DTB (ft)	Description	Th (ft)
374	411	Sandstone	37
456	502	Sandstone	46
519	550	Sandstone	31
590	628	Sandstone	38
660	702	Sandstone	42
737	739	Coal	2
905	911	Sandstone	6
922	932	Sandstone	10
974	980	Sandstone	6
1048	1070	Sandstone	22
1074	1099	Sandstone	25
1104	1116	Sandstone	12
1116	1116	R-V Contact	
1144	1160	Sandstone	16
1183	1190	Coal	7
1197	1199	Coal	2
1238	1258	Sandstone	20
1262	1266	Coal	4
1300	1308	Sandstone	8
1314	1315	Coal	1
1318	1335	Sandstone	17
1400	1402	Coal	2
1427	1432	Coal	5
1448	1448	V-T Contact	

VPR D 48			
DTT (ft)	DTB (ft)	Description	Th (ft)
348	351	Coal	3
402	404	Coal	2
439	441	Coal	2
530	532	Coal	2
578	580	Coal	2
688	689	Coal	1
720	722	Coal	2
725	726	Coal	1
772	774	Coal	2
809	810	Coal	1
853	855	Coal	2
646	680	Sandstone	34
860	893	Sandstone	33
1102	1136	Sandstone	34
1109	1110	Coal	1
1188	1191	Coal	3
1220	1222	Coal	2
1346	1382	Sandstone	36
1382	1385	Coal	3
1395	1403	Sandstone	8
1407	1420	Sandstone	13
1432	1441	Sandstone	9
1444	1484	Sandstone	40
1510	1512	Coal	2
1510	1510	R-V Contact	
1521	1528	Coal	7
1536	1544	Sandstone	8
1556	1558	Coal	2
1558	1576	Sandstone	18
1600	1602	Coal	2
1605	1608	Coal	3
1615	1742	Sandstone	127
1644	1646	Coal	2
1652	1654	Coal	2
1713	1765	Sandstone	52
1765	1767	Coal	2
1772	1780	Sandstone	8
1789	1791	Coal	2
1796	1798	Coal	2
1804	1804	V-T Contact	

W.S. Ranch 3

DTT (ft)	DTB (ft)	Description	Th (ft)	*-log begins at 891
891	907	Sandstone	16	
1062	1073	Sandstone	11	
1369	1382	Sandstone	13	
1396	1400	Coal	4	
1442	1448	Sandstone	6	
1478	1480	Coal	2	
1484	1486	Coal	2	
1567	1577	Sandstone	10	
1582	1594	Sandstone	12	
1613	1651	Sandstone	38	
1680	1704	Sandstone	24	
1700	1792	Sandstone	92	
1820	1820	R-V Contact		
1800	1820	Sandstone	20	
1838	1862	Sandstone	24	
1892	1910	Sandstone	18	
1916	1933	Sandstone	17	
1938	1940	Coal	2	
2108	2108	V-T Contact		

APPENDIX 3. WELL LOG AND OUTCROP DATA FOR TOP SURFACE OF TRINIDAD SANDSTONE

The following well log information was collected by examination of well logs stored at the New Mexico Bureau of Geology and Mineral Resources. The well log information provided is the accumulation of interpretations conducted by Brian Brister and Gretchen Hoffman of the New Mexico Bureau of Geology and Mineral Resources as well as the author. The outcrop data was derived from the state map published by the New Mexico Bureau of Geology and Mineral Resources (2003).

Well Name	Well Id	Latitude	Longitude	Ele. (ft)
CASTLE ROCK 3017	031F	36.865043	-105.126811	6652
CASTLE ROCK 3117	271G	36.895167	-105.122975	6945
CERROSOSO CANYON 2918	111D	36.766269	-105.005044	5504
GACHUPIN CANYON 3019	201	36.81567	-104.943646	5800
Kaiser Steel	003	36.763449	-104.653623	6675
Kaiser Strat Test	009	36.81858755	-104.6385197	6660
Kaiser-Eustace	001	36.965075	-104.878349	5865
LORETTA RIDGE	001	36.69426485	-104.8156985	6324
ODESSA NATURAL W S RANCH	005	36.810029	-105.009017	5838
ODESSA NATURAL WS RANCH	003	36.723068	-104.883146	6055
ODESSA NATURAL WS RANCH	004N	36.74775	-104.96527	5528
PHELPS DODGE	001	36.749874	-104.731361	6415
RAIL CANYON	001	36.70772	-104.75922	6435
SALTPETER CANYON	001	36.74409	-104.73177	6416
St. Louis, Rocky Mountain and Pacific RR	7A	36.9582584	-104.7758673	5860
St. Louis, Rocky Mountain and Pacific RR	002	36.89482249	-104.6682864	6226
St. Louis, Rocky Mountain and Pacific RR	003	36.8403071	-104.6431658	6642
VALDEZ CANYON 2918	011D	36.782132	-104.989567	5554
VALDEZ CANYON 2918	012J	36.773083	-104.976566	5567
Valdez Canyon 2919	071	36.767411	-104.964552	5582
Van Bremmer Canyon 2919	041D	36.782472	-104.935356	5673
Van Bremmer Canyon 3018	241M	36.813965	-104.98755	5692
Van Bremmer Canyon 3019	302E	36.806918	-104.967348	5687
Van Bremmer Canyon 3019	311G	36.792297	-104.959164	5668
Van Bremmer Canyon 3019	322	36.795401	-104.94931	5696
VERMEJO PARK	002	36.839542	-104.920308	5955
Vermejo Ranch	1	36.884345	-105.121473	6766
Vermejo Ranch	2	36.948757	-105.082007	7272
Vermejo Ranch 36	005	36.971158	-105.084784	7570
VPR ""A"" (aka Canadian River 3120)	2	36.956324	-104.857929	5831
VPR A	07	36.95496	-104.871173	5819
VPR A	08	36.955303	-104.877322	5836
VPR A	14	36.961433	-104.878587	5818
VPR A	20	36.970461	-104.848241	5799
VPR A	21	36.961194	-104.851815	5832
VPR A	22	36.970121	-104.840869	5817
VPR A	09	36.948846	-104.88015	5934
VPR A	10	36.947398	-104.866779	5852
VPR A	11	36.953529	-104.88561	5854
VPR A	12	36.946777	-104.884651	5885
VPR A	13	36.962749	-104.888086	5831
VPR A	15	36.981698	-104.843465	5779
VPR A	16	36.97524	-104.841675	5798
VPR A	17	36.982996	-104.848537	5766
VPR A	18	36.976554	-104.860076	5752
VPR A	19	36.974887	-104.852042	5772
VPR A	23X	36.962944	-104.845158	5925
VPR A	43	36.94828	-104.90371	5884
VPR A	28	36.954124	-104.902264	5862
VPR A	30	36.962121	-104.912112	5890

Well Name	Well Id	Latitude	Longitude	Ele. (ft)
VPR A	31	36.961938	-104.901324	5868
VPR A	32	36.961102	-104.893225	5848
VPR A	33	36.968097	-104.895341	5827
VPR A	34	36.982394	-104.860892	5813
VPR A	35	36.983832	-104.834343	5806
VPR A	36	36.983448	-104.823118	5850
VPR A	38	36.990825	-104.850897	5825
VPR A	39	36.988801	-104.839264	5807
VPR A	40	36.99029	-104.831981	5802
VPR A	41	36.990021	-104.822765	5809
VPR A	44	36.961406	-104.83222	5864
VPR A	45	36.968821	-104.83257	5853
VPR A	46	36.975312	-104.822721	5840
VPR A	47	36.974467	-104.812586	5880
VPR A	48	36.976269	-104.804939	5856
VPR A	49	36.976713	-104.793681	5837
VPR A	50	36.984356	-104.801568	5804
VPR A	51	36.98521	-104.795513	5807
VPR A	52	36.990231	-104.815293	5819
VPR A	53	36.989693	-104.804483	5818
VPR A	54	36.989374	-104.793727	5785
VPR A	55	36.989769	-104.78846	5797
VPR A	56	36.988693	-104.777181	5811
VPR A	57	36.988814	-104.777041	5818
VPR A	58	36.983403	-104.786118	5832
VPR A	59	36.9764	-104.786908	5834
VPR A	60	36.977876	-104.777208	5827
VPR A	39X	36.98915	-104.839233	5787
VPR A	62	36.940435	-104.912807	5898
VPR A	63	36.947102	-104.913733	5883
VPR A	64	36.9529	-104.914586	5893
VPR A	68	36.930624	-104.929659	5985
VPR A	69	36.933651	-104.922203	5944
VPR A	70	36.932621	-104.912312	5922
VPR A	71	36.931711	-104.902043	5906
VPR A	76	36.940149	-104.921085	5928
VPR A	77	36.938862	-104.904849	5882
VPR A	72	36.932191	-104.894392	5887
VPR A	73	36.932304	-104.885383	5892
VPR A	75	36.954857	-104.850722	5843
VPR A	78	36.939652	-104.893676	5872
VPR A	79	36.938632	-104.884698	5873
VPR A	80	36.938293	-104.877756	5883
VPR A	81	36.941523	-104.868806	5894
VPR A	66	36.968381	-104.887668	5796
VPR A	67	36.969369	-104.874704	5770
VPR A	83	36.960569	-104.813691	5881
VPR A	90	36.967999	-104.815249	5866
VPR A	84	36.961346	-104.804207	5849
VPR A	85	36.961643	-104.795217	5849

Well Name	Well Id	Latitude	Longitude	Ele. (ft)
VPR A	86	36.961552	-104.786532	5857
VPR A	87	36.964104	-104.779259	5857
VPR A	91	36.965495	-104.804464	5838
VPR A	94	36.967845	-104.77706	5855
VPR A	26	36.971523	-104.869141	5767
VPR A	88	36.961339	-104.772825	5876
VPR A	95	36.968813	-104.770062	5852
VPR A (AKA Canadian River 3119)	01	36.955235	-104.869742	5816
VPR A (aka Canadian River 3219)	25 (341)	36.970936	-104.902833	5827
VPR A (aka Canadian River 3219)	03	36.962162	-104.868523	5803
VPR A (aka Canadian River 3220)	24 (291)	36.977695	-104.829439	5761
VPR A (aka Canadian River 3220)	06	36.968964	-104.860426	5786
VPR B	09	36.788187	-104.959702	5724
VPR B	17	36.796454	-104.974072	5710
VPR B	18	36.802069	-105.000537	5711
VPR B	19	36.792553	-104.986305	5709
VPR B	20	36.801341	-104.984757	5704
VPR B	21	36.802256	-104.975835	5712
VPR B	24	36.811883	-104.993129	5767
VPR B	01	36.780909	-104.999855	5572
VPR B	02	36.781343	-104.976828	5814
VPR B	03	36.779648	-104.965667	5627
VPR B	04	36.778849	-104.957201	5636
VPR B	05	36.788328	-105.002821	5608
VPR B	06	36.78691	-104.983932	5594
VPR B	07	36.786246	-104.977378	5617
VPR B	08	36.788083	-104.966123	5651
VPR B	12	36.786267	-104.994775	5585
VPR B	15	36.794639	-104.992613	5630
VPR B	16	36.988718	-104.839264	5620
VPR B	31	36.77974	-104.995295	5580
VPR B	32	36.781678	-104.985156	5574
VPR B	33	36.78702	-105.013256	5672
VPR B	34	36.793075	-105.009685	5675
VPR B	35	36.801135	-105.009606	5725
VPR B	37	36.809957	-105.004763	5775
VPR B	38	36.828657	-105.075531	6054
VPR B	39	36.828818	-105.066163	6060
VPR B	40	36.828764	-105.0582	6033
VPR B	41	36.833042	-105.049306	6067
VPR B	42	36.831622	-105.038263	6021
VPR B	43	36.830934	-105.030669	6006
VPR B	44	36.829325	-105.022382	5959
VPR B (aka VALDEZ CANYON 3018)	11 (351)	36.79179	-105.00272	5602
VPR B (aka Van Bremmer 30)	30-33	36.799258	-104.959134	5707
VPR B (aka Van Bremmer Canyon 3018)	25 (251E)	36.808488	-104.985826	5670
VPR B (aka Van Bremmer Canyon 3018)	26 (252G)	36.806211	-104.976291	5660
VPR B (aka Van Bremmer Canyon 3018)	253B	36.812016	-104.979147	5685
VPR B (aka Van Bremmer Canyon 3019)	10 (321)	36.78894	-104.947765	5671
VPR B (aka Van Bremmer Canyon 3019)	13 (312)	36.791287	-104.970537	5630

Well Name	Well Id	Latitude	Longitude	Ele. (ft)
VPR C	95	36.988339	-104.760403	5783
VPR D	11	36.860839	-105.058044	6546
VPR D	12	36.858833	-105.050001	6494
VPR D	15	36.86778	-105.064488	6624
VPR D	16	36.865193	-105.057245	6595
VPR D	17	36.865154	-105.048838	6614
VPR D	19	36.875451	-105.066169	6815
VPR D	22	36.880625	-105.071544	6788
VPR D	23	36.881741	-105.067312	6782
VPR D	01	36.845943	-105.083334	6317
VPR D	02	36.846028	-105.075026	6311
VPR D	03	36.853146	-105.084164	6424
VPR D	04	36.852806	-105.074517	6396
VPR D	07	36.853158	-105.046423	6375
VPR D	08	36.859963	-105.083218	6507
VPR D	09	36.860628	-105.073932	6505
VPR D	10	36.859798	-105.065841	6431
VPR D	13	36.868047	-105.083721	6638
VPR D	14	36.866889	-105.07339	6582
VPR D	05	36.852338	-105.066191	6372
VPR D	06	36.852703	-105.057581	6314
VPR D	31	36.839016	-105.071745	6196
VPR D	32	36.839164	-105.066389	6236
VPR D	33	36.838481	-105.058214	6158
VPR D	34	36.839848	-105.049697	6161
VPR D	35	36.839013	-105.0383	6135
VPR D	36	36.837757	-105.031204	6099
VPR D	38	36.846641	-105.06551	6288
VPR D	39	36.846665	-105.057065	6287
VPR D	40	36.845646	-105.048646	6260
VPR D	41	36.844	-105.040416	6237
VPR D	42	36.846665	-105.031371	6290
VPR D	43	36.853616	-105.036346	6400
VPR D	44	36.854325	-105.03018	6473
VPR D	48	36.86055	-105.038488	6555
VPR D	49	36.860795	-105.027814	6719
VPR D	52	36.868017	-105.037479	6762
VPR D	53	36.868164	-105.03028	6931
VPR D	56	36.872993	-105.03923	6842
VPR D	61	36.883695	-105.050654	6792
VPR D	62	36.88352	-105.040106	7044
VPR D	64	36.885438	-105.06847	6767
VPR D	65	36.88667	-105.056793	6765
VPR D	66	36.886651	-105.046575	6884
VPR D	27	36.859192	-105.093438	6517
VPR D	28	36.875118	-105.084425	6708
VPR D	29	36.88055	-105.086246	6772
VPR D	45	36.883092	-105.091744	6791
VPR D	47	36.863729	-105.098736	6593
VPR D	50	36.886833	-105.109141	6795

Well Name	Well Id	Latitude	Longitude	Ele. (ft)
VPR D	51	36.869007	-105.094755	6652
VPR D	58	36.884761	-105.11834	6806
VPR D	59	36.883448	-105.111136	6765
VPR D	60	36.882834	-105.100055	6772
VPR D	70	36.888657	-105.08453	6822
VPR D	30	36.841595	-105.080125	6266
VPR D	67	36.892686	-105.111457	6855
VPR D	68	36.859206	-105.10158	6529
VPR D	69	36.890303	-105.093204	6852
VPR D	80	36.835918	-105.020498	6005
VPR D	37	36.892762	-105.07496	6839
VPR D	46	36.866137	-105.013553	7266
VPR D	54	36.86755	-105.021333	7173
VPR D	63	36.859157	-105.01345	6916
VPR D	71	36.889104	-105.075833	6814
VPR D	81	36.840578	-105.013255	6165
VPR D	82	36.84543	-105.021581	6304
VPR D	83	36.844168	-105.012943	6267
VPR D	84	36.854143	-105.017294	6640
VPR D	85	36.853654	-105.011579	6660
VPR D	87	36.892834	-105.060539	6793
VPR D	88	36.892967	-105.04566	6961
VPR D (aka CASTLE ROCK 3017)	21 (322)	36.858174	-105.113388	6523
VPR D (aka CASTLE ROCK 3117)	141	36.922178	-105.105966	7138
VPR D (aka Castle Rock 3118)	18 (311)	36.872882	-105.076298	6663
VPR D (aka Castle Rock 3118)	24 (322)	36.880623	-105.055707	6717
VPR D (aka Castle Rock 3118)	20 (323)	36.872887	-105.055667	6624
VPR E	20	36.968611	-104.96696	7679
VPR E	21	36.968702	-104.956738	7275
VPR E	02	36.947183	-104.966052	6931
VPR E	04	36.946779	-104.95109	6220
VPR E	05	36.948697	-104.938669	6100
VPR E	08	36.955706	-104.967658	7230
VPR E	09	36.955185	-104.957313	6697
VPR E	10	36.954906	-104.948515	6353
VPR E	11	36.954256	-104.938904	6091
VPR E	16	36.961551	-104.948877	6350
VPR E	17	36.961938	-104.939048	6079
VPR E	23	36.967487	-104.941845	6128
VPR E	34	36.954433	-104.936757	6074
VPR E	06	36.946552	-104.929925	5996
VPR E	12	36.955118	-104.931761	5986
VPR E	18	36.961551	-104.931166	5956
VPR E	19	36.960954	-104.921811	5910
VPR E	24	36.969541	-104.93037	5942
VPR E	25	36.968581	-104.923198	5901
VPR E	28	36.93283	-104.957206	6609
VPR E	30	36.932482	-104.942354	6183
VPR E	31	36.938716	-104.963878	6834
VPR ST	18	36.81756516	-104.9288765	5742

Well Name	Well Id	Latitude	Longitude	Ele. (ft)
VPR ST	17	36.74576779	-104.9371406	5720
VPR ST	21	36.98424165	-104.7346769	5810
VPR ST	14	36.95472772	-104.9567766	6558
VPR ST	19	36.89592034	-104.8073184	6059
VPR ST	20	36.89218282	-104.6846193	6182
VPR ST	22	36.8695083	-104.784479	6027
VPR ST	23	36.81968053	-104.7970785	5987
VPR ST	24	36.86007183	-104.8521791	6150
VPR ST (aka corehole)	1	36.90254	-104.93968	6420
W. S. Ranch NM-B	002	36.828591	-105.027079	5948
W. S. RANCH NM-B	004	36.836251	-105.064471	5943
W. S. Ranch NM-B	005	36.800459	-104.9563	5705
WS Ranch NM-B	10	36.901473	-104.874548	6012
W-S RANCH NM-B	001	36.865908	-104.959643	6780
W-S RANCH NM-B	003	36.822934	-105.008663	5851
Outcrop Data		Latitude	Longitude	Ele. (ft)
1		36.898216	-105.025206	7608
2		36.922266	-105.015277	7855
3		36.927152	-105.005009	8018
4		36.928068	-104.993788	8198
5		36.921654	-104.982189	8017
6		36.903025	-104.973639	7802
7		36.87325	-104.968708	7368
8		36.876918	-104.98315	7583
9		36.885622	-105.000824	7948
10		36.994564	-105.106682	9416
11		36.952656	-105.122414	8582
12		36.919196	-105.136828	8395
14		36.699785	-104.710263	6802
15		36.713947	-104.673229	6872
16		36.719339	-104.65185	6879
17		36.739466	-104.651238	6785

APPENDIX 4. PRODUCED WATER CHEMISTRY FOR THE VERMEJO PARK RANCH

The following information was provided by the Oil Conservation Division (OCD) of New Mexico. A total of eight companies performed analysis on these samples. Those that could be contacted indicated EPA protocol was followed. Locations are given by section, township, and range. Below is a list of the abbreviations used and their explanations.

Abbreviation	Explanation
s.u.	Standard Units (in the case of pH, standard pH units)
umhos/cm	micro mhos (1/ohm) per centimeter
mg/L	milligrams per liter
meq/L	milliequivalents per liter

Produced water chemistry

Well		VPR A 1	VPR A 1	VPR A 1	VPR A 1	VPR A 1	VPR A 1	VPR A 1	VPR A 1	VPR A 2	VPR A 2
Date		6/28/1999	9/25/1999	10/21/1999	11/4/1999	11/11/1999	1/5/2000	5/4/2000	6/9/2000	8/10/1999	8/31/1999
Analyte	Unit										
Chloride	mg/L	92	667	848	727	545	272	630	440	320	190
Sulfate	mg/L		147	20	14	30	13	8	6	0	0
Bicarbonate	ppm	439	1464	1720	1622	1647	1427	1488	1561	1293	1351
Calcium	mg/L	19	64	152	72	148	144	24	36	8	7
Magnesium	mg/L	9	29	22	5	22	34	10	5	5	3
Iron	ppm		2	4	3	8	1	1	2	0	3
Barium	mg/L		0	0	0	0	0		0	0	0
Strontium	mg/L		0	0	0	0	0		0	0	0
pH	s.u.	7.81	8.2	8.1	8.1	7.8	8.4	8.3	8.2	7.5	7.8
Temp	F	70	90	100	100	100	100		100	100	100
Dis. CO2	ppm		2	2	2	2	2		2	9	0
mole % CO2 in gas				0	0	0	0		0	0	0
Dis. H2S	ppm			0.5	0	0	2		1	0	0
Pressure	psia		50	25	25	25	25		25	25	25
Sodium	ppm	186	927	992	997	777	786	927	826	676	619
TDS	mg/L	767	3301	3754	3437	3169	3131	3087	2874	2302	2170
Resistivity	ohm-m	14.1		1.7048	1.8621	8.2368	2.0441		2.2269	2.7802	2.9493
Ionic Strength	mol/L		0.05	0.05	0.05	0.04	0.04		0.04	0.03	0.03
Calcite	SI		1.43	2.71	2.33	2.73	2.59		2.07	0.67	
Gypsum	SI		-2.32	-2.82	-3.24	-2.64	-3.02		-3.86		
Barite	SI										
Celestite	SI										
Calcite	PTB		53.6	132.6	62.6	129.1	125.5		31.2	5.5	
Gypsum	PTB										
Barite	PTB										
Celestite	PTB										

Produced water chemistry (cont.)

Well		VPR A 2	VPR A 2	VPR A 2	VPR A 2	VPR A 2	VPR A 2	VPR A 3	VPR A 3	VPR A 3	VPR A 3
Date		9/25/1999	10/14/1999	10/21/1999	11/4/1999	5/4/2000	6/9/2000	6/28/1999	9/25/1999	1/5/2000	2/9/2000
Analyte	Unit										
Chloride	mg/L	182	364	606	667	150	120	201	49	848	606
Sulfate	mg/L	12	11	8	18	17	8		31	18	15
Bicarbonate	ppm	1462	1488	1476	1220	1390	1464		1317	1451	1634
Calcium	mg/L	60	92	204	44	20	12		96	184	36
Magnesium	mg/L	44	66	46	24	5	2		49	39	2
Iron	ppm	5	1	1	1	2	9		12	4	3
Barium	mg/L	0	0	0	0		0		0	0	0
Strontium	mg/L	0	0	0	0		0		0	0	0
pH	s.u.	7.8	7.9	7.8	8.2	7.6	8	10.03	7.9	7.8	7.8
Temp	F	90	100	100	100		100	70	90	100	100
Dis. CO2	ppm	2	3	2	2		2		2	2	2
mole % CO2 in gas			0	0	0		0			0	0
Dis. H2S	ppm		0.5	1	0		0.5		0.03	0.5	0.5
Pressure	psia	50	25	25	25		25		50	25	25
Sodium	ppm	523	572	632	805	597	616	371	340	820	971
TDS	mg/L	2288	2593	2972	2778	2179	2222	1053	1894	3360	3264
Resistivity	ohm-m		2.4682	2.1534	2.3038		2.88	4.4		1.9048	1.9608
Ionic Strength	mol/L	0.03	0.03	0.04	0.04		0.03			0.05	0.04
Calcite	SI	1.1	2.33	2.77	1.94		1.61		1.36	2.64	2.11
Gypsum	SI	-3.39	-3.27	-3.12	-3.32		-4.16		-2.8	-2.81	-3.46
Barite	SI										
Celestite	SI										
Calcite	PTB	47.8	80	177.9	38		10.2			160.3	31.2
Gypsum	PTB										
Barite	PTB										
Celestite	PTB										

Produced water chemistry (cont.)

Well		VPR A 3	VPR A 3	VPR A 4	VPR A 4	VPR A 4	VPR A 4	VPR A 4	VPR A 6	VPR A 6	VPR A 6
Date		5/4/2000	6/9/2000	8/4/1999	9/25/1999	1/5/2000	2/9/2000	6/9/2000	6/28/1999	8/10/1999	8/31/1999
Analyte	Unit										
Chloride	mg/L	460	370	51	17	485	303	90	132	600	105
Sulfate	mg/L	8	11	210	27	18	11	8	115	0	0
Bicarbonate	ppm	1561	1488	927	1356	1305	1342	1351	268	1239	1337
Calcium	mg/L	16	16	19	180	168	16	12	29	9	3
Magnesium	mg/L	5	2	2	51	27	5	2	9	7	2
Iron	ppm	1	2	0	25	3	1	1		0	3
Barium	mg/L		0	0	0	0	0	0		0	0
Strontium	mg/L		0	0	0	0	0	0		0	0
pH	s.u.	8.2	8	8.8	7.7	8	7.6	7.9	8.45	7.4	7.8
Temp	F		100	90	90	100	100	100	72	100	100
Dis. CO2	ppm		2		2	2	2	2		8	0
mole % CO2 in gas			0			0	0	0		0	0
Dis. H2S	ppm		3			1	0	1.5		0	0
Pressure	psia		25	50	50	25	25	25		25	25
Sodium	ppm	862	784	459	323	571	680	554	229	832	565
TDS	mg/L	2912	2671	1672	1888	2574	2357	2017	1076	2687	2012
Resistivity	ohm-m		2.3961			2.4864	2.7153	3.173	6.4	2.3818	3.1809
Ionic Strength	mol/L		0.04	0.02	0.03	0.04	0.03	0.02		0.04	0.02
Calcite	SI		1.67	1.47	1.45	2.58	1.66	1.64		0.66	
Gypsum	SI		-3.93	-2.6	-2.63	-2.82	-3.91	-4.13			
Barite	SI										
Celestite	SI										
Calcite	PTB		13.7	16	148.8	146.3	13.7	10.2		6.1	
Gypsum	PTB										
Barite	PTB										
Celestite	PTB										

Produced water chemistry (cont.)

Well		VPR A 6	VPR A 6	VPR A 7	VPR A 7	VPR A 7	VPR A 7	VPR A 7	VPR A 7	VPR A 7	VPR A 7
Date		5/4/2000	8/28/2002	7/15/1999	7/17/1999	10/14/1999	10/21/1999	10/28/1999	11/4/1999	11/11/1999	1/5/2000
Analyte	Unit										
Chloride	mg/L	50	186	151	756	424	788	788	424	485	424
Sulfate	mg/L	8	3	56	80	37	24	44	21	19	59
Bicarbonate	ppm	1464	1439.6	20	85	1229	1537	654	1366	1342	1360
Calcium	mg/L	24	3.6	80	32	152	176	200	52	216	144
Magnesium	mg/L	7	1	21	12	61	41	51	7	29	27
Iron	ppm	1	6	0	4	1	1		0	0	1
Barium	mg/L		0.5	0	0	0	0	0	0	0	0
Strontium	mg/L		0.6	0	0	0	0	0	0	0	0
pH	s.u.	7.9	8.11	7	5.6	7.6	7.9	8	8.1	7.9	7.7
Temp	F			100	100	100	100	100	100	100	100
Dis. CO2	ppm			26	21	1	2	2	2	2	2
mole % CO2 in gas				0	0	0	0	0	0	0	0
Dis. H2S	ppm			0	0	0	0.5	0	0	0	0.5
Pressure	psia			25	25	25	25	25	25	25	25
Sodium	ppm	547	650.3	1	501	466	822	453	727	527	599
TDS	mg/L	2100	2295.1	329	1466	2369	3388	2190	2597	2618	2613
Resistivity	ohm-m			19.4529	4.3656	2.7016	1.889	2.9224	2.4644	12.1442	2.4493
Ionic Strength	mol/L			0.01	0.02	0.03	0.05	0.03	0.03	0.04	0.04
Calcite	SI			-2.19	-1.36	2.86	2.67	2.13	2.19	2.71	2.55
Gypsum	SI			-2.53	-2.76	-2.56	-2.7	-2.37	-3.15	-2.71	-2.36
Barite	SI										
Celestite	SI										
Calcite	PTB					132.6	153.4	170.5	45.1	188.2	125.4
Gypsum	PTB										
Barite	PTB										
Celestite	PTB										

Produced water chemistry (cont.)

Well		VPR A 7	VPR A 7	VPR A 7	VPR A 8	VPR A 8	VPR A 8	VPR A 8	VPR A 8	VPR A 8
Date		2/9/2000	5/4/2000	8/28/2002	7/30/1999	9/25/1999	10/14/1999	10/21/1999	10/28/1999	11/4/1999
Analyte	Unit									
Chloride	mg/L	788	310	404	590	364	303	727	545	182
Sulfate	mg/L	50	11	3	485	21	14	14	16	11
Bicarbonate	ppm	1417	1439	1220	231	1513	1395	1647	703	1561
Calcium	mg/L	44	12	8	108	56	88	160	156	64
Magnesium	mg/L	2	7	2	26	24	22	73	34	12
Iron	ppm	0		2	19	5	5	1	3	1
Barium	mg/L	0		1	0	0	0	0	0	0
Strontium	mg/L	0		3	0	0	0	0	0	0
pH	s.u.	7	7.7	7.94	9.1	7.8	8		8.4	8.4
Temp	F	100			100	90	100	100	100	100
Dis. CO2	ppm	2			0	2	2	2	2	2
mole % CO2 in gas		0			0		0	0	0	0
Dis. H2S	ppm	0.5			0		0	1	0	0.5
Pressure	psia	25			25	50	25	25	25	25
Sodium	ppm	1015	721	704	529	707	586	777	383	615
TDS	mg/L	3316	2500	2352	1969	2690	2408	3398	1837	2445
Resistivity	ohm-m	1.93			3.2504		2.6578	1.8835	3.4839	2.6176
Ionic Strength	mol/L	0.05			0.03	0.04	0.03	0.05	0.03	0.03
Calcite	SI	2				1.03	1.83	2.69	2.09	2.39
Gypsum	SI	-2.89			-1.62	-3.18	-3.14	-2.99	-2.88	-3.35
Barite	SI									
Celestite	SI									
Calcite	PTB	38.1				43.9	75.6	139.5	133.9	55.7
Gypsum	PTB									
Barite	PTB									
Celestite	PTB									

Produced water chemistry (cont.)

Well		VPR A 8	VPR A 8	VPR A 8	VPR A 8	VPR A 8	VPR A 9	VPR A 9	VPR A 9	VPR A 9	VPR A 9
Date		11/11/1999	1/5/2000	2/9/2000	5/4/2000	6/9/2000	7/31/1999	9/25/1999	10/14/1999	10/21/1999	10/28/1999
Analyte	Unit										
Chloride	mg/L	424	242	182	770	410	84	485	242	545	667
Sulfate	mg/L	13	11	20	14	12	283	30	22	30	22
Bicarbonate	ppm	1549	1488	1634	1439	1488	146	1112	1054	1348	517
Calcium	mg/L	136	172	8	20	12	35	92	72	172	180
Magnesium	mg/L	27	17	2	5	2	17	44	27	22	12
Iron	ppm	1	1	1	3	4	2	9	4	7	3
Barium	mg/L	0	0	0		0	0	0	0	0	0
Strontium	mg/L	0	0	0		0	0	0	0	0	0
pH	s.u.	8.4	7.7	7.5	8.5	8.3	10.1	7.7	7.5	7.9	7.5
Temp	F	100	100	100		100	100	90	100	100	100
Dis. CO2	ppm	2	3			2	0	2	3	2	2
mole % CO2 in gas		0	0	0		0	0		0	0	0
Dis. H2S	ppm	0	1.5	0.5		0	0		0.5	1	0
Pressure	psia	25	25	25		25	25	50	25	25	25
Sodium	ppm	638	493	730	1016	815	173	559	431	637	409
TDS	mg/L	2807	2423	2576	3264	2739	738	2331	1848	2754	1807
Resistivity	ohm-m	9.7264	2.6414	2.4845		2.3366	8.6721		3.4632	2.3239	3.5417
Ionic Strength	mol/L	0.04	0.03	0.03		0.04	0.01	0.04	0.02	0.04	0.03
Calcite	SI	2.64	2.61			1.55		1.02	3.02	2.62	1.88
Gypsum	SI	-3.03	-3	-3.94		-4.02	-2.21	-2.84	-3	-2.58	-2.68
Barite	SI										
Celestite	SI										
Calcite	PTB	118.6	149.9			10.2		70.7	62.2	149.9	149.1
Gypsum	PTB										
Barite	PTB										
Celestite	PTB										

Produced water chemistry (cont.)

Well		VPR A 9	VPR A 9	VPR A 9	VPR A 9	VPR A 9	VPR A 9	VPR A 10	VPR A 10	VPR A 10	VPR A 10
Date		11/4/1999	11/11/1999	1/5/2000	2/9/2000	5/4/2000	6/9/2000	8/4/1999	9/25/1999	10/21/1999	10/28/1999
Analyte	Unit										
Chloride	mg/L	364	545	667	121	120	110	58	152	1151	1454
Sulfate	mg/L	63	28	30	20	16	14	205	22	17	20
Bicarbonate	ppm	1244	1244	1240	1342	1269	1220	777	1317	1354	644
Calcium	mg/L	224	148	112	8	12	8	16	108	188	228
Magnesium	mg/L	24	22	19	2	7	2	7	113	51	34
Iron	ppm	8	8	2	1		3	3	3	3	2
Barium	mg/L	0	0	0	0		0	0	0	0	0
Strontium	mg/L	0	0	0	0		0	0	0	0	0
pH	s.u.	7.9	8	7.9	7.8	7.8	8.2	6.5	7.8	7.9	8.2
Temp	F	100	100	100	100		100	90	90	100	100
Dis. CO2	ppm	2	2	2	2		2		3	2	2
mole % CO2 in gas		0	0	0	0		0			0	0
Dis. H2S	ppm	0.2	0.5	0.5	0		0			1	0
Pressure	psia	25	25	25	25		25	50	50	25	25
Sodium	ppm	433	624	750	581	537	525	397	268	953	869
TDS	mg/L	2352	2611	2818	2074	1961	1879		1983	3714	3249
Resistivity	ohm-m	2.7211	10.2564	2.2711	3.0858		3.4061			1.7232	1.9698
Ionic Strength	mol/L	0.03	0.04	0.04	0.03		0.02	0.02	0.03	0.06	0.05
Calcite	SI	2.74	2.58	2.36	1.36		1.37	-0.98	1.31	2.53	2.03
Gypsum	SI	-2.17	-2.67	-2.74	-3.94		-4.06	-2.69	-2.96	-2.85	-2.69
Barite	SI										
Celestite	SI										
Calcite	PTB	195.2	128.8	97.4	6.7		6.7		88.5	163.6	191.4
Gypsum	PTB										
Barite	PTB										
Celestite	PTB										

Produced water chemistry (cont.)

Well		VPR A 10	VPR A 10	VPR A 10	VPR A 10	VPR A 10	VPR A 10	VPR A 11	VPR A 11	VPR A 11	VPR A 11
Date		11/4/1999	11/11/1999	1/5/2000	2/9/2000	5/4/2000	6/9/2000	8/8/1999	9/25/1999	10/14/1999	10/21/1999
Analyte	Unit										
Chloride	mg/L	848	848	848	2485	610	620	108	909	788	1030
Sulfate	mg/L	62	15	14	43	10	12	190	27	14	20
Bicarbonate	ppm	1366	1366	1378	927	1391	1342	854	1366	1210	1220
Calcium	mg/L	216	196	204	16	24	16	17	56	128	176
Magnesium	mg/L	24	7	19	10	5	2	3	22	46	68
Iron	ppm	1	3	2	20	1	7	4	4	3	3
Barium	mg/L	0	0	0	0		0	0	0	0	0
Strontium	mg/L	0	0	0	0		0	0	0	0	0
pH	s.u.	8.4	8.3	8.4	7.6	8.1	8.3	6.6	7.5	7.9	7.9
Temp	F	100	100	100	100		100	100	90	100	100
Dis. CO2	ppm	2	2	2	2		2	0	2	3	2
mole % CO2 in gas		0	0	0	0		0	0		0	0
Dis. H2S	ppm	1.5	1.5	0.5	0		0.5	0		0	1
Pressure	psia	25	25	25	25		25	25	50	25	25
Sodium	ppm	801	834	806	1944	887	891	458	1011	740	807
TDS	mg/L	3317	3266	3269	5425	2927	2883	1630	3395	1926	3321
Resistivity	ohm-m	1.9295	7.6739	1.9578	1.1797		2.2199	3.9264		2.1873	1.9271
Ionic Strength	mol/L	0.05	0.05	0.05	0.09		0.04	0.02	0.05	0.04	0.05
Calcite	SI	2.66	2.62	2.64	0.99		1.58		0.64	2.22	2.47
Gypsum	SI	-2.21	-2.84	-2.87	-3.46		-3.9	-2.67	-3.09	-3.04	-2.8
Barite	SI										
Celestite	SI										
Calcite	PTB	188.2	170.7	177.7	12.5		13.6		36.7	111	153.1
Gypsum	PTB										
Barite	PTB										
Celestite	PTB										

Produced water chemistry (cont.)

Well		VPR A 11	VPR A 11	VPR A 11	VPR A 11	VPR A 11	VPR A 11	VPR A 11	VPR A 12	VPR A 12	VPR A 12
Date		10/28/1999	11/4/1999	11/11/1999	1/5/2000	2/9/2000	5/4/2000	6/9/2000	8/2/1999	9/25/1999	10/14/1999
Analyte	Unit										
Chloride	mg/L	1151	727	303	545	727	460	325	146	121	1394
Sulfate	mg/L	24	55	14	13	22	19	13	310	36	25
Bicarbonate	ppm	508	1183	1415	1220	1293	1293	1317	134	1044	939
Calcium	mg/L	196	212	188	152	28	20	12	33	68	84
Magnesium	mg/L	51	17	12	22	2	10	2	9	35	32
Iron	ppm	3	3	4	2	2	2	14	2	3	3
Barium	mg/L	0	0	0	0	0		0	0	0	0
Strontium	mg/L	0	0	0	0	0		0	0	0	0
pH	s.u.	8	8	7.8	8	7.6	8	8	9.7	9	8.2
Temp	F	100	100	100	100	100		100	100	90	100
Dis. CO2	ppm	2	2	2	2	2		2	0	2	2
mole % CO2 in gas		0	0	0	0	0		0	0		0
Dis. H2S	ppm	0	0	0.5	1	0		0	0		2
Pressure	psia	25	25	25	25	25		25	25	50	25
Sodium	ppm	628	668	498	603	933	753	696	139	3.43	1113
TDS	mg/L	2558	2862	2430	2555	3005	2555	2365	871	1652	3587
Resistivity	ohm-m	2.502	2.2362	12.8514	2.5049	2.1298		2.7061	7.3479		1.7842
Ionic Strength	mol/L	0.04	0.04	0.03	0.04	0.04		0.03	0.01	0.02	0.06
Calcite	SI	1.83	2.59	2.78	2.48	1.79		1.52		2.28	1.87
Gypsum	SI	-2.66	-2.25	-2.86	-2.99	-3.4		-3.95	-2.2	-2.84	-2.97
Barite	SI										
Celestite	SI										
Calcite	PTB	159.2	184.5	164	132.2	24.1		10.2		59.1	72.1
Gypsum	PTB										
Barite	PTB										
Celestite	PTB										

Produced water chemistry (cont.)

Well		VPR A 12	VPR A 12	VPR A 12	VPR A 12	VPR A 12	VPR A 12	VPR A 12	VPR A 13	VPR A 13	VPR A 13
Date		10/21/1999	10/28/1999	11/4/1999	11/11/1999	1/5/2000	2/9/2000	5/4/2000	8/4/1999	9/25/1999	11/4/1999
Analyte	Unit										
Chloride	mg/L	1030	667	1091	909	1151	545	120	160	2182	1394
Sulfate	mg/L	15	20	60	14	40	21	10	220	62	72
Bicarbonate	ppm	1110	634	1061	951	927	1439	1390	762	741	793
Calcium	mg/L	152	172	244	152	276	20	20	36	144	296
Magnesium	mg/L	63	41	19	17	15	5	7	7	39	32
Iron	ppm	1	3	3	1	2	1		4	98	16
Barium	mg/L	0	0	0	0	0	0		0	0	0
Strontium	mg/L	0	0	0	0	0	0		0	0	0
pH	s.u.	8	8	8.1	8.3	7.9	7.7	8.1	5.9	7.1	8
Temp	F	100	100	100	100	100	100		90	90	100
Dis. CO2	ppm	2	2	2	2	2	2			2	2
mole % CO2 in gas		0	0	0	0	0	0				0
Dis. H2S	ppm	3	0	2	0.5	1	1				0.5
Pressure	psia	25	25	25	25	25	25		50	50	25
Sodium	ppm	800	406	820	748	770	873	570	442	1485	837
TDS	mg/L	3170	1940	3295	2791	3179	2903	2117		4751	3424
Resistivity	ohm-m	2.0189	3.299	1.9423	8.5561	2.0132	2.2046				1.8692
Ionic Strength	mol/L	0.05	0.03	0.05	0.04	0.05	0.04		0.03	0.08	0.05
Calcite	SI	2.33	2.04	2.49	2.26	2.43	1.74		-1.3	0.27	2.33
Gypsum	SI	-2.97	-2.76	-2.18	-2.95	-2.31	-3.57		-2.34	-2.42	-2.05
Barite	SI										
Celestite	SI										
Calcite	PTB	131.9	146.6	211.7	131.6	238.4	17.2			42.3	252.8
Gypsum	PTB										
Barite	PTB										
Celestite	PTB										

Produced water chemistry (cont.)

Well		VPR A 13	VPR A 13	VPR A 13	VPR A 14	VPR A 14	VPR A 14	VPR A 14	VPR A 14	VPR A 14
Date		2/10/2000	5/4/2000	6/9/2000	8/4/1999	9/25/1999	10/21/1999	11/4/1999	11/11/1999	1/5/2000
Analyte	Unit									
Chloride	mg/L	2363	210	255	105	424	545	485	364	545
Sulfate	mg/L	24	15	16	190	20	32	54	15	14
Bicarbonate	ppm	1537	1244	1265	828	1327	1549	1464	1451	1366
Calcium	mg/L	72	24	20	38	72	136	232	192	256
Magnesium	mg/L	2	7	2	7	46	32	41	27	15
Iron	ppm	2	3	9	4	4	5	2	2	0
Barium	mg/L	0		0	0	0	0	0	0	0
Strontium	mg/L	0		0	0	0	0	0	0	0
pH	s.u.	7.6	7.9	8.1	9.6	8.2	7.8	8	8	7.8
Temp	F	100		100	90	90	100	100	100	100
Dis. CO2	ppm	2		2		2	2	2	2	2
mole % CO2 in gas		0		0			0	0	0	0
Dis. H2S	ppm	0		2.5			0.5	0.5	0.5	0.5
Pressure	psia	25		25	50	50	25	25	25	25
Sodium	ppm	2037		623	414	615	736	548	519	553
TDS	mg/L	6035	2071	2181		2508	3030	2824	2568	2749
Resistivity	ohm-m	1.0605		2.9344			2.1122	2.2663	12.3314	2.3281
Ionic Strength	mol/L	0.09		0.03	0.02	0.04	0.04	0.04	0.03	0.04
Calcite	SI	2.08		1.71	2.53	1.49	2.64	2.82	2.81	2.8
Gypsum	SI	-3.08		-3.65	-2.35	-3.12	-2.65	-2.25	-2.84	-2.78
Barite	SI									
Celestite	SI									
Calcite	PTB	62.4		17.1	33.1	60.6	118.6	202.3	167.5	223.2
Gypsum	PTB									
Barite	PTB									
Celestite	PTB									

Produced water chemistry (cont.)

Well		VPR A 14	VPR A 14	VPR A 14	VPR A 15	VPR A 15	VPR A 15	VPR A 15	VPR A 15	VPR A 15	VPR A 16
Date		2/10/2000	5/4/2000	6/9/2000	7/23/1999	8/31/1999	9/25/1999	11/11/1999	1/5/2000	5/4/2000	9/24/1999
Analyte	Unit										
Chloride	mg/L	303	80	144	110	1650	970	1879	909	280	1879
Sulfate	mg/L	34	14	8	9	4	21	37	27	11	23
Bicarbonate	ppm	1464	1378	1317	732	1088	1390	1183	1220	1464	1267
Calcium	mg/L	12	12	12	3	27	68	228	248	24	56
Magnesium	mg/L	2	5	2	3	6	51	17	36	2	53
Iron	ppm	7	1	6	7	1	8	27	3	2	7
Barium	mg/L	0		0	0	0	0	0	0		0
Strontium	mg/L	0		0	0	0	0	0	0		0
pH	s.u.	7.6	8	8	8	8.4	7.8	7.2	8.4	7.5	7.8
Temp	F	100		100	100	100	90	100	100		90
Dis. CO2	ppm	2		2	0	0	0	0	2		2
mole % CO2 in gas		0		0	0	0		0	0		
Dis. H2S	ppm	0.5		3	0	0.5		0	1		
Pressure	psia	25		25	25	25	50	25	25		50
Sodium	ppm	747	555	576	342	1440	988	1388	709	707	1543
TDS	mg/L	2562	2044	2059	1199	4215	3488	4732	3149	2488	4829
Resistivity	ohm-m	2.498		3.1083	5.3378	1.5184		4.611	2.0324		
Ionic Strength	mol/L	0.03		0.03	0.02	0.06	0.05	0.07	0.05		0.08
Calcite	SI	1.61		1.52			1.03		2.62		0.79
Gypsum	SI	-3.54		-4.16	-4.67	-4.2	-3.14	-2.43	-2.53		-3.23
Barite	SI										
Celestite	SI										
Calcite	PTB	10.2		10.2			53.1		215.8		40.2
Gypsum	PTB										
Barite	PTB										
Celestite	PTB										

Produced water chemistry (cont.)

Well		VPR A 16	VPR A 16	VPR A 16	VPR A 16	VPR A 16	VPR A 16	VPR A 16	VPR A 17	VPR A 17	VPR A 17
Date		10/21/1999	10/28/1999	11/4/1999	11/11/1999	1/5/2000	5/4/2000	6/9/2000	7/20/1999	9/24/1999	10/14/1999
Analyte	Unit										
Chloride	mg/L	1151	1454	545	848	667	550	470	63	485	424
Sulfate	mg/L	60	22	75	24	13	11	14	264	25	47
Bicarbonate	ppm	1488	625	1354	1317	1317	1366	1351	988	1512	1695
Calcium	mg/L	244	147	284	208	96	16	16	14	48	92
Magnesium	mg/L	51	39	27	27	41	2	2	4	36	46
Iron	ppm	32	3	25	11	1	1	12	0	4	3
Barium	mg/L	0	0	0	0	0		0	0	0	0
Strontium	mg/L	0	0	0	0	0		0	0	0	0
pH	s.u.	7.6	8.2	7.6	7.8	8.2	7.7	8.1	9	4.8	7.8
Temp	F	100	100	100	100	100		100	100	90	100
Dis. CO2	ppm	2	2	2	2	2		2		50	2
mole % CO2 in gas		0	0	0	0	0		0	0	3	0
Dis. H2S	ppm	0.2	0	0	0	0		3	0		0.5
Pressure	psia	25	25	25	25	25		25	2.5		25
Sodium	ppm	959	945	523	768	747	854	798	516	773	744
TDS	mg/L	3953	3233	2808	3192	2881	2799	2651	1849	2883	3048
Resistivity	ohm-m	1.619	1.9796	2.2792	8.3333	2.2215		2.4142	3.4613		2.0997
Ionic Strength	mol/L	0.06	0.05	0.04	0.05	0.04		0.04	0.02	0.04	0.04
Calcite	SI	2.73	1.82	2.84	2.61	2.34		1.59		0.97	2.54
Gypsum	SI	-2.21	-2.8	-2.03	-2.63	-3.17		-3.83	-2.63	-3.17	-2.64
Barite	SI										
Celestite	SI										
Calcite	PTB	212.7	124.8	247.6	181.1	83.5		13.6		37.1	80.2
Gypsum	PTB										
Barite	PTB										
Celestite	PTB										

Produced water chemistry (cont.)

Well		VPR A 17	VPR A 17	VPR A 17	VPR A 17	VPR A 17	VPR A 18	VPR A 18	VPR A 18	VPR A 18
Date		11/4/1999	1/5/2000	2/10/2000	5/4/2000	6/9/2000	7/26/1999	7/28/1999	9/24/1999	10/14/1999
Analyte	Unit									
Chloride	mg/L	424	364	303	185	280	210	4100	1333	2182
Sulfate	mg/L	59	14	14	8	11	42	630	67	77
Bicarbonate	ppm	1525	1537	1635	1586	1695	183	660	751	1024
Calcium	mg/L	216	96	16	12	20	20	152	92	212
Magnesium	mg/L	17	17	2	7	2	8	48	44	32
Iron	ppm	2	3	2	2	6	0	247	21	9
Barium	mg/L	0	0	0		0	0	0	0	0
Strontium	mg/L	0	0	0		0	0	0	0	0
pH	s.u.	7.7	8.2	7.7	8	7.9	8	8.9	7.1	7
Temp	F	100	100	100		100	100	100	90	100
Dis. CO2	ppm	2	2	2		2	0	0	2	4
mole % CO2 in gas		0	0	0		0	0	0		0
Dis. H2S	ppm	0.5	0	0		2.5	0	0		0
Pressure	psia	25	25	25		25	25	25	50	25
Sodium	ppm	598	680	797	694	799	187	2944	991	1534
TDS	mg/L	2839	2708	2767	2492	2807	650	8534	3299	5061
Resistivity	ohm-m	2.2543	2.3634	2.313		2.28	9.8642	0.7499		1.2646
Ionic Strength	mol/L	0.04	0.04	0.04		0.04	0.01	0.14	0.06	0.08
Calcite	SI	2.82	2.48	1.75		1.88			0.15	1.94
Gypsum	SI	-2.21	-3.12	-3.83		-3.84	-3.17	-1.5	-2.53	-2.16
Barite	SI									
Celestite	SI									
Calcite	PTB	188.4	83.6	13.7		17.2			18.9	180.9
Gypsum	PTB									
Barite	PTB									
Celestite	PTB									

Produced water chemistry (cont.)

Well		VPR A 18	VPR A 19	VPR A 19	VPR A 19	VPR A 19	VPR A 19	VPR A 19	VPR A 19	VPR A 19
Date		2/10/2000	7/26/1999	7/23/1999	9/24/1999	10/28/1999	11/4/1999	11/11/1999	1/5/2000	2/10/2000
Analyte	Unit									
Chloride	mg/L	7514	346	810	909	909	545	545	606	424
Sulfate	mg/L	48	46	250	35	34	93	41	22	22
Bicarbonate	ppm	366	219	305	1647	664	1451	1549	1464	1634
Calcium	mg/L	848	6	65	52	236	252	136	128	32
Magnesium	mg/L	58	1	18	31	24	32	19	10	5
Iron	ppm	0	1	8	4	25	22	10	4	5
Barium	mg/L	0	0	0	0	0	0	0	0	0
Strontium	mg/L	0	0	0	0	0	0	0	0	0
pH	s.u.	6.6	7.8	8.2	7.8	7.8	7.7	7.8	8	7.5
Temp	F	100	100	100	90	100	100	100	100	100
Dis. CO2	ppm	2	0	0	3	2	2	2	2	2
mole % CO2 in gas		0	0	0		0	0	0	0	0.5
Dis. H2S	ppm	0	0	0		0	0	0	0	0
Pressure	psia	25	25	25	50	25	25	25	25	25
Sodium	ppm	3951	320	651	1108	540	595	765	789	855
TDS	mg/L	12785	938	2099	3786	2407	2968	3055	3019	2972
Resistivity	ohm-m	0.5066	6.823	3.0491		2.6589	2.1563	8.366	2.1199	2.1534
Ionic Strength	mol/L	0.22	0.01	0.03	0.06	0.04	0.04	0.04	0.04	0.04
Calcite	SI	1.51			0.95	2.14	2.85	2.64	2.56	2.05
Gypsum	SI	-2	-3.63	-2.05	-3.03	-2.43	-1.98	-2.53	-2.81	-3.35
Barite	SI									
Celestite	SI									
Calcite	PTB	168.3			40	199.7	219.8	118.6	111.5	27.7
Gypsum	PTB									
Barite	PTB									
Celestite	PTB									

Produced water chemistry (cont.)

Well		VPR A 19	VPR A 19	VPR A 20	VPR A 20	VPR A 20	VPR A 21	VPR A 21	VPR A 21	VPR A 21	VPR A 21
Date		5/4/2000	8/28/2002	9/24/1999	2/10/2000	8/28/2002	7/19/1999	7/20/1999	9/24/1999	2/9/2000	5/4/2000
Analyte	Unit										
Chloride	mg/L	360	655	242	424	166	210	147	121	1818	180
Sulfate	mg/L	21	3	14	11	3	250	12	72	36	12
Bicarbonate	ppm	1573	1222.4	1539	1683	1317.6	634	848	1222	1317	1512
Calcium	mg/L	12	8.5	64	24	3	30	9	188	44	12
Magnesium	mg/L	5	1.5	27	2	1	4	3	46	2	5
Iron	ppm	4	2	6	1	0.6	0	1	25	2	1
Barium	mg/L		1	0	0	0.7	0	0	0	0	
Strontium	mg/L		2	0	0	0.6	0	0	0	0	
pH	s.u.	7.9	7.57	7.9	7.8	8.61	6.6	8.8	707	7	7.9
Temp	F			90	100		100	100	90	100	
Dis. CO2	ppm			2	2		0	0	2	2	
mole % CO2 in gas					0		0	0		0	
Dis. H2S	ppm				0		0	0		0.5	
Pressure	psia			50	25		25	25	50	25	
Sodium	ppm	813	830.7	61	883	596.8	453	416	271	1638	669
TDS	mg/L	2784	2631.1	2511	3027	2093.3	1581	1465	1945	4855	2390
Resistivity	ohm-m				2.1143		4.0481	4.3686		1.3182	
Ionic Strength	mol/L			0.04	0.04		0.02	0.02	0.03	-3.07	
Calcite	SI			1.2	1.96				1.42		
Gypsum	SI			-3.3	-3.76		-2.33	-4.08	-2.2	37.8	
Barite	SI										
Celestite	SI										
Calcite	PTB			52	20.7				154.1		
Gypsum	PTB										
Barite	PTB										
Celestite	PTB										

Produced water chemistry (cont.)

Well		VPR A 21	VPR A 22	VPR A 22	VPR A 22	VPR A 22	VPR A 22	VPR A 22	VPR A 22	VPR A 22	VPR A 22
Date		6/9/2000	7/29/1999	9/24/1999	10/14/1999	10/21/1999	10/28/1999	11/4/1999	11/11/1999	1/5/2000	2/9/2000
Analyte	Unit										
Chloride	mg/L	210	2800	364	727	545	848	545	364	242	121
Sulfate	mg/L	10	160	23	16	14	11	56	17	40	29
Bicarbonate	ppm	1464	841	143	1717	1512	644	1390	1378	1586	1610
Calcium	mg/L	12	304	76	144	156	212	212	128	136	12
Magnesium	mg/L	2	19	36	41	29	80	34	34	7	5
Iron	ppm	8	0	12	7	5		3	2	6	3
Barium	mg/L	0	0	0	0	0	0	0	0	0	0
Strontium	mg/L	0	0	0	0	0	0	0	0	0	0
pH	s.u.	8.2	11.9	7.7	7.8	7.7	8.2	7.8	7.8	7.8	7.3
Temp	F	100	100	90	100	100	100	100	100	100	100
Dis. CO2	ppm	2	0	1	4	2	2	2	2	2	2
mole % CO2 in gas		0	0		0	0	0	0	0	0	0
Dis. H2S	ppm	0.5	0		0	0.5	0	1	0.5	0.5	0.5
Pressure	psia	25	25	50	25	25	25	25	25	25	25
Sodium	ppm	675	1825	634	883	696	403	596	552	604	676
TDS	mg/L	2373	5949	2574	3528	2952	2198	2833	2473	2615	2453
Resistivity	ohm-m	2.697	1.0758		1.8141	2.168	2.9117	2.2591	11.5942	2.4474	2.6091
Ionic Strength	mol/L	0.03	0.1	0.04	0.05	0.04	0.03	0.04	0.03	0.03	0.03
Calcite	SI	1.61		1.04	2.38	2.67	2.14	2.74	2.59	2.73	1.69
Gypsum	SI	-4.07	-1.74	-3.03	-2.95	-2.95	-2.98	-2.26	-2.93	-2.51	-3.62
Barite	SI										
Celestite	SI										
Calcite	PTB	10.2		59.4	125.2	136	180.3	184.8	111.5	118.6	10.3
Gypsum	PTB										
Barite	PTB										
Celestite	PTB										

Produced water chemistry (cont.)

Well		VPR A 22	VPR A 22	VPR A 23	VPR A 23	VPR A 23	VPR A 23	VPR A 23	VPR A 23	VPR A 23	VPR A 23
Date		5/4/2000	6/9/2000	7/19/1999	7/21/1999	9/24/1999	10/14/1999	10/21/1999	10/28/1999	11/4/1999	11/11/1999
Analyte	Unit										
Chloride	mg/L	170	295	100	80	970	1333	909	1273	848	667
Sulfate	mg/L	16	25	270	150	15	38	27	29	58	21
Bicarbonate	ppm	1390	1390	402	122	1390	1102	1329	673	1281	1220
Calcium	mg/L	20	11	37	84	96	104	224	207	256	216
Magnesium	mg/L	5	2	1	23	56	56	27	53	22	17
Iron	ppm	1	6	0	0	8		3	5	3	4
Barium	mg/L		0	0	0	0	0	0	0	0	0
Strontium	mg/L		0	0	0	0	0	0	0	0	0
pH	s.u.	7.8	7.9	6.5	6.6	7.7	8	7.9	8.2	8	7.8
Temp	F		100	100	100	90	100	100	100	100	100
Dis. CO2	ppm		2	0		2	3	2	2	2	0
mole % CO2 in gas			0	0	0		0	0	0	0	0
Dis. H2S	ppm		2	0	0		0	1	0	0.5	0.5
Pressure	psia		25	25	25	50	25	25	25	25	25
Sodium	ppm	609	711	301	30	944	1073	795	754	725	662
TDS	mg/L	2210	2434	1111	489	3476	3706	3311	2990	3190	2763
Resistivity	ohm-m		2.6294	5.7606	13.0879		1.8269	1.933	2.1405	2.0063	10.2894
Ionic Strength	mol/L		0.03	0.02	0.01	0.06	0.06	0.05	0.05	0.05	0.04
Calcite	SI		1.53			1.04	1.92	2.65	2.03	2.68	
Gypsum	SI		-3.71	-2.22	-2.11	-3.17	-2.72	-2.56	-2.57	-2.18	-2.66
Barite	SI										
Celestite	SI										
Calcite	PTB		9.3			74.6	89.5	195.1	176.2	222.9	
Gypsum	PTB										
Barite	PTB										
Celestite	PTB										

Produced water chemistry (cont.)

Well		VPR A 23	VPR A 23	VPR A 24	VPR A 24	VPR A 24	VPR A 30	VPR A 96	VPR A 97
Date		1/5/2000	5/4/2000	9/24/1999	10/21/1999	5/4/2000	8/28/2002	8/28/2002	8/28/2002
Analyte	Unit								
Chloride	mg/L	242	120	1454	1212	750	391	7264	1888
Sulfate	mg/L	30	11	13	77	14	3	3	3
Bicarbonate	ppm	1330	1390	1586	1500	1390	1230	1098	1512.8
Calcium	mg/L	56	16	188	168	24	4	166	30
Magnesium	mg/L	41	5	63	83	7	1	47	7.5
Iron	ppm	2	1		31	2	1	20	4
Barium	mg/L	0		0	0		0.7	26	5
Strontium	mg/L	0		0	0		1	32	5.5
pH	s.u.	7.6	7.8	7.6	7.5	7.9	8.63	6.83	7.28
Temp	F	100		90	100				
Dis. CO2	ppm	2		1	2				
mole % CO2 in gas		0			0				
Dis. H2S	ppm	2			0.5				
Pressure	psia	25		50	25				
Sodium	ppm	531	579	1212	1038	976	707.4	4795.3	1733.9
TDS	mg/L	2230	2121	4516	4078	3161	2344.1	13466.3	5198.7
Resistivity	ohm-m	2.87			1.5694				
Ionic Strength	mol/L	0.03		0.07	0.06				
Calcite	SI	2.2		1.25	2.57				
Gypsum	SI	-3		-2.99	-2.26				
Barite	SI								
Celestite	SI								
Calcite	PTB	48.6		151.2	146.3				
Gypsum	PTB								
Barite	PTB								
Celestite	PTB								

Produced water chemistry (cont.)

Well		VC 2919 071	VC 2918 012J	VC 2918 012J	VBC 3019 311G	VBC 3019 311G	VBC 3019 322	VBC 3019 322
Date		1/30/1990	1/5/1990	1/25/1990	1/5/1990	3/1/1990	10/10/1989	1/5/1990
Component	Unit							
pH	s.u.	7.25	6.52	6.72	7.5	7.28	8.12	7.91
SG 75F		1.0121	1.0101	1.0145	1.0051	1.0041		1.0031
Resistivity	ohm-m	0.392	0.158	0.361	0.751	275	1.4339	1.09
Filter Solids	mg/L	764.8	428.8	386.4	306.4	128.8		150.8
CO2	mg/L							
Sulfide	mg/L							
Hardness	mg/L							
Sodium	mg/L	5656	4513	5908	2899	2950	2060	2136
Calcium	mg/L	305	603	854	132	90	48.01	24
Magnesium	mg/L	124	57	216	36	33	5.69	30
Iron	mg/L	8	0	121	0	6		0
Potassium	mg/L						11.6	
Barium	mg/L							
Chloride	mg/L	9249	7955	11014	4396	4467	2388.75	2634
Sulfate	mg/L	0	0	10	0	0	0.1	0
Carbonate	mg/L	0	0	0	0	0	0	0
Bicarbonate	mg/L	665	409	683	714	592	1492.84	1360
Hydroxide	mg/L	0	0	0	0	0		0
TDS	mg/L	16007	13537	18816	8177	8138	5620	6184
Conductivity	umhos/cm						6974	
Alkalinity	mg/L						1223.64	
Sodium Ad. Ratio							74.89	
Cations	meq/L						92.76	
Anions	meq/L						91.86	
% Diff							0.49	

Produced water chemistry (cont.)

Well		VBC 3019 322	VBC 3018 253B	VBC 3018 253B	VBC 3018 253B	VBC 3018 241M	VBC 3018 241M
Date		3/1/1990	10/10/1989	1/5/1990	3/1/1990	10/10/1989	10/10/1989
Component	Unit						
pH	s.u.	8.41	8.13	7.97	8.14	8.03	8.07
SG 75F		1.0029		1.0005	1.0005		
Resistivity	ohm-m	1.17	2.2836	2.18	1.98	1.7161	1.6966
Filter Solids	mg/L	140.8		20.493	10.8		
CO2	mg/L						
Sulfide	mg/L						
Hardness	mg/L						
Sodium	mg/L	2177	1307.4	1120	1235	1746	1818
Calcium	mg/L	30	25.27	12	18	40.43	48.85
Magnesium	mg/L	19	4.12	18	9	9.26	4.15
Iron	mg/L	0		0	0		
Potassium	mg/L		9.12			13.2	11
Barium	mg/L						
Chloride	mg/L	2751	1199.33	1085	1134	1823.77	1863.42
Sulfate	mg/L	0	0.1	0	0	0.1	0.1
Carbonate	mg/L	0	0	0	0		0
Bicarbonate	mg/L	1226	1397.57	1238	1421	1562.89	1555.65
Hydroxide	mg/L	0		0	0		
TDS	mg/L	6206	3572	3473	3817	4832	4804
Conductivity	umhos/cm		4379			5827	5894
Alkalinity	mg/L		1145.55			1281.06	1275.12
Sodium Ad. Ratio			63.58			64.43	67.09
Cations	meq/L		58.7			79.06	82.14
Anions	meq/L		56.74			77.07	78.07
% Diff			1.7			1.28	2.54

Produced water chemistry (cont.)

Well		VBC 3018 241M	VBC 3018 241M	VBC 2919 041D	VBC 2919 041D	VC 2918 011D	VC 2918 011D	VPR B 26
Date		1/5/1990	3/1/1990	1/5/1990	1/25/1990	1/5/1990	1/30/1990	1/30/1990
Component	Unit							
pH	s.u.	7.66	8.33	7.28	7.5	6.16	6.37	8.64
SG 75F		1.0035	1.0019	1.0061	1.009	1.0101	1.0141	1.0031
Resistivity	ohm-m	1.19	1.34	0.541	0.46	0.369	0.31	1.62
Filter Solids	mg/L	201.6	40.8	228.4	154.8	410	566	214.8
CO2	mg/L							
Sulfide	mg/L							
Hardness	mg/L							
Sodium	mg/L	1915	1864	3950	3920	6039	6948	1504
Calcium	mg/L	34	20	144	104	461	653	8
Magnesium	mg/L	28	13	63	382	51	92	13
Iron	mg/L	0	3	0	0	3	31	0
Potassium	mg/L							
Barium	mg/L							
Chloride	mg/L	2322	2276	6122	6774	10195	111961	1854
Sulfate	mg/L	0	58	0	0	0	5	0
Carbonate	mg/L	0	0	0	0	0	0	78
Bicarbonate	mg/L	1336	1092	702	970	134	366	732
Hydroxide	mg/L	0	0	0	0	0	0	0
TDS	mg/L	5635	5326	10981	12150	16883	20056	4176
Conductivity	umhos/cm							
Alkalinity	mg/L							
Sodium Ad. Ratio								
Cations	meq/L							
Anions	meq/L							
% Diff								

Produced water chemistry (cont.)

Well		VPR B 26	VPR B 25	VPR B 25	VPR B 23	VPR B 13	VPR B 11	VPR B 11	VPR B 10	VPR B 10
Date		3/7/1990	1/5/1990	3/1/1990	10/16/1987	1/5/1990	1/5/1990	1/25/1990	10/18/1989	1/5/1990
Component	Unit									
pH	s.u.	8.62	7.79	8.09	7.77	7.01	6.26	6.61	7.46	6.95
SG 75F		1.0009	1.0021	1.031	1	1.0051	1.011	1.0121		1.004
Resistivity	ohm-m	1.92	1.28	1.19	0.837	0.79	0.551	0.31		0.81
Filter Solids	mg/L	38.4	78.4	166.8		341.2	587.6	396.8	1.1408	248.4
CO2	mg/L									
Sulfide	mg/L									
Hardness	mg/L									
Sodium	mg/L	1156	1844	1963	2990	2936	5134	5559	2467.5	2499
Calcium	mg/L	14	28	30	94.8	12	651	511	138.12	261
Magnesium	mg/L	17	28	30	18.4	9	120	175	4.25	19
Iron	mg/L	0	0	20	1.2	0	39	59		0
Potassium	mg/L				12				10.92	
Barium	mg/L				10.8					
Chloride	mg/L	1368	2237	2524	4018.6	3779	9196	9781	3588.08	4162
Sulfate	mg/L	0	0	0	20.3	0	0	10	0.1	0
Carbonate	mg/L	12	0	0	7.5	0	0	0	0	0
Bicarbonate	mg/L	824	1275	1153	651.7	1366	464	470	53317	366
Hydroxide	mg/L	0	0	0		0	0	0		0
TDS	mg/L	3391	5412	5720	7825.3	8102	15604	16565	6866	7307
Conductivity	umhos/cm								8766	
Alkalinity	mg/L								453.42	
Sodium Ad. Ratio									56.4	
Cations	meq/L								114.85	
Anions	meq/L								110.28	
% Diff									2.03	

Produced water chemistry (cont.)

Well		CR 3017 161H	CR 3017 161H	CR 3117 141G	CR 3117 141G	CR 3117 141G	CR 3117 141G	CR 3117 141G
Date		5/2/1991	6/20/1991	7/6/1990	8/9/1990	9/10/1990	10/2/1990	3/11/1991
Component	Unit							
pH	s.u.	8.32	8.42	8.08	8.25	8.7	8.77	8.52
SG 75F		1.0018	1.0001	0.9997			1.0005	0.997
Resistivity	ohm-m	1.39	3.39	12.4	10.5932	13.9	13.1	10.2
Filter Solids	mg/L	67.2	31.6	60.8			37.2	65.6
CO2	mg/L							
Sulfide	mg/L							
Hardness	mg/L							
Sodium	mg/L	1648	655	195	239.6	218	184	182
Calcium	mg/L	12	16	2	3.1	16.1	2	0
Magnesium	mg/L	10	2	0	1	2.46	2	0
Iron	mg/L	0	0	0			0	0
Potassium	mg/L				2.8	0.64		
Barium	mg/L							
Chloride	mg/L	2113	603	32	44.1	42	21	14
Sulfate	mg/L	0	0	0	2.9	0.82	0	0
Carbonate	mg/L	12	12	0	0	20.4	24	12
Bicarbonate	mg/L	799	732	470	570.9	522	427	433
Hydroxide	mg/L	0	0	0			0	0
TDS	mg/L	4594	2020	699	604	544	660	641
Alkalinity	mg/L				467.95	462		
Sodium Ad. Ratio					30.03	13.4		
Cations	meq/L				10.73	10.5		
Anions	meq/L				10.66	10.4		
% Diff					0.33	0.41		
Conductivity	umhos/cm				944	720		

Produced water chemistry (cont.)

Well		CR 3117 141G	CR 3117 141G	CR 3017 322	CR 3017 322	CR 3017 322	CR 3017 322	CR 3017 322
Date		9/7/1994	10/10/1989	1/8/1990	3/1/1990	3/25/1991	5/2/1991	7/6/1990
Component	Unit							
pH	s.u.	8.7	8.41	8.55	8.66	8.76	8.57	7.48
SG 75F				0.999	1.0001	1.0016	0.9993	1.0011
Resistivity	ohm-m	11	7.8864	7.45	7.19	8	7.11	2.91
Filter Solids	mg/L			10.4	8.8	88.4	83.6	238.4
CO2	mg/L							
Sulfide	mg/L							
Hardness	mg/L							
Sodium	mg/L	198	337.5	356	326	326	349	984
Calcium	mg/L	1	10.95	4	4	2	2	4
Magnesium	mg/L	2	3.6	4	2	0	0	1
Iron	mg/L	0.14		0	0	0	3	0
Potassium	mg/L	0.4	2.25					
Barium	mg/L							
Chloride	mg/L	0.04	59.47	57	78	92	163	1067
Sulfate	mg/L	0	0.1	0	0	0	0	0
Carbonate	mg/L	14	7.13	27	57	33	24	0
Bicarbonate	mg/L	0	898.6	824	641	647	610	799
Hydroxide	mg/L			0	0	0	0	0
TDS	mg/L	464	1250	1272	1108	1100	1151	2855
Alkalinity	mg/L	405	748.44					
Sodium Ad. Ratio		5.8	22.62					
Cations	meq/L	8.83	15.58					
Anions	meq/L	8.51	16.65					
% Diff		1.81	3.31					
Conductivity	umhos/cm	557	1268					

Produced water chemistry (cont.)

Well		VPR D 18	VPR D 18	VPR D 18	VPR D 18	VPR D 18	VPR D 18	VPR D 18	VPR D 18	VPR D 24	VPR D 21
Date		8/9/1990	9/10/1990	9/10/1990	9/10/1990	9/10/1990	10/2/1990	10/13/1990	5/13/1991	5/3/1991	7/24/1990
Component	Unit										
pH	s.u.			8.56			7.22	7.91	8.32	8.41	8.1
SG 75F							1.006	1.01	1.0022	1.0017	1.0005
Resistivity	ohm-m			5.17			0.518	0.59	2.03	2.18	4.11
Filter Solids	mg/L						385.6	304	136.8	56.4	288.4
CO2	mg/L										
Sulfide	mg/L			0.82							
Hardness	mg/L										
Sodium	mg/L	543		589		599	3993	3214	1150	1129	641
Calcium	mg/L	17	12	16.1		4	457	399	28	8	8
Magnesium	mg/L		1.6	4.9	2	3.7	27	98	6	0	1
Iron	mg/L	7.11	10		0.38		0	3	0	0	3
Potassium	mg/L			2.6	0.01	4					
Barium	mg/L										
Chloride	mg/L			369		382	6828	5707	1202	1127	262
Sulfate	mg/L					5	0	0	0	0	0
Carbonate	mg/L			71.7			0	0	0	12	0
Bicarbonate	mg/L			824		979	378	415	1104	1055	1287
Hydroxide	mg/L						0	0	0	0	0
TDS	mg/L			1490		1530	11683	9836	3490	3331	2202
Alkalinity	mg/L			795							
Sodium Ad. Ratio				33							
Cations	meq/L			26.9							
Anions	meq/L			26.3							
% Diff				1.04							
Conductivity	umhos/cm			1930							

Produced water chemistry (cont.)

Well		VPR D 21	VPR D 21	VPR D 20	VPR D 21	VPR D 21	VPR D 21	CR 3117 271G	CR 3117 271G
Date		9/10/1990	10/13/1990	5/13/1991	2/19/1991	3/11/1991	5/10/1991	7/24/1990	9/10/1990
Component	Unit								
pH	s.u.	8.44	8.56	8.32	8.04	8.2	8.46	7.95	8.36
SG 75F			1.0015	1.0022	1.0035	1.0007	1.0015	0.9995	
Resistivity	ohm-m	3.69	2.95	2.03	0.161	3.6	2.81	3.96	8.55
Filter Solids	mg/L		150.4	136.8	659.2	53.2	132.8	120.4	
CO2	mg/L								
Sulfide	mg/L	0.82							
Hardness	mg/L	68.3							
Sodium	mg/L	829	759	1150	1547	681	876	623	369
Calcium	mg/L	24.1	26	28	26	12	4	16	12
Magnesium	mg/L	1.98	16	6	7	2	1	1	4.9
Iron	mg/L		0	0	0	0	0	0	0.15
Potassium	mg/L	1.5							1.44
Barium	mg/L								
Chloride	mg/L	569	603	1202	1656	454	734	355	139
Sulfate	mg/L		0	0	0	0	0	0	1.65
Carbonate	mg/L	30.9	24	0	0	0	12	0	10.2
Bicarbonate	mg/L	1200	1086	1104	1373	1080	1061	1098	763
Hydroxide	mg/L		0	0	0	0	0	0	
TDS	mg/L	2070	2514	3490	4609	2229	2688	2093	924
Alkalinity	mg/L	1030							641
Sodium Ad. Ratio		43.6							22.7
Cations	meq/L	37.5							17.1
Anions	meq/L	36.8							16.8
% Diff		0.96							0.96
Conductivity	umhos/cm	2710							1170

Produced water chemistry (cont.)

Well		CR 3117 271G	CR 3117 271G	CR 3117 271G	CR 3017 31F	CR 3017 31F	CR 3017 31F
Date		10/13/1990	3/11/1991	6/6/1991	8/9/1990	9/10/1990	9/10/1990
Component	Unit						
pH	s.u.	8.82	8.58	8.77	8.11		8.12
SG 75F		0.995	1.0005				
Resistivity	ohm-m	8.25	10.1	9.49	9.2678		13.9
Filter Solids	mg/L	101.6	28.8				
CO2	mg/L						
Sulfide	mg/L						
Hardness	mg/L				44.18		60.2
Sodium	mg/L	264	228	249	254.8		218
Calcium	mg/L	6	2	3.72	11.2	8	16.1
Magnesium	mg/L	18	0	0	3.9	2.4	4.9
Iron	mg/L	0	0				
Potassium	mg/L			0.84	4.4	2	1.06
Barium	mg/L						
Chloride	mg/L	103	43	52.7	94.4	36	44.1
Sulfate	mg/L	0	0	0.41	2.5	5	16.5
Carbonate	mg/L	36	12	0	0	0	0
Bicarbonate	mg/L	561	512	584	570.9	514	553
Hydroxide	mg/L	0	0				
TDS	mg/L	988	797	608	690	555	548
Alkalinity	mg/L			479	467395		543
Sodium Ad. Ratio				35.5	16.68	219	12.2
Cations	meq/L			11	12.08		10.7
Anions	meq/L			11.1	12.07		10.6
% Diff				0.2	0.01		0.35
Conductivity	umhos/cm			1050	1079		717

Produced water chemistry (cont.)

Well		VPR E 4	VPR E 6	VPR E 7	VPR E 12	VPR E 13	VPR E 18	VPR E 19	VPR E 26	VPR E 28	VPR E 29
Date		8/28/2002	8/28/2002	8/28/2002	8/28/2002	8/28/2002	8/28/2002	8/28/2002	8/28/2002	8/28/2002	8/28/2002
Component	Unit										
TDS	mg/L	2100	1978.7	1580.5	1758.4	2693	1783.9	1484.2	1476.6	2809.5	2572.9
Density	gm/cm^3	1.002	1.002	1.001	1.001	1.002	1.001	1.001	1.001	1.002	1.002
Cation/Anion Ratio		1	1	1	1	1	1	1	1	1	1
pH	s.u.	8.38	8.46	8.32	8.24	8.11	8.22	8.36	8.38	8.05	8.16
Chloride	mg/L	119	291	120	126	265	121	133	118	224	447
Bicarbonate	mg/L	1378.6	1073.6	1000	1122.4	1634.8	1146.8	915	927.2	1769	1329.8
Carbonate	mg/L	0	0	0	0	0	0	0	0	0	0
Sulfate	mg/L	3	12	3	3	3	3	3	3	3	3
Sodium	mg/L	589.2	579.8	446.7	496.4	771	501.5	424	419.1	797.5	773.4
Magnesium	mg/L	0.9	0.8	0.7	0.8	1.5	0.7	0.7	0.7	2	1.5
Calcium	mg/L	3	3.5	4	4	8	4.5	3.5	3	6.5	9.5
Strontium	mg/L	0.5	0.3	0.3	0.4	0.9	0.5	0.3	0.3	1	1
Barium	mg/L	0.6	0.2	0.4	0.4	0.8	0.4	0.3	0.3	0.5	0.7
Iron	mg/L	0.7	13	1.5	1	3	1.5	0.9	1	1	1.5
Potassium	mg/L	4.5	4.5	3.5	4	5	4	3.5	4	5	5.5
Chloride	meq/L	3.36	8.21	3.38	3.55	7.47	3.41	3.75	3.33	6.32	12.61
Bicarbonate	meq/L	22.59	17.6	16.4	18.39	26.79	18.79	15	15.2	28.99	21.79
Carbonate	meq/L	0	0	0	0	0	0	0	0	0	0
Sulfate	meq/L	0.06	0.25	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06
Sodium	meq/L	25.63	25.22	19.43	21.59	33.54	21.81	18.44	18.23	34.69	33.64
Magnesium	meq/L	0.07	0.07	0.06	0.07	0.12	0.06	0.06	0.06	0.16	0.12
Calcium	meq/L	0.15	0.17	0.2	0.2	0.4	0.22	0.17	0.15	0.32	0.47
Strontium	meq/L	0.01	0.01	0.01	0.01	0.02	0.01	0.01	0.01	0.02	0.02
Barium	meq/L	0.01	0	0.01	0.01	0.01	0.01	0	0	0.01	0.01
Iron	meq/L	0.03	0.47	0.05	0.04	0.11	0.05	0.03	0.04	0.04	0.05
Potassium	meq/L	0.12	0.12	0.09	0.1	0.13	0.1	0.09	0.1	0.13	0.14

Produced water chemistry (cont.)

Well		VPR E 31	VPR E 33	VPR E 34
Date		8/28/2002	8/28/2002	8/28/2002
Component	Unit			
TDS (mg/L)	mg/L	2028.3	1183.8	1516.5
Density (gm/cm^3)	gm/cm^3	1.002	1.001	1.001
Cation/Anion Ratio		1.000001	0.999999	1
pH	s.u.	8.35	8.25	7.95
Chloride	mg/L	126	93	101
Bicarbonate	mg/L	1317.6	744.2	976
Carbonate	mg/L	0	0	0
Sulfate	mg/L	3	3	3
Sodium	mg/L	559.1	334.3	422.7
Magnesium	mg/L	1.5	0.5	0.6
Calcium	mg/L	5.5	2.5	3.5
Strontium	mg/L	0.7	0.3	0.3
Barium	mg/L	0.9	0.5	0.4
Iron	mg/L	10	2	5
Potassium	mg/L	4	3.5	4
Chloride	meq/L	3.55	2.62	2.85
Bicarbonate	meq/L	21.59	12.2	16
Carbonate	meq/L	0	0	0
Sulfate	meq/L	0.06	0.06	0.06
Sodium	meq/L	24.32	14.54	18.39
Magnesium	meq/L	0.12	0.04	0.05
Calcium	meq/L	0.27	0.12	0.17
Strontium	meq/L	0.02	0.01	0.01
Barium	meq/L	0.01	0.01	0.01
Iron	meq/L	0.36	0.07	0.18
Potassium	meq/L	0.1	0.09	0.1

APPENDIX 5. SURFACE AND NEAR SURFACE WATER CHEMISTRY FOR THE VALLE VIDAL UNIT AND VERMEJO PARK RANCH

The following is a review of methods used to collect water samples on the Valle Vidal Unit and Vermejo Park Ranch. An interpretation of data collected during this study as well water chemistry information from the Oil Conservation Division (OCD) of New Mexico is also provided.

Methods: surface and groundwater sampling

Surface water samples were collected from the Valle Vidal Unit (Table 1). Three samples were collected along the length of Middle Ponil Creek. Two samples were collected from North Ponil Creek and one from McCrystal Creek. Sample locations were recorded with a Garmin GPS III Personal Navigator. One-liter plastic bottles were used to collect samples. The bottles were submerged and sealed under water. This was done to keep air out of the bottle, as air is known to affect the chemistry of water. The bottles were labeled and placed in an ice chest. This was done to limit the deterioration of phosphates and nitrates by biologic processes. The samples were returned to the chemistry laboratory at the New Mexico Bureau of Geology within 48 hours. These procedures are standard U.S. Environmental Protection Agency (EPA) protocol (2004). Twelve samples were collected from windmill-equipped shallow wells in the Valle Vidal Unit and Vermejo Park Ranch (Table 2). Well depth records were unavailable for these wells but similar wells on adjacent properties ranged from 50-160 ft (15-49 m) in depth.

A campsite well was also sampled that was known to have a total depth of approximately 140 ft (43 m). One liter plastic bottles were used. Samples were collected from water being pumped from the well. The campsite well sample was collected from a spigot off of a system using a storage tank. The bottles were rinsed once, filled, and capped. The same EPA protocol mentioned above was used.

The samples were analyzed at the chemistry laboratory of the New Mexico Bureau of Geology and Mineral Resources (NMBGMR). Table 3 indicates the parameters that were measured, the method of measurement, and the detection limits for the method of measurement (U.S. Environmental Protection Agency, 2004).

Surface water chemistry

Six surface water samples were collected in the Valle Vidal Unit (Figure 1). General chemistries are given in Table 1. Figure 2 displays the major ion ratios using a Piper diagram. Total dissolved solids (TDS) appeared to increase with distance from headwaters in North Ponil Creek. TDS remained relatively constant with distance in Middle Ponil Creek. Similar patterns in conductivity, hardness, chloride, bicarbonate, sulfate, potassium, sodium, magnesium, and calcium are observed in both drainages. The pH remains constant in the Middle Ponil but is variable in North Ponil Creek. The Piper diagram indicates that samples from Middle Ponil Creek maintain nearly constant ion ratios with distance from source. North Ponil Creek has a similar, less constrained clustering of ratios.

Seven stream samples were obtained from the OCD (Figure 1). These samples are located on the Vermejo Park Ranch. Chemistries of these samples are given in Table 4. Figure 3 displays the major ion ratios. TDS values are higher in the Vermejo River than in the Canadian River, Middle Ponil Creek, and North Ponil Creek. TDS values are comparable between the Canadian River, Middle Ponil and the southernmost sample from North Ponil. Increase in TDS with distance from headwaters is seen in the Vermejo and Canadian Rivers. However, the Vermejo River appears to level off around 300 mg/L. This is similar to the behavior of the Middle Ponil Creek. Major ion chemistry ratios are reasonably clustered for the Vermejo and Canadian Rivers. They are similar to Middle and North Ponil Creeks with slightly higher ratios of sodium + potassium and bicarbonate + carbonate.

Water chemistry and stream flow information from the National Water Information System (2004) was obtained for three stream gauge stations (Figure 1). One gauge is located on Ponil Creek near Cimarron, one on Vermejo River near Dawson, and one on the Canadian River near Hebron. The Ponil Creek gauge samples are higher in dissolved solids than those taken on the Middle Ponil Creek at a similar time of year. An inverse relationship is observed when comparing conductivity to stream flow, as noted by Abbott et al. (1983). Similar to higher levels of dissolved solids and conductivity were seen comparing Vermejo River gauge and OCD samples of the Vermejo River at similar times of year. The same inverse relationship between conductivity and flow is present. Conductivity and dissolved solids measured at the Canadian River gauge are all extremely higher than the samples taken further upstream. Mining activity in the drainage of the river at the time measurements were recorded could account for the higher values.

Surface water chemistry between the Valle Vidal Unit and Vermejo Park Ranch is reasonably similar. One difference is the TDS values for the Vermejo River compared to

North and Middle Ponil Creek. The difference can readily be explained by comparing the amounts of land being drained by each. The Vermejo River drains approximately 302 square miles (Abbott et al., 1983). The Canadian River drains 229 square miles and the North Ponil Creek 171 square miles. Abbott et al. (1983) noted there is an increase in specific conductance moving downstream. This is generally confirmed by the information gathered in this study.

Alluvial aquifer chemistry

Nine shallow well samples were collected in the Valle Vidal Unit (Figure 1). Eight were from windmills and one from a campsite well. Three windmills were also sampled on Vermejo Park Ranch. No records were available but similar wells ranged from 50-160 ft (15-48 m) in depth. General chemistries are given in Table 4. Major ion ratios are shown in Figure 4. TDS generally ranges between 200-300 part per million (ppm). Two wells on the Vermejo Park Ranch and one well in the Valle Vidal Unit exceed this range. Generally wells with higher TDS values had longer durations of pumping to retrieve samples. This is a possible indication these waters were derived from greater depths. Increasing TDS with depth is a common relationship in many aquifers. Chemistries of the waters were generally similar. pH is fairly constant between all samples. Ion ratios are for the most part are along a continuum between sodium + potassium and calcium + magnesium. The Beatty Lakes Windmill #2 is the only outlier. This well has the highest TDS and sulfate levels. Geldon (1989) noted an increase in sulfate with depth for groundwater in the basin. The depth of the well is supported by the duration of pumping needed to retrieve a sample. If Beatty Lakes Windmill #2 is significantly deeper than the other wells sampled it should have a different chemistry.

Eight well samples were obtained from the OCD for the Vermejo Park Ranch (Figure 1). Five samples were taken from windmills. One was taken from a hand-pump well, one from a waterhole, and one from a stock tank. Table 5 gives the chemistries. Figure 5 displays the major ion ratios. The Van Bremmer Canyon well samples match with the Vermejo Park B and C well samples collected in this study. The remaining five samples correlate strongly with most of the well samples collected in the Valle Vidal Unit.

Groundwater chemistry is fairly similar between the Valle Vidal Unit and Vermejo Park Ranch. The variation between them is on the same order as the variation within them. Comparing these groundwater samples to the surface water samples a possible trend is seen. The surface water samples lie on one end of the continuum discussed for groundwater ion ratios. It has been established that increased time in subsurface can increase ion content in water (Abbott et al., 1983). This is particularly true of sodium and bicarbonate in regions similar to the Valle Vidal Unit and Vermejo Park Ranch. A relationship may exist between groundwater age and the sodium/bicarbonate contents of the water. If so, a relative age between groundwater samples could be employed. This could be used to indicate flow direction of groundwater.

Table 1. Surface water samples from the Valle Vidal Unit

Site		North Ponil Creek #1		North Ponil Creek #2		McCrystal Creek
Date		6/30/2003		8/24/2003		8/18/2003
		36.7770		36.7675		36.8044
		-105.0983		-105.1281		-105.1423
pH		7.73		8.34		8.31
TDS (ppm)		80		160		70
Conductivity (uS/cm)		117		237		104
Component	ppm	epm	ppm	epm	ppm	epm
Hardness	52		111		42	

Carbonate				0		0
Bicarbonate	68	1.11	149	2.44	51	0.84
Bromide	<.1	0	<.1	0	<.1	0
Chloride	<1.0	0	1.9	0.05	<1.0	0
Fluoride	0.81	0.04	0.48	0.03	1	0.05
Nitrate	0.36	0.01	<.1	0	0.87	0.01
Phosphate	<.5	0	<.5	0	<.5	0
Sulfate	10	0.21	17	0.35	8.8	0.18
Sodium	4.7	0.2	16	0.7	4.5	0.2
Potassium	0.87	0.02	1	0.03	0.69	0.02
Magnesium	3.6	0.3	9.3	0.77	3	0.25
Calcium	15	0.75	29	1.45	12	0.6
Aluminum	0.68	0.08	0.164	0.002	0.21	0.02
Arsenic	<.001		<.001		<.001	
Barium	0.023		0.03		0.012	
Beryllium	<.001		<.001		<.001	
Boron	0.005		0.012		0.009	
Cadmium	<.001		<.001		<.001	
Chromium	<.001		<.001		<.001	
Cobalt	<.001		<.001		<.001	
Copper	0.001		0.012		0.005	
Iron	0.57	0.03	0.19	0.01	0.19	0.01
Lead	<.001		<.001		<.001	
Lithium	0.002		<.001		0.003	
Manganese	0.021	0	0.007	0	0.007	0
Mercury	<.0001		<.0001		<.0001	
Molybdenum	<.001		<.001		<.001	
Nickel	0.001		<.001		<.001	
Selenium	<.001		<.001		<.001	
Strontium	0.13	0	0.28	0.01	0.12	0
Silicia	10		7.2		9.5	
Silver	<.001		<.001		<.001	
Thorium	<.001		<.001		<.001	
Uranium	<.001		<.001		<.001	
Vanadium	0.001		<.001		<.001	
Zinc	0.003	0	0.005	0	0.002	0
Total Cations		1.38		2.97		1.1
Total Anions		1.37		2.87		1.09
%Difference		0.4		1.61		0.46
Site		Middle Ponil Creek #1		Middle Ponil Creek #2		Middle Ponil Creek #3
Date		6/30/2003		6/30/2003		6/30/2003
		36.7774		36.7390		36.7247
		-105.2154		-105.1897		-105.1816
pH		8.25		8.25		8.26
TDS (ppm)		220		220		210
Conductivity (uS/cm)		330		330		309

Component	ppm	epm	ppm	epm	ppm	epm
Hardness	181		169		164	
Carbonate						
Bicarbonate	177	2.9	179	2.93	171	2.8
Bromide	<.1	0	<.1	0	<.1	0
Chloride	<1.0	0	<1.0	0	<1.0	0
Fluoride	0.4	0.02	0.39	0.02	0.37	0.02
Nitrate	0.24	0	<.1	0	<.1	0
Phosphate	<.5	0	<.5	0	<.5	0
Sulfate	47	0.98	45	0.94	44	0.92
Sodium	6.9	0.3	7.6	0.33	7.7	0.33
Potassium	0.75	0.02	0.87	0.02	0.87	0.02
Magnesium	10	0.82	10	0.82	10	0.82
Calcium	56	2.79	51	2.54	49	2.45
Aluminum	0.28	0.03	0.27	0.03	0.16	0.02
Arsenic	<.001		<.001		<.001	
Barium	0.095		0.044		0.04	
Beryllium	<.001		<.001		<.001	
Boron	0.015		0.016		0.015	
Cadmium	<.001		<.001		<.001	
Chromium	<.001		<.001		<.001	
Cobalt	<.001		<.001		<.001	
Copper	0.001		0.001		<.001	
Iron	0.41	0.02	0.47	0.03	0.28	0.02
Lead	<.001		<.001		<.001	
Lithium	0.011		0.011		0.01	
Manganese	0.027	0	0.033	0	0.015	0
Mercury	<.0001		<.0001		<.0001	
Molybdenum	<.001		<.001		<.001	
Nickel	0.001		<.001		<.001	
Selenium	<.001		<.001		<.001	
Strontium	0.47	0.01	0.44	0.01	0.38	0.01
Silicia	8		8		8	
Silver	<.001		<.001		<.001	
Thorium	<.001		<.001		<.001	
Uranium	<.001		<.001		<.001	
Vanadium	<.001		<.001		<.001	
Zinc	0.003	0	0.003	0	0.002	0
Total Cations		4		3.79		3.67
Total Anions		3.9		3.89		3.74
%Difference		1.24		-1.34		-0.95

Table 2. Alluvial aquifer water chemistries for samples from the Valle Vidal Unit and Vermejo Park Ranch.

Site	Cimarron Campsite	VVU Windmill #1	VVU Windmill #2

Date		6/30/2003		8/19/2003		8/18/2003
Latitude		36.7694		36.7338		36.7948
Longitude		-105.2024		-105.1585		-105.0893
pH		7.88		7.47		7.68
TDS (ppm)		230		300		260
Conductivity (uS/cm)		349		414		394
Component	ppm	epm	ppm	epm	ppm	epm
Hardness	86		148		138	
Carbonate				0		0
Bicarbonate	234	3.84	304	4.98	242	3.97
Bromide	0.13	0	0.13	0	0.2	0
Chloride	4.2	0.12	11	0.31	15	0.42
Fluoride	0.76	0.04	0.69	0.04	0.32	0.02
Nitrate	<.1	0	3.9	0.06	1.2	0.02
Phosphate	<.5	0	<.5	0	<.5	0
Sulfate	9.6	0.2	6.6	0.14	17	0.35
Sodium	57	2.48	56	2.44	46	2
Potassium	0.39	0.01	0.89	0.02	0.54	0.01
Magnesium	5.2	0.43	7.5	0.62	9.8	0.81
Calcium	26	1.3	47	2.35	39	1.95
Aluminum	0.006	0	0.002	0	0.006	0
Arsenic	<.001		<.001		<.001	
Barium	0.027		0.56		0.075	
Beryllium	<.001		<.001		<.001	
Boron	0.01		0.016		0.011	
Cadmium	<.001		<.001		<.001	
Chromium	<.001		<.001		<.001	
Cobalt	<.001		<.001		<.001	
Copper	0.008		0.003		0.051	
Iron	0.06	0	0.91	0.05	0.24	0.01
Lead	0.006		0.001		0.002	
Lithium	0.009		0.002		<.001	
Manganese	0.25	0.02	0.19	0.01	0.017	0
Mercury	<.0001		<.0001		<.0001	
Molybdenum	<.001		<.001		<.001	
Nickel	<.001		<.001		<.001	
Selenium	<.001		<.001		0.001	
Strontium	0.33	0.01	0.88	0.02	0.51	0.01
Silicia	10		11		7	
Silver	<.001		<.001		<.001	
Thorium	<.001		<.001		<.001	
Uranium	<.001		<.001		0.002	
Vanadium	<.001		<.001		<.001	
Zinc	1.2	0.04	0.31	0.01	1.1	0.03
Total Cations		4.28		5.51		4.83
Total Anions		4.2		5.53		4.78
%Difference		1.01		-0.016		1.1

Site		VVU Windmill #3		VVU Windmill #4		VVU Windmill #5
Date		8/18/2003		8/19/2003		8/19/2003
		36.7961		36.7814		36.7718
		-105.0715		-105.0507		-105.0267
pH		7.62		7.37		8.21
TDS (ppm)		230		300		260
Conductivity (uS/cm)		347		443		364
Component	ppm	epm	ppm	epm	ppm	epm
Hardness	136		224		43	
Carbonate		0		0		0
Bicarbonate	229	3.75	294	4.82	261	4.28
Bromide	0.1	0	<.1	0	<.01	0
Chloride	8.7	0.25	7.5	0.21	7	0.2
Fluoride	0.46	0.02	0.2	0.01	1	0.05
Nitrate	1.1	0.02	4.8	0.08	0.32	0.01
Phosphate	<.5	0	<.5	0	<.5	0
Sulfate	13	0.27	26	0.54	3.6	0.07
Sodium	37	1.61	25	1.09	88	3.83
Potassium	0.6	0.02	0.48	0.01	1.2	0.03
Magnesium	9.3	0.77	21	1.73	0.75	0.06
Calcium	39	1.95	55	2.74	16	0.8
Aluminum	0.004	0	0.004	0	0.039	0
Arsenic	<.001		<.001		<.001	
Barium	0.11		0.056		0.2	
Beryllium	<.001		<.001		<.001	
Boron	<.001		0.015		0.012	
Cadmium	<.001		<.001		<.001	
Chromium	<.001		<.001		<.001	
Cobalt	<.001		<.001		<.001	
Copper	0.02		0.017		0.13	
Iron	0.16	0.01	0.18	0.01	0.23	0.01
Lead	<.001		<.001		0.003	
Lithium	<.001		<.001		0.001	
Manganese	0.12	0.01	0.004	0	0.019	0
Mercury	<.0001		<.0001		<.0001	
Molybdenum	<.001		<.001		<.001	
Nickel	<.001		<.001		<.001	
Selenium	<.001		<.001		<.001	
Strontium	0.53	0.01	0.61	0.01	0.4	0.01
Silicia	8.5		11		10	
Silver	<.001		<.001		<.001	
Thorium	<.001		<.001		<.001	
Uranium	<.001		0.002		<.001	
Vanadium	<.001		<.001		<.001	
Zinc	0.044	0	0.23	0.01	0.12	0
Total Cations		4.37		5.6		4.75
Total Anions		4.31		5.66		4.61

%Difference		0.63		-0.5		1.51
Site		Whiteman Vega Windmill 1		Beauty Windmill #1		Beauty Windmill #2
Date		8/18/2003		8/24/2003		8/24/2003
		36.8076		36.7286		36.7300
		-105.1081		-105.0712		-105.1154
pH		7.59		8.21		7.59
TDS (ppm)		280		300		1220
Conductivity (uS/cm)		425		461		1630
Component	ppm	epm	ppm	epm	ppm	epm
Hardness	163		56		612	
Carbonate				0		0
Bicarbonate	257	3.84	272	4.46	196	3.21
Bromide	<.1	0	0.12	0	1.3	0.02
Chloride	6.6	0.12	15	0.42	232	6.54
Fluoride	0.47	0.04	0.4	0.02	0.23	0.01
Nitrate	1.2	0	0.63	0.01	0.27	0
Phosphate	<.5	0	<.5	0	<.5	0
Sulfate	33	0.2	24	0.5	470	9.79
Sodium	42	2.48	92	4	171	7.44
Potassium	0.81	0.01	1.1	0.03	2.4	0.06
Magnesium	11	0.43	0.85	0.07	28	2.3
Calcium	47	1.3	21	1.05	199	9.93
Aluminum	0.016	0	0.003	0	0.002	0
Arsenic	<.001		<.001		<.001	
Barium	0.029		0.034		0.014	
Beryllium	<.001		<.001		<.001	
Boron	0.006		0.012		0.017	
Cadmium	<.001		<.001		<.001	
Chromium	<.001		<.001		<.001	
Cobalt	<.001		<.001		<.001	
Copper	0.005		0.013		0.006	
Iron	0.21	0	0.01	0	0.62	0.03
Lead	<.001		<.001		<.001	
Lithium	<.001		0.001		0.003	
Manganese	0.008	0.02	0.013	0	0.39	0.03
Mercury	<.0001		<.0001		<.0001	
Molybdenum	<.001		<.001		<.001	
Nickel	<.001		<.001		0.001	
Selenium	0.001		<.001		0.002	
Strontium	0.32	0.01	0.48	0.01	4.6	0.1
Silicia	7.8		11		13	
Silver	<.001		<.001		<.001	
Thorium	<.001		<.001		<.001	
Uranium	0.002		<.001		<.001	
Vanadium	<.001		<.001		<.001	
Zinc	0.22	0.04	0.18	0.01	0.046	0

Total Cations		5.13		5.17		19.9
Total Anions		5.13		5.41		19.58
%Difference		-0.04		-2.34		0.83
Site		VP Windmill A		VP Windmill B		VP Windmill C
Date		8/19/2003		8/19/2003		8/19/2003
		36.8111		36.8310		36.8282
		-105.0630		-105.0462		-105.0246
pH		7.25		7.88		7.69
TDS (ppm)		250		410		680
Conductivity (uS/cm)		376		623		973
Component	ppm	epm	ppm	epm	ppm	epm
Hardness	187		99		347	
Carbonate		0		0		0
Bicarbonate	244	4	430	7.05	601	9.85
Bromide	<.1	0	<.1	0	0.1	0
Chloride	5	0.14	16	0.45	27	0.76
Fluoride	0.22	0.01	0.64	0.03	0.57	0.03
Nitrate	0.62	0.01	0.1	0	<.1	0
Phosphate	<.5	0	<.5	0	<.5	0
Sulfate	23	0.48	<1	0	89	1.85
Sodium	22	0.96	125	5.44	132	5.74
Potassium	0.65	0.02	4	0.1	0.66	0.02
Magnesium	17	1.4	5.8	0.48	37	3.04
Calcium	47	2.35	30	1.5	78	3.89
Aluminum	0.016	0	0.007	0	0.002	0
Arsenic	<.001		<.001		<.001	
Barium	0.081		1.4		0.12	
Beryllium	<.001		<.001		<.001	
Boron	0.01		0.015		0.012	
Cadmium	<.001		<.001		<.001	
Chromium	<.001		0.001		0.002	
Cobalt	<.001		<.001		<.001	
Copper	0.023		0.01		0.22	
Iron	0.24	0.01	0.18	0.01	0.06	0.01
Lead	0.004		<.001		<.001	
Lithium	<.001		0.008		0.002	
Manganese	0.032	0	0.036	0	<.001	0
Mercury	<.0001		<.0001		<.0001	
Molybdenum	<.001		<.001		<.001	
Nickel	<.001		<.001		<.001	
Selenium	0.001		<.001		<.001	
Strontium	0.62	0.01	1.7	0.04	1.4	0.03
Silicia	10		12		10	
Silver	<.001		<.001		<.001	
Thorium	<.001		<.001		<.001	
Uranium	0.001		<.001		0.005	
Vanadium	<.001		<.001		<.001	

Zinc	0.19	0.01	0.043	0	0.026	0
Total Cations		4.75		7.57		12.74
Total Anions		4.64		7.53		12.5
%Difference		1.21		0.22		0.96

Table 3. Environmental Protection Agency (EPA) parameter/method list.

Parameter	Method	Detection Limit
pH	USEPA 150.1	7.4-10.0 s.u.
TDS	USEPA 120.1	10 mg/L
Conductivity	USEPA 160.1	10 umho/cm
Hardness	Ca + Mg	3 mg/L
Carbonate	USEPA 310.1	10 mg/L
Bicarbonate	USEPA 310.1	5 mg/L
Bromide	USEPA 300	0.1 mg/L
Chloride	USEPA 300	1 mg/L
Fluoride	USEPA 300	0.1 mg/L
Nitrate	USEPA 300	0.1 mg/L
Phosphate	USEPA 300	0.5 mg/L
Sulfate	USEPA 300	1 mg/L
Sodium	USEPA 200.0/6020	1 mg/L
Potassium	USEPA 200.0/6020	1 mg/L
Magnesium	USEPA 200.0/6020	1 mg/L
Calcium	USEPA 200.0/6020	1 mg/L
Aluminum	USEPA 200.8/6020	0.001 mg/L
Arsenic	USEPA 200.8/6020	0.001 mg/L
Barium	USEPA 200.8/6020	0.001 mg/L
Beryllium	USEPA 200.8/6020	0.001 mg/L
Boron	USEPA 200.8/6020	0.02 mg/L
Cadmium	USEPA 200.8/6020	0.001 mg/L
Chromium	USEPA 200.8/6020	0.001 mg/L
Cobalt	USEPA 200.8/6020	0.001 mg/L
Copper	USEPA 200.8/6020	0.001 mg/L
Iron	USEPA 200.0/6020	0.05 mg/L
Lead	USEPA 200.8/6020	0.001 mg/L
Lithium	USEPA 200.8/6020	0.05 mg/L
Manganese	USEPA 200.0/6020	0.2 mg/L
Mercury	USEPA 245.1	0.002 mg/L
Molybdenum	USEPA 200.0/6020	0.001 mg/L
Nickel	USEPA 200.8/6020	0.001 mg/L
Selenium	USEPA 200.8/6020	0.001 mg/L
Strontium	USEPA 200.8/6020	0.001 mg/L
Silica	USEPA 200.8/6020	10 mg/L
Silver	USEPA 200.8/6020	0.001 mg/L
Thorium	USEPA 200.8/6020	0.001 mg/L
Uranium	USEPA 200.8/6020	0.001 mg/L

Vanadium	USEPA	200.8/6020	0.001 mg/L
Zinc	USEPA	200.8/6020	0.001 mg/L

Table 4. Surface water samples from the Vermejo Park Ranch.

Site		Upper Vermejo River	Middle Vermejo River	Lower Vermejo River	Vermejo River at Dawson
Location		16-31N-18E NE NE/4	23-30N-19E SW/4	14-28N-20E SE/4 SE/4 SE/4	14-28N-20E NE/4
Date		9/7/1994	9/7/1994	10/20/1994	10/20/1994
Component	Units				
pH	s.u.	7.9	8.3	8.3	7.1
Conductivity	umhos/cm	391	528	537	558
TDS sampled	mg/L	226	314	304	308
TDS calculated	mg/L	206	309	301	322
Hardness	mg/L	156	204	200	208
Alkalinity	mg/L	155	196	181	178
Bicarbonate	mg/L	189	238	221	218
Carbonate	mg/L	0	0.6	0	0
Hydroxide	mg/L	0	0	0	0
Chloride	mg/L	4.1	6	6	5.3
Nitrate	mg/L	0.04	0.13	0.04	0.44
Sulfate	mg/L	33	78	79	0.99
Calcium	mg/L	44	54	52	56
Magnesium	mg/L	11	17	14	17
Potassium	mg/L	1.1	1.8	2.2	2
Sodium	mg/L	19	35	39	36
Cations	meq/L	3.98	5.64	5.5	5.77
Anions	meq/L	3.9	5.71	5.43	5.81
% Diff		1	0.62	0.57	0.32
Sample Name		SCR #1	SCR #2	SCR#3	
Location		6-31N-20E	31-32N-20E	33-32N-20E	
Description		Canadian River	Canadian River	Canadian River	
Date		6/22/1999	6/22/1999	6/22/1999	
Analyte	Units				
Aluminum	mg/L		1.96	0.6	
Barium	mg/L	0.13	0.12	0.16	
Copper	mg/L	0.02			
Iron	mg/L	0.7	2.1	1.1	
Magnesium	mg/L	10.1	12.6	13.7	
Manganese	mg/L	0.084	0.179	0.138	
Silicon	mg/L	5.5	8.4	5.9	
Sodium	mg/L	30	23	25	
Zinc	mg/L	0.02			

Calcium	mg/L	27.7	35.6	388
Analyte	Units			
Bicarbonate	mg/L	150	170	190
Chloride	mg/L	4.8	1.5	0.5
Conductance	umhos/cm	304	322	356
Sulfate	mg/L	11	19	
TDS	mg/L	180	210	220

Table 5. Alluvial water chemistry samples from the Vermejo Park Ranch.

Sample Name		SP #1	CR #1	CR #2	CR #4	PC #1
Location		1-31N-19E	36-32N-19E	35-32N-19E	31-32N-20E	2-31N-19E
Description		Handpump	Windmill	Windmill	Windmill	Windmill
Date		6/22/99	6/22/99	6/22/99	6/22/99	6/22/99
Analyte	Units					
Aluminum	mg/L	0.07		0.08		
Barium	mg/L	0.15	0.54	0.2	0.06	0.26
Copper	mg/L	0.04		0.03	0.04	0.02
Iron	mg/L	4.4	0.1	0.1	0.2	0.2
Magnesium	mg/L	10.4	2.8	12.5	0.4	17
Manganese	mg/L	0.512	0.117	0.005	0.017	
Silicon	mg/L	3.6	5.4	5.1	4.2	3.3
Sodium	mg/L	33	83	21	101	25
Zinc	mg/L	0.68	0.7	0.54	0.29	0.24
Calcium	mg/L	34.9	27.1	42	3	58.2
Analyte	Units					
Bicarbonate	mg/L	280	150	250	160	220
Chloride	mg/L	4.3	7.3	0.5	0.75	1.8
Conductance	umhos/cm	322	290	426	382	446
Sulfate	mg/L	8	21			37
TDS	mg/L	210	200	270	240	270

Site		Van Bremmer Canyon		
Description		Waterhole	Windmill	Stocktank
Location		30-30N-19E SW SE	25-30N-18E NW NW	15-30N-18E SW SW
Date		4/17/1991	4/17/1991	4/17/1990
Component	Units			
pH	s.u.	8.27	8.34	8.29
Conductivity	umhos/cm	758	1070	748
Resistivity	ohm-m	13.2	9.33	13.4
TDS samp	mg/L	428	634	430
TDS calc	mg/L	447	516	408
Alkalinity	mg/L	363	324	320
Hardness	mg/L	225	178	71.7

Sodium Ad. Ratio		2.76	4.43	7.4
Bicarbonate	mg/L	443	396	390
Carbonate	mg/L	0	0	0
Chloride	mg/L	21.3	35.5	20.3
Sulfate	mg/L	39.9	97.9	25.9
Calcium	mg/L	44	20.1	16
Magnesium	mg/L	27.9	31.1	7.75
Potassium	mg/L	1.53	0.71	2.55
Sodium	mg/L	95.1	136	144
Cations	meq/L	8.67	9.5	7.76
Anions	meq/L	8.69	9.53	7.5
% Difference		0.11	0.13	1.69

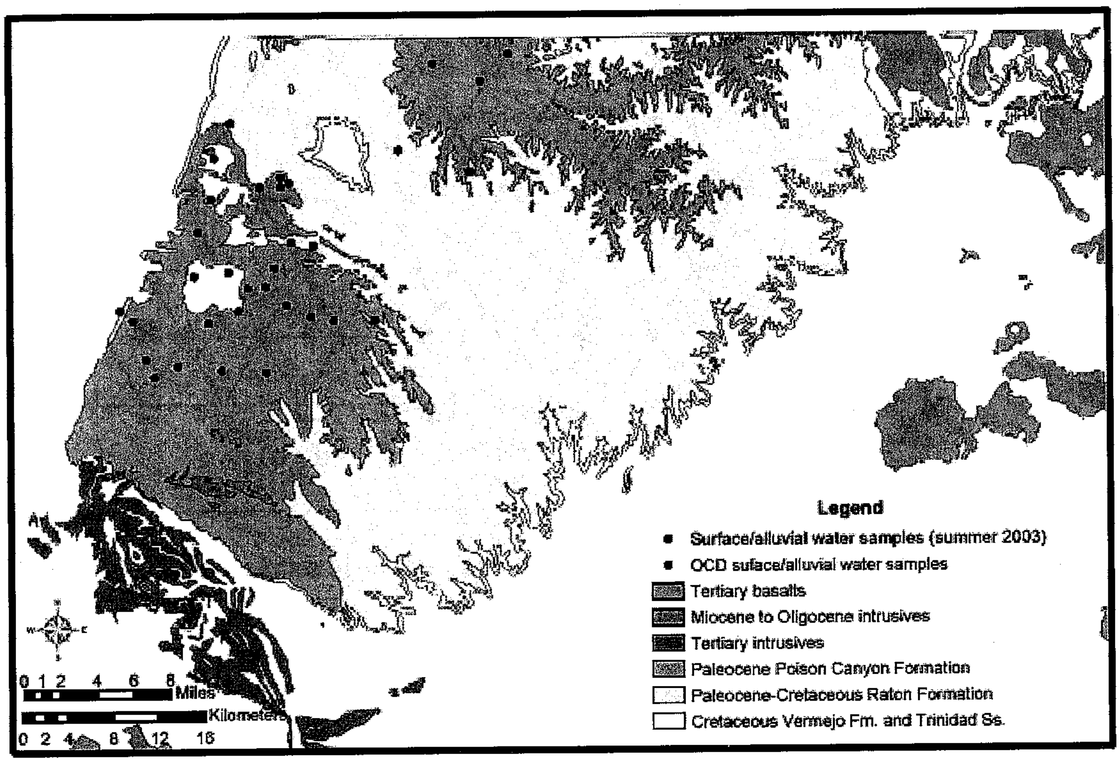

Figure 1. Location of surface/alluvial water chemistry samples. The sample locations listed include those collected in this study, during the summer of 2003, as well as ones obtained from the Oil Conservation Division (OCD) of New Mexico.

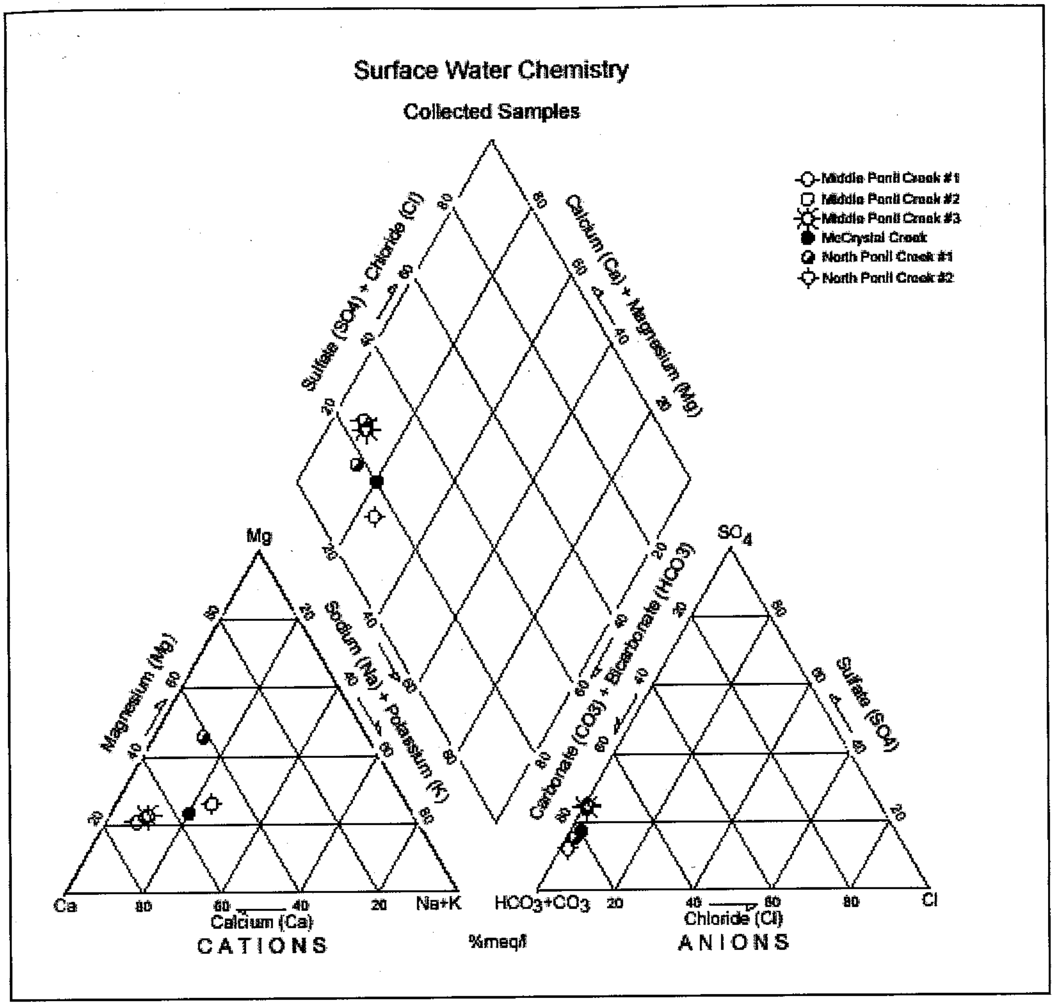

Figure 2. Piper diagram of stream samples from the Valle Vidal Unit. A fairly tight clustering between the samples is revealed.

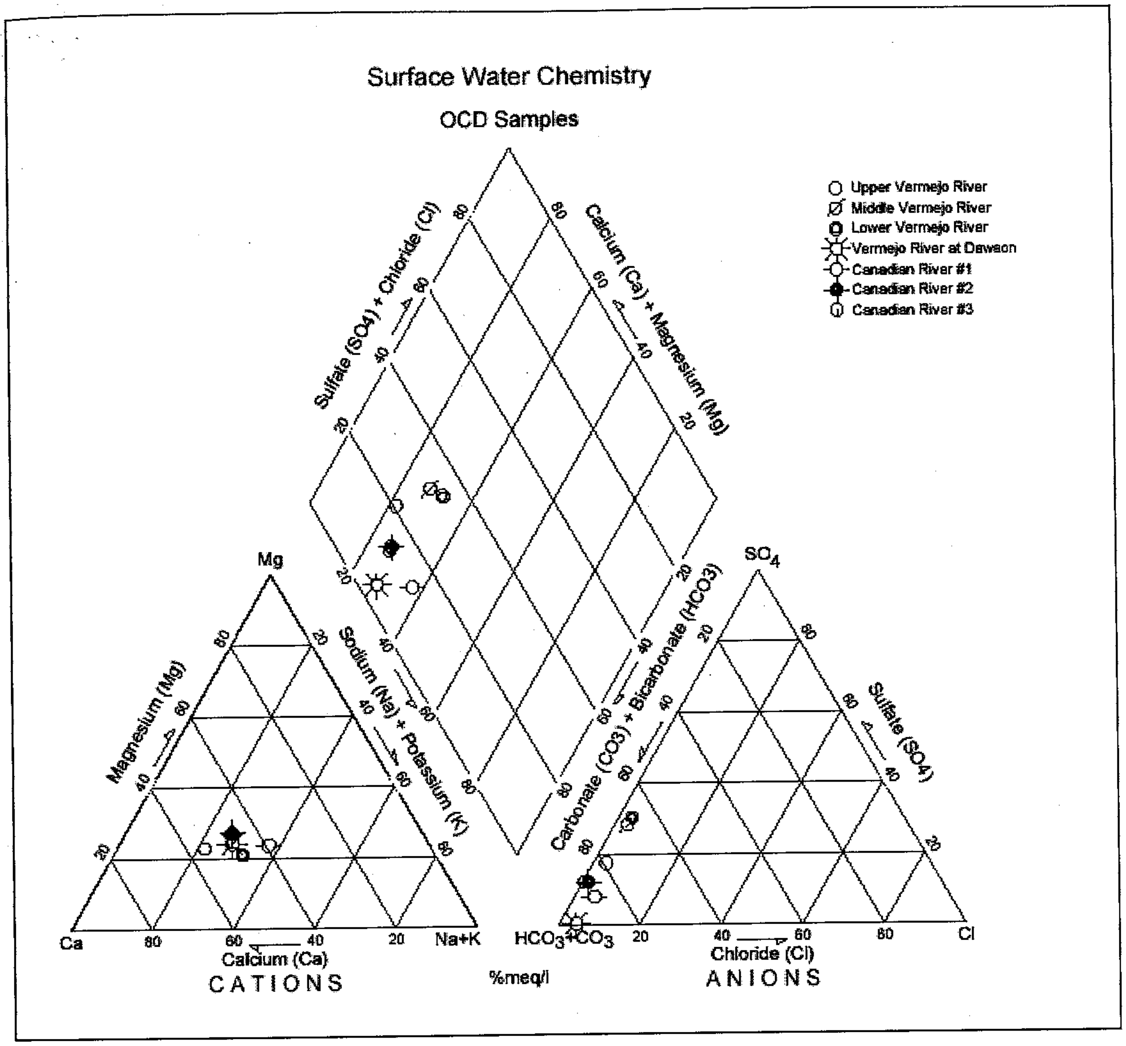

Figure 3. Piper diagram of stream samples from the Vermejo Park Ranch. These samples are similar to those collected in the Valle Vidal Unit.

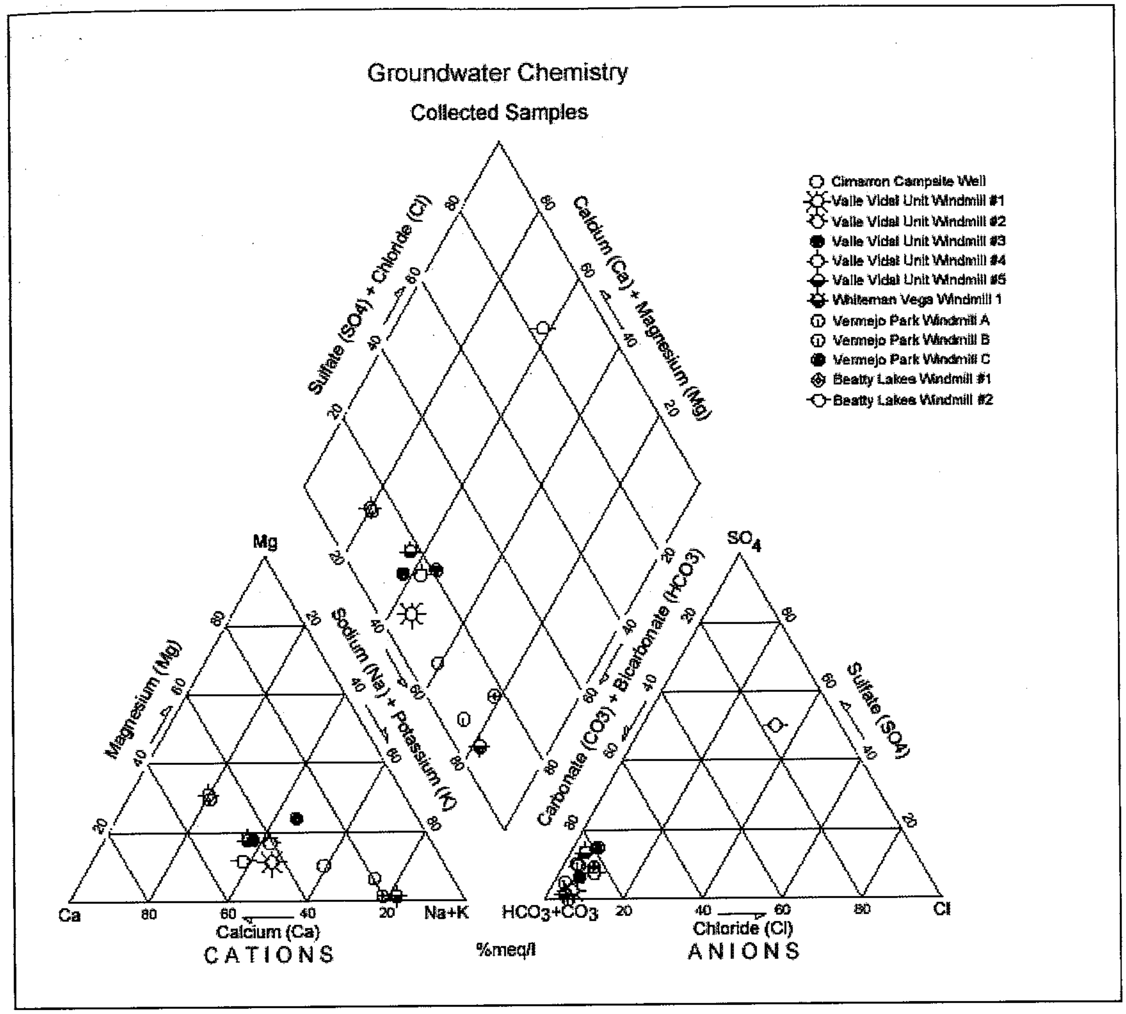

Figure 4. Piper diagram of alluvial aquifer samples from the Valle Vidal Unit. It appears chemistries are on a continuum based primarily on sodium + potassium content.

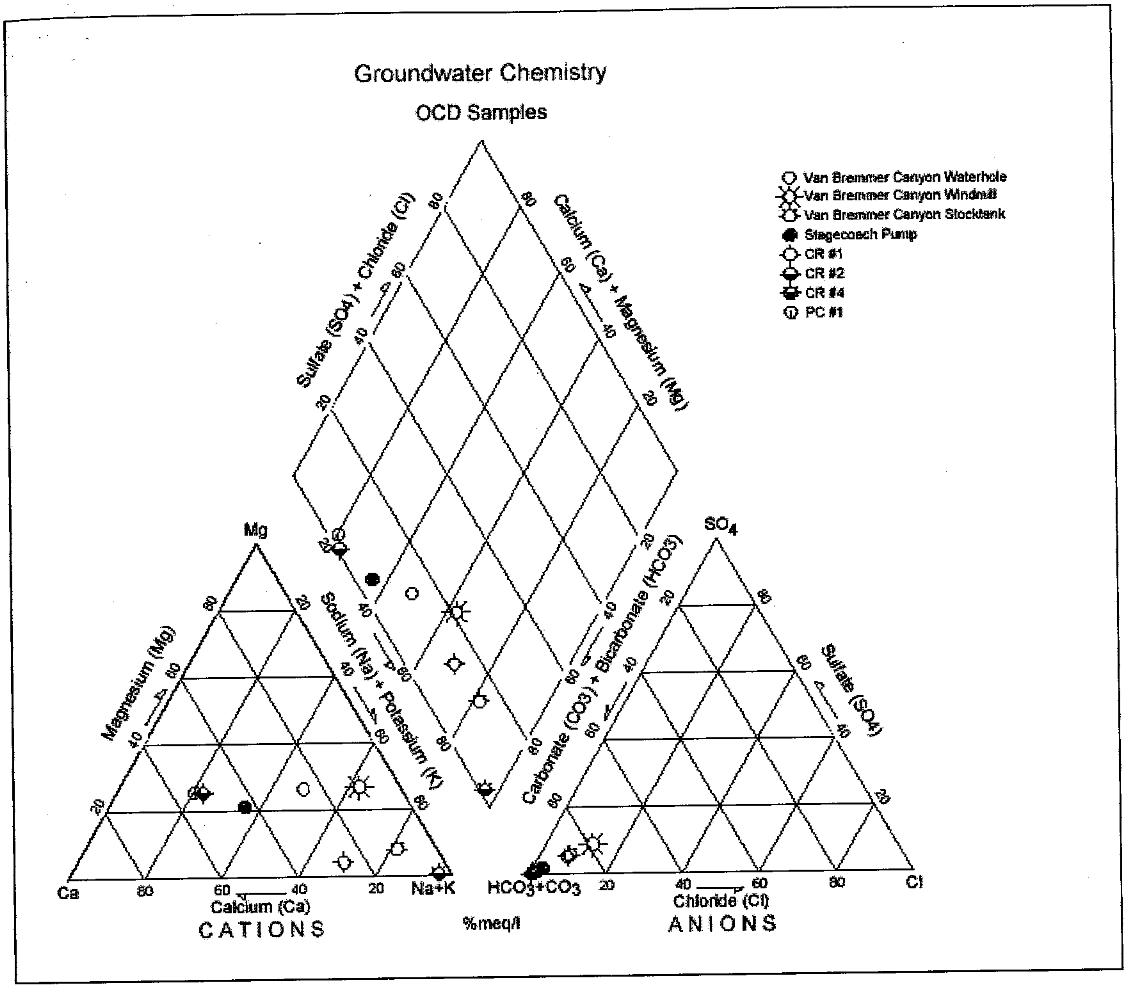

Figure 5. Piper diagram of alluvial aquifer samples from the Vermejo Park Ranch. These chemistries also exhibit a continuum behavior similar to the one noticed in alluvial aquifer samples in the Valle Vidal Unit.

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APPENDIX 6. POTENTIOMETRIC SURFACE DATA FOR VERMEJO PARK RANCH

The following data was obtained from the Vermejo Park Ranch and the Mineral and Mining Division (MMD) of New Mexico. Well elevation (ft) and location (UTM X and Y) data were obtained from the Vermejo Park Ranch. Location coordinates are in UTM Zone 13 N. The MMD provided depth to water (DTW) (ft) and dates of the measurements. Potentiometric surface (PS) (ft) was determined by subtracting the depth to water from the surface elevation.

Site Name	Elevation	UTM X	UTM Y	Date	DTW	PS
MA-15	7584	508467.4	4074923.6	4/12/83	8.36	7575.64
MA-15	7584	508467.4	4074923.6	7/12/83	7.95	7576.05
MA-15	7584	508467.4	4074923.6	1/16/84	10.00	7574
MA-15	7584	508467.4	4074923.6	4/16/84	10.00	7574
MA-15	7584	508467.4	4074923.6	7/17/84	7.95	7576.05
MA-15	7584	508467.4	4074923.6	10/16/84	10.12	7573.88
MA-15	7584	508467.4	4074923.6	1/18/85	11.13	7572.87
MA-15	7584	508467.4	4074923.6	4/15/85	9.84	7574.16
MA-15	7584	508467.4	4074923.6	7/17/85	10.00	7574
MA-15	7584	508467.4	4074923.6	10/10/85	9.83	7574.17
MA-15	7584	508467.4	4074923.6	1/6/86	11.36	7572.64
MA-15	7584	508467.4	4074923.6	4/8/86	11.51	7572.49
MA-15	7584	508467.4	4074923.6	7/14/86	9.79	7574.21
MA-15	7584	508467.4	4074923.6	10/11/86	9.89	7574.11
MA-15	7584	508467.4	4074923.6	1/4/87	9.30	7574.7
MA-15	7584	508467.4	4074923.6	1/13/87	9.80	7574.2
MA-15	7584	508467.4	4074923.6	7/1/87	8.40	7575.6
MA-15	7584	508467.4	4074923.6	10/7/87	8.76	7575.24
MA-15	7584	508467.4	4074923.6	4/18/88	9.51	7574.49
MA-15	7584	508467.4	4074923.6	7/26/88	9.52	7574.48
MA-15	7584	508467.4	4074923.6	3/21/91	12.73	7571.27
MA-15	7584	508467.4	4074923.6	5/9/91	12.62	7571.38
MA-15	7584	508467.4	4074923.6	8/20/91	11.32	7572.68
MA-15	7584	508467.4	4074923.6	10/28/91	13.60	7570.4
MA-15	7584	508467.4	4074923.6	2/6/92	14.16	7569.84
MA-15	7584	508467.4	4074923.6	5/5/92	13.88	7570.12
MA-15	7584	508467.4	4074923.6	9/26/92	40.92	7543.08
MA-15	7584	508467.4	4074923.6	11/18/92	14.20	7569.8
MA-15	7584	508467.4	4074923.6	3/9/93	13.72	7570.28
MA-15	7584	508467.4	4074923.6	5/5/93	14.36	7569.64
MA-15	7584	508467.4	4074923.6	9/21/93	14.98	7569.02
MA-15	7584	508467.4	4074923.6	2/9/94	14.42	7569.58
MA-15	7584	508467.4	4074923.6	3/15/94	14.95	7569.05
MA-15	7584	508467.4	4074923.6	7/13/94	14.88	7569.12
MA-15	7584	508467.4	4074923.6	8/23/94	13.24	7570.76
MA-15	7584	508467.4	4074923.6	1/18/95	14.62	7569.38
MA-15	7584	508467.4	4074923.6	6/9/95	13.25	7570.75
MA-15	7584	508467.4	4074923.6	8/1/95	13.68	7570.32
MA-15	7584	508467.4	4074923.6	11/1/95	13.76	7570.24
MA-15	7584	508467.4	4074923.6	3/13/96	13.97	7570.03
MA-15	7584	508467.4	4074923.6	4/16/96	13.75	7570.25
MA-15	7584	508467.4	4074923.6	7/29/96	14.26	7569.74
MA-15	7584	508467.4	4074923.6	10/22/96	14.29	7569.71
MA-15	7584	508467.4	4074923.6	2/12/97	14.17	7569.83
MA-15	7584	508467.4	4074923.6	5/7/97	13.70	7570.3
MA-15	7584	508467.4	4074923.6	7/30/97	13.73	7570.27
MA-15	7584	508467.4	4074923.6	11/19/97	14.30	7569.7
MA-15	7584	508467.4	4074923.6	2/11/98	14.41	7569.59
MA-15	7584	508467.4	4074923.6	2/11/98	10.58	7573.42
MA-15	7584	508467.4	4074923.6	5/20/98	14.07	7569.93

Site Name	Elevation	UTM X	UTM Y	Date	DTW	PS
MA-15	7584	508467.4	4074923.6	8/27/98	14.04	7569.96
MA-15	7584	508467.4	4074923.6	11/16/98	14.25	7569.75
MA-15	7584	508467.4	4074923.6	1/24/01	15.35	7568.65
MA-15	7584	508467.4	4074923.6	2/23/01	14.13	7569.87
MA-15	7584	508467.4	4074923.6	3/12/01	14.08	7569.92
MA-15	7584	508467.4	4074923.6	4/25/01	13.96	7570.04
MA-15	7584	508467.4	4074923.6	5/23/01	13.73	7570.27
MA-15	7584	508467.4	4074923.6	6/13/01	14.10	7569.9
MA-15	7584	508467.4	4074923.6	7/25/01	14.16	7569.84
MA-15	7584	508467.4	4074923.6	8/27/01	14.30	7569.7
MA-15	7584	508467.4	4074923.6	9/11/01	14.34	7569.66
MA-15	7584	508467.4	4074923.6	10/26/01	14.37	7569.63
MA-15	7584	508467.4	4074923.6	10/31/01	14.37	7569.63
MA-15	7584	508467.4	4074923.6	12/18/01	14.18	7569.82
MA-15	7584	508467.4	4074923.6	1/9/02	14.34	7569.66
MA-15	7584	508467.4	4074923.6	2/14/02	14.20	7569.8
MA-15	7584	508467.4	4074923.6	3/4/02	14.09	7569.91
MA-15	7584	508467.4	4074923.6	4/25/02	14.36	7569.64
MA-15	7584	508467.4	4074923.6	5/14/02	14.37	7569.63
MA-15	7584	508467.4	4074923.6	6/11/02	14.45	7569.55
MA-15	7584	508467.4	4074923.6	7/17/02	14.62	7569.38
MA-15	7584	508467.4	4074923.6	8/28/02	14.88	7569.12
MA-15	7584	508467.4	4074923.6	9/5/02	14.91	7569.09
MA-16	6880.95	512748.4	4070008.7	4/11/83	10.09	6870.86
MA-16	6880.95	512748.4	4070008.7	7/13/83	10.16	6870.79
MA-16	6880.95	512748.4	4070008.7	1/16/84	11.76	6869.19
MA-16	6880.95	512748.4	4070008.7	4/16/84	11.94	6869.01
MA-16	6880.95	512748.4	4070008.7	7/17/84	10.16	6870.79
MA-16	6880.95	512748.4	4070008.7	10/16/84	11.53	6869.42
MA-16	6880.95	512748.4	4070008.7	1/16/85	11.10	6869.85
MA-16	6880.95	512748.4	4070008.7	4/16/85	11.06	6869.89
MA-16	6880.95	512748.4	4070008.7	7/16/85	11.73	6869.22
MA-16	6880.95	512748.4	4070008.7	1/6/86	11.24	6869.71
MA-16	6880.95	512748.4	4070008.7	4/8/86	11.52	6869.43
MA-16	6880.95	512748.4	4070008.7	7/14/86	11.67	6869.28
MA-16	6880.95	512748.4	4070008.7	10/9/86	11.65	6869.3
MA-16	6880.95	512748.4	4070008.7	1/13/87	11.20	6869.75
MA-16	6880.95	512748.4	4070008.7	1/6/88	10.16	6870.79
MA-16	6880.95	512748.4	4070008.7	1/14/88	10.08	6870.87
MA-16	6880.95	512748.4	4070008.7	4/4/88	45.92	6835.03
MA-16	6880.95	512748.4	4070008.7	10/5/88	10.12	6870.83
MA-16	6880.95	512748.4	4070008.7	8/11/89	11.11	6869.84
MA-16	6880.95	512748.4	4070008.7	11/18/89	10.35	6870.6
MA-16	6880.95	512748.4	4070008.7	3/20/90	9.96	6870.99
MA-16	6880.95	512748.4	4070008.7	5/15/90	10.29	6870.66
MA-16	6880.95	512748.4	4070008.7	12/13/90	10.42	6870.53
MA-16	6880.95	512748.4	4070008.7	3/20/91	10.60	6870.35
MA-16	6880.95	512748.4	4070008.7	5/9/91	10.57	6870.38
MA-16	6880.95	512748.4	4070008.7	8/20/91	9.14	6871.81
MA-16	6880.95	512748.4	4070008.7	10/28/91	10.50	6870.45

Site Name	Elevation	UTM X	UTM Y	Date	DTW	PS
MA-16	6880.95	512748.4	4070008.7	2/6/92	10.34	6870.61
MA-16	6880.95	512748.4	4070008.7	6/22/92	10.26	6870.69
MA-16	6880.95	512748.4	4070008.7	7/7/92	10.56	6870.39
MA-16	6880.95	512748.4	4070008.7	11/18/92	10.68	6870.27
MA-16	6880.95	512748.4	4070008.7	3/10/93	10.61	6870.34
MA-16	6880.95	512748.4	4070008.7	5/4/93	10.40	6870.55
MA-16	6880.95	512748.4	4070008.7	9/22/93	10.78	6870.17
MA-16	6880.95	512748.4	4070008.7	2/15/94	10.54	6870.41
MA-16	6880.95	512748.4	4070008.7	6/15/94	10.42	6870.53
MA-16	6880.95	512748.4	4070008.7	7/13/94	10.55	6870.4
MA-16	6880.95	512748.4	4070008.7	8/24/94	10.05	6870.9
MA-16	6880.95	512748.4	4070008.7	1/18/95	10.48	6870.47
MA-16	6880.95	512748.4	4070008.7	5/10/95	10.22	6870.73
MA-16	6880.95	512748.4	4070008.7	8/1/95	10.53	6870.42
MA-16	6880.95	512748.4	4070008.7	11/2/95	10.52	6870.43
MA-16	6880.95	512748.4	4070008.7	3/13/96	10.52	6870.43
MA-16	6880.95	512748.4	4070008.7	4/17/96	10.48	6870.47
MA-16	6880.95	512748.4	4070008.7	7/30/96	10.70	6870.25
MA-16	6880.95	512748.4	4070008.7	10/22/96	10.80	6870.15
MA-16	6880.95	512748.4	4070008.7	2/12/97	10.47	6870.48
MA-16	6880.95	512748.4	4070008.7	5/7/97	10.21	6870.74
MA-16	6880.95	512748.4	4070008.7	8/13/97	10.02	6870.93
MA-16	6880.95	512748.4	4070008.7	11/19/97	10.62	6870.33
MA-16	6880.95	512748.4	4070008.7	5/19/98	10.47	6870.48
MA-16	6880.95	512748.4	4070008.7	8/26/98	10.50	6870.45
MA-16	6880.95	512748.4	4070008.7	11/16/98	10.55	6870.4
MA-16	6880.95	512748.4	4070008.7	1/24/01	12.41	6868.54
MA-16	6880.95	512748.4	4070008.7	2/23/01	11.00	6869.95
MA-16	6880.95	512748.4	4070008.7	3/12/01	10.80	6870.15
MA-16	6880.95	512748.4	4070008.7	4/25/01	10.85	6870.1
MA-16	6880.95	512748.4	4070008.7	5/22/01	10.60	6870.35
MA-16	6880.95	512748.4	4070008.7	6/13/01	11.05	6869.9
MA-16	6880.95	512748.4	4070008.7	7/25/01	11.27	6869.68
MA-16	6880.95	512748.4	4070008.7	8/27/01	11.33	6869.62
MA-16	6880.95	512748.4	4070008.7	9/10/01	11.36	6869.59
MA-16	6880.95	512748.4	4070008.7	10/17/01	11.34	6869.61
MA-16	6880.95	512748.4	4070008.7	11/19/01	11.25	6869.7
MA-16	6880.95	512748.4	4070008.7	12/17/01	11.17	6869.78
MA-16	6880.95	512748.4	4070008.7	1/8/02	11.07	6869.88
MA-16	6880.95	512748.4	4070008.7	2/13/02	11.08	6869.87
MA-16	6880.95	512748.4	4070008.7	3/8/02	11.08	6869.87
MA-16	6880.95	512748.4	4070008.7	4/30/02	11.24	6869.71
MA-16	6880.95	512748.4	4070008.7	5/6/02	11.31	6869.64
MA-16	6880.95	512748.4	4070008.7	6/11/02	11.47	6869.48
MA-16	6880.95	512748.4	4070008.7	7/17/02	11.40	6869.55
MA-16	6880.95	512748.4	4070008.7	8/15/02	11.66	6869.29
MA-17	7370	507114.2	4080886.6	3/10/93	9.04	7360.96
MA-17	7370	507114.2	4080886.6	5/4/93	8.00	7362
MA-17	7370	507114.2	4080886.6	9/21/93	8.88	7361.12
MA-17	7370	507114.2	4080886.6	2/9/94	9.25	7360.75

Site Name	Elevation	UTM X	UTM Y	Date	DTW	PS
MA-17	7370	507114.2	4080886.6	3/15/94	9.65	7360.35
MA-17	7370	507114.2	4080886.6	7/12/94	9.23	7360.77
MA-17	7370	507114.2	4080886.6	8/17/94	8.70	7361.3
MA-17	7370	507114.2	4080886.6	1/17/95	9.67	7360.33
MA-17	7370	507114.2	4080886.6	5/9/95	9.61	7360.39
MA-17	7370	507114.2	4080886.6	7/25/95	8.53	7361.47
MA-17	7370	507114.2	4080886.6	11/1/95	9.00	7361
MA-17	7370	507114.2	4080886.6	3/19/96	9.13	7360.87
MA-17	7370	507114.2	4080886.6	4/16/96	9.17	7360.83
MA-17	7370	507114.2	4080886.6	7/29/96	8.45	7361.55
MA-17	7370	507114.2	4080886.6	10/15/96	8.46	7361.54
MA-17	7370	507114.2	4080886.6	2/11/97	8.30	7361.7
MA-17	7370	507114.2	4080886.6	5/6/97	8.06	7361.94
MA-17	7370	507114.2	4080886.6	7/29/97	8.24	7361.76
MA-17	7370	507114.2	4080886.6	11/20/97	8.16	7361.84
MA-17	7370	507114.2	4080886.6	2/10/98	8.21	7361.79
MA-17	7370	507114.2	4080886.6	5/18/98	8.53	7361.47
MA-17	7370	507114.2	4080886.6	8/25/98	8.23	7361.77
MA-17	7370	507114.2	4080886.6	11/10/98	8.26	7361.74
MA-17	7370	507114.2	4080886.6	12/28/00	8.16	7361.84
MA-17	7370	507114.2	4080886.6	1/29/01	8.21	7361.79
MA-17	7370	507114.2	4080886.6	2/23/01	8.04	7361.96
MA-17	7370	507114.2	4080886.6	3/14/01	7.96	7362.04
MA-17	7370	507114.2	4080886.6	4/26/01	8.30	7361.7
MA-17	7370	507114.2	4080886.6	5/24/01	8.29	7361.71
MA-17	7370	507114.2	4080886.6	6/12/01	8.39	7361.61
MA-17	7370	507114.2	4080886.6	7/25/01	8.45	7361.55
MA-17	7370	507114.2	4080886.6	8/27/01	8.43	7361.57
MA-17	7370	507114.2	4080886.6	9/11/01	8.46	7361.54
MA-17	7370	507114.2	4080886.6	10/26/01	8.49	7361.51
MA-17	7370	507114.2	4080886.6	11/7/01	8.47	7361.53
MA-17	7370	507114.2	4080886.6	11/20/01	8.48	7361.52
MA-17	7370	507114.2	4080886.6	12/20/01	8.42	7361.58
MA-17	7370	507114.2	4080886.6	1/11/02	8.25	7361.75
MA-17	7370	507114.2	4080886.6	2/12/02	8.30	7361.7
MA-17	7370	507114.2	4080886.6	3/12/02	8.38	7361.62
MA-17	7370	507114.2	4080886.6	4/26/02	8.59	7361.41
MA-17	7370	507114.2	4080886.6	5/13/02	8.73	7361.27
MA-17	7370	507114.2	4080886.6	6/12/02	8.92	7361.08
MA-17	7370	507114.2	4080886.6	8/19/02	8.80	7361.2
MA-18	6840	513181.7	4069881.3	7/13/94	11.77	6828.23
MA-18	6840	513181.7	4069881.3	8/24/94	11.36	6828.64
MA-18	6840	513181.7	4069881.3	1/18/95	11.73	6828.27
MA-18	6840	513181.7	4069881.3	5/10/95	11.72	6828.28
MA-18	6840	513181.7	4069881.3	8/1/95	11.58	6828.42
MA-18	6840	513181.7	4069881.3	11/2/95	11.85	6828.15
MA-18	6840	513181.7	4069881.3	3/3/96	11.91	6828.09
MA-18	6840	513181.7	4069881.3	4/17/96	11.93	6828.07
MA-18	6840	513181.7	4069881.3	7/30/96	12.08	6827.92
MA-18	6840	513181.7	4069881.3	10/22/96	12.29	6827.71

Site Name	Elevation	UTM X	UTM Y	Date	DTW	PS
MA-18	6840	513181.7	4069881.3	2/12/97	11.97	6828.03
MA-18	6840	513181.7	4069881.3	5/7/97	12.03	6827.97
MA-18	6840	513181.7	4069881.3	8/13/97	11.95	6828.05
MA-18	6840	513181.7	4069881.3	11/19/97	12.24	6827.76
MA-18	6840	513181.7	4069881.3	2/11/98	11.92	6828.08
MA-18	6840	513181.7	4069881.3	5/19/98	12.07	6827.93
MA-18	6840	513181.7	4069881.3	8/26/98	12.20	6827.8
MA-18	6840	513181.7	4069881.3	11/16/98	12.27	6827.73
MA-18	6840	513181.7	4069881.3	1/24/01	12.90	6827.1
MA-18	6840	513181.7	4069881.3	2/23/01	10.18	6829.82
MA-18	6840	513181.7	4069881.3	3/12/01	10.41	6829.59
MA-18	6840	513181.7	4069881.3	4/25/01	11.35	6828.65
MA-18	6840	513181.7	4069881.3	5/22/01	11.46	6828.54
MA-18	6840	513181.7	4069881.3	6/13/01	12.02	6827.98
MA-18	6840	513181.7	4069881.3	7/25/01	12.38	6827.62
MA-18	6840	513181.7	4069881.3	8/27/01	12.07	6827.93
MA-18	6840	513181.7	4069881.3	9/10/01	12.49	6827.51
MA-18	6840	513181.7	4069881.3	10/17/01	12.51	6827.49
MA-18	6840	513181.7	4069881.3	11/19/01	12.49	6827.51
MA-18	6840	513181.7	4069881.3	12/17/01	11.65	6828.35
MA-18	6840	513181.7	4069881.3	1/8/02	11.68	6828.32
MA-18	6840	513181.7	4069881.3	2/13/02	11.36	6828.64
MA-18	6840	513181.7	4069881.3	3/8/02	10.23	6829.77
MA-18	6840	513181.7	4069881.3	4/30/02	11.98	6828.02
MA-18	6840	513181.7	4069881.3	5/6/02	12.17	6827.83
MA-18	6840	513181.7	4069881.3	6/11/02	12.43	6827.57
MA-18	6840	513181.7	4069881.3	7/17/02	12.45	6827.55
MA-18	6840	513181.7	4069881.3	8/15/02	12.71	6827.29
MA-19	6920	513239.1	4070745.5	7/13/94	11.48	6908.52
MA-19	6920	513239.1	4070745.5	8/24/94	10.23	6909.77
MA-19	6920	513239.1	4070745.5	1/18/95	10.67	6909.33
MA-19	6920	513239.1	4070745.5	5/10/95	10.38	6909.62
MA-19	6920	513239.1	4070745.5	8/1/95	11.11	6908.89
MA-19	6920	513239.1	4070745.5	11/2/95	10.99	6909.01
MA-19	6920	513239.1	4070745.5	3/13/96	9.43	6910.57
MA-19	6920	513239.1	4070745.5	4/17/96	9.70	6910.3
MA-19	6920	513239.1	4070745.5	7/30/96	11.08	6908.92
MA-19	6920	513239.1	4070745.5	10/16/96	11.05	6908.95
MA-19	6920	513239.1	4070745.5	2/12/97	10.14	6909.86
MA-19	6920	513239.1	4070745.5	5/7/97	10.38	6909.62
MA-19	6920	513239.1	4070745.5	8/13/97	9.80	6910.2
MA-19	6920	513239.1	4070745.5	11/19/97	10.65	6909.35
MA-19	6920	513239.1	4070745.5	2/10/98	10.34	6909.66
MA-19	6920	513239.1	4070745.5	5/19/98	10.17	6909.83
MA-19	6920	513239.1	4070745.5	8/26/98	11.97	6908.03
MA-19	6920	513239.1	4070745.5	11/16/98	10.48	6909.52
MA-19	6920	513239.1	4070745.5	1/24/01	11.65	6908.35
MA-19	6920	513239.1	4070745.5	2/23/01	9.46	6910.54
MA-19	6920	513239.1	4070745.5	3/12/01	9.25	6910.75
MA-19	6920	513239.1	4070745.5	4/25/01	9.37	6910.63

Site Name	Elevation	UTM X	UTM Y	Date	DTW	PS
MA-19	6920	513239.1	4070745.5	5/22/01	9.50	6910.5
MA-19	6920	513239.1	4070745.5	6/13/01	9.98	6910.02
MA-19	6920	513239.1	4070745.5	7/23/01	10.55	6909.45
MA-19	6920	513239.1	4070745.5	8/14/01	10.37	6909.63
MA-19	6920	513239.1	4070745.5	9/10/01	11.21	6908.79
MA-19	6920	513239.1	4070745.5	10/26/01	11.27	6908.73
MA-19	6920	513239.1	4070745.5	11/19/01	10.99	6909.01
MA-19	6920	513239.1	4070745.5	11/20/01	10.87	6909.13
MA-19	6920	513239.1	4070745.5	12/20/01	10.70	6909.3
MA-19	6920	513239.1	4070745.5	2/12/02	10.02	6909.98
MA-19	6920	513239.1	4070745.5	3/8/02	9.57	6910.43
MA-19	6920	513239.1	4070745.5	4/22/02	9.48	6910.52
MA-19	6920	513239.1	4070745.5	5/6/02	9.67	6910.33
MA-19	6920	513239.1	4070745.5	6/11/02	10.18	6909.82
MA-19	6920	513239.1	4070745.5	7/15/02	10.42	6909.58
MA-19	6920	513239.1	4070745.5	8/15/02	10.99	6909.01
MA-21	6780	514897.4	4068445.6	1/24/01	6.97	6773.03
MA-21	6780	514897.4	4068445.6	2/23/01	5.66	6774.34
MA-21	6780	514897.4	4068445.6	3/12/01	5.60	6774.4
MA-21	6780	514897.4	4068445.6	4/25/01	5.58	6774.42
MA-21	6780	514897.4	4068445.6	6/13/01	5.65	6774.35
MA-21	6780	514897.4	4068445.6	7/25/01	5.66	6774.34
MA-21	6780	514897.4	4068445.6	8/27/01	5.74	6774.26
MA-21	6780	514897.4	4068445.6	9/10/01	5.75	6774.25
MA-21	6780	514897.4	4068445.6	10/17/01	5.75	6774.25
MA-21	6780	514897.4	4068445.6	11/19/01	5.72	6774.28
MA-21	6780	514897.4	4068445.6	12/17/01	5.79	6774.21
MA-21	6780	514897.4	4068445.6	1/8/02	5.73	6774.27
MA-21	6780	514897.4	4068445.6	2/13/02	5.67	6774.33
MA-21	6780	514897.4	4068445.6	3/8/02	5.68	6774.32
MA-21	6780	514897.4	4068445.6	4/30/02	5.78	6774.22
MA-21	6780	514897.4	4068445.6	5/6/02	5.83	6774.17
MA-21	6780	514897.4	4068445.6	6/11/02	5.90	6774.1
MA-21	6780	514897.4	4068445.6	7/17/02	5.80	6774.2
MA-21	6780	514897.4	4068445.6	8/15/02	5.99	6774.01
MA-22	7226	506593	4073102.5	12/28/00	14.24	7211.76
MA-22	7226	506593	4073102.5	1/31/01	0.10	7225.9
MA-22	7226	506593	4073102.5	2/23/01	14.63	7211.37
MA-22	7226	506593	4073102.5	3/12/01	14.50	7211.5
MA-22	7226	506593	4073102.5	3/20/01	14.55	7211.45
MA-22	7226	506593	4073102.5	4/25/01	14.62	7211.38
MA-22	7226	506593	4073102.5	5/22/01	14.61	7211.39
MA-22	7226	506593	4073102.5	6/13/01	14.71	7211.29
MA-22	7226	506593	4073102.5	7/25/01	14.55	7211.45
MA-22	7226	506593	4073102.5	8/27/01	14.57	7211.43
MA-22	7226	506593	4073102.5	9/10/01	14.54	7211.46
MA-22	7226	506593	4073102.5	10/17/01	14.63	7211.37
MA-22	7226	506593	4073102.5	11/19/01	14.70	7211.3
MA-22	7226	506593	4073102.5	12/17/01	15.75	7210.25
MA-22	7226	506593	4073102.5	1/14/02	14.73	7211.27

Site Name	Elevation	UTM X	UTM Y	Date	DTW	PS
MA-22	7226	506593	4073102.5	2/14/02	14.11	7211.89
MA-22	7226	506593	4073102.5	3/11/02	14.95	7211.05
MA-22	7226	506593	4073102.5	5/8/02	14.55	7211.45
MA-22	7226	506593	4073102.5	6/11/02	14.73	7211.27
MA-22	7226	506593	4073102.5	7/26/02	14.79	7211.21
MA-22	7226	506593	4073102.5	8/26/02	14.81	7211.19
MA-23	6935	511804.7	4070764.5	12/28/00	11.16	6923.84
MA-23	6935	511804.7	4070764.5	1/30/01	12.52	6922.48
MA-23	6935	511804.7	4070764.5	2/23/01	10.78	6924.22
MA-23	6935	511804.7	4070764.5	3/12/01	10.01	6924.99
MA-23	6935	511804.7	4070764.5	4/25/01	10.75	6924.25
MA-23	6935	511804.7	4070764.5	5/22/01	10.76	6924.24
MA-23	6935	511804.7	4070764.5	6/13/01	10.96	6924.04
MA-23	6935	511804.7	4070764.5	7/25/01	10.98	6924.02
MA-23	6935	511804.7	4070764.5	8/27/01	11.30	6923.7
MA-23	6935	511804.7	4070764.5	9/10/01	11.37	6923.63
MA-23	6935	511804.7	4070764.5	10/17/01	11.28	6923.72
MA-23	6935	511804.7	4070764.5	11/19/01	11.07	6923.93
MA-23	6935	511804.7	4070764.5	12/17/01	11.34	6923.66
MA-23	6935	511804.7	4070764.5	1/8/02	11.05	6923.95
MA-23	6935	511804.7	4070764.5	2/14/02	10.27	6924.73
MA-23	6935	511804.7	4070764.5	3/8/02	10.70	6924.3
MA-23	6935	511804.7	4070764.5	4/25/02	11.12	6923.88
MA-23	6935	511804.7	4070764.5	5/8/02	11.27	6923.73
MA-23	6935	511804.7	4070764.5	6/11/02	11.78	6923.22
MA-23	6935	511804.7	4070764.5	7/26/02	12.43	6922.57
MA-23	6935	511804.7	4070764.5	8/15/02	12.97	6922.03
MA-23	6935	511804.7	4070764.5	8/26/02	13.14	6921.86
MA-24	6835	513739.2	4069103	1/24/01	0.10	6834.9
MA-24	6835	513739.2	4069103	2/23/01	17.34	6817.66
MA-24	6835	513739.2	4069103	3/12/01	16.95	6818.05
MA-24	6835	513739.2	4069103	4/25/01	16.68	6818.32
MA-24	6835	513739.2	4069103	5/22/01	17.12	6817.88
MA-24	6835	513739.2	4069103	6/12/01	17.20	6817.8
MA-24	6835	513739.2	4069103	8/27/01	17.15	6817.85
MA-24	6835	513739.2	4069103	9/10/01	17.26	6817.74
MA-24	6835	513739.2	4069103	10/17/01	17.40	6817.6
MA-24	6835	513739.2	4069103	11/19/01	17.51	6817.49
MA-24	6835	513739.2	4069103	12/17/01	17.50	6817.5
MA-24	6835	513739.2	4069103	1/8/02	17.48	6817.52
MA-24	6835	513739.2	4069103	2/13/02	17.53	6817.47
MA-24	6835	513739.2	4069103	3/8/02	17.54	6817.46
MA-24	6835	513739.2	4069103	4/30/02	17.53	6817.47
MA-24	6835	513739.2	4069103	5/6/02	17.52	6817.48
MA-24	6835	513739.2	4069103	6/11/02	17.52	6817.48
MA-24	6835	513739.2	4069103	7/17/02	17.53	6817.47
MA-24	6835	513739.2	4069103	8/15/02	17.29	6817.71
MA-24	6835	513739.2	4069103	8/26/02	17.29	6817.71
AW86-2	7950	503456.2	4086883.8	1/17/95	14.89	7935.11
AW86-2	7950	503456.2	4086883.8	4/16/95	13.08	7936.92

Site Name	Elevation	UTM X	UTM Y	Date	DTW	PS
AW86-2	7950	503456.2	4086883.8	5/9/95	12.84	7937.16
AW86-2	7950	503456.2	4086883.8	7/29/96	13.61	7936.39
AW86-2	7950	503456.2	4086883.8	10/15/96	14.52	7935.48
AW86-2	7950	503456.2	4086883.8	2/11/97	14.03	7935.97
AW86-2	7950	503456.2	4086883.8	5/6/97	13.45	7936.55
AW86-2	7950	503456.2	4086883.8	7/29/97	14.42	7935.58
AW86-2	7950	503456.2	4086883.8	11/18/97	14.88	7935.12
AW86-2	7950	503456.2	4086883.8	2/9/98	14.68	7935.32
AW86-2	7950	503456.2	4086883.8	5/18/98	14.49	7935.51
AW86-2	7950	503456.2	4086883.8	8/25/98	15.07	7934.93
AW86-2	7950	503456.2	4086883.8	11/9/98	15.18	7934.82
AW86-2	7950	503456.2	4086883.8	5/12/99	11.30	7938.7
AW86-2	7950	503456.2	4086883.8	1/23/01	17.75	7932.25
AW86-2	7950	503456.2	4086883.8	2/23/01	14.88	7935.12
AW86-2	7950	503456.2	4086883.8	3/14/01	13.61	7936.39
AW86-2	7950	503456.2	4086883.8	4/23/01	13.38	7936.62
AW86-2	7950	503456.2	4086883.8	5/23/01	13.32	7936.68
AW86-2	7950	503456.2	4086883.8	6/13/01	14.02	7935.98
AW86-2	7950	503456.2	4086883.8	7/23/01	14.66	7935.34
AW86-2	7950	503456.2	4086883.8	8/27/01	14.79	7935.21
AW86-2	7950	503456.2	4086883.8	9/13/01	15.11	7934.89
AW86-2	7950	503456.2	4086883.8	11/20/01	15.66	7934.34
AW86-2	7950	503456.2	4086883.8	1/11/02	15.64	7934.36
AW86-2	7950	503456.2	4086883.8	2/11/02	15.92	7934.08
AW86-2	7950	503456.2	4086883.8	3/4/02	15.82	7934.18
AW86-2	7950	503456.2	4086883.8	4/29/02	15.61	7934.39
AW86-2	7950	503456.2	4086883.8	5/13/02	15.16	7934.84
AW86-2	7950	503456.2	4086883.8	6/12/02	15.83	7934.17
AW86-2	7950	503456.2	4086883.8	7/25/02	16.28	7933.72
AW86-2	7950	503456.2	4086883.8	8/20/02	16.50	7933.5
AW86-2	7950	503456.2	4086883.8	9/13/02	16.41	7933.59
AW86-2	7950	503456.2	4086883.8	10/14/02	16.30	7933.7
AW86-2	7950	503456.2	4086883.8	11/14/02	16.29	7933.71
AW86-2	7950	503456.2	4086883.8	12/5/02	16.35	7933.65
AW86-2	7950	503456.2	4086883.8	1/27/03	16.33	7933.67
AW86-2	7950	503456.2	4086883.8	2/13/03	16.35	7933.65
AW86-2	7950	503456.2	4086883.8	3/11/03	16.27	7933.73
AW86-2	7950	503456.2	4086883.8	4/9/03	13.50	7936.5
AW86-2	7950	503456.2	4086883.8	5/8/03	13.56	7936.44
AW86-2	7950	503456.2	4086883.8	6/10/03	13.43	7936.57
AW86-2	7950	503456.2	4086883.8	7/18/03	15.20	7934.8
AW86-2	7950	503456.2	4086883.8	8/20/03	15.74	7934.26
AW86-2	7950	503456.2	4086883.8	9/12/03	15.57	7934.43
AW86-2	7950	503456.2	4086883.8	10/14/03	15.84	7934.16
UY-79-16	8095	504485.6	4086163.3	8/27/81	234.45	7860.55
UY-79-16	8095	504485.6	4086163.3	8/17/83	237.41	7857.59
UY-79-16	8095	504485.6	4086163.3	8/14/84	237.49	7857.51
UY-79-16	8095	504485.6	4086163.3	8/15/85	236.94	7858.06
UY-79-16	8095	504485.6	4086163.3	8/18/86	246.07	7848.93
UY-79-16	8095	504485.6	4086163.3	8/9/87	252.86	7842.14

Site Name	Elevation	UTM X	UTM Y	Date	DTW	PS
UY-79-16	8095	504485.6	4086163.3	4/5/88	256.59	7838.41
UY-79-16	8095	504485.6	4086163.3	7/12/88	259.06	7835.94
UY-79-16	8095	504485.6	4086163.3	8/3/88	259.70	7835.3
UY-79-16	8095	504485.6	4086163.3	12/18/89	258.93	7836.07
UY-79-16	8095	504485.6	4086163.3	10/9/91	257.30	7837.7
UY-81-2	7786.3	504978.4	4085718.5	2/22/82	10.20	7776.1
UY-81-2	7786.3	504978.4	4085718.5	6/16/82	16.00	7770.3
UY-81-2	7786.3	504978.4	4085718.5	4/13/83	7.79	7778.51
UY-81-2	7786.3	504978.4	4085718.5	7/15/83	8.44	7777.86
UY-81-2	7786.3	504978.4	4085718.5	10/17/83	12.48	7773.82
UY-81-2	7786.3	504978.4	4085718.5	1/18/84	12.49	7773.81
UY-81-2	7786.3	504978.4	4085718.5	4/18/84	9.17	7777.13
UY-81-2	7786.3	504978.4	4085718.5	7/16/84	10.55	7775.75
UY-81-2	7786.3	504978.4	4085718.5	10/19/84	13.74	7772.56
UY-81-2	7786.3	504978.4	4085718.5	1/17/85	11.27	7775.03
UY-81-2	7786.3	504978.4	4085718.5	4/10/85	9.88	7776.42
UY-81-2	7786.3	504978.4	4085718.5	1/9/86	11.87	7774.43
UY-81-2	7786.3	504978.4	4085718.5	4/9/86	12.26	7774.04
UY-81-2	7786.3	504978.4	4085718.5	7/24/86	11.70	7774.6
UY-81-2	7786.3	504978.4	4085718.5	10/13/86	12.60	7773.7
UY-81-2	7786.3	504978.4	4085718.5	1/14/87	11.40	7774.9
UY-81-2	7786.3	504978.4	4085718.5	4/20/87	9.54	7776.76
UY-81-2	7786.3	504978.4	4085718.5	7/9/87	10.56	7775.74
UY-81-2	7786.3	504978.4	4085718.5	10/14/87	9.76	7776.54
UY-81-2	7786.3	504978.4	4085718.5	1/11/88	11.77	7774.53
UY-81-2	7786.3	504978.4	4085718.5	4/19/88	9.68	7776.62
UY-81-2	7786.3	504978.4	4085718.5	7/20/88	13.69	7772.61
UY-81-2	7786.3	504978.4	4085718.5	7/20/88	13.69	7772.61
UY-81-2	7786.3	504978.4	4085718.5	10/5/88	10.14	7776.16
UY-81-2	7786.3	504978.4	4085718.5	8/14/89	10.20	7776.1
UY-81-2	7786.3	504978.4	4085718.5	10/10/89	10.30	7776
UY-81-2	7786.3	504978.4	4085718.5	3/13/90	8.62	7777.68
UY-81-2	7786.3	504978.4	4085718.5	4/24/90	9.21	7777.09
UY-81-2	7786.3	504978.4	4085718.5	10/17/90	11.23	7775.07
UY-81-2	7786.3	504978.4	4085718.5	1/29/91	12.11	7774.19
UY-81-2	7786.3	504978.4	4085718.5	4/26/91	11.35	7774.95
UY-81-2	7786.3	504978.4	4085718.5	7/25/91	8.71	7777.59
UY-81-2	7786.3	504978.4	4085718.5	10/24/91	8.14	7778.16
UY-81-2	7786.3	504978.4	4085718.5	3/5/92	14.86	7771.44
UY-81-2	7786.3	504978.4	4085718.5	4/28/92	8.60	7777.7
UY-81-2	7786.3	504978.4	4085718.5	9/26/92	10.30	7776
UY-81-2	7786.3	504978.4	4085718.5	11/17/92	10.30	7776
UY-81-2	7786.3	504978.4	4085718.5	3/9/93	13.36	7772.94
UY-81-2	7786.3	504978.4	4085718.5	5/4/93	14.96	7771.34
UY-81-2	7786.3	504978.4	4085718.5	1/24/94	10.72	7775.58
UY-81-2	7786.3	504978.4	4085718.5	3/15/94	8.51	7777.79
UY-81-2	7786.3	504978.4	4085718.5	7/12/94	9.58	7776.72
UY-81-2	7786.3	504978.4	4085718.5	8/17/94	9.10	7777.2
UY-81-2	7786.3	504978.4	4085718.5	1/17/95	9.45	7776.85
UY-81-2	7786.3	504978.4	4085718.5	4/16/95	9.26	7777.04

Site Name	Elevation	UTM X	UTM Y	Date	DTW	PS
UY-81-2	7786.3	504978.4	4085718.5	5/9/95	9.49	7776.81
UY-81-2	7786.3	504978.4	4085718.5	7/29/96	9.18	7777.12
UY-81-2	7786.3	504978.4	4085718.5	10/15/96	9.50	7776.8
UY-81-2	7786.3	504978.4	4085718.5	2/11/97	9.65	7776.65
UY-81-2	7786.3	504978.4	4085718.5	6/6/97	9.37	7776.93
UY-81-2	7786.3	504978.4	4085718.5	11/18/97	9.73	7776.57
UY-81-2	7786.3	504978.4	4085718.5	2/9/98	9.88	7776.42
UY-81-2	7786.3	504978.4	4085718.5	8/25/98	9.66	7776.64
UY-81-2	7786.3	504978.4	4085718.5	11/10/98	9.40	7776.9
UY-81-2	7786.3	504978.4	4085718.5	5/12/99	8.27	7778.03
UY-81-2	7786.3	504978.4	4085718.5	1/23/01	11.59	7774.71
UY-81-2	7786.3	504978.4	4085718.5	2/23/01	10.40	7775.9
UY-81-2	7786.3	504978.4	4085718.5	3/14/01	9.25	7777.05
UY-81-2	7786.3	504978.4	4085718.5	4/23/01	9.25	7777.05
UY-81-2	7786.3	504978.4	4085718.5	5/23/01	9.34	7776.96
UY-81-2	7786.3	504978.4	4085718.5	6/13/01	9.49	7776.81
UY-81-2	7786.3	504978.4	4085718.5	7/23/01	9.71	7776.59
UY-81-2	7786.3	504978.4	4085718.5	9/13/01	9.91	7776.39
UY-81-2	7786.3	504978.4	4085718.5	10/1/01	10.21	7776.09
UY-81-2	7786.3	504978.4	4085718.5	11/20/01	10.78	7775.52
UY-81-2	7786.3	504978.4	4085718.5	12/17/01	11.21	7775.09
UY-81-2	7786.3	504978.4	4085718.5	1/11/02	11.36	7774.94
UY-81-2	7786.3	504978.4	4085718.5	3/4/02	11.72	7774.58
UY-81-2	7786.3	504978.4	4085718.5	4/29/02	11.92	7774.38
UY-81-2	7786.3	504978.4	4085718.5	5/13/02	11.99	7774.31
UY-81-2	7786.3	504978.4	4085718.5	6/12/02	12.10	7774.2
UY-81-2	7786.3	504978.4	4085718.5	7/25/02	10.67	7775.63
UY-81-2	7786.3	504978.4	4085718.5	8/20/02	11.56	7774.74
UY-81-2	7786.3	504978.4	4085718.5	9/13/02	10.35	7775.95
UY-81-2	7786.3	504978.4	4085718.5	10/14/02	11.15	7775.15
UY-81-2	7786.3	504978.4	4085718.5	11/14/02	11.16	7775.14
UY-81-2	7786.3	504978.4	4085718.5	12/5/02	11.97	7774.33
UY-81-2	7786.3	504978.4	4085718.5	1/27/03	12.18	7774.12
UY-81-2	7786.3	504978.4	4085718.5	2/13/03	12.22	7774.08
UY-81-2	7786.3	504978.4	4085718.5	3/11/03	12.29	7774.01
UY-81-2	7786.3	504978.4	4085718.5	4/9/03	9.06	7777.24
UY-81-2	7786.3	504978.4	4085718.5	5/8/03	9.40	7776.9
UY-81-2	7786.3	504978.4	4085718.5	6/10/03	10.08	7776.22
UY-81-2	7786.3	504978.4	4085718.5	7/18/03	9.75	7776.55
UY-81-2	7786.3	504978.4	4085718.5	8/20/03	9.41	7776.89
UY-81-2	7786.3	504978.4	4085718.5	9/12/03	9.03	7777.27
UY-81-2	7786.3	504978.4	4085718.5	10/13/03	10.48	7775.82
MA-1	7504.56	506015.5	4082016.1	6/13/78	16.41	7488.15
MA-1	7504.56	506015.5	4082016.1	11/10/78	11.40	7493.16
MA-1	7504.56	506015.5	4082016.1	1/10/79	17.34	7487.22
MA-1	7504.56	506015.5	4082016.1	2/12/79	18.30	7486.26
MA-1	7504.56	506015.5	4082016.1	3/9/79	17.80	7486.76
MA-1	7504.56	506015.5	4082016.1	4/18/79	17.40	7487.16
MA-1	7504.56	506015.5	4082016.1	5/22/79	16.35	7488.21
MA-1	7504.56	506015.5	4082016.1	6/13/79	15.25	7489.31

Site Name	Elevation	UTM X	UTM Y	Date	DTW	PS
MA-1	7504.56	506015.5	4082016.1	7/20/79	15.52	7489.04
MA-1	7504.56	506015.5	4082016.1	8/16/79	14.80	7489.76
MA-1	7504.56	506015.5	4082016.1	9/17/79	15.00	7489.56
MA-1	7504.56	506015.5	4082016.1	10/16/79	16.17	7488.39
MA-1	7504.56	506015.5	4082016.1	11/19/79	16.90	7487.66
MA-1	7504.56	506015.5	4082016.1	12/17/79	16.98	7487.58
MA-1	7504.56	506015.5	4082016.1	1/15/80	17.05	7487.51
MA-1	7504.56	506015.5	4082016.1	2/15/80	17.15	7487.41
MA-1	7504.56	506015.5	4082016.1	3/19/80	17.14	7487.42
MA-1	7504.56	506015.5	4082016.1	4/23/80	17.11	7487.45
MA-1	7504.56	506015.5	4082016.1	5/13/80	12.80	7491.76
MA-1	7504.56	506015.5	4082016.1	6/19/80	12.22	7492.34
MA-1	7504.56	506015.5	4082016.1	7/14/80	12.52	7492.04
MA-1	7504.56	506015.5	4082016.1	8/15/80	14.18	7490.38
MA-1	7504.56	506015.5	4082016.1	9/15/80	16.35	7488.21
MA-1	7504.56	506015.5	4082016.1	10/15/80	16.54	7488.02
MA-1	7504.56	506015.5	4082016.1	11/14/80	18.98	7485.58
MA-1	7504.56	506015.5	4082016.1	12/15/80	16.52	7488.04
MA-1	7504.56	506015.5	4082016.1	1/15/81	16.61	7487.95
MA-1	7504.56	506015.5	4082016.1	2/16/81	16.81	7487.75
MA-1	7504.56	506015.5	4082016.1	3/11/81	16.44	7488.12
MA-1	7504.56	506015.5	4082016.1	4/15/81	16.44	7488.12
MA-1	7504.56	506015.5	4082016.1	6/12/81	16.47	7488.09
MA-1	7504.56	506015.5	4082016.1	11/13/81	10.58	7493.98
MA-1	7504.56	506015.5	4082016.1	2/15/82	12.69	7491.87
MA-1	7504.56	506015.5	4082016.1	9/17/83	13.99	7490.57
MA-1	7504.56	506015.5	4082016.1	10/17/83	9.56	7495
MA-1	7504.56	506015.5	4082016.1	1/12/84	15.36	7489.2
MA-1	7504.56	506015.5	4082016.1	4/18/84	14.62	7489.94
MA-1	7504.56	506015.5	4082016.1	7/16/84	14.70	7489.86
MA-1	7504.56	506015.5	4082016.1	8/15/84	15.67	7488.89
MA-1	7504.56	506015.5	4082016.1	1/17/85	14.62	7489.94
MA-1	7504.56	506015.5	4082016.1	4/17/85	13.44	7491.12
MA-1	7504.56	506015.5	4082016.1	8/15/85	15.26	7489.3
MA-1	7504.56	506015.5	4082016.1	1/10/86	15.84	7488.72
MA-1	7504.56	506015.5	4082016.1	4/18/86	15.81	7488.75
MA-1	7504.56	506015.5	4082016.1	10/14/86	16.89	7487.67
MA-1	7504.56	506015.5	4082016.1	1/22/87	15.00	7489.56
MA-1	7504.56	506015.5	4082016.1	4/15/87	14.07	7490.49
MA-1	7504.56	506015.5	4082016.1	10/13/87	16.85	7487.71
MA-1	7504.56	506015.5	4082016.1	1/14/88	16.86	7487.7
MA-1	7504.56	506015.5	4082016.1	4/12/88	16.36	7488.2
MA-1	7504.56	506015.5	4082016.1	7/20/88	7.64	7496.92
MA-1	7504.56	506015.5	4082016.1	10/12/88	16.54	7488.02
MA-1	7504.56	506015.5	4082016.1	2/25/89	15.80	7488.76
MA-1	7504.56	506015.5	4082016.1	8/10/89	17.24	7487.32
MA-1	7504.56	506015.5	4082016.1	10/10/89	17.35	7487.21
MA-1	7504.56	506015.5	4082016.1	4/18/90	16.51	7488.05
MA-1	7504.56	506015.5	4082016.1	10/17/90	17.08	7487.48
MA-1	7504.56	506015.5	4082016.1	1/29/91	17.19	7487.37

Site Name	Elevation	UTM X	UTM Y	Date	DTW	PS
MA-1	7504.56	506015.5	4082016.1	4/25/91	16.72	7487.84
MA-1	7504.56	506015.5	4082016.1	8/25/91	15.77	7488.79
MA-1	7504.56	506015.5	4082016.1	10/24/91	16.42	7488.14
MA-1	7504.56	506015.5	4082016.1	3/4/92	16.46	7488.1
MA-1	7504.56	506015.5	4082016.1	6/22/92	16.50	7488.06
MA-1	7504.56	506015.5	4082016.1	7/16/92	16.44	7488.12
MA-1	7504.56	506015.5	4082016.1	11/17/92	16.88	7487.68
MA-1	7504.56	506015.5	4082016.1	3/9/93	16.38	7488.18
MA-1	7504.56	506015.5	4082016.1	5/4/93	16.64	7487.92
MA-1	7504.56	506015.5	4082016.1	9/21/93	16.60	7487.96
MA-1	7504.56	506015.5	4082016.1	2/9/94	17.09	7487.47
MA-1	7504.56	506015.5	4082016.1	3/15/94	17.14	7487.42
MA-1	7504.56	506015.5	4082016.1	7/12/94	16.76	7487.8
MA-1	7504.56	506015.5	4082016.1	8/17/94	16.89	7487.67
MA-1	7504.56	506015.5	4082016.1	10/25/94	16.67	7487.89
MA-1	7504.56	506015.5	4082016.1	1/17/95	17.10	7487.46
MA-1	7504.56	506015.5	4082016.1	5/9/95	16.96	7487.6
MA-1	7504.56	506015.5	4082016.1	7/25/95	16.66	7487.9
MA-1	7504.56	506015.5	4082016.1	11/1/95	16.72	7487.84
MA-1	7504.56	506015.5	4082016.1	3/18/96	16.97	7487.59
MA-1	7504.56	506015.5	4082016.1	4/16/96	16.94	7487.62
MA-1	7504.56	506015.5	4082016.1	7/29/96	16.93	7487.63
MA-1	7504.56	506015.5	4082016.1	10/15/96	16.78	7487.78
MA-1	7504.56	506015.5	4082016.1	2/11/97	17.00	7487.56
MA-1	7504.56	506015.5	4082016.1	5/6/97	15.10	7489.46
MA-1	7504.56	506015.5	4082016.1	7/29/97	16.64	7487.92
MA-1	7504.56	506015.5	4082016.1	11/18/97	16.84	7487.72
MA-1	7504.56	506015.5	4082016.1	2/9/98	17.01	7487.55
MA-1	7504.56	506015.5	4082016.1	5/18/98	16.78	7487.78
MA-1	7504.56	506015.5	4082016.1	8/25/98	170.50	7334.06
MA-1	7504.56	506015.5	4082016.1	11/10/98	17.24	7487.32
MA-3	7599.29	507081.5	4079805	11/10/78	21.00	7578.29
MA-3	7599.29	507081.5	4079805	1/10/79	24.65	7574.64
MA-3	7599.29	507081.5	4079805	2/12/79	25.30	7573.99
MA-3	7599.29	507081.5	4079805	4/18/79	25.00	7574.29
MA-3	7599.29	507081.5	4079805	5/22/79	25.97	7573.32
MA-3	7599.29	507081.5	4079805	6/13/79	24.47	7574.82
MA-3	7599.29	507081.5	4079805	8/16/79	24.30	7574.99
MA-3	7599.29	507081.5	4079805	9/17/79	24.57	7574.72
MA-3	7599.29	507081.5	4079805	10/16/79	24.75	7574.54
MA-3	7599.29	507081.5	4079805	11/19/79	24.59	7574.7
MA-3	7599.29	507081.5	4079805	12/17/79	25.14	7574.15
MA-3	7599.29	507081.5	4079805	2/15/80	26.17	7573.12
MA-3	7599.29	507081.5	4079805	3/19/80	26.23	7573.06
MA-3	7599.29	507081.5	4079805	4/23/80	26.43	7572.86
MA-3	7599.29	507081.5	4079805	5/13/80	24.80	7574.49
MA-3	7599.29	507081.5	4079805	6/11/80	25.32	7573.97
MA-3	7599.29	507081.5	4079805	8/15/80	23.70	7575.59
MA-3	7599.29	507081.5	4079805	9/15/80	23.86	7575.43
MA-3	7599.29	507081.5	4079805	10/15/80	24.42	7574.87

Site Name	Elevation	UTM X	UTM Y	Date	DTW	PS
MA-3	7599.29	507081.5	4079805	11/11/80	23.04	7576.25
MA-3	7599.29	507081.5	4079805	12/15/80	24.72	7574.57
MA-3	7599.29	507081.5	4079805	1/15/81	24.46	7574.83
MA-3	7599.29	507081.5	4079805	2/16/81	24.61	7574.68
MA-3	7599.29	507081.5	4079805	3/11/81	24.38	7574.91
MA-3	7599.29	507081.5	4079805	4/15/81	24.60	7574.69
MA-3	7599.29	507081.5	4079805	5/12/81	24.64	7574.65
MA-3	7599.29	507081.5	4079805	6/12/81	25.00	7574.29
MA-3	7599.29	507081.5	4079805	11/13/81	21.40	7577.89
MA-3	7599.29	507081.5	4079805	2/18/82	22.45	7576.84
MA-3	7599.29	507081.5	4079805	4/13/83	11.00	7588.29
MA-3	7599.29	507081.5	4079805	7/15/83	21.03	7578.26
MA-3	7599.29	507081.5	4079805	10/17/83	21.68	7577.61
MA-3	7599.29	507081.5	4079805	1/19/84	22.02	7577.27
MA-3	7599.29	507081.5	4079805	4/19/84	25.00	7574.29
MA-3	7599.29	507081.5	4079805	7/16/84	21.77	7577.52
MA-3	7599.29	507081.5	4079805	10/19/84	24.75	7574.54
MA-3	7599.29	507081.5	4079805	4/15/85	22.37	7576.92
MA-3	7599.29	507081.5	4079805	7/19/85	20.87	7578.42
MA-3	7599.29	507081.5	4079805	10/17/85	23.98	7575.31
MA-3	7599.29	507081.5	4079805	1/13/86	24.70	7574.59
MA-3	7599.29	507081.5	4079805	4/16/86	24.97	7574.32
MA-3	7599.29	507081.5	4079805	7/28/86	20.70	7578.59
MA-3	7599.29	507081.5	4079805	10/27/86	22.60	7576.69
MA-3	7599.29	507081.5	4079805	1/22/87	24.43	7574.86
MA-3	7599.29	507081.5	4079805	4/20/87	20.00	7579.29
MA-3	7599.29	507081.5	4079805	10/15/87	23.07	7576.22
MA-3	7599.29	507081.5	4079805	1/15/88	23.12	7576.17
MA-3	7599.29	507081.5	4079805	7/27/88	16.89	7582.4
MA-3	7599.29	507081.5	4079805	10/13/88	20.46	7578.83
MA-3	7599.29	507081.5	4079805	7/14/89	23.70	7575.59
MA-3	7599.29	507081.5	4079805	8/11/89	20.74	7578.55
MA-3	7599.29	507081.5	4079805	10/10/89	22.05	7577.24
MA-3	7599.29	507081.5	4079805	3/14/90	23.54	7575.75
MA-3	7599.29	507081.5	4079805	4/18/90	23.43	7575.86
MA-3	7599.29	507081.5	4079805	9/24/91	19.70	7579.59
MA-3	7599.29	507081.5	4079805	12/3/91	21.00	7578.29
MA-3	7599.29	507081.5	4079805	2/12/92	21.70	7577.59
MA-3	7599.29	507081.5	4079805	6/22/92	21.00	7578.29
MA-3	7599.29	507081.5	4079805	7/14/92	22.22	7577.07
MA-3	7599.29	507081.5	4079805	8/17/94	21.36	7577.93
MA-3	7599.29	507081.5	4079805	10/25/94	21.56	7577.73
MA-3	7599.29	507081.5	4079805	5/9/95	24.19	7575.1
MA-3	7599.29	507081.5	4079805	8/2/95	20.72	7578.57
MA-3	7599.29	507081.5	4079805	11/1/95	22.61	7576.68
MA-3	7599.29	507081.5	4079805	3/18/96	23.39	7575.9
MA-3	7599.29	507081.5	4079805	4/17/96	23.35	7575.94
MA-3	7599.29	507081.5	4079805	7/30/96	23.40	7575.89
MA-3	7599.29	507081.5	4079805	10/15/96	23.14	7576.15
MA-3	7599.29	507081.5	4079805	5/6/97	23.11	7576.18

Site Name	Elevation	UTM X	UTM Y	Date	DTW	PS
MA-3	7599.29	507081.5	4079805	7/30/97	22.21	7577.08
MA-3	7599.29	507081.5	4079805	11/18/97	23.34	7575.95
MA-3	7599.29	507081.5	4079805	2/10/98	23.68	7575.61
MA-3	7599.29	507081.5	4079805	5/20/98	23.31	7575.98
MA-3	7599.29	507081.5	4079805	8/28/98	22.31	7576.98
MA-3	7599.29	507081.5	4079805	11/13/98	23.23	7576.06
MA-4	7281.75	507798.3	4078333.4	11/10/78	16.30	7265.45
MA-4	7281.75	507798.3	4078333.4	11/13/78	12.31	7269.44
MA-4	7281.75	507798.3	4078333.4	1/10/79	14.83	7266.92
MA-4	7281.75	507798.3	4078333.4	2/12/79	14.70	7267.05
MA-4	7281.75	507798.3	4078333.4	3/9/79	14.70	7267.05
MA-4	7281.75	507798.3	4078333.4	3/9/79	25.80	7255.95
MA-4	7281.75	507798.3	4078333.4	4/18/79	14.60	7267.15
MA-4	7281.75	507798.3	4078333.4	5/22/79	14.51	7267.24
MA-4	7281.75	507798.3	4078333.4	6/13/79	14.50	7267.25
MA-4	7281.75	507798.3	4078333.4	7/20/79	14.30	7267.45
MA-4	7281.75	507798.3	4078333.4	8/16/79	14.20	7267.55
MA-4	7281.75	507798.3	4078333.4	9/17/79	14.27	7267.48
MA-4	7281.75	507798.3	4078333.4	10/16/79	14.65	7267.1
MA-4	7281.75	507798.3	4078333.4	11/19/79	15.93	7265.82
MA-4	7281.75	507798.3	4078333.4	12/17/79	14.14	7267.61
MA-4	7281.75	507798.3	4078333.4	1/15/80	13.10	7268.65
MA-4	7281.75	507798.3	4078333.4	2/15/80	14.11	7267.64
MA-4	7281.75	507798.3	4078333.4	3/19/80	14.25	7267.5
MA-4	7281.75	507798.3	4078333.4	4/23/80	14.48	7267.27
MA-4	7281.75	507798.3	4078333.4	5/13/80	14.26	7267.49
MA-4	7281.75	507798.3	4078333.4	6/19/80	13.91	7267.84
MA-4	7281.75	507798.3	4078333.4	7/14/80	13.98	7267.77
MA-4	7281.75	507798.3	4078333.4	8/15/80	14.00	7267.75
MA-4	7281.75	507798.3	4078333.4	9/15/80	13.92	7267.83
MA-4	7281.75	507798.3	4078333.4	10/15/80	13.96	7267.79
MA-4	7281.75	507798.3	4078333.4	11/14/80	12.92	7268.83
MA-4	7281.75	507798.3	4078333.4	12/15/80	13.30	7268.45
MA-4	7281.75	507798.3	4078333.4	1/16/81	12.76	7268.99
MA-4	7281.75	507798.3	4078333.4	2/16/81	13.18	7268.57
MA-4	7281.75	507798.3	4078333.4	3/11/81	13.14	7268.61
MA-4	7281.75	507798.3	4078333.4	4/15/81	13.92	7267.83
MA-4	7281.75	507798.3	4078333.4	5/12/81	13.09	7268.66
MA-4	7281.75	507798.3	4078333.4	6/12/81	13.18	7268.57
MA-4	7281.75	507798.3	4078333.4	2/15/82	12.67	7269.08
MA-4	7281.75	507798.3	4078333.4	4/13/83	14.57	7267.18
MA-4	7281.75	507798.3	4078333.4	7/15/83	17.10	7264.65
MA-4	7281.75	507798.3	4078333.4	10/12/83	15.19	7266.56
MA-4	7281.75	507798.3	4078333.4	1/19/84	15.23	7266.52
MA-4	7281.75	507798.3	4078333.4	4/19/84	15.30	7266.45
MA-4	7281.75	507798.3	4078333.4	7/16/84	15.40	7266.35
MA-4	7281.75	507798.3	4078333.4	10/17/84	15.37	7266.38
MA-4	7281.75	507798.3	4078333.4	4/17/85	15.15	7266.6
MA-4	7281.75	507798.3	4078333.4	7/19/85	15.13	7266.62
MA-4	7281.75	507798.3	4078333.4	10/10/85	15.22	7266.53

Site Name	Elevation	UTM X	UTM Y	Date	DTW	PS
MA-4	7281.75	507798.3	4078333.4	1/13/86	15.29	7266.46
MA-4	7281.75	507798.3	4078333.4	4/7/86	15.53	7266.22
MA-4	7281.75	507798.3	4078333.4	7/24/86	15.36	7266.39
MA-4	7281.75	507798.3	4078333.4	1/12/87	15.20	7266.55
MA-4	7281.75	507798.3	4078333.4	4/4/87	14.78	7266.97
MA-4	7281.75	507798.3	4078333.4	10/6/87	15.30	7266.45
MA-4	7281.75	507798.3	4078333.4	1/15/88	15.32	7266.43
MA-4	7281.75	507798.3	4078333.4	7/20/88	7.64	7274.11
MA-4	7281.75	507798.3	4078333.4	10/12/88	13.78	7267.97
MA-4	7281.75	507798.3	4078333.4	7/12/89	15.61	7266.14
MA-4	7281.75	507798.3	4078333.4	10/11/89	15.39	7266.36
MA-4	7281.75	507798.3	4078333.4	3/14/90	15.28	7266.47
MA-4	7281.75	507798.3	4078333.4	4/16/90	15.41	7266.34
MA-4	7281.75	507798.3	4078333.4	10/16/90	14.88	7266.87
MA-4	7281.75	507798.3	4078333.4	2/14/91	15.29	7266.46
MA-4	7281.75	507798.3	4078333.4	4/26/91	15.38	7266.37
MA-4	7281.75	507798.3	4078333.4	7/25/91	13.86	7267.89
MA-4	7281.75	507798.3	4078333.4	10/24/91	13.58	7268.17
MA-4	7281.75	507798.3	4078333.4	2/6/92	13.86	7267.89
MA-4	7281.75	507798.3	4078333.4	6/9/92	14.06	7267.69
MA-4	7281.75	507798.3	4078333.4	9/26/92	14.76	7134.15
MA-4	7281.75	507798.3	4078333.4	11/17/92	13.68	7268.07
MA-4	7281.75	507798.3	4078333.4	3/9/93	13.92	7267.83
MA-4	7281.75	507798.3	4078333.4	5/5/93	14.18	7267.57
MA-4	7281.75	507798.3	4078333.4	9/22/93	14.64	7267.11
MA-4	7281.75	507798.3	4078333.4	2/8/94	15.04	7266.71
MA-4	7281.75	507798.3	4078333.4	3/15/94	14.94	7266.81
MA-4	7281.75	507798.3	4078333.4	7/13/94	14.85	7266.9
MA-4	7281.75	507798.3	4078333.4	8/17/94	14.00	7267.75
MA-4	7281.75	507798.3	4078333.4	10/25/94	14.90	7266.85
MA-4	7281.75	507798.3	4078333.4	5/9/95	15.10	7266.65
MA-4	7281.75	507798.3	4078333.4	9/2/95	15.00	7266.75
MA-4	7281.75	507798.3	4078333.4	11/1/95	15.03	7266.72
MA-4	7281.75	507798.3	4078333.4	3/13/96	15.17	7266.58
MA-4	7281.75	507798.3	4078333.4	4/16/96	15.25	7266.5
MA-4	7281.75	507798.3	4078333.4	7/30/96	14.58	7267.17
MA-4	7281.75	507798.3	4078333.4	10/16/96	15.13	7266.62
MA-4	7281.75	507798.3	4078333.4	2/11/97	15.30	7266.45
MA-4	7281.75	507798.3	4078333.4	5/6/97	15.01	7266.74
MA-4	7281.75	507798.3	4078333.4	7/29/97	14.94	7266.81
MA-4	7281.75	507798.3	4078333.4	11/18/97	15.33	7266.42
MA-4	7281.75	507798.3	4078333.4	2/9/98	15.19	7266.56
MA-4	7281.75	507798.3	4078333.4	5/18/98	15.37	7266.38
MA-4	7281.75	507798.3	4078333.4	8/25/98	14.91	7266.84
MA-4	7281.75	507798.3	4078333.4	11/10/98	15.29	7266.46
MA-7	7280	504715.1	4079323.4	4/18/78	17.50	7262.5
MA-7	7280	504715.1	4079323.4	11/10/78	18.05	7261.95
MA-7	7280	504715.1	4079323.4	1/10/79	17.50	7262.5
MA-7	7280	504715.1	4079323.4	2/12/79	17.40	7262.6
MA-7	7280	504715.1	4079323.4	3/9/79	18.20	7261.8

Site Name	Elevation	UTM X	UTM Y	Date	DTW	PS
MA-7	7280	504715.1	4079323.4	8/17/79	13.00	7267
MA-7	7280	504715.1	4079323.4	9/11/79	16.97	7263.03
MA-7	7280	504715.1	4079323.4	10/16/79	17.47	7262.53
MA-7	7280	504715.1	4079323.4	11/19/79	17.27	7262.73
MA-7	7280	504715.1	4079323.4	12/17/79	18.24	7261.76
MA-7	7280	504715.1	4079323.4	1/15/80	17.07	7262.93
MA-7	7280	504715.1	4079323.4	2/15/80	17.25	7262.75
MA-7	7280	504715.1	4079323.4	3/19/80	17.12	7262.88
MA-7	7280	504715.1	4079323.4	4/23/80	17.11	7262.89
MA-7	7280	504715.1	4079323.4	5/13/80	15.40	7264.6
MA-7	7280	504715.1	4079323.4	6/19/80	16.59	7263.41
MA-7	7280	504715.1	4079323.4	7/14/80	16.92	7263.08
MA-7	7280	504715.1	4079323.4	8/15/80	17.10	7262.9
MA-7	7280	504715.1	4079323.4	9/15/80	17.02	7262.98
MA-7	7280	504715.1	4079323.4	10/15/80	17.13	7262.87
MA-7	7280	504715.1	4079323.4	11/14/80	16.88	7263.12
MA-7	7280	504715.1	4079323.4	12/15/80	16.92	7263.08
MA-7	7280	504715.1	4079323.4	1/15/81	16.70	7263.3
MA-7	7280	504715.1	4079323.4	1/15/81	16.70	7263.3
MA-7	7280	504715.1	4079323.4	2/16/81	16.80	7263.2
MA-7	7280	504715.1	4079323.4	3/11/81	17.00	7263
MA-7	7280	504715.1	4079323.4	4/15/81	16.94	7263.06
MA-7	7280	504715.1	4079323.4	5/12/81	16.98	7263.02
MA-7	7280	504715.1	4079323.4	6/12/81	16.95	7263.05
MA-7	7280	504715.1	4079323.4	11/13/81	15.65	7264.35
MA-7	7280	504715.1	4079323.4	2/15/82	16.27	7263.73
MA-7	7280	504715.1	4079323.4	4/13/83	16.78	7263.22
MA-7	7280	504715.1	4079323.4	7/15/83	15.85	7264.15
MA-7	7280	504715.1	4079323.4	10/17/83	16.85	7263.15
MA-7	7280	504715.1	4079323.4	1/19/84	16.87	7263.13
MA-7	7280	504715.1	4079323.4	4/19/84	17.00	7263
MA-7	7280	504715.1	4079323.4	7/16/84	15.69	7264.31
MA-7	7280	504715.1	4079323.4	10/17/84	14.15	7265.85
MA-7	7280	504715.1	4079323.4	4/16/85	14.71	7265.29
MA-7	7280	504715.1	4079323.4	7/16/85	16.31	7263.69
MA-7	7280	504715.1	4079323.4	10/10/85	17.00	7163
MA-7	7280	504715.1	4079323.4	1/10/86	16.92	7263.08
MA-7	7280	504715.1	4079323.4	4/15/86	18.15	7261.85
MA-7	7280	504715.1	4079323.4	7/28/86	16.43	7263.57
MA-7	7280	504715.1	4079323.4	10/28/86	16.77	7263.23
MA-7	7280	504715.1	4079323.4	1/21/87	17.17	7262.83
MA-7	7280	504715.1	4079323.4	4/20/87	14.79	7265.21
MA-7	7280	504715.1	4079323.4	10/8/87	17.06	7262.94
MA-7	7280	504715.1	4079323.4	1/13/88	17.66	7262.34
MA-7	7280	504715.1	4079323.4	4/28/88	16.85	7263.15
MA-7	7280	504715.1	4079323.4	7/13/88	16.46	7263.54
MA-7	7280	504715.1	4079323.4	10/5/88	13.79	7266.21
MA-7	7280	504715.1	4079323.4	5/22/89	17.10	7262.9
MA-7	7280	504715.1	4079323.4	7/14/89	16.87	7263.13
MA-7	7280	504715.1	4079323.4	11/10/89	16.53	7263.47

Site Name	Elevation	UTM X	UTM Y	Date	DTW	PS
MA-7	7280	504715.1	4079323.4	7/25/91	11.98	7268.02
MA-7	7280	504715.1	4079323.4	10/10/91	13.44	7266.56
MA-7	7280	504715.1	4079323.4	2/12/92	15.40	7264.6
MA-7	7280	504715.1	4079323.4	5/4/92	13.72	7266.28
MA-7	7280	504715.1	4079323.4	9/26/92	11.44	7268.56
MA-7	7280	504715.1	4079323.4	11/17/92	15.50	7264.5
MA-7	7280	504715.1	4079323.4	3/9/93	15.80	7264.2
MA-7	7280	504715.1	4079323.4	5/4/93	14.84	7265.16
MA-7	7280	504715.1	4079323.4	9/21/93	15.88	7264.12
MA-7	7280	504715.1	4079323.4	2/8/94	15.91	7264.09
MA-7	7280	504715.1	4079323.4	3/15/94	15.92	7264.08
MA-7	7280	504715.1	4079323.4	7/12/94	14.58	7265.42
MA-7	7280	504715.1	4079323.4	8/23/94	11.73	7268.27
MA-7	7280	504715.1	4079323.4	10/27/94	15.47	7264.53
MA-7	7280	504715.1	4079323.4	1/18/95	14.92	7265.08
MA-7	7280	504715.1	4079323.4	5/10/95	14.60	7265.4
MA-7	7280	504715.1	4079323.4	7/26/95	13.59	7266.41
MA-7	7280	504715.1	4079323.4	11/1/95	14.11	7265.89
MA-7	7280	504715.1	4079323.4	3/12/96	14.37	7265.63
MA-7	7280	504715.1	4079323.4	4/16/96	14.24	7265.76
MA-7	7280	504715.1	4079323.4	7/29/96	13.72	7266.28
MA-7	7280	504715.1	4079323.4	10/22/96	13.85	7266.15
MA-7	7280	504715.1	4079323.4	2/12/97	14.82	7265.18
MA-7	7280	504715.1	4079323.4	5/8/97	13.92	7266.08
MA-7	7280	504715.1	4079323.4	7/29/97	13.60	7266.4
MA-7	7280	504715.1	4079323.4	11/19/97	14.70	7265.3
MA-7	7280	504715.1	4079323.4	2/11/98	14.95	7265.05
MA-7	7280	504715.1	4079323.4	5/20/98	14.73	7265.27
MA-7	7280	504715.1	4079323.4	8/27/98	14.47	7265.53
MA-7	7280	504715.1	4079323.4	11/13/98	14.29	7265.71
MA-8	7250	506127.3	4078340.7	11/10/78	16.16	7233.84
MA-8	7250	506127.3	4078340.7	1/10/79	15.45	7234.55
MA-8	7250	506127.3	4078340.7	2/12/79	15.70	7234.3
MA-8	7250	506127.3	4078340.7	3/9/79	15.00	7235
MA-8	7250	506127.3	4078340.7	4/18/79	15.00	7235
MA-8	7250	506127.3	4078340.7	5/22/79	15.58	7234.42
MA-8	7250	506127.3	4078340.7	6/13/79	14.54	7235.46
MA-8	7250	506127.3	4078340.7	8/17/79	15.75	7234.25
MA-8	7250	506127.3	4078340.7	9/17/79	15.61	7234.39
MA-8	7250	506127.3	4078340.7	10/16/79	16.22	7233.78
MA-8	7250	506127.3	4078340.7	11/19/79	14.72	7235.28
MA-8	7250	506127.3	4078340.7	12/17/79	14.72	7235.28
MA-8	7250	506127.3	4078340.7	1/15/80	15.46	7234.54
MA-8	7250	506127.3	4078340.7	2/15/80	15.07	7234.93
MA-8	7250	506127.3	4078340.7	3/19/80	15.37	7234.63
MA-8	7250	506127.3	4078340.7	4/23/80	15.22	7234.78
MA-8	7250	506127.3	4078340.7	5/13/80	14.45	7235.55
MA-8	7250	506127.3	4078340.7	6/19/80	15.50	7234.5
MA-8	7250	506127.3	4078340.7	7/14/80	15.50	7234.5
MA-8	7250	506127.3	4078340.7	8/15/80	15.72	7234.28

Site Name	Elevation	UTM X	UTM Y	Date	DTW	PS
MA-8	7250	506127.3	4078340.7	9/15/80	15.94	7234.06
MA-8	7250	506127.3	4078340.7	10/15/80	15.96	7234.04
MA-8	7250	506127.3	4078340.7	11/14/80	15.94	7234.06
MA-8	7250	506127.3	4078340.7	12/15/80	15.41	7234.59
MA-8	7250	506127.3	4078340.7	1/15/81	15.24	7234.76
MA-8	7250	506127.3	4078340.7	2/16/81	15.31	7234.69
MA-8	7250	506127.3	4078340.7	3/11/81	15.16	7234.84
MA-8	7250	506127.3	4078340.7	4/14/81	15.01	7234.99
MA-8	7250	506127.3	4078340.7	5/12/81	15.12	7234.88
MA-8	7250	506127.3	4078340.7	6/12/81	15.24	7234.76
MA-8	7250	506127.3	4078340.7	11/13/81	12.71	7237.29
MA-8	7250	506127.3	4078340.7	2/15/82	14.03	7235.97
MA-8	7250	506127.3	4078340.7	4/13/83	13.80	7236.2
MA-8	7250	506127.3	4078340.7	7/15/83	13.62	7236.38
MA-8	7250	506127.3	4078340.7	10/17/83	9.83	7240.17
MA-8	7250	506127.3	4078340.7	1/19/84	15.00	7235
MA-8	7250	506127.3	4078340.7	4/19/84	14.98	7235.02
MA-8	7250	506127.3	4078340.7	7/18/84	15.20	7234.8
MA-8	7250	506127.3	4078340.7	10/17/84	15.13	7234.87
MA-8	7250	506127.3	4078340.7	4/16/85	14.22	7235.78
MA-8	7250	506127.3	4078340.7	7/16/85	15.38	7234.62
MA-8	7250	506127.3	4078340.7	10/10/85	14.37	7235.63
MA-8	7250	506127.3	4078340.7	1/10/86	14.77	7235.23
MA-8	7250	506127.3	4078340.7	4/15/86	14.11	7235.89
MA-8	7250	506127.3	4078340.7	7/28/86	14.97	7235.03
MA-8	7250	506127.3	4078340.7	10/28/86	14.30	7235.7
MA-8	7250	506127.3	4078340.7	1/14/87	13.09	7236.91
MA-8	7250	506127.3	4078340.7	4/15/87	14.32	7235.68
MA-8	7250	506127.3	4078340.7	1/13/88	15.49	7234.51
MA-8	7250	506127.3	4078340.7	4/21/88	13.40	7236.6
MA-8	7250	506127.3	4078340.7	7/13/88	13.66	7236.34
MA-8	7250	506127.3	4078340.7	10/5/88	13.70	7236.3
MA-8	7250	506127.3	4078340.7	7/14/89	16.38	7233.62
MA-8	7250	506127.3	4078340.7	11/10/89	15.00	7235
MA-8	7250	506127.3	4078340.7	3/20/90	15.26	7234.74
MA-8	7250	506127.3	4078340.7	4/18/90	14.90	7235.1
MA-8	7250	506127.3	4078340.7	10/17/90	14.54	7235.46
MA-8	7250	506127.3	4078340.7	2/14/91	14.51	7235.49
MA-8	7250	506127.3	4078340.7	4/26/91	14.67	7235.33
MA-8	7250	506127.3	4078340.7	7/25/91	14.82	7235.18
MA-8	7250	506127.3	4078340.7	12/16/91	15.36	7234.64
MA-8	7250	506127.3	4078340.7	2/6/92	15.46	7234.54
MA-8	7250	506127.3	4078340.7	5/4/92	14.86	7235.14
MA-8	7250	506127.3	4078340.7	7/7/92	15.00	7235
MA-8	7250	506127.3	4078340.7	9/26/92	15.58	7234.42
MA-8	7250	506127.3	4078340.7	11/17/92	15.90	7234.1
MA-8	7250	506127.3	4078340.7	3/9/93	12.16	7237.84
MA-8	7250	506127.3	4078340.7	5/4/93	15.24	7234.76
MA-8	7250	506127.3	4078340.7	2/9/94	15.92	7234.08
MA-8	7250	506127.3	4078340.7	3/15/94	15.44	7234.56

Site Name	Elevation	UTM X	UTM Y	Date	DTW	PS
MA-8	7250	506127.3	4078340.7	7/12/94	14.19	7235.81
MA-8	7250	506127.3	4078340.7	8/23/94	14.82	7235.18
MA-8	7250	506127.3	4078340.7	10/27/94	15.44	7234.56
MA-8	7250	506127.3	4078340.7	5/10/95	15.41	7234.59
MA-8	7250	506127.3	4078340.7	7/16/95	15.04	7234.96
MA-8	7250	506127.3	4078340.7	11/1/95	15.66	7234.34
MA-8	7250	506127.3	4078340.7	3/12/96	15.26	7234.74
MA-8	7250	506127.3	4078340.7	4/16/96	15.33	7234.67
MA-8	7250	506127.3	4078340.7	7/29/96	15.40	7234.6
MA-8	7250	506127.3	4078340.7	10/22/96	15.14	7234.86
MA-8	7250	506127.3	4078340.7	2/12/97	15.39	7234.61
MA-8	7250	506127.3	4078340.7	5/7/97	15.10	7234.9
MA-8	7250	506127.3	4078340.7	7/29/97	15.22	7234.78
MA-8	7250	506127.3	4078340.7	11/19/97	15.60	7234.4
MA-8	7250	506127.3	4078340.7	2/11/98	15.68	7234.32
MA-8	7250	506127.3	4078340.7	5/20/98	15.21	7234.79
MA-8	7250	506127.3	4078340.7	8/27/98	14.88	7235.12
MA-8	7250	506127.3	4078340.7	11/13/98	15.43	7234.57
M-1	7599.87	507526.6	4082781.9	8/17/86	74.00	7525.87
M-1	7599.87	507526.6	4082781.9	8/11/87	75.46	7524.41
M-1	7599.87	507526.6	4082781.9	4/6/88	75.96	7523.91
M-1	7599.87	507526.6	4082781.9	7/18/88	75.87	7524
M-1	7599.87	507526.6	4082781.9	8/23/88	75.95	7523.92
M-1	7599.87	507526.6	4082781.9	12/12/89	77.75	7522.12
M-1	7599.87	507526.6	4082781.9	6/27/90	78.37	7521.5
M-1	7599.87	507526.6	4082781.9	9/18/91	78.99	7520.88
M-1	7599.87	507526.6	4082781.9	2/15/93	80.40	7519.47
M-1	7599.87	507526.6	4082781.9	12/9/93	150.70	7449.17
M-1	7599.87	507526.6	4082781.9	9/10/94	81.97	7517.9
M-1	7599.87	507526.6	4082781.9	11/28/95	82.87	7517
M-1	7599.87	507526.6	4082781.9	11/19/96	83.95	7515.92
M-1	7599.87	507526.6	4082781.9	9/16/98	85.81	7514.06
M-1	7599.87	507526.6	4082781.9	10/28/98	84.01	7515.86
M-11	7832.14	509932.4	4082320.3	8/18/86	11.00	7821.14
M-11	7832.14	509932.4	4082320.3	8/6/87	263.17	7568.97
M-11	7832.14	509932.4	4082320.3	4/4/88	12.25	7819.89
M-11	7832.14	509932.4	4082320.3	7/18/88	12.64	7819.5
M-11	7832.14	509932.4	4082320.3	8/23/88	10.24	7821.9
M-11	7832.14	509932.4	4082320.3	6/22/89	13.28	7818.86
M-11	7832.14	509932.4	4082320.3	6/19/90	10.92	7821.22
M-11	7832.14	509932.4	4082320.3	9/18/91	7.92	7824.22
M-11	7832.14	509932.4	4082320.3	2/15/93	10.82	7821.32
M-11	7832.14	509932.4	4082320.3	12/13/93	11.50	7820.64
M-11	7832.14	509932.4	4082320.3	9/19/94	11.36	7820.78
M-11	7832.14	509932.4	4082320.3	12/1/95	11.15	7820.99
M-11	7832.14	509932.4	4082320.3	11/20/96	11.26	7820.88
M-11	7832.14	509932.4	4082320.3	10/28/97	11.24	7820.9
M-11	7832.14	509932.4	4082320.3	9/15/98	12.49	7819.65
M-13	7745.09	508722.8	4084892.4	8/11/81	74.39	7670.7
M-13	7745.09	508722.8	4084892.4	8/17/83	68.96	7676.13

Site Name	Elevation	UTM X	UTM Y	Date	DTW	PS
M-13	7745.09	508722.8	4084892.4	8/13/85	68.82	7676.27
M-13	7745.09	508722.8	4084892.4	8/19/86	70.00	7675.09
M-13	7745.09	508722.8	4084892.4	8/10/87	70.97	7674.12
M-13	7745.09	508722.8	4084892.4	4/5/88	72.16	7672.93
M-13	7745.09	508722.8	4084892.4	7/25/88	69.55	7675.54
M-13	7745.09	508722.8	4084892.4	8/23/88	69.73	7675.36
M-13	7745.09	508722.8	4084892.4	12/13/89	72.10	7672.99
M-13	7745.09	508722.8	4084892.4	6/28/90	72.55	7672.54
M-13	7745.09	508722.8	4084892.4	9/17/91	72.36	7672.73
M-13	7745.09	508722.8	4084892.4	2/15/93	73.12	7671.97
M-13	7745.09	508722.8	4084892.4	12/13/93	74.24	7670.85
M-13	7745.09	508722.8	4084892.4	9/9/94	75.07	7670.02
M-13	7745.09	508722.8	4084892.4	11/28/95	85.60	7659.49
M-13	7745.09	508722.8	4084892.4	11/19/96	95.24	7649.85
M-13	7745.09	508722.8	4084892.4	10/28/97	97.74	7647.35
M-13	7745.09	508722.8	4084892.4	9/16/98	101.44	7643.65
M-14	7744.97	508718.6	4084886.6	8/11/81	139.27	7605.7
M-14	7744.97	508718.6	4084886.6	8/17/83	139.10	7605.87
M-14	7744.97	508718.6	4084886.6	8/15/84	140.33	7604.64
M-14	7744.97	508718.6	4084886.6	8/13/85	144.70	7600.27
M-14	7744.97	508718.6	4084886.6	8/19/86	146.27	7598.7
M-14	7744.97	508718.6	4084886.6	8/10/87	147.37	7597.6
M-14	7744.97	508718.6	4084886.6	4/5/88	147.75	7597.22
M-14	7744.97	508718.6	4084886.6	7/25/88	147.93	7597.04
M-14	7744.97	508718.6	4084886.6	8/3/88	42.99	7701.98
M-14	7744.97	508718.6	4084886.6	12/13/89	150.00	7594.97
M-14	7744.97	508718.6	4084886.6	5/24/91	150.39	7594.58
M-14	7744.97	508718.6	4084886.6	9/23/91	151.31	7593.66
M-14	7744.97	508718.6	4084886.6	2/15/93	151.32	7593.65
M-14	7744.97	508718.6	4084886.6	12/13/93	152.16	7592.81
M-14	7744.97	508718.6	4084886.6	9/9/94	152.83	7592.14
M-14	7744.97	508718.6	4084886.6	11/28/95	153.45	7591.52
M-14	7744.97	508718.6	4084886.6	11/19/96	154.26	7590.71
M-14	7744.97	508718.6	4084886.6	10/28/97	154.87	7590.1
M-14	7744.97	508718.6	4084886.6	9/16/98	155.75	7589.22
M-15	7745.84	508713.8	4084880.2	8/11/81	42.99	7702.85
M-15	7745.84	508713.8	4084880.2	8/17/83	43.06	7702.78
M-15	7745.84	508713.8	4084880.2	8/15/84	43.24	7702.6
M-15	7745.84	508713.8	4084880.2	8/13/85	42.89	7702.95
M-15	7745.84	508713.8	4084880.2	8/19/86	42.60	7703.24
M-15	7745.84	508713.8	4084880.2	8/10/87	42.52	7703.32
M-15	7745.84	508713.8	4084880.2	4/5/88	40.20	7705.64
M-15	7745.84	508713.8	4084880.2	7/25/88	40.23	7705.61
M-15	7745.84	508713.8	4084880.2	8/23/88	40.22	7705.62
M-15	7745.84	508713.8	4084880.2	6/29/89	42.42	7703.42
M-15	7745.84	508713.8	4084880.2	6/14/90	41.81	7704.03
M-15	7745.84	508713.8	4084880.2	9/25/91	39.71	7706.13
M-15	7745.84	508713.8	4084880.2	2/15/93	39.46	7706.38
M-15	7745.84	508713.8	4084880.2	12/9/93	40.86	7704.98
M-15	7745.84	508713.8	4084880.2	9/9/94	40.30	7705.54

Site Name	Elevation	UTM X	UTM Y	Date	DTW	PS
M-15	7745.84	508713.8	4084880.2	11/28/95	40.44	7705.4
M-15	7745.84	508713.8	4084880.2	11/19/96	40.13	7705.71
M-15	7745.84	508713.8	4084880.2	10/28/97	40.53	7705.31
M-15	7745.84	508713.8	4084880.2	9/16/98	40.88	7704.96
M-2	7599.84	507523.3	4082775.5	8/18/86	145.33	7454.51
M-2	7599.84	507523.3	4082775.5	8/11/87	145.15	7454.69
M-2	7599.84	507523.3	4082775.5	4/6/88	141.80	7458.04
M-2	7599.84	507523.3	4082775.5	7/29/88	147.67	7452.17
M-2	7599.84	507523.3	4082775.5	8/3/88	147.77	7452.07
M-2	7599.84	507523.3	4082775.5	12/12/89	152.00	7447.84
M-2	7599.84	507523.3	4082775.5	6/27/90	152.80	7447.04
M-2	7599.84	507523.3	4082775.5	9/18/91	152.32	7447.52
M-2	7599.84	507523.3	4082775.5	2/15/93	150.26	7449.58
M-2	7599.84	507523.3	4082775.5	9/10/94	151.41	7448.43
M-2	7599.84	507523.3	4082775.5	11/28/95	151.10	7448.74
M-2	7599.84	507523.3	4082775.5	11/19/96	151.70	7448.14
M-2	7599.84	507523.3	4082775.5	10/28/97	151.63	7448.21
M-2	7599.84	507523.3	4082775.5	9/16/98	152.05	7447.79
M-3	7599.29	507520.9	4082771.2	8/17/86	47.62	7551.67
M-3	7599.29	507520.9	4082771.2	8/11/87	50.10	7549.19
M-3	7599.29	507520.9	4082771.2	4/6/88	49.38	7549.91
M-3	7599.29	507520.9	4082771.2	7/29/88	39.85	7559.44
M-3	7599.29	507520.9	4082771.2	8/2/88	39.76	7559.53
M-3	7599.29	507520.9	4082771.2	6/22/89	39.63	7559.66
M-3	7599.29	507520.9	4082771.2	6/27/90	41.12	7558.17
M-3	7599.29	507520.9	4082771.2	9/18/91	142.34	7456.95
M-3	7599.29	507520.9	4082771.2	12/9/92	147.50	7451.79
M-3	7599.29	507520.9	4082771.2	2/15/93	147.70	7451.59
M-3	7599.29	507520.9	4082771.2	9/10/94	147.97	7451.32
M-3	7599.29	507520.9	4082771.2	12/28/95	148.95	7450.34
M-3	7599.29	507520.9	4082771.2	11/19/96	149.65	7449.64
M-3	7599.29	507520.9	4082771.2	10/28/97	150.08	7449.21
M-3	7599.29	507520.9	4082771.2	9/16/98	150.59	7448.7
M-4	7677.41	509869.8	4080857.3	8/18/86	32.55	7644.86
M-4	7677.41	509869.8	4080857.3	10/27/86	15.26	7662.15
M-4	7677.41	509869.8	4080857.3	8/6/87	26.65	7650.76
M-4	7677.41	509869.8	4080857.3	7/18/88	36.28	7641.13
M-4	7677.41	509869.8	4080857.3	8/23/88	36.28	7641.13
M-4	7677.41	509869.8	4080857.3	6/22/89	45.81	7631.6
M-4	7677.41	509869.8	4080857.3	6/27/90	44.38	7633.03
M-4	7677.41	509869.8	4080857.3	9/18/91	24.38	7653.03
M-4	7677.41	509869.8	4080857.3	2/15/93	45.96	7631.45
M-4	7677.41	509869.8	4080857.3	12/9/93	50.14	7627.27
M-4	7677.41	509869.8	4080857.3	9/19/94	46.38	7631.03
M-4	7677.41	509869.8	4080857.3	12/1/95	57.00	7620.41
M-4	7677.41	509869.8	4080857.3	11/20/96	57.68	7619.73
M-4	7677.41	509869.8	4080857.3	10/29/97	54.62	7622.79
M-4	7677.41	509869.8	4080857.3	9/15/98	60.94	7616.47
M-5	7677.93	509868.8	4080865.9	8/11/81	39.23	7638.7
M-5	7677.93	509868.8	4080865.9	8/18/86	33.97	7643.96

Site Name	Elevation	UTM X	UTM Y	Date	DTW	PS
M-5	7677.93	509868.8	4080865.9	8/6/87	29.53	7648.4
M-5	7677.93	509868.8	4080865.9	7/18/88	33.05	7644.88
M-5	7677.93	509868.8	4080865.9	8/23/88	32.98	7644.95
M-5	7677.93	509868.8	4080865.9	6/22/89	34.42	7643.51
M-5	7677.93	509868.8	4080865.9	6/27/90	34.20	7643.73
M-5	7677.93	509868.8	4080865.9	9/18/91	23.60	7654.33
M-5	7677.93	509868.8	4080865.9	12/9/92	31.70	7646.23
M-5	7677.93	509868.8	4080865.9	2/15/93	30.48	7647.45
M-5	7677.93	509868.8	4080865.9	9/19/94	28.99	7648.94
M-5	7677.93	509868.8	4080865.9	12/1/95	29.91	7648.02
M-5	7677.93	509868.8	4080865.9	11/20/96	31.01	7646.92
M-5	7677.93	509868.8	4080865.9	10/29/97	29.42	7648.51
M-5	7677.93	509868.8	4080865.9	9/15/98	32.27	7645.66
M-7	7622.08	507721.2	4079779.9	8/17/83	150.11	7471.97
M-7	7622.08	507721.2	4079779.9	8/15/84	155.59	7466.49
M-7	7622.08	507721.2	4079779.9	8/13/85	155.70	7466.38
M-7	7622.08	507721.2	4079779.9	8/18/86	157.30	7464.78
M-7	7622.08	507721.2	4079779.9	8/8/87	156.02	7466.06
M-7	7622.08	507721.2	4079779.9	4/13/88	157.32	7464.76
M-7	7622.08	507721.2	4079779.9	7/18/88	157.42	7464.66
M-7	7622.08	507721.2	4079779.9	8/4/88	157.47	7464.61
M-7	7622.08	507721.2	4079779.9	12/12/89	161.37	7460.71
M-7	7622.08	507721.2	4079779.9	6/27/90	162.93	7459.15
M-7	7622.08	507721.2	4079779.9	9/18/91	165.10	7456.98
M-7	7622.08	507721.2	4079779.9	12/9/92	166.16	7455.92
M-7	7622.08	507721.2	4079779.9	12/15/92	66.08	7556
M-7	7622.08	507721.2	4079779.9	2/15/93	167.08	7455
M-7	7622.08	507721.2	4079779.9	9/19/94	141.94	7480.14
M-7	7622.08	507721.2	4079779.9	11/29/95	143.49	7478.59
M-7	7622.08	507721.2	4079779.9	11/19/96	144.88	7477.2
M-7	7622.08	507721.2	4079779.9	10/28/97	144.53	7477.55
M-7	7622.08	507721.2	4079779.9	9/16/98	143.62	7478.46
M-8	7843.47	509938.5	4082323.7	8/11/81	300.06	7543.41
M-8	7843.47	509938.5	4082323.7	8/18/86	261.50	7581.97
M-8	7843.47	509938.5	4082323.7	8/6/87	10.24	7833.23
M-8	7843.47	509938.5	4082323.7	4/4/88	259.09	7584.38
M-8	7843.47	509938.5	4082323.7	7/18/88	256.24	7587.23
M-8	7843.47	509938.5	4082323.7	8/3/88	256.21	7587.26
M-8	7843.47	509938.5	4082323.7	12/13/89	259.67	7583.8
M-8	7843.47	509938.5	4082323.7	6/28/90	261.71	7581.76
M-8	7843.47	509938.5	4082323.7	9/17/91	252.64	7590.83
M-8	7843.47	509938.5	4082323.7	2/15/93	256.42	7587.05
M-8	7843.47	509938.5	4082323.7	12/13/93	270.40	7573.07
M-8	7843.47	509938.5	4082323.7	9/19/94	280.64	7562.83
M-8	7843.47	509938.5	4082323.7	12/1/95	250.35	7593.12
M-8	7843.47	509938.5	4082323.7	11/20/96	242.11	7601.36
M-8	7843.47	509938.5	4082323.7	10/29/97	244.63	7598.84
M-8	7843.47	509938.5	4082323.7	9/15/98	245.25	7598.22
MA-12	6999	513065.3	4072073.4	4/11/83	11.06	6987.94
MA-12	6999	513065.3	4072073.4	7/13/83	11.35	6987.65

Site Name	Elevation	UTM X	UTM Y	Date	DTW	PS
MA-12	6999	513065.3	4072073.4	1/16/84	11.38	6987.62
MA-12	6999	513065.3	4072073.4	4/16/84	12.81	6986.19
MA-12	6999	513065.3	4072073.4	7/17/84	11.35	6987.65
MA-12	6999	513065.3	4072073.4	10/16/84	12.92	6986.08
MA-12	6999	513065.3	4072073.4	1/16/85	12.68	6986.32
MA-12	6999	513065.3	4072073.4	4/16/85	12.70	6986.3
MA-12	6999	513065.3	4072073.4	7/17/85	12.95	6986.05
MA-12	6999	513065.3	4072073.4	10/15/85	12.31	6986.69
MA-12	6999	513065.3	4072073.4	1/6/86	12.67	6986.33
MA-12	6999	513065.3	4072073.4	4/29/86	12.67	6986.33
MA-12	6999	513065.3	4072073.4	10/9/86	12.38	6986.62
MA-12	6999	513065.3	4072073.4	1/13/87	12.38	6986.62
MA-12	6999	513065.3	4072073.4	7/6/87	11.37	6987.63
MA-12	6999	513065.3	4072073.4	10/1/87	11.52	6987.48
MA-12	6999	513065.3	4072073.4	1/12/88	11.21	6987.79
MA-12	6999	513065.3	4072073.4	4/20/88	9.30	6989.7
MA-12	6999	513065.3	4072073.4	7/27/88	9.21	6989.79
MA-12	6999	513065.3	4072073.4	10/4/88	10.48	6988.52
MA-12	6999	513065.3	4072073.4	8/14/89	12.20	6986.8
MA-12	6999	513065.3	4072073.4	11/17/89	12.07	6986.93
MA-12	6999	513065.3	4072073.4	3/20/90	11.38	6987.62
MA-12	6999	513065.3	4072073.4	5/16/90	12.14	6986.86
MA-12	6999	513065.3	4072073.4	11/20/90	11.44	6987.56
MA-12	6999	513065.3	4072073.4	3/20/91	11.13	6987.87
MA-12	6999	513065.3	4072073.4	5/22/91	11.28	6987.72
MA-12	6999	513065.3	4072073.4	8/20/91	10.20	6988.8
MA-12	6999	513065.3	4072073.4	11/13/91	11.34	6987.66
MA-12	6999	513065.3	4072073.4	1/7/92	11.40	6987.6
MA-12	6999	513065.3	4072073.4	6/22/92	11.36	6987.64
MA-12	6999	513065.3	4072073.4	9/24/92	11.32	6987.68
MA-12	6999	513065.3	4072073.4	11/18/92	11.46	6987.54
MA-12	6999	513065.3	4072073.4	3/10/93	11.26	6987.74
MA-12	6999	513065.3	4072073.4	5/6/93	11.62	6987.38
MA-12	6999	513065.3	4072073.4	9/22/93	16.92	6982.08
MA-12	6999	513065.3	4072073.4	2/9/94	11.62	6987.38
MA-12	6999	513065.3	4072073.4	3/15/94	11.23	6987.77
MA-12	6999	513065.3	4072073.4	7/13/94	12.13	6986.87
MA-12	6999	513065.3	4072073.4	8/24/94	11.64	6987.36
MA-12	6999	513065.3	4072073.4	1/18/95	11.43	6987.57
MA-12	6999	513065.3	4072073.4	5/10/95	11.56	6987.44
MA-12	6999	513065.3	4072073.4	8/1/95	11.60	6987.4
MA-12	6999	513065.3	4072073.4	11/2/95	11.25	6987.75
MA-12	6999	513065.3	4072073.4	3/13/96	11.03	6987.97
MA-12	6999	513065.3	4072073.4	4/17/96	11.30	6987.7
MA-12	6999	513065.3	4072073.4	7/30/96	11.50	6987.5
MA-12	6999	513065.3	4072073.4	10/16/96	11.22	6987.78
MA-12	6999	513065.3	4072073.4	2/11/97	10.74	6988.26
MA-12	6999	513065.3	4072073.4	5/7/97	11.13	6987.87
MA-12	6999	513065.3	4072073.4	8/13/97	10.53	6988.47
MA-12	6999	513065.3	4072073.4	11/19/97	10.55	6988.45

Site Name	Elevation	UTM X	UTM Y	Date	DTW	PS
MA-12	6999	513065.3	4072073.4	2/10/98	10.65	6988.35
MA-12	6999	513065.3	4072073.4	5/19/98	10.94	6988.06
MA-12	6999	513065.3	4072073.4	8/26/98	10.91	6988.09
MA-12	6999	513065.3	4072073.4	11/13/98	10.67	6988.33
MA-14	7328.4	510394	4076496.5	4/12/83	17.04	7311.36
MA-14	7328.4	510394	4076496.5	7/13/83	16.48	7311.92
MA-14	7328.4	510394	4076496.5	1/19/84	18.64	7309.76
MA-14	7328.4	510394	4076496.5	4/17/84	18.90	7309.5
MA-14	7328.4	510394	4076496.5	7/17/84	16.48	7311.92
MA-14	7328.4	510394	4076496.5	10/16/84	19.42	7308.98
MA-14	7328.4	510394	4076496.5	1/16/85	19.10	7309.3
MA-14	7328.4	510394	4076496.5	4/15/85	18.02	7310.38
MA-14	7328.4	510394	4076496.5	7/15/85	16.27	7312.13
MA-14	7328.4	510394	4076496.5	10/14/85	18.15	7310.25
MA-14	7328.4	510394	4076496.5	1/6/86	18.90	7309.5
MA-14	7328.4	510394	4076496.5	4/29/86	19.23	7135.17
MA-14	7328.4	510394	4076496.5	10/9/86	18.81	7309.59
MA-14	7328.4	510394	4076496.5	1/13/87	19.35	7309.05
MA-14	7328.4	510394	4076496.5	7/6/87	14.22	7314.18
MA-14	7328.4	510394	4076496.5	10/7/87	18.05	7310.35
MA-14	7328.4	510394	4076496.5	1/12/88	19.31	7309.09
MA-14	7328.4	510394	4076496.5	4/20/88	19.59	7308.81
MA-14	7328.4	510394	4076496.5	7/27/88	19.42	7308.98
MA-14	7328.4	510394	4076496.5	10/4/88	19.69	7308.71
MA-14	7328.4	510394	4076496.5	9/21/89	20.60	7307.8
MA-14	7328.4	510394	4076496.5	11/10/89	20.70	7307.7
MA-14	7328.4	510394	4076496.5	3/20/90	20.32	7308.08
MA-14	7328.4	510394	4076496.5	5/15/90	20.48	7307.92
MA-14	7328.4	510394	4076496.5	11/20/90	19.90	7308.5
MA-14	7328.4	510394	4076496.5	3/21/91	20.30	7308.1
MA-14	7328.4	510394	4076496.5	5/22/91	20.41	7307.99
MA-14	7328.4	510394	4076496.5	8/20/91	15.92	7312.48
MA-14	7328.4	510394	4076496.5	12/2/91	16.90	7311.5
MA-14	7328.4	510394	4076496.5	5/4/92	17.18	7311.22
MA-14	7328.4	510394	4076496.5	7/16/92	17.34	7311.06
MA-14	7328.4	510394	4076496.5	11/18/92	17.26	7311.14
MA-14	7328.4	510394	4076496.5	3/10/93	16.70	7311.7
MA-14	7328.4	510394	4076496.5	5/5/93	16.81	7311.59
MA-14	7328.4	510394	4076496.5	9/22/93	16.54	7311.86
MA-14	7328.4	510394	4076496.5	2/8/94	19.14	7309.26
MA-14	7328.4	510394	4076496.5	3/15/94	19.34	7309.06
MA-14	7328.4	510394	4076496.5	7/14/94	19.21	7309.19
MA-14	7328.4	510394	4076496.5	8/25/94	16.91	7311.49
MA-14	7328.4	510394	4076496.5	1/19/95	18.89	7309.51
MA-14	7328.4	510394	4076496.5	5/10/95	19.48	7308.92
MA-14	7328.4	510394	4076496.5	8/1/95	16.34	7312.06
MA-14	7328.4	510394	4076496.5	11/2/95	17.30	7311.1
MA-14	7328.4	510394	4076496.5	3/12/96	18.66	7309.74
MA-14	7328.4	510394	4076496.5	4/17/96	18.90	7309.5
MA-14	7328.4	510394	4076496.5	7/30/96	18.90	7309.5

Site Name	Elevation	UTM X	UTM Y	Date	DTW	PS
MA-14	7328.4	510394	4076496.5	10/16/96	19.00	7309.4
MA-14	7328.4	510394	4076496.5	2/11/97	19.19	7309.21
MA-14	7328.4	510394	4076496.5	5/7/97	19.46	7308.94
MA-14	7328.4	510394	4076496.5	7/30/97	16.32	7312.08
MA-14	7328.4	510394	4076496.5	11/18/97	17.08	7311.32
MA-14	7328.4	510394	4076496.5	2/10/98	18.15	7310.25
MA-14	7328.4	510394	4076496.5	5/19/98	18.58	7309.82
MA-14	7328.4	510394	4076496.5	8/26/98	17.67	7310.73
MA-14	7328.4	510394	4076496.5	11/12/98	19.46	7308.94
MA-2	7589.41	507562.9	4082739.5	10/10/78	13.62	7575.79
MA-2	7589.41	507562.9	4082739.5	11/13/78	15.13	7574.28
MA-2	7589.41	507562.9	4082739.5	1/10/79	19.75	7569.66
MA-2	7589.41	507562.9	4082739.5	2/12/79	18.30	7571.11
MA-2	7589.41	507562.9	4082739.5	3/9/79	18.80	7570.61
MA-2	7589.41	507562.9	4082739.5	4/18/79	22.00	7567.41
MA-2	7589.41	507562.9	4082739.5	5/22/79	17.98	7571.43
MA-2	7589.41	507562.9	4082739.5	7/20/79	17.51	7571.9
MA-2	7589.41	507562.9	4082739.5	8/16/79	15.90	7573.51
MA-2	7589.41	507562.9	4082739.5	9/17/79	17.86	7571.55
MA-2	7589.41	507562.9	4082739.5	10/16/79	18.50	7570.91
MA-2	7589.41	507562.9	4082739.5	11/19/79	16.90	7572.51
MA-2	7589.41	507562.9	4082739.5	12/17/79	18.50	7570.91
MA-2	7589.41	507562.9	4082739.5	1/15/80	18.80	7570.61
MA-2	7589.41	507562.9	4082739.5	2/15/80	18.89	7570.52
MA-2	7589.41	507562.9	4082739.5	3/13/80	12.04	7577.37
MA-2	7589.41	507562.9	4082739.5	3/19/80	18.61	7570.8
MA-2	7589.41	507562.9	4082739.5	4/23/80	18.49	7570.92
MA-2	7589.41	507562.9	4082739.5	6/19/80	10.40	7579.01
MA-2	7589.41	507562.9	4082739.5	7/14/80	14.68	7574.73
MA-2	7589.41	507562.9	4082739.5	8/15/80	16.06	7573.35
MA-2	7589.41	507562.9	4082739.5	9/15/80	17.26	7572.15
MA-2	7589.41	507562.9	4082739.5	10/15/80	17.20	7572.21
MA-2	7589.41	507562.9	4082739.5	11/14/80	16.66	7572.75
MA-2	7589.41	507562.9	4082739.5	12/15/80	17.56	7571.85
MA-2	7589.41	507562.9	4082739.5	1/15/81	17.34	7572.07
MA-2	7589.41	507562.9	4082739.5	2/16/81	17.82	7571.59
MA-2	7589.41	507562.9	4082739.5	3/11/81	17.69	7571.72
MA-2	7589.41	507562.9	4082739.5	4/15/81	17.54	7571.87
MA-2	7589.41	507562.9	4082739.5	5/12/81	16.42	7572.99
MA-2	7589.41	507562.9	4082739.5	5/12/81	18.62	7570.79
MA-2	7589.41	507562.9	4082739.5	6/12/81	17.83	7571.58
MA-2	7589.41	507562.9	4082739.5	6/13/81	16.92	7572.49
MA-2	7589.41	507562.9	4082739.5	2/15/82	14.99	7574.42
MA-2	7589.41	507562.9	4082739.5	4/16/86	16.13	7573.28
MA-2	7589.41	507562.9	4082739.5	7/24/86	15.65	7573.76
MA-2	7589.41	507562.9	4082739.5	10/14/86	16.76	7572.65
MA-2	7589.41	507562.9	4082739.5	1/20/87	16.65	7572.76
MA-2	7589.41	507562.9	4082739.5	4/8/87	12.38	7577.03
MA-2	7589.41	507562.9	4082739.5	10/19/87	16.90	7572.51
MA-2	7589.41	507562.9	4082739.5	1/12/88	16.93	7572.48

Site Name	Elevation	UTM X	UTM Y	Date	DTW	PS
MA-2	7589.41	507562.9	4082739.5	4/12/88	16.61	7572.8
MA-2	7589.41	507562.9	4082739.5	7/22/88	13.15	7576.26
MA-2	7589.41	507562.9	4082739.5	3/22/89	15.20	7574.21
MA-2	7589.41	507562.9	4082739.5	8/14/89	15.65	7573.76
MA-2	7589.41	507562.9	4082739.5	11/17/89	12.80	7576.61
MA-2	7589.41	507562.9	4082739.5	5/15/90	6.10	7583.31
MA-2	7589.41	507562.9	4082739.5	11/20/90	16.40	7573.01
MA-2	7589.41	507562.9	4082739.5	3/20/91	16.51	7572.9
MA-2	7589.41	507562.9	4082739.5	5/22/91	15.86	7573.55
MA-2	7589.41	507562.9	4082739.5	8/27/91	6.92	7582.49
MA-2	7589.41	507562.9	4082739.5	2/12/92	15.22	7574.19
MA-2	7589.41	507562.9	4082739.5	6/9/92	11.02	7578.39
MA-2	7589.41	507562.9	4082739.5	7/14/92	13.74	7575.67
MA-2	7589.41	507562.9	4082739.5	10/24/92	16.42	7572.99
MA-2	7589.41	507562.9	4082739.5	11/17/92	16.80	7572.61
MA-2	7589.41	507562.9	4082739.5	3/9/93	14.60	7574.81
MA-2	7589.41	507562.9	4082739.5	5/4/93	9.38	7580.03
MA-2	7589.41	507562.9	4082739.5	9/21/93	16.06	7573.35
MA-2	7589.41	507562.9	4082739.5	2/9/94	16.72	7572.69
MA-2	7589.41	507562.9	4082739.5	3/15/94	14.86	7574.55
MA-2	7589.41	507562.9	4082739.5	7/12/94	15.16	7574.25
MA-2	7589.41	507562.9	4082739.5	8/17/94	13.89	7575.52
MA-2	7589.41	507562.9	4082739.5	10/25/94	16.42	7572.99
MA-2	7589.41	507562.9	4082739.5	1/17/95	17.15	7572.26
MA-2	7589.41	507562.9	4082739.5	5/9/95	12.72	7576.69
MA-2	7589.41	507562.9	4082739.5	7/25/95	8.60	7580.81
MA-2	7589.41	507562.9	4082739.5	11/1/95	15.71	7573.7
MA-2	7589.41	507562.9	4082739.5	3/19/96	13.91	7575.5
MA-2	7589.41	507562.9	4082739.5	4/16/96	14.39	7575.02
MA-2	7589.41	507562.9	4082739.5	7/29/96	12.77	7576.64
MA-2	7589.41	507562.9	4082739.5	10/15/96	12.26	7577.15
MA-2	7589.41	507562.9	4082739.5	2/11/97	16.15	7573.26
MA-2	7589.41	507562.9	4082739.5	5/6/97	7.75	7581.66
MA-2	7589.41	507562.9	4082739.5	7/29/97	13.49	7575.92
MA-2	7589.41	507562.9	4082739.5	11/18/97	16.55	7572.86
MA-2	7589.41	507562.9	4082739.5	2/10/98	16.70	7572.71
MA-2	7589.41	507562.9	4082739.5	5/19/98	13.54	7575.87
MA-2	7589.41	507562.9	4082739.5	8/25/98	16.19	7573.22
MA-2	7589.41	507562.9	4082739.5	11/10/98	16.74	7572.67
MA-6	7661.56	509825	4080412.2	11/10/78	18.20	7643.36
MA-6	7661.56	509825	4080412.2	1/10/79	17.40	7644.16
MA-6	7661.56	509825	4080412.2	2/12/79	17.30	7644.26
MA-6	7661.56	509825	4080412.2	3/9/79	17.60	7643.96
MA-6	7661.56	509825	4080412.2	4/18/79	17.30	7644.26
MA-6	7661.56	509825	4080412.2	5/22/79	17.27	7644.29
MA-6	7661.56	509825	4080412.2	6/13/79	16.83	7644.73
MA-6	7661.56	509825	4080412.2	8/17/79	17.10	7644.46
MA-6	7661.56	509825	4080412.2	9/17/79	16.91	7644.65
MA-6	7661.56	509825	4080412.2	10/16/79	17.00	7644.56
MA-6	7661.56	509825	4080412.2	11/19/79	17.27	7644.29

Site Name	Elevation	UTM X	UTM Y	Date	DTW	PS
MA-6	7661.56	509825	4080412.2	12/17/79	15.53	7646.03
MA-6	7661.56	509825	4080412.2	1/15/80	17.42	7644.14
MA-6	7661.56	509825	4080412.2	2/15/80	17.44	7644.12
MA-6	7661.56	509825	4080412.2	3/19/80	17.42	7644.14
MA-6	7661.56	509825	4080412.2	4/23/80	17.58	7643.98
MA-6	7661.56	509825	4080412.2	5/13/80	17.10	7644.46
MA-6	7661.56	509825	4080412.2	6/19/80	13.20	7648.36
MA-6	7661.56	509825	4080412.2	7/14/80	15.70	7645.86
MA-6	7661.56	509825	4080412.2	8/15/80	16.00	7645.56
MA-6	7661.56	509825	4080412.2	9/15/80	16.54	7645.02
MA-6	7661.56	509825	4080412.2	10/15/80	16.58	7644.98
MA-6	7661.56	509825	4080412.2	11/14/80	16.46	7645.1
MA-6	7661.56	509825	4080412.2	12/15/80	16.06	7645.5
MA-6	7661.56	509825	4080412.2	1/15/81	16.36	7645.2
MA-6	7661.56	509825	4080412.2	2/16/81	16.58	7644.98
MA-6	7661.56	509825	4080412.2	3/11/81	16.64	7644.92
MA-6	7661.56	509825	4080412.2	4/15/81	16.62	7644.94
MA-6	7661.56	509825	4080412.2	5/12/81	16.62	7644.94
MA-6	7661.56	509825	4080412.2	6/12/81	16.57	7644.99
MA-6	7661.56	509825	4080412.2	11/13/81	15.56	7646
MA-6	7661.56	509825	4080412.2	2/15/82	16.02	7645.54
MA-6	7661.56	509825	4080412.2	1/6/86	16.74	7644.82
MA-6	7661.56	509825	4080412.2	4/8/86	16.83	7644.73
MA-6	7661.56	509825	4080412.2	7/14/86	17.00	7644.56
MA-6	7661.56	509825	4080412.2	10/9/86	16.81	7644.75
MA-6	7661.56	509825	4080412.2	1/13/87	16.95	7644.61
MA-6	7661.56	509825	4080412.2	4/13/87	13.04	7648.52
MA-6	7661.56	509825	4080412.2	10/6/87	16.41	7645.15
MA-6	7661.56	509825	4080412.2	1/12/88	16.86	7644.7
MA-6	7661.56	509825	4080412.2	2/27/88	16.56	7645
MA-6	7661.56	509825	4080412.2	4/20/88	16.62	7644.94
MA-6	7661.56	509825	4080412.2	10/4/88	16.59	7644.97
MA-6	7661.56	509825	4080412.2	9/21/89	17.47	7644.09
MA-6	7661.56	509825	4080412.2	11/10/89	17.14	7644.42
MA-6	7661.56	509825	4080412.2	3/20/90	17.00	7644.56
MA-6	7661.56	509825	4080412.2	5/15/90	17.10	7644.46
MA-6	7661.56	509825	4080412.2	11/20/90	16.82	7644.74
MA-6	7661.56	509825	4080412.2	5/22/91	17.21	7644.35
MA-6	7661.56	509825	4080412.2	8/20/91	12.04	7649.52
MA-6	7661.56	509825	4080412.2	12/3/91	13.76	7647.8
MA-6	7661.56	509825	4080412.2	3/4/92	16.72	7644.84
MA-6	7661.56	509825	4080412.2	5/4/92	15.35	7646.21
MA-6	7661.56	509825	4080412.2	7/16/92	15.04	7646.52
MA-6	7661.56	509825	4080412.2	11/18/92	15.82	7645.74
MA-6	7661.56	509825	4080412.2	3/10/93	16.04	7645.52
MA-6	7661.56	509825	4080412.2	5/5/93	13.06	7648.5
MA-6	7661.56	509825	4080412.2	9/22/93	16.28	7645.28
MA-6	7661.56	509825	4080412.2	2/9/94	16.80	7644.76
MA-6	7661.56	509825	4080412.2	3/15/94	16.78	7644.78
MA-6	7661.56	509825	4080412.2	7/14/94	15.68	7645.88

Site Name	Elevation	UTM X	UTM Y	Date	DTW	PS
MA-6	7661.56	509825	4080412.2	8/17/94	15.85	7645.71
MA-6	7661.56	509825	4080412.2	10/26/94	16.49	7645.07
MA-6	7661.56	509825	4080412.2	1/19/95	16.86	7644.7
MA-6	7661.56	509825	4080412.2	5/10/95	16.81	7644.75
MA-6	7661.56	509825	4080412.2	8/1/95	15.04	7646.52
MA-6	7661.56	509825	4080412.2	11/2/95	16.04	7645.52
MA-6	7661.56	509825	4080412.2	3/12/96	16.79	7644.77
MA-6	7661.56	509825	4080412.2	4/17/96	16.90	7644.66
MA-6	7661.56	509825	4080412.2	7/30/96	16.92	7644.64
MA-6	7661.56	509825	4080412.2	10/16/96	16.93	7644.63
MA-6	7661.56	509825	4080412.2	2/11/97	16.98	7644.58
MA-6	7661.56	509825	4080412.2	5/7/97	16.08	7645.48
MA-6	7661.56	509825	4080412.2	11/18/97	16.21	7645.35
MA-6	7661.56	509825	4080412.2	2/10/98	16.72	7644.84
MA-6	7661.56	509825	4080412.2	5/19/98	16.28	7645.28
MA-6	7661.56	509825	4080412.2	7/30/98	15.30	7646.26
MA-6	7661.56	509825	4080412.2	8/26/98	16.82	7644.74
MA-6	7661.56	509825	4080412.2	11/12/98	17.29	7644.27
MA-9	7740.23	508723.9	4084868	4/18/79	12.00	7728.23
MA-9	7740.23	508723.9	4084868	5/22/79	11.49	7728.74
MA-9	7740.23	508723.9	4084868	6/13/79	11.30	7728.93
MA-9	7740.23	508723.9	4084868	7/20/79	11.90	7728.33
MA-9	7740.23	508723.9	4084868	8/17/79	11.30	7728.93
MA-9	7740.23	508723.9	4084868	9/17/79	11.91	7728.32
MA-9	7740.23	508723.9	4084868	10/16/79	12.12	7728.11
MA-9	7740.23	508723.9	4084868	11/19/79	11.88	7728.35
MA-9	7740.23	508723.9	4084868	12/17/79	12.38	7727.85
MA-9	7740.23	508723.9	4084868	1/15/80	12.25	7727.98
MA-9	7740.23	508723.9	4084868	2/15/80	12.19	7728.04
MA-9	7740.23	508723.9	4084868	3/19/80	12.10	7728.13
MA-9	7740.23	508723.9	4084868	4/23/80	11.83	7728.4
MA-9	7740.23	508723.9	4084868	5/13/80	10.60	7729.63
MA-9	7740.23	508723.9	4084868	6/19/80	10.24	7729.99
MA-9	7740.23	508723.9	4084868	7/14/80	10.30	7729.93
MA-9	7740.23	508723.9	4084868	8/15/80	10.96	7729.27
MA-9	7740.23	508723.9	4084868	9/15/80	11.03	7729.2
MA-9	7740.23	508723.9	4084868	10/15/80	11.66	7728.57
MA-9	7740.23	508723.9	4084868	11/13/80	9.30	7730.93
MA-9	7740.23	508723.9	4084868	11/14/80	10.82	7729.41
MA-9	7740.23	508723.9	4084868	12/15/80	10.62	7729.61
MA-9	7740.23	508723.9	4084868	1/15/81	10.20	7730.03
MA-9	7740.23	508723.9	4084868	2/1/81	11.38	7728.85
MA-9	7740.23	508723.9	4084868	3/11/81	10.98	7729.25
MA-9	7740.23	508723.9	4084868	4/15/81	11.08	7729.15
MA-9	7740.23	508723.9	4084868	5/12/81	11.20	7729.03
MA-9	7740.23	508723.9	4084868	6/12/81	10.84	7729.39
MA-9	7740.23	508723.9	4084868	2/15/82	9.90	7730.33
MA-9	7740.23	508723.9	4084868	4/13/83	10.00	7730.23
MA-9	7740.23	508723.9	4084868	7/15/83	14.01	7726.22
MA-9	7740.23	508723.9	4084868	10/17/83	12.43	7727.8

Site Name	Elevation	UTM X	UTM Y	Date	DTW	PS
MA-9	7740.23	508723.9	4084868	1/17/84	12.06	7728.17
MA-9	7740.23	508723.9	4084868	4/18/84	11.63	7728.6
MA-9	7740.23	508723.9	4084868	7/19/84	12.67	7727.56
MA-9	7740.23	508723.9	4084868	10/17/84	12.77	7727.46
MA-9	7740.23	508723.9	4084868	4/10/85	11.76	7728.47
MA-9	7740.23	508723.9	4084868	7/17/85	12.26	7727.97
MA-9	7740.23	508723.9	4084868	10/10/85	12.47	7727.76
MA-9	7740.23	508723.9	4084868	1/7/86	12.25	7727.98
MA-9	7740.23	508723.9	4084868	4/15/86	11.97	7728.26
MA-9	7740.23	508723.9	4084868	7/24/86	12.33	7727.9
MA-9	7740.23	508723.9	4084868	10/21/86	12.56	7727.67
MA-9	7740.23	508723.9	4084868	1/20/87	12.10	7728.13
MA-9	7740.23	508723.9	4084868	4/8/87	11.12	7729.11
MA-9	7740.23	508723.9	4084868	10/19/87	11.54	7728.69
MA-9	7740.23	508723.9	4084868	1/4/88	11.23	7729
MA-9	7740.23	508723.9	4084868	4/21/88	10.09	7730.14
MA-9	7740.23	508723.9	4084868	7/25/88	10.18	7730.05
MA-9	7740.23	508723.9	4084868	10/12/88	10.36	7729.87
MA-9	7740.23	508723.9	4084868	8/14/89	11.53	7728.7
MA-9	7740.23	508723.9	4084868	11/17/89	11.82	7728.41
MA-9	7740.23	508723.9	4084868	3/14/90	10.67	7729.56
MA-9	7740.23	508723.9	4084868	5/15/90	11.41	7728.82
MA-9	7740.23	508723.9	4084868	11/20/90	11.58	7728.65
MA-9	7740.23	508723.9	4084868	3/20/91	11.46	7728.77
MA-9	7740.23	508723.9	4084868	5/22/91	10.30	7729.93
MA-9	7740.23	508723.9	4084868	8/27/91	9.56	7730.67
MA-9	7740.23	508723.9	4084868	10/24/91	10.42	7729.81
MA-9	7740.23	508723.9	4084868	2/12/92	10.56	7729.67
MA-9	7740.23	508723.9	4084868	6/10/92	10.92	7729.31
MA-9	7740.23	508723.9	4084868	7/14/92	11.20	7729.03
MA-9	7740.23	508723.9	4084868	3/9/93	11.00	7729.23
MA-9	7740.23	508723.9	4084868	5/4/93	10.92	7729.31
MA-9	7740.23	508723.9	4084868	9/21/93	11.34	7728.89
MA-9	7740.23	508723.9	4084868	2/9/94	10.95	7729.28
MA-9	7740.23	508723.9	4084868	3/15/94	10.50	7729.73
MA-9	7740.23	508723.9	4084868	7/12/94	11.26	7728.97
MA-9	7740.23	508723.9	4084868	8/17/94	11.13	7729.1
MA-9	7740.23	508723.9	4084868	1/17/95	11.08	7729.15
MA-9	7740.23	508723.9	4084868	5/9/95	10.82	7729.41
MA-9	7740.23	508723.9	4084868	7/25/95	13.86	7726.37
MA-9	7740.23	508723.9	4084868	11/1/95	11.31	7728.92
MA-9	7740.23	508723.9	4084868	3/19/96	11.08	7729.15
MA-9	7740.23	508723.9	4084868	4/16/96	11.18	7729.05
MA-9	7740.23	508723.9	4084868	7/29/96	11.27	7728.96
MA-9	7740.23	508723.9	4084868	10/15/96	11.46	7728.77
MA-9	7740.23	508723.9	4084868	2/11/97	11.59	7728.64
MA-9	7740.23	508723.9	4084868	5/6/97	10.74	7729.49
MA-9	7740.23	508723.9	4084868	7/29/97	11.45	7728.78
MA-9	7740.23	508723.9	4084868	11/18/97	11.69	7728.54
MA-9	7740.23	508723.9	4084868	2/10/98	11.21	7729.02

Site Name	Elevation	UTM X	UTM Y	Date	DTW	PS
MA-9	7740.23	508723.9	4084868	5/19/98	11.52	7728.71
MA-9	7740.23	508723.9	4084868	8/25/98	11.57	7728.66
MA-9	7740.23	508723.9	4084868	11/10/98	11.74	7728.49
102	8305	509961.6	4087324.6	6/26/01	9.37	8295.63
102	8305	509961.6	4087324.6	7/26/01	10.55	8294.45
102	8305	509961.6	4087324.6	8/27/01	11.05	8293.95
102	8305	509961.6	4087324.6	9/10/01	11.18	8293.82
102	8305	509961.6	4087324.6	10/11/01	11.56	8293.44
102	8305	509961.6	4087324.6	1/12/02	12.68	8292.32
102	8305	509961.6	4087324.6	2/11/02	13.00	8292
102	8305	509961.6	4087324.6	3/15/02	13.28	8291.72
102	8305	509961.6	4087324.6	5/21/02	13.55	8291.45
102	8305	509961.6	4087324.6	6/13/02	13.62	8291.38
102	8305	509961.6	4087324.6	7/9/02	13.72	8291.28
102	8305	509961.6	4087324.6	8/9/02	13.75	8291.25
116	8140	510140	4085067.4	6/5/01	8.34	8131.66
116	8140	510140	4085067.4	7/21/01	10.00	8130
116	8140	510140	4085067.4	8/2/01	11.11	8128.89
116	8140	510140	4085067.4	9/25/01	14.72	8125.28
116	8140	510140	4085067.4	10/11/01	16.30	8123.7
116	8140	510140	4085067.4	12/24/01	16.80	8123.2
116	8140	510140	4085067.4	1/17/02	17.18	8122.82
116	8140	510140	4085067.4	2/8/02	17.52	8122.48
116	8140	510140	4085067.4	3/15/02	18.00	8122
116	8140	510140	4085067.4	4/15/02	18.86	8121.14
116	8140	510140	4085067.4	5/16/02	18.87	8121.13
116	8140	510140	4085067.4	7/8/02	11.00	8141
116	8140	510140	4085067.4	12/18/02	16.84	8123.16
117	8232	511136.2	4087196.6	5/18/01	7.08	8224.92
117	8232	511136.2	4087196.6	6/5/01	12.00	8220
117	8232	511136.2	4087196.6	7/7/01	12.61	8219.39
117	8232	511136.2	4087196.6	8/14/01	13.45	8218.55
117	8232	511136.2	4087196.6	9/25/01	14.43	8217.57
117	8232	511136.2	4087196.6	10/11/01	14.71	8217.29
117	8232	511136.2	4087196.6	12/27/01	15.57	8216.43
117	8232	511136.2	4087196.6	1/17/02	15.82	8216.18
117	8232	511136.2	4087196.6	2/8/02	15.94	8216.06
117	8232	511136.2	4087196.6	3/15/02	16.22	8215.78
117	8232	511136.2	4087196.6	4/15/02	16.41	8215.59
117	8232	511136.2	4087196.6	5/16/02	16.56	8215.44
117	8232	511136.2	4087196.6	6/12/02	16.67	8215.33
117	8232	511136.2	4087196.6	7/8/02	16.78	8215.22
117	8232	511136.2	4087196.6	8/8/02	16.90	8215.1
117	8232	511136.2	4087196.6	9/25/02	16.77	8215.23
117	8232	511136.2	4087196.6	10/23/02	16.66	8215.34
117	8232	511136.2	4087196.6	11/18/02	16.64	8215.36
117	8232	511136.2	4087196.6	12/18/02	16.35	8215.65
117	8232	511136.2	4087196.6	1/22/03	16.70	8215.3
117	8232	511136.2	4087196.6	2/11/03	16.91	8215.09
117	8232	511136.2	4087196.6	3/24/03	17.13	8214.87

Site Name	Elevation	UTM X	UTM Y	Date	DTW	PS
117	8232	511136.2	4087196.6	4/10/03	17.63	8214.37
117	8232	511136.2	4087196.6	5/6/03	15.62	8216.38
117	8232	511136.2	4087196.6	6/9/03	15.25	8216.75
117	8232	511136.2	4087196.6	7/11/03	14.97	8217.03
117	8232	511136.2	4087196.6	8/5/03	15.14	8216.86
117	8232	511136.2	4087196.6	9/12/03	15.22	8216.78
119	7950	513820.1	4086268.3	6/5/01	10.25	7939.75
119	7950	513820.1	4086268.3	7/7/01	10.72	7939.28
119	7950	513820.1	4086268.3	8/14/01	10.96	7939.04
119	7950	513820.1	4086268.3	9/25/01	11.75	7938.25
119	7950	513820.1	4086268.3	10/11/01	11.79	7938.21
119	7950	513820.1	4086268.3	12/27/01	12.75	7937.25
119	7950	513820.1	4086268.3	1/17/02	12.68	7937.32
119	7950	513820.1	4086268.3	2/8/02	12.70	7937.3
119	7950	513820.1	4086268.3	3/15/02	12.41	7937.59
119	7950	513820.1	4086268.3	4/15/02	12.48	7937.52
119	7950	513820.1	4086268.3	5/16/02	12.81	7937.19
119	7950	513820.1	4086268.3	6/12/02	13.04	7936.96
119	7950	513820.1	4086268.3	7/8/02	13.52	7936.48
119	7950	513820.1	4086268.3	8/8/02	13.41	7936.59
119	7950	513820.1	4086268.3	9/25/02	13.31	7936.69
119	7950	513820.1	4086268.3	10/23/02	13.16	7936.84
119	7950	513820.1	4086268.3	11/18/02	13.77	7936.23
119	7950	513820.1	4086268.3	12/18/02	13.35	7936.65
119	7950	513820.1	4086268.3	1/22/03	13.83	7936.17
119	7950	513820.1	4086268.3	2/11/03	13.59	7936.41
119	7950	513820.1	4086268.3	4/10/03	10.25	7939.75
119	7950	513820.1	4086268.3	5/6/03	10.06	7939.94
119	7950	513820.1	4086268.3	6/9/03	11.30	7938.7
119	7950	513820.1	4086268.3	7/11/03	12.65	7937.35
119	7950	513820.1	4086268.3	8/5/03	12.74	7937.26
119	7950	513820.1	4086268.3	9/12/03	12.48	7937.52
120	7809	514600.1	4085141.5	6/5/01	17.32	7791.68
120	7809	514600.1	4085141.5	7/7/01	17.82	7791.18
120	7809	514600.1	4085141.5	8/14/01	18.11	7790.89
120	7809	514600.1	4085141.5	9/25/01	18.57	7790.43
120	7809	514600.1	4085141.5	10/11/01	18.60	7790.4
120	7809	514600.1	4085141.5	12/27/01	18.60	7790.4
120	7809	514600.1	4085141.5	1/17/02	18.79	7790.21
120	7809	514600.1	4085141.5	2/8/02	18.48	7790.52
120	7809	514600.1	4085141.5	3/15/02	17.84	7791.16
120	7809	514600.1	4085141.5	4/15/02	17.03	7791.97
120	7809	514600.1	4085141.5	5/16/02	17.83	7791.17
120	7809	514600.1	4085141.5	6/12/02	18.51	7790.49
120	7809	514600.1	4085141.5	7/8/02	19.04	7789.96
120	7809	514600.1	4085141.5	8/8/02	19.16	7789.84
120	7809	514600.1	4085141.5	9/25/02	18.13	7790.87
120	7809	514600.1	4085141.5	10/23/02	18.86	7790.14
120	7809	514600.1	4085141.5	11/18/02	18.89	7790.11
120	7809	514600.1	4085141.5	12/18/02	18.31	7790.69

Site Name	Elevation	UTM X	UTM Y	Date	DTW	PS
120	7809	514600.1	4085141.5	1/22/03	18.54	7790.46
120	7809	514600.1	4085141.5	2/11/03	18.20	7790.8
120	7809	514600.1	4085141.5	4/10/03	15.86	7793.14
120	7809	514600.1	4085141.5	5/6/03	15.91	7793.09
120	7809	514600.1	4085141.5	6/9/03	16.07	7792.93
120	7809	514600.1	4085141.5	7/11/03	17.24	7791.76
120	7809	514600.1	4085141.5	8/5/03	17.29	7791.71
120	7809	514600.1	4085141.5	9/12/03	17.18	7791.82
122	7271	519230.7	4079236	6/5/01	16.17	7254.83
122	7271	519230.7	4079236	7/7/01	17.14	7253.86
122	7271	519230.7	4079236	8/14/01	18.52	7252.48
122	7271	519230.7	4079236	9/25/01	20.86	7250.14
122	7271	519230.7	4079236	10/11/01	21.55	7249.45
122	7271	519230.7	4079236	12/27/01	22.55	7248.45
122	7271	519230.7	4079236	1/17/02	22.66	7248.34
122	7271	519230.7	4079236	2/8/02	22.80	7248.2
122	7271	519230.7	4079236	3/15/02	22.91	7248.09
122	7271	519230.7	4079236	4/15/02	22.77	7248.23
122	7271	519230.7	4079236	5/16/02	22.91	7248.09
122	7271	519230.7	4079236	6/12/02	23.08	7247.92
122	7271	519230.7	4079236	7/8/02	23.18	7247.82
122	7271	519230.7	4079236	8/8/02	23.43	7247.57
122	7271	519230.7	4079236	9/25/02	22.96	7248.04
122	7271	519230.7	4079236	10/23/02	22.59	7248.41
122	7271	519230.7	4079236	11/18/02	22.80	7248.2
122	7271	519230.7	4079236	12/18/02	22.67	7248.33
122	7271	519230.7	4079236	1/22/03	22.33	7248.67
122	7271	519230.7	4079236	2/11/03	22.43	7248.57
122	7271	519230.7	4079236	4/10/03	15.96	7255.04
122	7271	519230.7	4079236	5/6/03	16.18	7254.82
122	7271	519230.7	4079236	6/9/03	17.14	7253.86
122	7271	519230.7	4079236	7/11/03	17.63	7253.37
122	7271	519230.7	4079236	8/5/03	18.24	7252.76
122	7271	519230.7	4079236	9/12/03	20.23	7250.77
123	7117	518276.1	4076544.6	6/5/01	11.40	7105.6
123	7117	518276.1	4076544.6	8/14/01	12.85	7104.15
123	7117	518276.1	4076544.6	9/25/01	13.38	7103.62
123	7117	518276.1	4076544.6	10/11/01	13.61	7103.39
123	7117	518276.1	4076544.6	12/27/01	15.46	7101.54
123	7117	518276.1	4076544.6	1/17/02	15.68	7101.32
123	7117	518276.1	4076544.6	2/8/02	15.83	7101.17
123	7117	518276.1	4076544.6	3/15/02	16.00	7101
123	7117	518276.1	4076544.6	5/16/02	44.35	7072.65
123	7117	518276.1	4076544.6	12/18/02	25.24	7091.76
124	8180	502445.6	4088175	5/17/01	5.70	8174.3
124	8180	502445.6	4088175	6/22/01	5.72	8174.28
124	8180	502445.6	4088175	7/21/01	5.85	8174.15
124	8180	502445.6	4088175	8/2/01	6.06	8173.94
124	8180	502445.6	4088175	9/25/01	6.07	8173.93
124	8180	502445.6	4088175	10/9/01	6.12	8173.88

Site Name	Elevation	UTM X	UTM Y	Date	DTW	PS
124	8180	502445.6	4088175	1/12/02	6.60	8173.4
124	8180	502445.6	4088175	2/11/02	6.69	8173.31
124	8180	502445.6	4088175	3/15/02	6.72	8173.28
124	8180	502445.6	4088175	5/16/02	6.79	8173.21
124	8180	502445.6	4088175	6/13/02	6.81	8173.19
124	8180	502445.6	4088175	7/9/02	7.02	8172.98
124	8180	502445.6	4088175	8/8/02	6.60	8173.4
124	8180	502445.6	4088175	9/29/02	6.81	8173.19
124	8180	502445.6	4088175	10/25/02	6.87	8173.13
124	8180	502445.6	4088175	11/14/02	6.61	8173.39
124	8180	502445.6	4088175	12/18/02	6.65	8173.35
124	8180	502445.6	4088175	2/11/03	6.60	8173.4
124	8180	502445.6	4088175	3/5/03	6.62	8173.38
124	8180	502445.6	4088175	4/10/03	6.68	8173.32
124	8180	502445.6	4088175	5/6/03	6.66	8173.34
124	8180	502445.6	4088175	6/13/03	6.58	8173.42
124	8180	502445.6	4088175	7/8/03	6.45	8173.55
124	8180	502445.6	4088175	8/6/03	6.58	8173.42
124	8180	502445.6	4088175	9/9/03	6.70	8173.3
132	8050	504536.9	4088336.5	1/12/02	79.74	7970.26
132	8050	504536.9	4088336.5	2/11/02	79.29	7970.71
132	8050	504536.9	4088336.5	3/15/02	79.95	7970.05
132	8050	504536.9	4088336.5	5/16/02	80.05	7969.95
132	8050	504536.9	4088336.5	6/13/02	80.11	7969.89
132	8050	504536.9	4088336.5	7/9/02	80.18	7969.82
132	8050	504536.9	4088336.5	8/8/02	80.23	7969.77
132	8050	504536.9	4088336.5	9/29/02	80.04	7969.96
132	8050	504536.9	4088336.5	10/25/02	76.72	7973.28
132	8050	504536.9	4088336.5	11/14/02	76.17	7973.83
132	8050	504536.9	4088336.5	12/18/02	78.45	7971.55
132	8050	504536.9	4088336.5	2/11/03	79.03	7970.97
132	8050	504536.9	4088336.5	4/10/03	62.87	7987.13
132	8050	504536.9	4088336.5	5/6/03	62.48	7987.52
132	8050	504536.9	4088336.5	6/13/03	75.16	7974.84
132	8050	504536.9	4088336.5	7/8/03	77.60	7972.4
132	8050	504536.9	4088336.5	8/6/03	78.41	7971.59
133	8010	508903.7	4087482.9	1/12/02	27.30	7982.7
133	8010	508903.7	4087482.9	2/11/02	27.71	7982.29
133	8010	508903.7	4087482.9	3/15/02	28.09	7981.91
133	8010	508903.7	4087482.9	5/21/02	28.59	7981.41
133	8010	508903.7	4087482.9	6/13/02	28.67	7981.33
133	8010	508903.7	4087482.9	7/9/02	28.74	7981.26
133	8010	508903.7	4087482.9	8/9/02	28.81	7981.19
133	8010	508903.7	4087482.9	9/29/02	28.80	7981.2
133	8010	508903.7	4087482.9	11/14/02	28.81	7981.19
133	8010	508903.7	4087482.9	12/27/02	28.66	7981.34
133	8010	508903.7	4087482.9	2/11/03	28.68	7981.32
133	8010	508903.7	4087482.9	3/5/03	28.82	7981.18
133	8010	508903.7	4087482.9	4/9/03	28.42	7981.58
133	8010	508903.7	4087482.9	5/6/03	24.72	7985.28

Site Name	Elevation	UTM X	UTM Y	Date	DTW	PS
133	8010	508903.7	4087482.9	6/13/03	22.93	7987.07
133	8010	508903.7	4087482.9	7/8/03	23.34	7986.66
133	8010	508903.7	4087482.9	8/6/03	23.99	7986.01
133	8010	508903.7	4087482.9	9/12/03	24.54	7985.46
201	8400.4	488195.8	4082118.3	5/16/01	25.65	8374.75
201	8400.4	488195.8	4082118.3	6/8/01	25.44	8374.96
201	8400.4	488195.8	4082118.3	7/20/01	24.91	8375.49
201	8400.4	488195.8	4082118.3	8/13/01	25.27	8375.13
201	8400.4	488195.8	4082118.3	9/11/01	25.55	8374.85
201	8400.4	488195.8	4082118.3	12/20/01	26.24	8374.16
201	8400.4	488195.8	4082118.3	1/30/02	26.27	8374.13
201	8400.4	488195.8	4082118.3	2/20/02	26.33	8374.07
201	8400.4	488195.8	4082118.3	3/22/02	26.38	8374.02
201	8400.4	488195.8	4082118.3	4/26/02	26.48	8373.92
201	8400.4	488195.8	4082118.3	5/24/02	26.50	8373.9
201	8400.4	488195.8	4082118.3	6/20/02	26.65	8373.75
201	8400.4	488195.8	4082118.3	7/16/02	26.69	8373.71
201	8400.4	488195.8	4082118.3	8/9/02	26.74	8373.66
201	8400.4	488195.8	4082118.3	9/28/02	26.67	8373.73
201	8400.4	488195.8	4082118.3	10/24/02	26.71	8373.69
201	8400.4	488195.8	4082118.3	11/20/02	26.77	8373.63
201	8400.4	488195.8	4082118.3	12/17/02	26.67	8373.73
201	8400.4	488195.8	4082118.3	2/24/03	26.82	8373.58
201	8400.4	488195.8	4082118.3	4/16/03	26.88	8373.52
201	8400.4	488195.8	4082118.3	5/20/03	26.93	8373.47
201	8400.4	488195.8	4082118.3	6/24/03	26.94	8373.46
201	8400.4	488195.8	4082118.3	7/24/03	27.01	8373.39
201	8400.4	488195.8	4082118.3	8/18/03	26.98	8373.42
201	8400.4	488195.8	4082118.3	9/23/03	26.93	8373.47
204	8255.2	490058	4079780.1	5/16/01	25.80	8229.4
204	8255.2	490058	4079780.1	6/23/01	27.09	8228.11
204	8255.2	490058	4079780.1	7/20/01	27.32	8227.88
204	8255.2	490058	4079780.1	8/13/01	26.92	8228.28
204	8255.2	490058	4079780.1	9/12/01	26.88	8228.32
204	8255.2	490058	4079780.1	12/20/01	26.34	8228.86
204	8255.2	490058	4079780.1	1/30/02	27.13	8228.07
204	8255.2	490058	4079780.1	2/20/02	27.38	8227.82
204	8255.2	490058	4079780.1	3/22/02	27.70	8227.5
204	8255.2	490058	4079780.1	4/26/02	26.27	8228.93
204	8255.2	490058	4079780.1	5/24/02	27.30	8227.9
204	8255.2	490058	4079780.1	6/20/02	28.07	8227.13
204	8255.2	490058	4079780.1	7/16/02	28.90	8226.3
204	8255.2	490058	4079780.1	8/9/02	29.88	8225.32
204	8255.2	490058	4079780.1	9/28/02	32.06	8223.14
204	8255.2	490058	4079780.1	10/24/02	32.16	8223.04
204	8255.2	490058	4079780.1	11/20/02	32.03	8223.17
204	8255.2	490058	4079780.1	12/17/02	31.50	8223.7
204	8255.2	490058	4079780.1	2/24/03	31.70	8223.5
204	8255.2	490058	4079780.1	3/27/03	28.00	8227.2
204	8255.2	490058	4079780.1	4/22/03	29.58	8225.62

Site Name	Elevation	UTM X	UTM Y	Date	DTW	PS
204	8255.2	490058	4079780.1	5/20/03	31.04	8224.16
204	8255.2	490058	4079780.1	6/24/03	27.84	8227.36
204	8255.2	490058	4079780.1	7/22/03	30.34	8224.86
204	8255.2	490058	4079780.1	8/18/03	30.39	8224.81
204	8255.2	490058	4079780.1	9/23/03	29.28	8225.92
205	8419.9	494478.3	4078849.6	5/16/01	11.87	8408.03
205	8419.9	494478.3	4078849.6	6/6/01	11.91	8407.99
205	8419.9	494478.3	4078849.6	7/19/01	11.91	8407.99
205	8419.9	494478.3	4078849.6	8/17/01	11.90	8408
205	8419.9	494478.3	4078849.6	9/24/01	11.95	8407.95
205	8419.9	494478.3	4078849.6	12/20/01	12.63	8407.27
205	8419.9	494478.3	4078849.6	1/30/02	12.71	8407.19
205	8419.9	494478.3	4078849.6	2/20/02	12.69	8407.21
205	8419.9	494478.3	4078849.6	3/22/02	12.67	8407.23
205	8419.9	494478.3	4078849.6	4/26/02	12.71	8407.19
205	8419.9	494478.3	4078849.6	5/24/02	12.77	8407.13
205	8419.9	494478.3	4078849.6	6/20/02	12.91	8406.99
205	8419.9	494478.3	4078849.6	7/16/02	12.91	8406.99
205	8419.9	494478.3	4078849.6	8/9/02	12.85	8407.05
205	8419.9	494478.3	4078849.6	9/30/02	12.65	8407.25
205	8419.9	494478.3	4078849.6	10/24/02	12.70	8407.2
205	8419.9	494478.3	4078849.6	11/20/02	12.72	8407.18
205	8419.9	494478.3	4078849.6	12/18/02	12.73	8407.17
205	8419.9	494478.3	4078849.6	2/24/03	12.87	8407.03
205	8419.9	494478.3	4078849.6	3/27/03	12.86	8407.04
205	8419.9	494478.3	4078849.6	4/16/03	12.91	8406.99
205	8419.9	494478.3	4078849.6	5/20/03	13.02	8406.88
205	8419.9	494478.3	4078849.6	6/17/03	13.12	8406.78
205	8419.9	494478.3	4078849.6	7/22/03	13.20	8406.7
205	8419.9	494478.3	4078849.6	8/21/03	13.27	8406.63
205	8419.9	494478.3	4078849.6	9/19/03	13.84	8406.06
206	8234.2	495918.4	4078995.9	5/16/01	8.25	8225.95
206	8234.2	495918.4	4078995.9	6/6/01	8.36	8225.84
206	8234.2	495918.4	4078995.9	7/19/01	8.40	8225.8
206	8234.2	495918.4	4078995.9	8/17/01	8.54	8225.66
206	8234.2	495918.4	4078995.9	9/24/01	8.85	8225.35
206	8234.2	495918.4	4078995.9	12/20/01	9.51	8224.69
206	8234.2	495918.4	4078995.9	1/30/02	9.62	8224.58
206	8234.2	495918.4	4078995.9	2/20/02	9.74	8224.46
206	8234.2	495918.4	4078995.9	3/22/02	9.88	8224.32
206	8234.2	495918.4	4078995.9	4/26/02	9.95	8224.25
206	8234.2	495918.4	4078995.9	5/24/02	10.08	8224.12
206	8234.2	495918.4	4078995.9	6/28/02	10.25	8223.95
206	8234.2	495918.4	4078995.9	7/16/02	10.35	8223.85
206	8234.2	495918.4	4078995.9	8/13/02	10.49	8223.71
206	8234.2	495918.4	4078995.9	9/30/02	10.62	8223.58
206	8234.2	495918.4	4078995.9	10/24/02	10.74	8223.46
206	8234.2	495918.4	4078995.9	11/20/02	10.93	8223.27
206	8234.2	495918.4	4078995.9	12/18/02	10.86	8223.34
206	8234.2	495918.4	4078995.9	2/26/03	10.97	8223.23

Site Name	Elevation	UTM X	UTM Y	Date	DTW	PS
206	8234.2	495918.4	4078995.9	3/27/03	10.91	8223.29
206	8234.2	495918.4	4078995.9	4/16/03	11.02	8223.18
206	8234.2	495918.4	4078995.9	5/20/03	11.29	8222.91
206	8234.2	495918.4	4078995.9	6/17/03	11.38	8222.82
206	8234.2	495918.4	4078995.9	7/22/03	11.54	8222.66
206	8234.2	495918.4	4078995.9	8/21/03	11.65	8222.55
206	8234.2	495918.4	4078995.9	9/19/03	11.54	8222.66
207	8446.6	494743.4	4080360.8	5/16/01	16.36	8430.24
207	8446.6	494743.4	4080360.8	6/6/01	16.34	8430.26
207	8446.6	494743.4	4080360.8	7/19/01	16.45	8430.15
207	8446.6	494743.4	4080360.8	8/17/01	16.53	8430.07
207	8446.6	494743.4	4080360.8	9/24/01	16.72	8429.88
207	8446.6	494743.4	4080360.8	12/20/01	16.91	8429.69
207	8446.6	494743.4	4080360.8	1/30/02	16.96	8429.64
207	8446.6	494743.4	4080360.8	2/20/02	17.05	8429.55
207	8446.6	494743.4	4080360.8	3/22/02	17.21	8429.39
207	8446.6	494743.4	4080360.8	4/26/02	17.30	8429.3
207	8446.6	494743.4	4080360.8	5/24/02	17.35	8429.25
207	8446.6	494743.4	4080360.8	6/20/02	17.44	8429.16
207	8446.6	494743.4	4080360.8	7/16/02	17.51	8429.09
207	8446.6	494743.4	4080360.8	8/9/02	17.50	8429.1
207	8446.6	494743.4	4080360.8	9/30/02	17.46	8429.14
207	8446.6	494743.4	4080360.8	10/24/02	17.52	8429.08
207	8446.6	494743.4	4080360.8	11/20/02	17.62	8428.98
207	8446.6	494743.4	4080360.8	12/18/02	17.56	8429.04
207	8446.6	494743.4	4080360.8	2/26/03	17.75	8428.85
207	8446.6	494743.4	4080360.8	3/27/03	17.79	8428.81
207	8446.6	494743.4	4080360.8	4/16/03	17.78	8428.82
207	8446.6	494743.4	4080360.8	5/20/03	18.34	8428.26
207	8446.6	494743.4	4080360.8	6/17/03	18.30	8428.3
207	8446.6	494743.4	4080360.8	7/22/03	18.20	8428.4
207	8446.6	494743.4	4080360.8	8/21/03	17.65	8428.95
207	8446.6	494743.4	4080360.8	9/19/03	17.52	8429.08
208	8651.9	494947.8	4081246.5	5/16/01	6.79	8645.11
208	8651.9	494947.8	4081246.5	6/6/01	7.00	8644.9
208	8651.9	494947.8	4081246.5	7/19/01	7.56	8644.34
208	8651.9	494947.8	4081246.5	8/17/01	7.85	8644.05
208	8651.9	494947.8	4081246.5	9/24/01	8.15	8643.75
208	8651.9	494947.8	4081246.5	12/20/01	8.42	8643.48
208	8651.9	494947.8	4081246.5	1/30/02	8.45	8643.45
208	8651.9	494947.8	4081246.5	2/20/02	8.55	8643.35
208	8651.9	494947.8	4081246.5	3/22/02	8.61	8643.29
208	8651.9	494947.8	4081246.5	4/26/02	8.64	8643.26
208	8651.9	494947.8	4081246.5	5/24/02	8.76	8643.14
208	8651.9	494947.8	4081246.5	6/20/02	8.94	8642.96
208	8651.9	494947.8	4081246.5	7/16/02	9.00	8642.9
208	8651.9	494947.8	4081246.5	8/9/02	9.16	8642.74
208	8651.9	494947.8	4081246.5	9/30/02	9.30	8642.6
208	8651.9	494947.8	4081246.5	10/24/02	9.38	8642.52
208	8651.9	494947.8	4081246.5	11/20/02	9.50	8642.4

Site Name	Elevation	UTM X	UTM Y	Date	DTW	PS
208	8651.9	494947.8	4081246.5	12/18/02	9.52	8642.38
208	8651.9	494947.8	4081246.5	2/26/03	9.71	8642.19
208	8651.9	494947.8	4081246.5	3/27/03	9.72	8642.18
208	8651.9	494947.8	4081246.5	4/16/03	9.82	8642.08
208	8651.9	494947.8	4081246.5	5/20/03	9.91	8641.99
208	8651.9	494947.8	4081246.5	6/17/03	9.91	8641.99
208	8651.9	494947.8	4081246.5	7/22/03	9.98	8641.92
208	8651.9	494947.8	4081246.5	8/21/03	10.05	8641.85
208	8651.9	494947.8	4081246.5	9/19/03	10.00	8641.9
230	8181.5	491274.8	4081202.3	7/19/01	7.47	8174.03
230	8181.5	491274.8	4081202.3	9/11/01	8.10	8173.4
230	8181.5	491274.8	4081202.3	1/30/02	6.45	8175.05
230	8181.5	491274.8	4081202.3	2/20/02	6.25	8175.25
230	8181.5	491274.8	4081202.3	3/22/02	6.13	8175.37
230	8181.5	491274.8	4081202.3	4/26/02	6.31	8175.19
230	8181.5	491274.8	4081202.3	5/24/02	7.32	8174.18
230	8181.5	491274.8	4081202.3	6/20/02	8.05	8173.45
230	8181.5	491274.8	4081202.3	7/16/02	8.65	8172.85
230	8181.5	491274.8	4081202.3	8/9/02	9.26	8172.24
230	8181.5	491274.8	4081202.3	9/28/02	9.85	8171.65
230	8181.5	491274.8	4081202.3	10/24/02	9.68	8171.82
230	8181.5	491274.8	4081202.3	11/20/02	6.12	8175.38
230	8181.5	491274.8	4081202.3	12/17/02	8.71	8172.79
230	8181.5	491274.8	4081202.3	2/24/03	8.18	8173.32
230	8181.5	491274.8	4081202.3	3/27/03	7.92	8173.58
230	8181.5	491274.8	4081202.3	4/22/03	8.24	8173.26
230	8181.5	491274.8	4081202.3	5/20/03	8.52	8172.98
230	8181.5	491274.8	4081202.3	6/24/03	9.23	8172.27
230	8181.5	491274.8	4081202.3	7/24/03	10.80	8170.7
230	8181.5	491274.8	4081202.3	8/18/03	11.56	8169.94
230	8181.5	491274.8	4081202.3	9/23/03	12.03	8169.47
231	8458.3	489256.7	4078347.9	8/13/01	7.68	8450.62
231	8458.3	489256.7	4078347.9	9/12/01	15.88	8442.42
231	8458.3	489256.7	4078347.9	12/20/01	17.00	8441.3
231	8458.3	489256.7	4078347.9	1/30/02	17.90	8440.4
231	8458.3	489256.7	4078347.9	2/20/02	18.29	8440.01
231	8458.3	489256.7	4078347.9	3/22/02	18.18	8440.12
231	8458.3	489256.7	4078347.9	4/26/02	14.85	8443.45
231	8458.3	489256.7	4078347.9	5/24/02	15.91	8442.39
231	8458.3	489256.7	4078347.9	6/20/02	17.75	8440.55
231	8458.3	489256.7	4078347.9	7/16/02	18.84	8439.46
231	8458.3	489256.7	4078347.9	8/9/02	19.58	8438.72
231	8458.3	489256.7	4078347.9	9/28/02	20.30	8438
231	8458.3	489256.7	4078347.9	10/24/02	16.10	8442.2
231	8458.3	489256.7	4078347.9	11/20/02	15.03	8443.27
231	8458.3	489256.7	4078347.9	12/18/02	15.71	8442.59
231	8458.3	489256.7	4078347.9	2/24/03	16.94	8441.36
231	8458.3	489256.7	4078347.9	3/27/03	15.18	8443.12
231	8458.3	489256.7	4078347.9	4/16/03	14.25	8444.05
232	8490	488862.3	4078139	8/13/01	15.51	8474.49

Site Name	Elevation	UTM X	UTM Y	Date	DTW	PS
232	8490	488862.3	4078139	12/20/01	26.71	8463.29
232	8490	488862.3	4078139	1/30/02	27.51	8462.49
232	8490	488862.3	4078139	2/20/02	26.93	8463.07
232	8490	488862.3	4078139	3/22/02	23.35	8466.65
232	8490	488862.3	4078139	4/26/02	21.60	8468.4
232	8490	488862.3	4078139	5/24/02	26.01	8463.99
232	8490	488862.3	4078139	6/20/02	28.47	8461.53
232	8490	488862.3	4078139	7/16/02	29.63	8460.37
232	8490	488862.3	4078139	8/9/02	30.20	8459.8
232	8490	488862.3	4078139	9/28/02	20.13	8469.87
232	8490	488862.3	4078139	10/24/02	20.30	8469.7
232	8490	488862.3	4078139	11/20/02	21.58	8468.42
232	8490	488862.3	4078139	12/18/02	23.66	8466.34
232	8490	488862.3	4078139	2/24/03	23.59	8466.41
232	8490	488862.3	4078139	3/27/03	19.40	8470.6
232	8490	488862.3	4078139	4/16/03	18.05	8471.95
232	8490	488862.3	4078139	5/20/03	19.64	8470.36
232	8490	488862.3	4078139	6/24/03	20.32	8469.68
232	8490	488862.3	4078139	7/24/03	22.34	8467.66
232	8490	488862.3	4078139	8/18/03	23.80	8466.2
232	8490	488862.3	4078139	9/23/03	25.06	8464.94
233	8495	488822.6	4078141	12/20/01	14.38	8480.62
233	8495	488822.6	4078141	1/30/02	14.60	8480.4
233	8495	488822.6	4078141	2/20/02	13.98	8481.02
233	8495	488822.6	4078141	3/22/02	13.26	8481.74
233	8495	488822.6	4078141	4/26/02	12.61	8482.39
233	8495	488822.6	4078141	5/24/02	14.61	8480.39
233	8495	488822.6	4078141	6/20/02	15.71	8479.29
233	8495	488822.6	4078141	7/16/02	16.84	8478.16
233	8495	488822.6	4078141	8/9/02	17.48	8477.52
233	8495	488822.6	4078141	9/28/02	11.86	8483.14
233	8495	488822.6	4078141	10/24/02	12.55	8482.45
233	8495	488822.6	4078141	11/20/02	13.16	8481.84
233	8495	488822.6	4078141	12/18/02	13.41	8481.59
233	8495	488822.6	4078141	2/24/03	0.00	8495
233	8495	488822.6	4078141	3/27/03	11.65	8483.35
233	8495	488822.6	4078141	4/16/03	11.50	8483.5
233	8495	488822.6	4078141	5/20/03	12.93	8482.07
233	8495	488822.6	4078141	6/24/03	13.45	8481.55
233	8495	488822.6	4078141	7/24/03	14.18	8480.82
233	8495	488822.6	4078141	8/18/03	14.91	8480.09
233	8495	488822.6	4078141	9/23/03	15.31	8479.69
234	8500	488785.3	4078138.4	12/20/01	19.23	8480.77
234	8500	488785.3	4078138.4	1/30/02	19.62	8480.38
234	8500	488785.3	4078138.4	2/20/02	19.01	8480.99
234	8500	488785.3	4078138.4	3/22/02	17.30	8482.7
234	8500	488785.3	4078138.4	4/26/02	16.96	8483.04
234	8500	488785.3	4078138.4	5/24/02	19.72	8480.28
234	8500	488785.3	4078138.4	6/20/02	21.00	8479
234	8500	488785.3	4078138.4	7/16/02	21.71	8478.29

Site Name	Elevation	UTM X	UTM Y	Date	DTW	PS
234	8500	488785.3	4078138.4	8/9/02	22.12	8477.88
234	8500	488785.3	4078138.4	9/28/02	16.00	8484
234	8500	488785.3	4078138.4	10/24/02	16.53	8483.47
234	8500	488785.3	4078138.4	11/20/02	17.07	8482.93
234	8500	488785.3	4078138.4	12/18/02	17.41	8482.59
234	8500	488785.3	4078138.4	2/24/03	16.88	8483.12
234	8500	488785.3	4078138.4	3/27/03	16.17	8483.83
234	8500	488785.3	4078138.4	4/16/03	16.15	8483.85
234	8500	488785.3	4078138.4	5/20/03	17.10	8482.9
234	8500	488785.3	4078138.4	6/24/03	17.43	8482.57
234	8500	488785.3	4078138.4	7/24/03	18.34	8481.66
234	8500	488785.3	4078138.4	8/18/03	19.41	8480.59
234	8500	488785.3	4078138.4	9/23/03	20.07	8479.93
235	8217.3	491290	4081694	1/30/02	9.13	8208.17
235	8217.3	491290	4081694	2/20/02	9.21	8208.09
235	8217.3	491290	4081694	3/22/02	9.35	8207.95
235	8217.3	491290	4081694	4/26/02	9.47	8207.83
235	8217.3	491290	4081694	5/24/02	9.65	8207.65
235	8217.3	491290	4081694	6/20/02	9.88	8207.42
235	8217.3	491290	4081694	7/16/02	10.07	8207.23
235	8217.3	491290	4081694	8/9/02	10.22	8207.08
235	8217.3	491290	4081694	10/24/02	10.64	8206.66
235	8217.3	491290	4081694	11/20/02	10.67	8206.63
235	8217.3	491290	4081694	12/17/02	10.76	8206.54
235	8217.3	491290	4081694	2/24/03	10.97	8206.33
235	8217.3	491290	4081694	3/27/03	11.10	8206.2
235	8217.3	491290	4081694	4/22/03	11.18	8206.12
235	8217.3	491290	4081694	5/20/03	11.23	8206.07
235	8217.3	491290	4081694	6/24/03	11.45	8205.85
235	8217.3	491290	4081694	7/24/03	11.78	8205.52
235	8217.3	491290	4081694	8/18/03	12.05	8205.25
235	8217.3	491290	4081694	9/23/03	12.41	8204.89
236	7515	503787	4074559	12/24/01	26.97	7488.03
236	7515	503787	4074559	1/30/02	21.50	7493.5
236	7515	503787	4074559	2/20/02	23.80	7491.2
236	7515	503787	4074559	3/22/02	20.71	7494.29
236	7515	503787	4074559	4/26/02	26.24	7488.76
236	7515	503787	4074559	5/24/02	29.41	7485.59
236	7515	503787	4074559	6/28/02	29.12	7485.88
236	7515	503787	4074559	7/16/02	28.02	7486.98
236	7515	503787	4074559	9/30/02	20.26	7494.74
236	7515	503787	4074559	10/24/02	33.03	7481.97
236	7515	503787	4074559	11/20/02	25.31	7489.69
236	7515	503787	4074559	12/18/02	25.62	7489.38
236	7515	503787	4074559	2/26/03	20.96	7494.04
236	7515	503787	4074559	3/27/03	19.68	7495.32
236	7515	503787	4074559	4/16/03	24.57	7490.43
236	7515	503787	4074559	5/21/03	27.26	7487.74
236	7515	503787	4074559	6/26/03	25.02	7489.98
236	7515	503787	4074559	7/24/03	25.56	7489.44

Site Name	Elevation	UTM X	UTM Y	Date	DTW	PS
236	7515	503787	4074559	8/21/03	25.57	7489.43
305	8021.2	498123.7	4077234.8	5/16/01	17.82	8003.38
305	8021.2	498123.7	4077234.8	6/6/01	17.92	8003.28
305	8021.2	498123.7	4077234.8	6/26/01	47.29	7973.91
305	8021.2	498123.7	4077234.8	7/7/01	15.00	8006.2
305	8021.2	498123.7	4077234.8	7/19/01	18.26	8002.94
305	8021.2	498123.7	4077234.8	8/17/01	18.39	8002.81
305	8021.2	498123.7	4077234.8	9/24/01	18.82	8002.38
305	8021.2	498123.7	4077234.8	12/24/01	19.47	8001.73
305	8021.2	498123.7	4077234.8	1/30/02	19.67	8001.53
305	8021.2	498123.7	4077234.8	2/20/02	19.91	8001.29
305	8021.2	498123.7	4077234.8	3/22/02	19.80	8001.4
305	8021.2	498123.7	4077234.8	4/26/02	19.37	8001.83
305	8021.2	498123.7	4077234.8	5/24/02	19.64	8001.56
305	8021.2	498123.7	4077234.8	6/28/02	20.42	8000.78
305	8021.2	498123.7	4077234.8	7/16/02	20.77	8000.43
305	8021.2	498123.7	4077234.8	8/13/02	21.25	7999.95
305	8021.2	498123.7	4077234.8	9/30/02	21.53	7999.67
305	8021.2	498123.7	4077234.8	10/24/02	21.55	7999.65
305	8021.2	498123.7	4077234.8	11/20/02	21.82	7999.38
305	8021.2	498123.7	4077234.8	12/18/02	21.65	7999.55
305	8021.2	498123.7	4077234.8	2/26/03	21.85	7999.35
305	8021.2	498123.7	4077234.8	3/27/03	21.80	7999.4
305	8021.2	498123.7	4077234.8	4/16/03	23.94	7997.26
305	8021.2	498123.7	4077234.8	5/21/03	22.01	7999.19
305	8021.2	498123.7	4077234.8	6/26/03	22.04	7999.16
305	8021.2	498123.7	4077234.8	7/24/03	22.18	7999.02
305	8021.2	498123.7	4077234.8	8/21/03	22.37	7998.83
305	8021.2	498123.7	4077234.8	9/23/03	22.34	7998.86
307	7754.3	500902.6	4075482.1	6/8/01	8.62	7745.68
307	7754.3	500902.6	4075482.1	7/19/01	16.45	7737.85
307	7754.3	500902.6	4075482.1	12/24/01	19.06	7735.24
307	7754.3	500902.6	4075482.1	1/30/02	19.13	7735.17
307	7754.3	500902.6	4075482.1	2/20/02	19.19	7735.11
307	7754.3	500902.6	4075482.1	3/22/02	19.31	7734.99
307	7754.3	500902.6	4075482.1	4/26/02	19.26	7735.04
307	7754.3	500902.6	4075482.1	5/24/02	19.31	7734.99
307	7754.3	500902.6	4075482.1	6/28/02	19.37	7734.93
307	7754.3	500902.6	4075482.1	7/16/02	19.44	7734.86
309	7848.5	498885.4	4078200.8	5/26/01	8.52	7839.98
309	7848.5	498885.4	4078200.8	8/3/01	9.13	7839.37
309	7848.5	498885.4	4078200.8	9/24/01	9.21	7839.29
309	7848.5	498885.4	4078200.8	12/20/01	9.27	7839.23
309	7848.5	498885.4	4078200.8	1/25/02	9.35	7839.15
309	7848.5	498885.4	4078200.8	2/26/02	9.40	7839.1
309	7848.5	498885.4	4078200.8	3/24/02	9.00	7839.5
309	7848.5	498885.4	4078200.8	4/26/02	9.17	7839.33
309	7848.5	498885.4	4078200.8	5/24/02	9.53	7838.97
309	7848.5	498885.4	4078200.8	6/20/02	10.13	7838.37
309	7848.5	498885.4	4078200.8	7/16/02	10.64	7837.86

Site Name	Elevation	UTM X	UTM Y	Date	DTW	PS
309	7848.5	498885.4	4078200.8	8/9/02	11.11	7837.39
309	7848.5	498885.4	4078200.8	9/30/02	11.29	7837.21
309	7848.5	498885.4	4078200.8	10/24/02	11.48	7837.02
309	7848.5	498885.4	4078200.8	11/20/02	12.31	7836.19
309	7848.5	498885.4	4078200.8	12/17/02	11.98	7836.52
309	7848.5	498885.4	4078200.8	3/27/03	11.36	7837.14
309	7848.5	498885.4	4078200.8	4/23/03	11.37	7837.13
309	7848.5	498885.4	4078200.8	5/20/03	11.50	7837
309	7848.5	498885.4	4078200.8	6/17/03	11.32	7837.18
309	7848.5	498885.4	4078200.8	7/22/03	12.84	7835.66
309	7848.5	498885.4	4078200.8	8/21/03	13.34	7835.16
309	7848.5	498885.4	4078200.8	9/19/03	13.31	7835.19
314	8314.2	496284.8	4081444.4	5/26/01	37.98	8276.22
314	8314.2	496284.8	4081444.4	6/9/01	37.95	8276.25
314	8314.2	496284.8	4081444.4	7/19/01	38.64	8275.56
314	8314.2	496284.8	4081444.4	9/24/01	40.13	8274.07
314	8314.2	496284.8	4081444.4	12/20/01	40.67	8273.53
314	8314.2	496284.8	4081444.4	1/30/02	40.62	8273.58
314	8314.2	496284.8	4081444.4	2/20/02	40.74	8273.46
314	8314.2	496284.8	4081444.4	3/22/02	40.85	8273.35
314	8314.2	496284.8	4081444.4	4/26/02	40.82	8273.38
314	8314.2	496284.8	4081444.4	5/24/02	40.90	8273.3
314	8314.2	496284.8	4081444.4	6/20/02	41.11	8273.09
314	8314.2	496284.8	4081444.4	7/16/02	41.07	8273.13
314	8314.2	496284.8	4081444.4	8/9/02	41.20	8273
314	8314.2	496284.8	4081444.4	9/30/02	40.71	8273.49
314	8314.2	496284.8	4081444.4	10/24/02	41.18	8273.02
314	8314.2	496284.8	4081444.4	11/20/02	41.67	8272.53
314	8314.2	496284.8	4081444.4	12/24/02	41.77	8272.43
314	8314.2	496284.8	4081444.4	2/26/03	41.92	8272.28
314	8314.2	496284.8	4081444.4	3/27/03	42.09	8272.11
314	8314.2	496284.8	4081444.4	4/23/03	41.97	8272.23
314	8314.2	496284.8	4081444.4	5/20/03	42.48	8271.72
314	8314.2	496284.8	4081444.4	6/17/03	42.13	8272.07
314	8314.2	496284.8	4081444.4	7/22/03	42.04	8272.16
314	8314.2	496284.8	4081444.4	8/21/03	42.12	8272.08
314	8314.2	496284.8	4081444.4	9/19/03	41.97	8272.23
324	7175	510309.3	4070265.7	6/8/01	46.88	7128.12
324	7175	510309.3	4070265.7	7/11/01	42.27	7132.73
RMA-2	7489	503248.8	4078942.2	7/11/01	11.37	7477.63
RMA-2	7489	503248.8	4078942.2	8/13/01	10.91	7478.09
RMA-2	7489	503248.8	4078942.2	9/21/01	12.00	7477
RMA-2	7489	503248.8	4078942.2	12/20/01	12.02	7476.98
RMA-2	7489	503248.8	4078942.2	1/30/02	12.12	7476.88
RMA-2	7489	503248.8	4078942.2	2/20/02	12.19	7476.81
RMA-2	7489	503248.8	4078942.2	3/22/02	12.15	7476.85
RMA-2	7489	503248.8	4078942.2	4/26/02	12.35	7476.65
RMA-2	7489	503248.8	4078942.2	5/24/02	12.58	7476.42
RMA-2	7489	503248.8	4078942.2	6/20/02	12.91	7476.09
RMA-2	7489	503248.8	4078942.2	7/16/02	13.21	7475.79

Site Name	Elevation	UTM X	UTM Y	Date	DTW	PS
RMA-2	7489	503248.8	4078942.2	8/9/02	13.49	7475.51
RMA-2	7489	503248.8	4078942.2	2/26/03	12.88	7476.12
RMA-2	7489	503248.8	4078942.2	3/24/03	12.34	7476.66
RMA-2	7489	503248.8	4078942.2	4/23/03	12.29	7476.71
RMA-2	7489	503248.8	4078942.2	5/20/03	12.37	7476.63
RMA-2	7489	503248.8	4078942.2	6/17/03	12.68	7476.32
RMA-2	7489	503248.8	4078942.2	7/22/03	13.02	7475.98
RMA-2	7489	503248.8	4078942.2	8/18/03	13.35	7475.65
RMA-3	7563.8	502657	4079151.4	6/9/01	12.95	7550.85
RMA-3	7563.8	502657	4079151.4	7/11/01	14.10	7549.7
RMA-3	7563.8	502657	4079151.4	8/13/01	13.58	7550.22
RMA-3	7563.8	502657	4079151.4	9/21/01	14.96	7548.84
RMA-3	7563.8	502657	4079151.4	12/20/01	14.84	7548.96
RMA-3	7563.8	502657	4079151.4	1/30/02	14.72	7549.08
RMA-3	7563.8	502657	4079151.4	2/20/02	14.71	7549.09
RMA-3	7563.8	502657	4079151.4	3/22/02	14.91	7548.89
RMA-3	7563.8	502657	4079151.4	4/26/02	15.01	7548.79
RMA-3	7563.8	502657	4079151.4	5/24/02	15.29	7548.51
RMA-3	7563.8	502657	4079151.4	6/20/02	15.31	7548.49
RMA-3	7563.8	502657	4079151.4	7/16/02	15.32	7548.48
RMA-3	7563.8	502657	4079151.4	8/9/02	16.27	7547.53
RMA-3	7563.8	502657	4079151.4	9/30/02	16.36	7547.44
RMA-3	7563.8	502657	4079151.4	10/24/02	14.80	7549
RMA-3	7563.8	502657	4079151.4	11/20/02	14.81	7548.99
RMA-3	7563.8	502657	4079151.4	12/26/02	14.80	7549
RMA-3	7563.8	502657	4079151.4	2/26/03	14.87	7548.93
RMA-3	7563.8	502657	4079151.4	3/24/03	14.71	7549.09
RMA-3	7563.8	502657	4079151.4	4/23/03	14.54	7549.26
RMA-3	7563.8	502657	4079151.4	5/20/03	14.91	7548.89
RMA-3	7563.8	502657	4079151.4	6/17/03	14.90	7548.9
RMA-3	7563.8	502657	4079151.4	8/18/03	15.29	7548.51
RMA-3	7563.8	502657	4079151.4	9/19/03	15.61	7548.19
RO-84-54-01	7781	500472.8	4079800.7	8/13/01	38.57	7742.43
RO-84-54-01	7781	500472.8	4079800.7	12/20/01	38.66	7742.34
RO-84-54-01	7781	500472.8	4079800.7	1/30/02	38.70	7742.3
RO-84-54-01	7781	500472.8	4079800.7	2/20/02	38.75	7742.25
RO-84-54-01	7781	500472.8	4079800.7	3/22/02	38.81	7742.19
RO-84-54-01	7781	500472.8	4079800.7	4/26/02	38.86	7742.14
RO-84-54-01	7781	500472.8	4079800.7	5/24/02	38.89	7742.11
RO-84-54-01	7781	500472.8	4079800.7	6/20/02	38.95	7742.05
RO-84-54-01	7781	500472.8	4079800.7	7/16/02	39.05	7741.95
RO-84-54-01	7781	500472.8	4079800.7	8/9/02	39.45	7741.55
RO-84-54-01	7781	500472.8	4079800.7	9/30/02	39.56	7741.44
RO-84-54-01	7781	500472.8	4079800.7	9/30/02	42.51	7738.49
RO-84-54-01	7781	500472.8	4079800.7	10/24/02	39.61	7741.39
RO-84-54-01	7781	500472.8	4079800.7	11/20/02	39.61	7741.39
RO-84-54-01	7781	500472.8	4079800.7	12/24/02	39.59	7741.41
RO-84-54-01	7781	500472.8	4079800.7	2/26/03	39.75	7741.25
RO-84-54-01	7781	500472.8	4079800.7	3/24/03	39.82	7741.18
RO-84-54-01	7781	500472.8	4079800.7	4/23/03	39.97	7741.03

Site Name	Elevation	UTM X	UTM Y	Date	DTW	PS
RO-84-54-01	7781	500472.8	4079800.7	5/20/03	39.80	7741.2
RO-84-54-01	7781	500472.8	4079800.7	6/17/03	39.51	7741.49
RO-84-54-01	7781	500472.8	4079800.7	7/22/03	39.77	7741.23
RO-84-54-01	7781	500472.8	4079800.7	8/21/03	39.80	7741.2
RO-84-54-01	7781	500472.8	4079800.7	9/19/03	40.21	7740.79
RO-84-54-02	7778	500471.3	4079801	8/13/01	40.92	7737.08
RO-84-54-02	7778	500471.3	4079801	12/20/01	41.14	7736.86
RO-84-54-02	7778	500471.3	4079801	1/30/02	41.25	7736.75
RO-84-54-02	7778	500471.3	4079801	2/20/02	41.51	7736.49
RO-84-54-02	7778	500471.3	4079801	3/22/02	41.58	7736.42
RO-84-54-02	7778	500471.3	4079801	4/26/02	41.46	7736.54
RO-84-54-02	7778	500471.3	4079801	5/24/02	41.53	7736.47
RO-84-54-02	7778	500471.3	4079801	6/20/02	41.84	7736.16
RO-84-54-02	7778	500471.3	4079801	7/16/02	42.12	7735.88
RO-84-54-02	7778	500471.3	4079801	8/9/02	42.32	7735.68
RO-84-54-02	7778	500471.3	4079801	10/24/02	42.64	7735.36
RO-84-54-02	7778	500471.3	4079801	11/20/02	42.25	7735.75
RO-84-54-02	7778	500471.3	4079801	12/24/02	42.46	7735.54
RO-84-54-02	7778	500471.3	4079801	2/26/03	43.06	7734.94
RO-84-54-02	7778	500471.3	4079801	3/24/03	43.30	7734.7
RO-84-54-02	7778	500471.3	4079801	4/23/03	43.43	7734.57
RO-84-54-02	7778	500471.3	4079801	5/20/03	40.01	7737.99
RO-84-54-02	7778	500471.3	4079801	6/17/03	41.17	7736.83
RO-84-54-02	7778	500471.3	4079801	7/22/03	42.29	7735.71
RO-84-54-02	7778	500471.3	4079801	8/21/03	43.14	7734.86
RO-84-54-02	7778	500471.3	4079801	9/19/03	42.85	7735.15
RO-84-54-03	7563.8	500473.1	4079802.2	8/13/01	62.28	7501.52
RO-84-54-03	7563.8	500473.1	4079802.2	12/20/01	62.25	7501.55
RO-84-54-03	7563.8	500473.1	4079802.2	1/30/02	62.68	7501.12
RO-84-54-03	7563.8	500473.1	4079802.2	2/20/02	62.96	7500.84
RO-84-54-03	7563.8	500473.1	4079802.2	3/22/02	62.73	7501.07
RO-84-54-03	7563.8	500473.1	4079802.2	4/26/02	62.73	7501.07
RO-84-54-03	7563.8	500473.1	4079802.2	5/24/02	62.97	7500.83
RO-84-54-03	7563.8	500473.1	4079802.2	6/20/02	63.06	7500.74
RO-84-54-03	7563.8	500473.1	4079802.2	7/16/02	63.22	7500.58
RO-84-54-03	7563.8	500473.1	4079802.2	8/9/02	63.51	7500.29
RO-84-54-03	7563.8	500473.1	4079802.2	9/30/02	62.82	7500.98
RO-84-54-03	7563.8	500473.1	4079802.2	10/24/02	63.77	7500.03
RO-84-54-03	7563.8	500473.1	4079802.2	11/20/02	64.72	7499.08
RO-84-54-03	7563.8	500473.1	4079802.2	12/24/02	65.09	7498.71
RO-84-54-03	7563.8	500473.1	4079802.2	2/26/03	64.94	7498.86
RO-84-54-03	7563.8	500473.1	4079802.2	3/24/03	64.54	7499.26
RO-84-54-03	7563.8	500473.1	4079802.2	4/23/03	64.07	7499.73
RO-84-54-03	7563.8	500473.1	4079802.2	5/20/03	64.81	7498.99
RO-84-54-03	7563.8	500473.1	4079802.2	6/17/03	64.50	7499.3
RO-84-54-03	7563.8	500473.1	4079802.2	7/22/03	65.39	7498.41
RO-84-54-03	7563.8	500473.1	4079802.2	8/21/03	65.60	7498.2
RO-84-54-03	7563.8	500473.1	4079802.2	9/19/03	65.67	7498.13
RO84-54-1	7781	500472.8	4079800.7	7/11/01	38.50	7742.5
RO84-54-1	7781	500472.8	4079800.7	9/21/01	38.60	7742.4

Site Name	Elevation	UTM X	UTM Y	Date	DTW	PS
RO84-54-2	7778	500471.3	4079801	7/11/01	40.82	7737.18
RO84-54-2	7778	500471.3	4079801	9/21/01	41.41	7736.59
RO84-54-3	7773	500473.1	4079802.2	7/11/01	62.65	7710.35
RO84-54-3	7773	500473.1	4079802.2	9/21/01	61.97	7711.03
RO-84-57-01	7911	500614.4	4080161.5	8/15/01	187.34	7723.66
RO-84-57-01	7911	500614.4	4080161.5	12/20/01	187.62	7723.38
RO-84-57-01	7911	500614.4	4080161.5	1/30/02	187.71	7723.29
RO-84-57-01	7911	500614.4	4080161.5	2/20/02	187.73	7723.27
RO-84-57-01	7911	500614.4	4080161.5	3/22/02	187.79	7723.21
RO-84-57-01	7911	500614.4	4080161.5	4/26/02	187.91	7723.09
RO-84-57-01	7911	500614.4	4080161.5	5/24/02	188.00	7723
RO-84-57-01	7911	500614.4	4080161.5	6/20/02	188.07	7722.93
RO-84-57-01	7911	500614.4	4080161.5	7/16/02	188.21	7722.79
RO-84-57-01	7911	500614.4	4080161.5	8/9/02	188.28	7722.72
RO-84-57-01	7911	500614.4	4080161.5	9/30/02	188.45	7722.55
RO-84-57-01	7911	500614.4	4080161.5	10/24/02	188.55	7722.45
RO-84-57-01	7911	500614.4	4080161.5	11/20/02	188.57	7722.43
RO-84-57-01	7911	500614.4	4080161.5	12/24/02	188.64	7722.36
RO-84-57-01	7911	500614.4	4080161.5	2/26/03	188.72	7722.28
RO-84-57-01	7911	500614.4	4080161.5	3/24/03	188.72	7722.28
RO-84-57-01	7911	500614.4	4080161.5	4/23/03	188.79	7722.21
RO-84-57-01	7911	500614.4	4080161.5	5/20/03	188.82	7722.18
RO-84-57-01	7911	500614.4	4080161.5	6/17/03	188.87	7722.13
RO-84-57-01	7911	500614.4	4080161.5	7/22/03	189.22	7721.78
RO-84-57-01	7911	500614.4	4080161.5	8/18/03	189.25	7721.75
RO-84-57-01	7911	500614.4	4080161.5	9/19/03	189.55	7721.45
RO-84-57-02	7930	500615.9	4080166.1	12/20/01	187.92	7742.08
RO-84-57-02	7930	500615.9	4080166.1	1/30/02	187.98	7742.02
RO-84-57-02	7930	500615.9	4080166.1	2/20/02	188.00	7742
RO-84-57-02	7930	500615.9	4080166.1	3/22/02	187.95	7742.05
RO-84-57-02	7930	500615.9	4080166.1	4/26/02	-1.00	7931
RO-84-57-02	7930	500615.9	4080166.1	5/24/02	188.13	7741.87
RO-84-57-02	7930	500615.9	4080166.1	6/20/02	188.20	7741.8
RO-84-57-02	7930	500615.9	4080166.1	7/16/02	188.47	7741.53
RO-84-57-02	7930	500615.9	4080166.1	8/9/02	188.57	7741.43
RO-84-57-02	7930	500615.9	4080166.1	9/30/02	188.57	7741.43
RO-84-57-02	7930	500615.9	4080166.1	10/24/02	188.60	7741.4
RO-84-57-02	7930	500615.9	4080166.1	11/20/02	188.74	7741.26
RO-84-57-02	7930	500615.9	4080166.1	12/24/02	188.96	7741.04
RO-84-57-02	7930	500615.9	4080166.1	2/26/03	189.29	7740.71
RO-84-57-02	7930	500615.9	4080166.1	3/24/03	189.24	7740.76
RO-84-57-02	7930	500615.9	4080166.1	4/23/03	189.54	7740.46
RO-84-57-02	7930	500615.9	4080166.1	5/20/03	189.68	7740.32
RO-84-57-02	7930	500615.9	4080166.1	6/17/03	190.15	7739.85
RO-84-57-02	7930	500615.9	4080166.1	7/22/03	190.51	7739.49
RO-84-57-02	7930	500615.9	4080166.1	8/18/03	190.61	7739.39
RO-84-57-02	7930	500615.9	4080166.1	9/19/03	190.54	7739.46
RO-84-57-03	7905	500618.4	4080162.8	8/15/01	184.40	7720.6
RO-84-57-03	7905	500618.4	4080162.8	12/20/01	185.30	7719.7
RO-84-57-03	7905	500618.4	4080162.8	1/30/02	183.95	7721.05

Site Name	Elevation	UTM X	UTM Y	Date	DTW	PS
RO-84-57-03	7905	500618.4	4080162.8	2/20/02	184.02	7720.98
RO-84-57-03	7905	500618.4	4080162.8	3/22/02	184.38	7720.62
RO-84-57-03	7905	500618.4	4080162.8	4/26/02	184.37	7720.63
RO-84-57-03	7905	500618.4	4080162.8	5/24/02	184.33	7720.67
RO-84-57-03	7905	500618.4	4080162.8	6/20/02	184.55	7720.45
RO-84-57-03	7905	500618.4	4080162.8	7/16/02	184.77	7720.23
RO-84-57-03	7905	500618.4	4080162.8	8/9/02	184.88	7720.12
RO-84-57-03	7905	500618.4	4080162.8	9/30/02	184.72	7720.28
RO-84-57-03	7905	500618.4	4080162.8	10/24/02	184.79	7720.21
RO-84-57-03	7905	500618.4	4080162.8	11/20/02	185.73	7719.27
RO-84-57-03	7905	500618.4	4080162.8	12/24/02	185.33	7719.67
RO-84-57-03	7905	500618.4	4080162.8	2/26/03	185.35	7719.65
RO-84-57-03	7905	500618.4	4080162.8	3/24/03	185.43	7719.57
RO-84-57-03	7905	500618.4	4080162.8	4/23/03	185.30	7719.7
RO-84-57-03	7905	500618.4	4080162.8	5/20/03	187.73	7717.27
RO-84-57-03	7905	500618.4	4080162.8	6/17/03	187.71	7717.29
RO-84-57-03	7905	500618.4	4080162.8	7/22/03	187.54	7717.46
RO-84-57-03	7905	500618.4	4080162.8	8/18/03	187.18	7717.82
RO-84-57-03	7905	500618.4	4080162.8	9/19/03	187.59	7717.41
RO84-57-1	7911	500614.4	4080161.5	7/11/01	187.26	7723.74

APPENIDIX 7. WATER BALANCE FOR VERMEJO RIVER WATERSHED

During the course of this study a water balance was performed on the Vermejo River Watershed. The aquifer containing the coalbeds of the Raton and Vermejo Formations is thought to be relatively isolated from the surface and near surface hydrology and therefore much of the water balance did not directly relate the hydrology of coalbeds. It was for this reason the water balance was not included in the main text. What follows is a description of the methods used as well as preliminary results and interpretations.

Methods: Water balance calculations

Below is the general mathematical equation used for the water balance:

$$P = ET + Q + \Delta S \qquad \text{(A7.1)}$$

where

P = precipitation

ET = evapotranspiration

Q = stream flow

ΔS = change in storage.

Precipitation is the rain and snow that falls directly on the area of the watershed. Evapotranspiration is the loss of water from the watershed attributed to climatic and biologic activity. Stream flow is water that is leaving the watershed through the surface drainage system. Change in storage represents the resultant change in groundwater level after combining groundwater flow into and out of the watershed.

In theory both sides of the equation will equal one another. However, because of the limited availability of information for the region, there is a degree of error in the calculations performed. The largest contributors to this error are believed to come from averaging of spatial and temporal information. Whenever the data permitted, the smallest time step (usually monthly) was used to ensure more accurate estimations. The largest number of spatial measurements was also utilized to improve estimates. Calculations described below indicate spatial and temporal averages used.

Water balance calculations were performed making use of public information. The Canadian River, Vermejo River, and Ponil Creek were considered the primary drainages for the study area. Three gauging stations (one on each river) were considered for the rivers from the U.S. Geological Survey National Water Information System (NWIS) database (National Water Information System, 2004). After examining the records for the stations it was concluded that the gauge on the Canadian River did not have adequate records for the calculations. Records from 1970 through 2002 were of interest. This period was chosen because it was close to the thirty- year average commonly used in meteorological studies and made the best use of the available data. Because potentiometric data was only available for wells near the Vermejo River, it was the only one of the three rivers used for a water balance calculation. Monthly stream flow data from the gauge on the Vermejo River was obtained and used in the calculation.

ArcMap^{TM} 8.2 software combined with a special tool package known as Arc Hydro (Maidment, 2003) was used to delineate the surface watershed for the Vermejo

River and is shown in Figure 1. Additional information concerning the watershed is given in Table 1. A 30 meter resolution digital elevation model (DEM) for the region was obtained from the U.S. Geological Survey National Map Seamless Data Distribution System (2004). A DEM is a file that stores the elevation of a surface. The DEM was analyzed using the Arc Hydro tool package to generate a watershed for the Vermejo River. The first step was to fill sinks in the DEM. Sinks are areas where water would accumulate (i.e. ponds and lakes). The next step is to establish a flow direction grid. This is essentially a vector grid that indicates the direction water would flow if it were placed on a specific point on the DEM. A flow accumulation grid is then generated. It shows were flow from an area accumulates and is used in the next step of the process that involves defining streams. After the streams are defined they are segmented. With this information a catchment grid is delineated, which outlines the area being drained by each segment of the stream. A batch point file was created for the gauge station to delineate the watershed being drained by the stream at the point where the gauge station is located. This is a file containing the coordinates of the gauge station. The batch point file and the catchment grid delineation file are used to generate a batch watershed delineation file. This file is the watershed outline for the gauge station. One of these files was generated for the Vermejo River gauge station. Finally, the original DEM was "cut" to fit the watershed outline.

Precipitation data was available for twelve weather stations in reasonable proximity (< 50 miles) of the study area. Data for these gauges was obtained from the Western Regional Climate Center (2004). Of these, four stations were used in the final calculation. Three of the stations are located in New Mexico in the towns of Springer, Cimarron, and Raton. The fourth is located in Trinidad, Colorado. Further station information can be found in Table 2. A number of stations were not considered because the geographic locations, while close to the study area, were believed to represent significantly different conditions for precipitation. Other stations lacked substantial portions of data for the period of interest.

Monthly average precipitation measurements were calculated for the remaining stations. A conversion factor of 0.1 was used to convert snowfall to rainfall, which was adopted from Abbott et al. (1983). The totals were added together. The total precipitation for each year was plotted on a graph against elevation. Linear trend equations were derived for each month (Table 3). Linear trend equations were chosen because they represented the best fit lines to the data, as determined by R^2 values.

Mean elevation for the watershed was determined from the DEM cut to the watershed outline using the raster calculator tool in ArcMap™ 8.2. The raster calculator computed the answer to the linear equations for every point on the DEM for the watershed. A precipitation map was generated (Figure 2). From this map a mean precipitation for the area could be determined.

The precipitation values calculated above were compared to estimates from the Spatial Climate Analysis Service (SCAS) for the region (Spatial Climate Analysis Service, 2004). Estimates calculated in this study were substantially higher than those of the SCAS. The SCAS used a model known as Parameter-elevation Regressions on Independent Slopes Model (PRISM). PRISM is able to account for effect of surrounding topography on precipitation. The source code for PRISM is not available to the public and therefore could not directly be utilized for calculations in this study. A scaling factor of .49 was determined by comparing average monthly PRISM values with those of this study. This factor was applied to the precipitation estimates of this study. These precipitation estimates are closer to previous calculations (Western Regional Climate Center, 2004).

Evapotranspiration estimates for the watershed were computed using several methods. The Thornthwaite equation (given below) was used to determine the monthly potential evaporation (Thornthwaite, 1948).

$$PE = 1.62b\left[\frac{10T}{I}\right]^{a} \qquad \text{(A7.2)}$$

where

PE = potential evapotranspiration (monthly) in centimeters of water.

T = mean monthly temperature in degrees Celsius.

I = annual heat index (dimensionless) computed as:

$$I = \sum_{m=1}^{12}\left[\frac{T_m}{5}\right]^{1.51} \qquad \text{(A7.3)}$$

where

T_m = monthly mean temperature for month m.

The factors *a* and *b* are determined from the following equation using I and Table 5.9 in Bras (1990) where *a* depends on I:

$$a = 67.5\times10^{-8}I^{3} - 77.1\times10^{-6}I^{2} + 0.0179I + 0.492 \qquad \text{(A7.4)}$$

For the study area, the latitude is 36^0N. For 35^0N (a close approximation), the values for *b* are:

	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
b	0.87	0.85	1.03	1.09	1.21	1.21	1.23	1.16	1.03	0.97	0.86	0.85

To use this equation it was necessary to calculate average monthly temperatures for the watersheds. The same four stations were used to create linear trend equations based on the relationship between temperature and elevation. A trend equation was found for each month of each year from 1970-2002 (Table 3). Using the average elevation a mean temperature for each month was determined. This is the same method employed to determine mean precipitation mentioned earlier.

Because the Thornthwaite equation is known to underestimate actual potential evapotranspiration, it was compared to available pan evaporation measurements. Average monthly pan evaporation measurements from stations at Eagles Nest, New Mexico and Trinidad, Colorado were averaged together. To compare, average monthly Thornthwaite evapotranspiration values were calculated over the 33-year period being examined. A scaling factor for each month was determined. The original Thornthwaite potential evapotranspiration values were multiplied by the corresponding monthly factor (4). This yielded monthly potential evapotranspiration values that were more in line with potential evapotranspiration values calculated from more complex methods for similar regions in New Mexico (WRCC, 2004).

Land coverage data for the watersheds was available from the U.S. Geological Survey National Map Seamless Data Distribution System (2004). It provided Anderson Level II classes for the study area (Anderson et al., 1976). The land coverage contained assigns values to each land type (K). Below is a list of K values used for the land types in the watersheds:

Generalized land-cover	K
Open water, stream, wetland	1
Pasture, grassland	0.75
Bare soil, open space	0.6
Evergreen woodland	0.7
Deciduous woodland	0.8
Urban	0.6

	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
m	0.5	0.5	0.6	0.7	0.8	0.9	1	1	1	0.9	0.7	0.5

These K values are multiplied by a monthly factor m given above. This produces monthly values (K_m) that when multiplied with the monthly potential evaporation values yield actual monthly evapotranspiration estimates, as shown in the equation below.

$$K_m = mK \qquad \text{(A7.5)}$$

An average K value for the watershed was calculated in ArcMap™ 8.2 using the land cover files. The m values (given above) were obtained from Bras (1990). The potential evaporation values calculated above were multiplied with their corresponding monthly Km value, yielding monthly actual evapotranspiration estimates.

To calculate the change in storage, potentiometric surface data was collected from the Vermejo Park Ranch and the Mineral and Mining Division of New Mexico. First, wells with a potentiometric surface that was less than 50 ft (15 m) from the top of the well were examined. Using available records, average changes in the depth to water were determined for the years between 1980-2002. The same process was done for wells with depths to water greater than 50 ft (15 m). For each year an average change in the potentiometric surface was calculated by averaging the changes in wells. These numbers were multiplied by the area of the watershed to give a volume.

The production volumes considered in the water balance section were obtained from Brister et al. (2004). Estimates for water producing wells in and adjacent to the Vermejo River watershed were considered. The volumes were converted from barrels/yr to m^3/yr for comparison to other estimations in the water balance.

Water balance

Water balance calculations were performed making use of public information. The purpose of the calculations was to quantify the inputs and outputs of the hydrologic system in the region. Precipitation, stream flow, evapotranspiration, and change in storage were calculated. The results of the water balance calculations are shown in Table 5. On average evapotranspiration is the largest component of the balance. This was expected for the study area. Precipitation is next largest followed by change in storage and lastly stream flow. Stream flow is about an order of magnitude less than any of the other components. The formula used to obtain the results in the balance column of Table 5 is shown below.

$$B = P - ET - Q + \Delta S \qquad \text{(A7.6)}$$

where

B = balance (in theory this should be 0)

P = precipitation

ET = evapotranspiration

Q = stream flow

ΔS = change in storage.

In theory this number should be zero. However, the calculations used were intended to produce rough estimates based on limited data.

The error of the balance was assessed by taking the absolute value of the balance and dividing it by the sum of the components used in the balance (Table 5). The range of error was from 2-58% with a mean of 19%. It is believed that a substantial portion of the error came from the change in storage estimate. Comparing the change in storage and error columns in Table 5, a correlation can be observed. Whenever the change in storage is extremely negative, such as in 1982, the error in the balance is high. The reason for this is believed to related to pumping associated with mine activity. The original purpose of the wells, from which potentiometric surface data was gathered, was to monitor changes in the potentiometric surface caused by mining activity. The pumping related to mine activity affected a small portion of the watershed. An assumption of the calculations used to determine change in storage is that the average changes in the wells reflected the average change for the watershed. This means that the change in storage calculations is likely to generally misrepresent the actual change in storage by making it more negative. Because pumping records for the mines could not be obtained, no correction factor for the storage calculations could be implemented. The calculations and the balance can still qualitatively provide valuable insight into interaction between the components of the water balance.

Figure 3 displays the estimates for precipitation, evapotranspiration, stream flow, and change in storage (shallow wells) through time. A yearly time step was chosen to display this information because relationships are more readily seen. Dramatic changes in the amount of precipitation are often mirrored in the change in storage. The change in storage is different from the other three variables. It is measuring change and not absolute value. If the potentiometric surface remains stable over time, the change in storage approaches zero. As shown in Figure 3, when the amount of precipitation is similar between years the change in storage approaches zero. This relationship and the one mentioned above between precipitation and change in storage support a relation between surface water and near surface groundwater levels.

Stream flow in Figure 3 shows limited correlation to precipitation or change in storage. The lack of correlation was initially thought to be the result of inconsistent upstream diversion of the river to lakes on the Vermejo Park Ranch. Examination of diversion measurements provided by Vermejo Park Ranch showed that the total amount of diversions on record were on average less than 5% of the total stream flow volume. It was concluded that the error in the estimation of precipitation and change in storage may be inhibiting more distinctive correlation with stream flow.

Figure 4 shows the changes in storage for shallow and deep wells through time. The same issues with the change in storage calculations for the shallow wells are thought to be magnified in the deep well calculations because of even fewer wells and less data. Initially there appears to be little correlation. However, if the entire curve for the deep wells is pushed back 2-3 years the curves match more consistently. A possible explanation for this behavior is that the shallower aquifer has a limited connection to the deeper portion of the aquifer. A limited connection would slow the response of the deeper aquifer to changes in changes in the shallower aquifer resulting from increased or decreased precipitation.

Figure 5 compares precipitation, evapotranspiration, stream flow, and water production from coalbed methane wells. It is apparent that water being produced from coalbed methane operations is relatively minor in comparison to precipitation and evapotranspiration. On average produced water is equivalent to 5 % of the stream flow measured from 1999 until 2002. As operations continue to expand this percentage is likely to increase. Like most of New Mexico water in the region is a serious concern. Because of the relatively low TDS values of water produced from these wells, it may be economically feasible to treat the produced water. It could be used as a supplemental water source in the surface water budget, helping to alleviate the burden on the budget especially during drier years.

Table 1. Charactertistics of the Vermejo River Watershed

Total area	779586 km^2
Mean elevation	2530 m

Table 2. Climatological station information

Station Name	Latitude (dd)	Longitude (dd)	Elevation (ft)
Cimarron, NM	36.28	104.57	6550
Raton Filter Plant, NM	36.55	104.26	6390
Springer, NM	36.22	104.35	5920
Trinidad, CO	37.1	104.29	6030

Table 3. Linear regression precipitation/temperature equations

	Precipitation with change in elevation		Temperature with change in elevation	
Year	Slope of linear regression	Y intercept	Slope of linear regression	Y intercept
1970				
Jan	-0.00057499	1.447728196	-0.01800317	67.55626113
Feb	0.001541083	-2.46090136	-0.015875903	69.25829567

Mar	-0.002020276	7.010735686	-0.014567944	64.27358282
Apr	0.003956209	-5.56365177	-0.016610709	77.37203294
May	0.004415202	-6.20808239	-0.01669737	91.01132733
Jun	0.005418988	-9.11731814	-0.01904282	101.7746668
July	0.003838337	-3.51706932	-0.016029663	101.7360896
Aug	0.004313157	-6.85923892	-0.017678349	105.1998841
Sep	0.008629854	-13.4746826	-0.015936585	91.5475936
Oct	0.001417588	0.455535737	-0.01353512	72.51528587
Nov	0.005063289	-7.63392091	-0.014053108	68.39667273
Dec	0.000797406	-0.24753396	-0.017096104	69.14628597
1971				
Jan	-8.53843E-05	0.839644535	-0.018718998	71.40549958
Feb	-0.00146028	4.32928653	-0.013380933	58.75404629
Mar	-0.000260318	1.616233338	-0.014806397	69.74881511
Apr	0.003699431	-5.09362321	-0.014212392	74.89169116
May	0.010255905	-16.2944985	-0.014810147	83.26961415
Jun	0.003676523	-6.13347467	-0.019258131	104.7586816
July	0.003251893	-1.22926685	-0.015740535	99.88620585
Aug	0.004599715	-6.75146058	-0.016591235	99.01393509
Sep	0.005660355	-8.55033769	-0.014199783	87.04128586
Oct	0.002473229	-1.79458169	-0.014125353	77.08156251
Nov	0.001633131	-1.55222547	-0.018314253	77.82973676
Dec	-0.000190345	0.953597816	-0.018548728	69.19366438
1972				
Jan	-0.001540666	3.670171385	-0.020154151	74.38171154
Feb	-0.000517929	1.197721848	-0.01844598	74.9787684
Mar	-0.002168137	5.589876222	-0.014860769	75.1016484
Apr	0.000877792	-1.03841881	-0.015528627	81.33972041
May	0.005161585	-7.88619462	-0.014867785	85.2796763
Jun	0.002515921	-2.58940396	-0.01892582	104.6032283
July	0.005383168	-8.53454043	-0.014738907	97.18944948
Aug	0.003114653	-2.85874064	-0.017683689	102.3167011
Sep	0.003921847	-5.73342897	-0.016273541	94.37582843
Oct	5.91443E-05	3.146343786	-0.013489063	78.96835475
Nov	0.001903029	-2.01524819	-0.014178957	60.45769436
Dec	-0.001559409	3.913020185	-0.016900839	64.39163553
1973				
Jan	-0.000207213	2.083161737	-0.018005931	65.62737315
Feb	0.000486066	-0.55187889	-0.019121786	72.16943084
Mar	0.001869708	1.373149676	-0.01544751	67.90269761
Apr	0.004524119	-6.22897042	-0.014964801	69.5018884
May	0.011296552	-18.2483369	-0.015239624	84.68261368
Jun	0.002831219	-4.17199378	-0.017255801	98.52971974
July	0.013510088	-20.3477802	-0.016119193	100.236733
Aug	0.003828132	-6.50918497	-0.017435799	102.7630847
Sep	0.01407175	-23.3921493	-0.015835402	90.81116192
Oct	0.003980991	-4.29708518	-0.017388835	87.74164433
Nov	-0.001350322	4.106573569	-0.016092681	75.83805907
Dec	0.002156058	-1.538707	-0.015525568	63.95045076

1974				
Jan	-0.00015036	1.253520376	-0.014827838	59.06376845
Feb	-0.000728474	2.386723372	-0.020956602	76.03265713
Mar	-0.001595229	5.105797893	-0.015603285	76.43994967
Apr	0.001481105	-2.1457852	-0.017726163	82.82820433
May	-0.000128493	1.445196775	-0.016663039	93.99784867
Jun	0.014673605	-25.2269608	-0.017596488	100.9312131
July	0.004482051	-7.11524311	-0.018712533	107.5336899
Aug	0.008662758	-14.8223505	-0.016652731	98.21003453
Sep	0.001750795	-2.45844294	-0.012292249	81.96462205
Oct	0.004124687	-5.76892599	-0.014206995	80.97224709
Nov	-0.001988205	4.534527739	-0.01492171	68.92902009
Dec	-0.003141934	8.216553891	-0.016646394	62.29850964
1975				
Jan	0.000168686	0.834360797	-0.017951208	66.19126347
Feb	0.00082323	-0.85279231	-0.016517062	64.17227924
Mar	-0.001937391	5.715470991	-0.015740361	69.89582096
Apr	0.000885914	-0.86265329	-0.017764804	80.92622174
May	0.003693392	-5.96303859	-0.016477975	86.98077234
Jun	0.00627658	-9.86033325	-0.018084017	100.2901883
July	0.01234782	-20.9007896	-0.017603809	103.2474164
Aug	0.004950624	-6.96646312	-0.01904708	106.6740935
Sep	0.007605451	-12.3793132	-0.013960252	86.40866775
Oct	0.001689151	-2.68040688	-0.017232007	87.6320605
Nov	0.001546081	-1.07966104	-0.013259711	64.05326376
Dec	-0.000341537	1.908578139	-0.019820007	74.94969878
1976				
Jan	-0.001419879	3.718479116	-0.017162196	64.8050594
Feb	0.001520257	-2.60440269	-0.016765465	73.04453302
Mar	-0.000525634	2.351226355	-0.015794854	71.35892286
Apr	0.002425331	-3.00063476	-0.01579835	80.25165887
May	0.009691327	-16.1650197	-0.013226279	80.06927315
Jun	0.012297006	-20.9817329	-0.018818735	102.5287321
July	0.005728246	-8.61932335	-0.017856064	105.1431933
Aug	0.007038166	-11.4650895	-0.0177185	102.3387439
Sep	0.007208101	-11.0629186	-0.013612315	87.36112947
Oct	0.001387183	-0.79117621	-0.012851622	72.42260012
Nov	-0.001326581	4.294965088	-0.013440514	64.46340827
Dec	-0.001056475	2.441577377	-0.019842266	72.41896193
1977				
Jan	0.000388186	-0.58033515	-0.017731117	65.00166804
Feb	-0.002486766	6.138305827	-0.017834546	71.01557112
Mar	0.001656039	-2.262374	-0.015928802	69.40786977
Apr	0.006747234	-10.0852031	-0.013630572	75.11653653
May	0.003015732	-3.18537197	-0.018163254	94.51555278
Jun	0.002772699	-3.73943253	-0.018768121	105.3067148
July	-0.003936217	11.84861305	-0.017989233	106.1354167
Aug	0.008338298	-12.2137013	-0.013342956	94.97249703
Sep	0.007396988	-12.0739615	-0.016996317	97.71294319
Oct	0.001744547	-2.26749334	-0.014705171	82.59478624

Nov	0.000977963	-0.0039774	-0.015367591	72.56582466
Dec	-0.000210545	0.739001523	-0.014279878	66.0110486
1978				
Jan	-0.001734967	4.140703948	-0.005390998	39.57110161
Feb	-0.001391139	3.828110956	-0.010107898	51.58032148
Mar	-0.000718269	2.048839025	-0.012377794	66.25144599
Apr	0.000324877	-0.36937921	-0.015638567	82.23803444
May	0.001046478	2.495941983	-0.014557326	83.29008353
Jun	-0.002214786	7.841633236	-0.015506248	97.332692
July	0.004162589	-5.76535356	-0.017648112	106.6279648
Aug	0.002934721	-3.91339215	-0.016605151	100.589734
Sep	0.00386895	-6.16072236	-0.016340479	95.38147403
Oct	0.000772207	-0.91337057	-0.014996477	83.10449206
Nov	0.004758613	-7.93994541	-0.013442654	67.0456434
Dec	-5.9769E-05	0.754751174	-0.012078781	52.21718437
1979				
Jan	0.002120446	-2.26629427	-0.009326572	41.11112749
Feb	0.000966717	-1.61426812	-0.018522018	70.33455303
Mar	-0.000412552	3.043038593	-0.016672049	73.03528768
Apr	0.00212711	-2.80797385	-0.018137803	84.64422607
May	-0.000478985	6.809469341	-0.013569394	81.23363856
Jun	0.002916395	-2.94127333	-0.015927914	95.50590422
July	0.006822831	-9.49769328	-0.016767596	102.7892491
Aug	0.001196005	1.903881554	-0.014614365	94.66631956
Sep	0.00216293	-1.96075156	-0.0155146	93.42367806
Oct	0.003693808	-5.28376857	-0.014613621	83.03217256
Nov	-0.00013953	1.184541069	-0.015407313	64.62123435
Dec	0.000494604	0.433156659	-0.01616273	67.69808735
1980				
Jan	-0.000198883	1.62856227	-0.009701704	50.92385063
Feb	-2.64483E-05	0.266353307	-0.013953301	64.20078325
Mar	0.000354241	0.719157674	-0.013867383	65.13813448
Apr	-0.001674157	8.514127841	-0.012576501	68.3462151
May	0.00469343	-5.93570458	-0.013671149	80.60383882
Jun	0.003796061	-6.48297702	-0.018016494	104.3157502
July	0.00322003	-5.07342389	-0.017408981	107.6062317
Aug	-0.000249281	2.166889044	-0.017189506	103.7304992
Sep	0.008172111	-11.8324419	-0.016074872	95.62614423
Oct	0.005772396	-8.96670052	-0.016207584	82.47485543
Nov	-0.001327622	3.796790022	-0.014341084	68.48150669
Dec	-0.001897406	4.425393551	-0.014306072	69.52151981
1981				
Jan	-0.000202007	0.64403707	-0.014928455	65.64894811
Feb	-0.000542294	1.430425289	-0.014464431	65.56199288
Mar	0.003750662	-4.21340993	-0.014551665	68.59255449
Apr	0.000231995	0.11340485	-0.017617675	89.0406038
May	0.006244092	-7.47339533	-0.014524772	84.38803607
Jun	0.001419254	-2.08738416	-0.017101892	103.0240968
July	-0.003762741	13.14457915	-0.0150658	99.70791353
Aug	0.009671751	-12.4407109	-0.013951233	93.21620731

Sep	0.012530876	-20.7016129	-0.014803124	90.85157231
Oct	0.0015819	-2.28243875	-0.014189917	80.27695074
Nov	-7.80954E-05	1.036870001	-0.016302827	76.98814313
Dec	-0.00218084	4.762140409	-0.015257255	66.11413442
1982				
Jan	-0.001417796	2.91482925	-0.015137555	62.96171956
Feb	-0.001148107	3.462171512	-0.011664932	55.08377392
Mar	-0.001440912	3.44534277	-0.014655602	69.99508424
Apr	-0.001675615	3.506682747	-0.013604317	73.63842898
May	-0.001993411	6.783652406	-0.014551744	83.05272877
Jun	0.001279307	0.567886886	-0.014286199	90.07753812
July	0.002537788	-2.64772756	-0.015933268	101.3252537
Aug	0.008644224	-13.9998667	-0.015375184	98.87262885
Sep	-0.001935308	6.361821125	-0.014026342	88.8324344
Oct	-0.00055354	1.710134569	-0.015238317	79.63972174
Nov	0.001038565	-1.26018852	-0.012790686	64.21273954
Dec	-0.003005111	6.606757649	-0.014554254	60.62078547
1983				
Jan	0.000195759	0.94691253	-0.01608113	65.53749512
Feb	0.002886198	-3.42835026	-0.013022412	58.93808564
Mar	0.003086122	-3.26873746	-0.010586985	58.06311383
Apr	0.007507155	-11.1770395	-0.013768271	68.42378433
May	0.001965505	-0.24474419	-0.013221244	78.29313036
Jun	0.011844886	-17.9593468	-0.014575197	89.51213577
July	0.008532391	-13.6038689	-0.018714411	107.8278468
Aug	0.005876939	-8.09992383	-0.017650728	105.2712535
Sep	0.006545019	-11.4408011	-0.017042908	97.5260551
Oct	0.010877961	-18.6347137	-0.015974819	84.19221187
Nov	0.003365391	-4.01818459	-0.014539557	69.12075746
Dec	-0.002985743	7.162813889	0.000263065	23.02279686
1984				
Jan	0.00228705	-3.89828361	-0.015844489	59.52877148
Feb	0.008215428	-13.1583591	-0.016762243	65.69990184
Mar	-0.001411965	5.694609623	-0.011130332	57.25812414
Apr	0.000690155	-0.48956582	-0.013514386	69.72189726
May	0.007432391	-12.7460093	-0.014549457	87.84266909
Jun	0.008620483	-13.7282582	-0.017054691	98.6246328
July	0.00537817	-8.23578075	-0.01600557	101.3577688
Aug	0.012738089	-18.5347747	-0.015767964	98.64441118
Sep	0.010168438	-16.9312041	-0.013192215	86.70888489
Oct	0.004630745	-7.1558436	-0.01162722	67.8128119
Nov	-0.002558197	6.593496255	-0.014783612	69.11338905
Dec	-0.001369481	4.210152342	-0.015223609	64.05217041
1985				
Jan	-0.001023987	3.534639457	-0.010718172	46.73094972
Feb	-0.000538754	1.944220515	-0.012790419	54.46964809
Mar	0.003665694	-6.26449537	-0.014682384	69.87810513
Apr	0.001175804	0.399285261	-0.014250038	78.03750948
May	0.007742482	-12.3594744	-0.015409999	88.01717805
Jun	0.004062419	-6.40979497	-0.015637119	96.45483053

July	0.005395039	-8.01534467	-0.016862022	102.6932275
Aug	0.010711357	-18.3327244	-0.017044643	102.3398949
Sep	0.005759276	-7.39370636	-0.01602371	91.19541459
Oct	0.002967417	-3.73069506	-0.013099579	77.10886626
Nov	-0.00133616	3.401754475	-0.011397874	62.12023399
Dec	-0.001282431	3.107587914	-0.011211352	53.53743347
1986				
Jan	-0.000652878	1.684233211	-0.0175746	73.36527195
Feb	-0.000554581	1.751959502	-0.011681614	59.55569425
Mar	0.001761416	-2.23705726	-0.016272492	77.86100798
Apr	-0.00451683	9.656195887	-0.013926399	76.53499509
May	-0.003911434	8.475179637	-0.015758422	87.66204165
Jun	-0.001385933	6.028986289	-0.01553085	94.90464165
July	0.005970862	-7.99453282	-0.016908388	102.3533436
Aug	0.005308821	-6.37424019	-0.014770114	96.62601696
Sep	0.008089642	-12.1079072	-0.018190696	97.42878573
Oct	0.004246307	-5.4520782	-0.013714131	76.10146368
Nov	-0.003206285	8.019334772	-0.012518029	63.39180826
Dec	-0.001326789	3.135330075	-0.013105687	55.92488604
1987				
Jan	0.000976713	0.028212517	-0.016684933	61.63130241
Feb	0.000343412	0.598136981	-0.014642471	62.24102163
Mar	-0.003041972	6.921360289	-0.014909717	66.84497932
Apr	2.74896E-05	0.62182176	-0.014707836	76.05068634
May	-7.91367E-06	3.473869493	-0.016196453	87.51272246
Jun	0.00747904	-11.6177663	-0.016787389	98.78055236
July	0.008064235	-13.7833788	-0.018497584	107.0129761
Aug	0.009370407	-12.4025752	-0.014626513	94.89820547
Sep	0.005140968	-8.49006094	-0.015849883	90.5907087
Oct	0.004720919	-7.83388282	-0.012895148	78.22893033
Nov	0.00022075	1.48311413	-0.014478324	68.05273997
Dec	-0.001900113	4.750138378	-0.013861545	57.84771347
1988				
Jan	-0.002857459	6.4879821	-0.013159773	52.52458557
Feb	-0.000780121	1.887240066	-0.013548187	61.79170568
Mar	-0.002225407	6.080247556	-0.01348726	64.38686474
Apr	0.000612684	-0.16379078	-0.014145788	76.42428734
May	0.009696533	-15.3341443	-0.013017425	80.18454752
Jun	0.007476333	-11.0830215	-0.01473397	94.95852353
July	0.001900113	-0.81013838	-0.015502332	99.90902711
Aug	0.001818686	-1.90742859	-0.015448039	99.05386823
Sep	0.004273589	-5.65989146	-0.015803104	90.83718149
Oct	0.003675274	-6.27128475	-0.013596431	80.29597724
Nov	0.000961719	-0.37550844	-0.014867231	69.80845015
Dec	-0.002688773	6.192342897	-0.016046167	64.04761605
1989				
Jan	-0.000217418	0.941046084	-0.021582048	77.13186517
Feb	-0.003281881	8.011824933	-0.006218941	41.61096489
Mar	-0.000638925	1.469779104	-0.015963043	78.08365063
Apr	-0.000513139	1.529327155	-0.012987835	76.60655988

May	0.010839017	-17.9564612	-0.015518121	90.18647007
Jun	0.004897727	-7.52375651	-0.012465495	87.15054239
July	0.008357041	-13.7165501	-0.016923103	104.1234102
Aug	0.010445624	-17.1470014	-0.016597814	100.1959958
Sep	0.008021127	-12.2478266	-0.013473368	87.61861978
Oct	0.002684816	-4.33540815	-0.015314102	81.93744361
Nov	-0.002242067	4.66944649	-0.016022139	75.69443848
Dec	-0.000736596	2.020957852	-0.010934175	51.39149666
1990				
Jan	-0.004082619	9.32519868	-0.01967809	72.20561524
Feb	-0.001337826	5.144674368	-0.013410405	59.44177152
Mar	-0.000944642	2.975579535	-0.012162911	64.96087734
Apr	0.00333457	-4.85416656	-0.013147653	74.8977631
May	-0.002281219	6.528063984	-0.015107328	84.9048229
Jun	0.003664028	-6.11157547	-0.018991724	108.0915835
July	0.008368703	-10.6169893	-0.014214129	95.398036
Aug	0.008741895	-13.5310454	-0.017195217	100.6631398
Sep	0.001702688	-0.61413101	-0.015168559	93.37283492
Oct	0.000346327	0.033027168	-0.016435384	84.63151299
Nov	0.001417171	-1.01373429	-0.016872934	76.91237833
Dec	-0.000578531	2.113932969	-0.012472907	53.63194605
1991				
Jan	-0.000344869	0.904417926	-0.017101812	64.0289186
Feb	-0.001289928	3.080727434	-0.018002879	74.00811817
Mar	0.000970882	-0.55156786	-0.018117348	76.19145563
Apr	0.000662249	-0.53065761	-0.016681443	80.69857911
May	0.003722339	-5.79377174	-0.0205426	100.0039086
Jun	0.009214424	-15.2492002	-0.019032787	103.4824614
July	0.011290721	-18.2681173	-0.016197669	100.1404135
Aug	0.003623418	-4.23040307	-0.015304083	97.1727714
Sep	0.007910335	-12.8936537	-0.01527496	90.32331682
Oct	-0.00047482	1.982169608	-0.01374599	79.24697252
Nov	0.000653086	1.765401803	-0.012953051	61.38957879
Dec	-3.47785E-05	1.510952774	-0.016919128	66.12461218
1992				
Jan	0.001572946	-2.04674432	-0.020236455	72.088862
Feb	0.002507383	-4.11443951	-0.018072956	72.24320843
Mar	0.001391764	-1.72920592	-0.016844995	75.85554481
Apr	0.002653578	-4.15066015	-0.016342746	84.61899149
May	0.011174098	-18.6237248	-0.016650891	89.90846211
Jun	0.008115882	-12.8838955	-0.016636638	95.88441747
July	0.002389095	-1.17712708	-0.016232968	99.52853561
Aug	0.010834644	-14.7187965	-0.017123935	99.72038087
Sep	0.001875956	-3.28779992	-0.018813986	99.58822092
Oct	0.001778701	-1.87735115	-0.01551049	84.12208137
Nov	-0.004457269	11.9518097	-0.013563191	60.45241168
Dec	-0.000760129	2.892201346	-0.017315612	66.11959108
1993				
Jan	0.000251988	-0.10163387	-0.013647943	59.31498027
Feb	-0.001271393	3.648243621	-0.011374175	54.73028449

Mar	0.004938961	-6.64602387	-0.015473644	71.33553477
Apr	0.003741915	-4.82808049	-0.01441963	75.76284166
May	0.008932031	-13.1342783	-0.016136913	87.70345063
Jun	0.005108272	-7.92275803	-0.01707362	98.61902628
July	0.00313048	-4.73647962	-0.016134903	101.9940027
Aug	0.005734285	-5.43990796	-0.013138257	91.34696681
Sep	0.006397159	-9.76166053	-0.013518051	85.02250908
Oct	0.005315277	-8.44555478	-0.014123694	77.36038993
Nov	-0.001552328	6.060610639	-0.014590704	65.78395412
Dec	-0.000222207	1.599440777	-0.01666452	66.38112452
1994	0	0		
Jan	-0.000997955	3.049016123	-0.018055763	69.90765794
Feb	0.000122454	-0.03461216	-0.020608547	75.24985867
Mar	-0.004190912	10.74499175	-0.015351298	71.91226532
Apr	0.000901325	0.670337692	-0.015958983	79.36966433
May	0.005890476	-6.97364796	-0.017142326	92.23108245
Jun	0.00377836	-5.62195315	-0.018820525	107.2026943
July	0.011434208	-18.9895931	-0.01549093	99.8587928
Aug	0.006083111	-9.01126063	-0.015731426	100.1935453
Oct	0.00618349	-9.71718421	-0.017225864	85.22596453
Nov	0.002329326	-2.3723759	-0.017105293	73.87662297
Dec	-0.00104273	2.477488257	-0.017612408	72.18644679
1995				
Jan	0.001275142	-1.96481338	-0.018680529	71.02035995
Feb	-0.000460034	1.216255554	-0.014438879	69.20794347
Mar	0.001875331	-2.66670496	-0.013967889	69.20057052
Apr	-0.001358027	4.820078075	-0.01459704	73.20797737
May	0.01147336	-16.1582106	-0.014039161	80.253305
Jun	0.004196326	-5.1144814	-0.016724858	95.41716298
July	0.004875236	-6.60433795	-0.018083242	104.3884744
Aug	0.00442499	-5.73523677	-0.017965311	106.4874754
Sep	0.004420616	-4.97757205	-0.016086415	92.65169148
Oct	0.007841195	-13.7424781	-0.017795501	88.05665917
Nov	-0.00015869	1.558119843	-0.014911529	73.52398786
Dec	0.000534797	-0.23728577	-0.014560187	63.67641487
1996				
Jan	0.001067929	-0.74165164	-0.01582016	63.13492692
Feb	0.000503767	-0.74290275	-0.013090515	63.76130798
Mar	-0.001653956	5.028724134	-0.013055571	64.71147098
Apr	0.001547747	-2.07258093	-0.015977531	80.82821358
May	0.001684362	-1.24201219	-0.018162799	99.32204509
Jun	0.007839529	-12.7895582	-0.016482287	99.41531629
July	0.01098542	-16.7430468	-0.015971947	101.1858559
Aug	0.002724801	-1.11548559	-0.016545529	100.8852796
Sep	0.006452554	-9.78874698	-0.017524846	94.45765879
Oct	0.002778114	-3.58892218	-0.017514411	86.11706295
Nov	-8.16357E-05	0.843074775	-0.017087363	76.93194164
Dec	0.000516054	-0.47443697	-0.016907188	68.57068742
1997				
Jan	-0.000553957	1.660864542	-0.014958806	60.22612007

Feb	0.000584154	0.436212391	-0.014637931	61.35097575
Mar	0.002679401	-4.2359185	-0.01699238	77.55422975
Apr	0.003589681	-3.12127523	-0.010924477	63.16253347
May	0.002185838	-3.24090009	-0.015559438	86.32290941
Jun	0.005021847	-6.71128856	-0.017610101	99.83383968
July	0.006470673	-9.22050083	-0.018842691	107.5792507
Aug	0.01250172	-16.9605148	-0.016108656	100.0459131
Sep	0.006198901	-9.62419322	-0.016608802	97.70031265
Oct	0.00286808	-1.67659642	-0.015999818	82.7125375
Nov	0.000715146	1.186635775	-0.012916493	61.76616966
Dec	0.000983377	-1.01346706	-0.015313286	60.53313753
1998				
Jan	0.000126619	-0.0819119	-0.017557038	69.00890332
Feb	-0.001603975	4.541127333	-0.018955069	71.69296047
Mar	0.000158065	1.712975117	-0.016144536	70.62532252
Apr	0.001439454	0.907212137	-0.016655872	78.21198702
May	0.01005369	-17.1400965	-0.019764026	99.61080595
Jun	0.010073682	-17.4051352	-0.017568616	101.3645288
July	-0.001842427	8.23903707	-0.015781541	101.0894592
Aug	0.005549563	-8.48616478	-0.015761184	98.98940499
Sep	0.005742615	-8.91450743	-0.017469099	100.2892826
Oct	0.002618383	-0.4289774	-0.016205803	83.96841471
Nov	-0.00309716	8.098081757	-0.016174832	75.71237207
Dec	-0.000866338	2.168344547	-0.011401091	56.06485444
1999				
Jan	0.001680821	-2.46580741	-0.0142409	64.55478515
Feb	0.000933188	-1.26550527	-0.019077267	79.23590378
Mar	-0.000509599	2.033122382	-0.015371116	74.73362511
Apr	0.003066754	-0.1647937	-0.014876067	74.52550526
May	0.007372831	-11.2716231	-0.016745649	88.09192725
Jun	0.004579306	-6.75569189	-0.017343455	98.75871234
July	0.005318818	-5.05175955	-0.016445439	101.9487655
Aug	0.005313403	-7.0722699	-0.015484009	98.03097504
Sep	0.00491772	-7.70879523	-0.014174301	87.59489118
Oct	0.002518629	-3.32414879	-0.013954208	79.91029052
Nov	-0.000886122	2.653018281	-0.015950208	78.54024308
Dec	0.001662703	-2.40405357	-0.01463488	60.72672306
2000				
Jan	4.35252E-05	0.183717786	-0.013669435	62.09504638
Feb	0.000266357	-0.32681795	-0.016743362	74.21061466
Mar	-0.003395796	10.87147264	-0.014124753	69.21523278
Apr	0.002363271	-3.17186873	-0.013888411	78.41717212
May	0.000185555	0.194796877	-0.017127391	95.51802898
Jun	0.010466658	-17.1838651	-0.016386842	99.13158168
July	0.004965202	-7.70201219	-0.018219981	107.4710977
Aug	0.003610507	-5.6277739	-0.019792825	110.6520426
Sep	0.005881104	-10.0172236	-0.018807675	102.5817543
Oct	0.003818553	-3.78239558	-0.015707494	82.51307993
Nov	0.000974006	-1.59704266	-0.016319899	66.82592689
Dec	-0.002932847	6.170107274	-0.013140433	59.24928436

2001				
Jan	0.000754506	-0.35234671	-0.016217388	62.58655398
Feb	-0.000843014	2.02746604	-0.014590365	63.96570335
Mar	0.003484721	-4.77732195	-0.014951711	69.91541879
Apr	-9.16319E-05	0.280594135	-0.016767485	84.61900362
May	0.001426751	-0.24052368	-0.0151479	87.5871145
Jun	0.002210829	-3.51469849	-0.018203693	103.9500497
July	0.004750283	-6.31534594	-0.018665546	109.4822024
Aug	0.002521544	-3.8592586	-0.018574646	105.936025
Sep	0.002155433	-2.69761204	-0.016426843	96.47261005
Oct	-0.000368819	0.876391393	-0.016342508	86.39596456
Nov	0.003160469	-5.1790377	-0.017151111	78.14802456
Dec	-0.001546497	3.410391012	-0.018780856	71.43989981
2002				
Jan	-9.3298E-05	0.753514028	-0.017266384	66.93564298
Mar	0.000321337	-0.51317443	-0.01630181	71.3058935
Apr	0.001110204	-1.82574394	-0.014655475	81.87980292
May	0.002324536	-3.95398121	-0.015819838	90.60171625
Jun	0.002312457	-2.98281198	-0.019196497	108.6297761
July	0.006991517	-11.4033325	-0.019847862	111.3013475
Aug	0.00519324	-8.50167259	-0.019352976	109.0235879
Sep	0.007522982	-11.5647785	-0.017930414	97.98274168
Oct	0.000845513	-0.72184588	-0.014227289	76.62466196
Nov	0.000846346	-1.22330583	-0.016104836	71.9074603
Dec	-0.000250322	1.408713977	-0.01791822	68.61325458

Table 4. Thornthwaite monthly scaling factors

Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sep	Oct	Nov	Dec
1	1	1	3.91	2.43	2.08	2.02	2.01	2.12	2.76	16.5	1

Table 5. Estimated precipitation, evapotranspiration, stream flow, and change in storage (shallow wells) for the Vermejo River watershed from 1970-2002 in m^3. The balance for each year was determined using the an equation where balance = precipitation – evapotranspiration - stream flow + change in storage. The percent error in the balance was calculated by taking the absolute value of the balance and dividing it by the sum of components initially used to determine the balance.

Year	Stream flow	Precipitation	Evapotranspiration	Change in storage (shallow wells)	Balance	% Error
1970	15058958	531752018	574496383			
1971	6870147	503951557	512343080			
1972	4921175	342839030	559018540			
1973	16157348	753333401	490750717			
1974	3286984	479493494	513066463			
1975	9206831	479493494	513066463			
1976	8128533	530579080	525298957			
1977	9917510	443274387	563847365			
1978	10571633	292085344	564147075			

1979	15690011	468262199	541404492	140690722	51858417	4
1980	18043067	401517403	525977512	-498022573	-640525749	44
1981	19735302	503759011	571233535	-241976199	-329186025	25
1982	21804085	207248019	526642068	-231189816	-572387951	58
1983	28933947	762274127	501731947	436709862	668318095	39
1984	13402443	683506880	509929936	196930787	357105288	25
1985	22924800	501383330	556307763	46935649	-30913585	3
1986	13790898	333589381	542497243	34281818	-188416941	20
1987	33866284	489268013	535655905	-36194080	-116448255	11
1988	14555157	463263796	569892653	-128413082	-249597096	21
1989	8191787	463263796	569892653	-109309579	-224130223	19
1990	11726579	405765613	580938963	133137725	-53762205	5
1991	25986302	482294280	559673413	-234337731	-337703166	26
1992	19174200	556376348	586369872	171285180	122117456	9
1993	15750289	597966785	525635815	154816054	211396736	16
1994	39655157	580305297	543900106	26570193	23320227	2
1995	29687043	554268110	518905975	-89107460	-83432368	7
1996	13015476	493109851	551672962	33602947	-37975640	3
1997	20245056	644659801	521330040	34132867	137217572	11
1998	11731044	509280673	536495073	18050618	-20894826	2
1999	65339327	546223758	530581186	415849502	366152747	24
2000	10817952	389975264	574036101	-3052939	-197931727	20
2001	8469362	274502391	568730700	-14680040	-317377710	37
2002	14919055	327264111	566136622	-52372197	-306163763	32
Average	17623447	484731213	543382048	8514093	-73723362	19

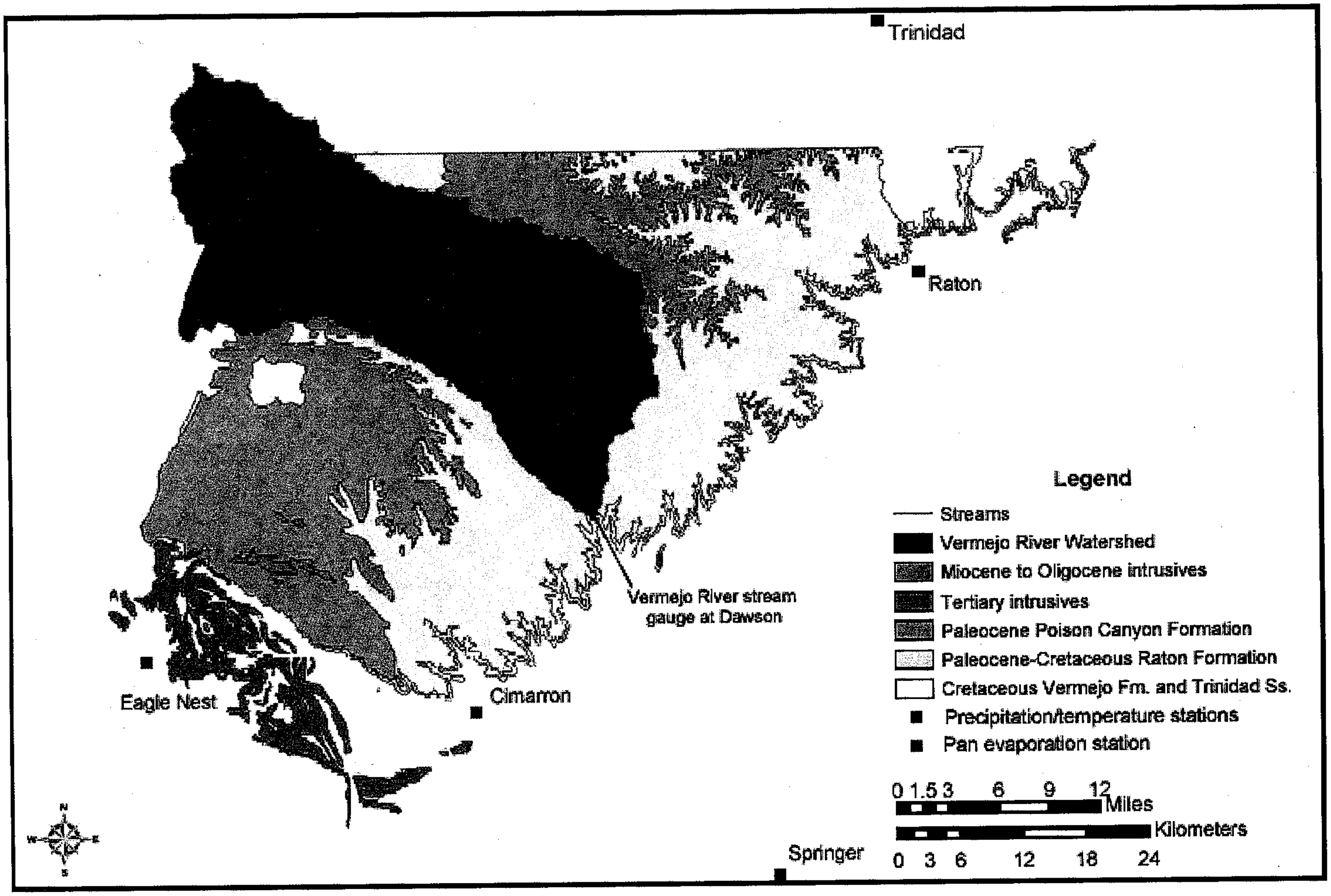

Figure 1. Vermejo River watershed. The watershed was delineated using ArcMap™ 8.2 with the Arc Hydro tool package (2004). Locations for weather stations are also shown. Stations indicated by red boxes had precipitation and temperature information. The blue box is a station with pan evaporation data. The station in Trinidad had precipitation, temperature, and pan evaporation data.

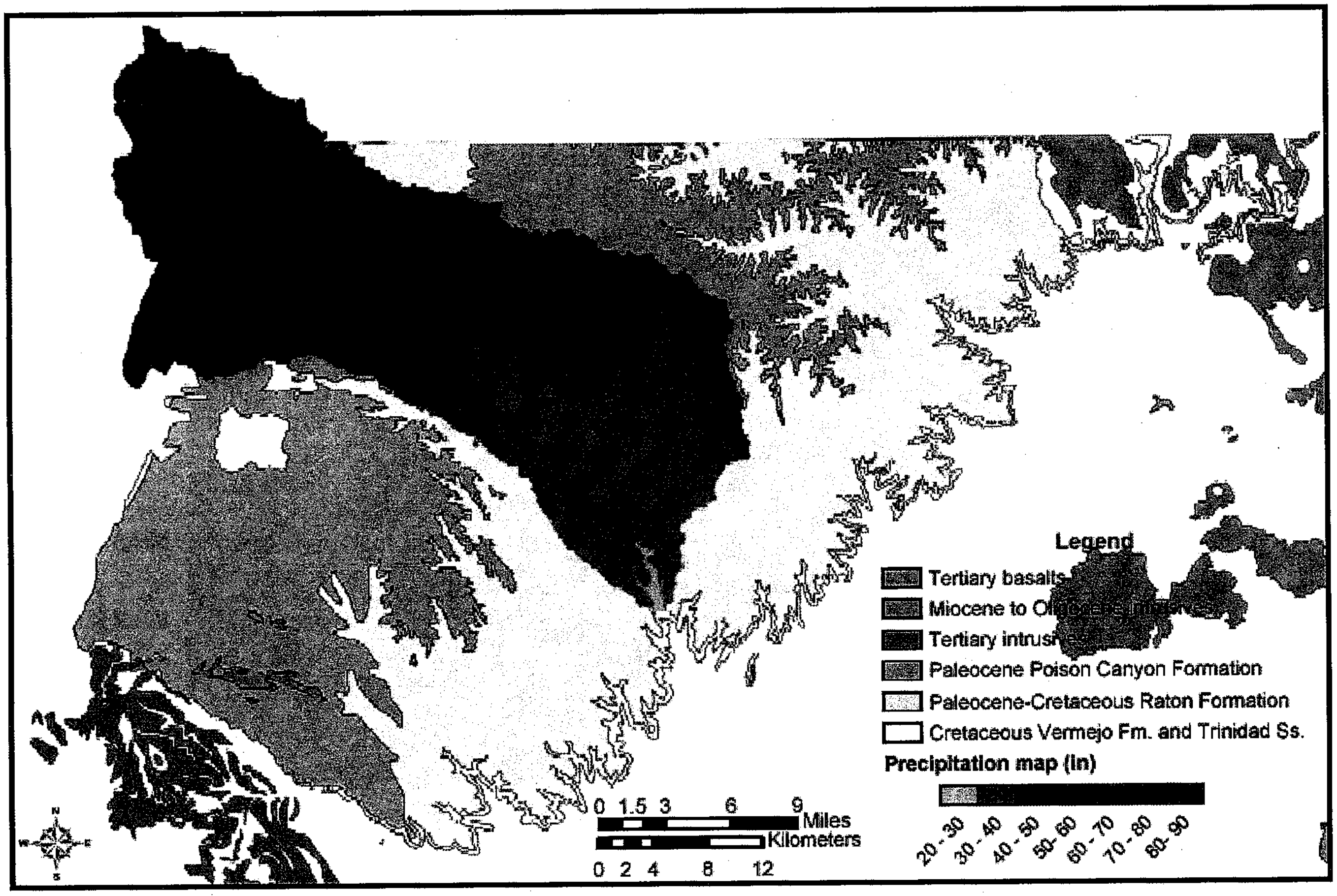

Figure 2. Precipitation for 1970 in the Vermejo River watershed. A linear regression equation was established between elevation and precipitation that was used to calculate the precipitation for the watershed. The raster calculator in ArcMap™ 8.2 was used to input the equation and based on the digital elevation model (DEM) for the watershed a precipitation map was created. A total precipitation was then calculated from this map. This total was nearly identical to that derived by substituting the average elevation into the linear regression equation and multiplying the answer by the area of the watershed.

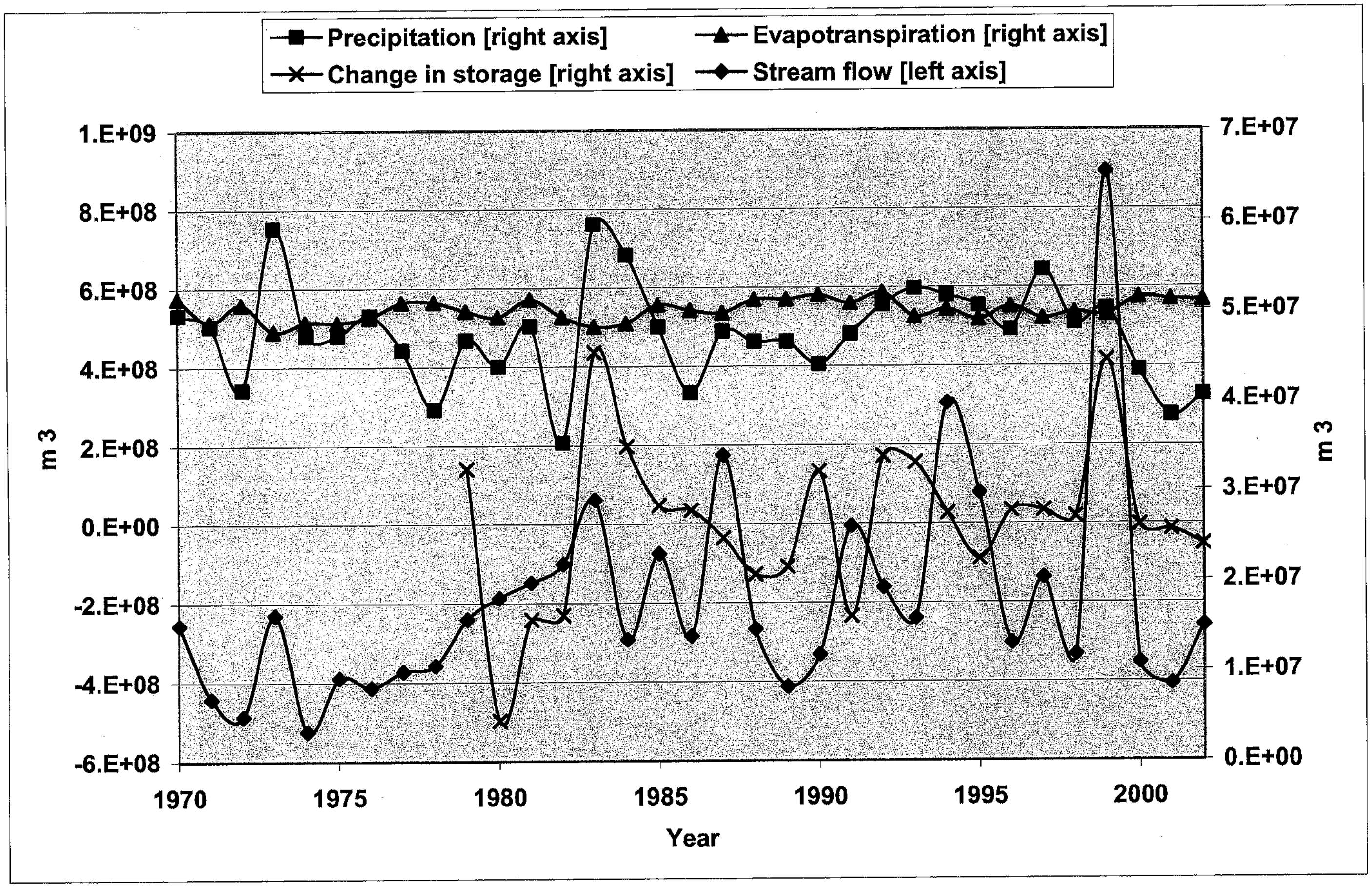

Figure 3. Estimated precipitation, evapotranspiration, stream flow, and change in storage (shallow wells) for the Vermejo River watershed from 1970-2002. Volumes are reported in m^3. Precipitation, evapotranspiration, and change in storage values are recorded on the right vertical axis while stream flow is recorded on the left vertical axis. Notice the direct response in the change in storage with substantial increase or decrease in precipitation.

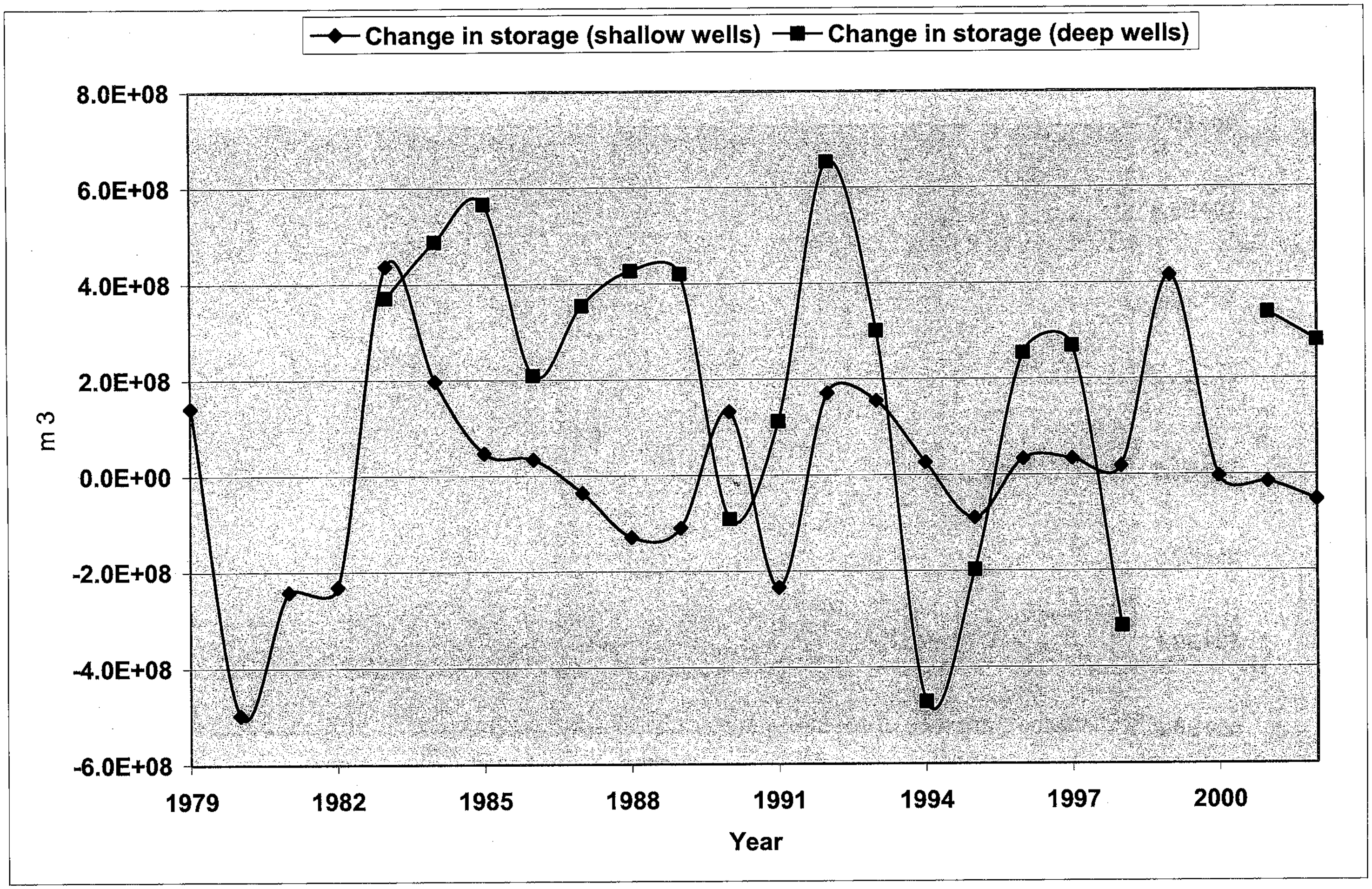

Figure 4. Estimated changes in storage for shallow and deep wells in the Vermejo River watershed. Volumes are given in m^3. Gaps in the record for deep wells are the result of a lack of data for wells at those periods of time. Notice that if the curve for deep wells were shift back 2-3 years that it would make more consistently with the shallow well curve.

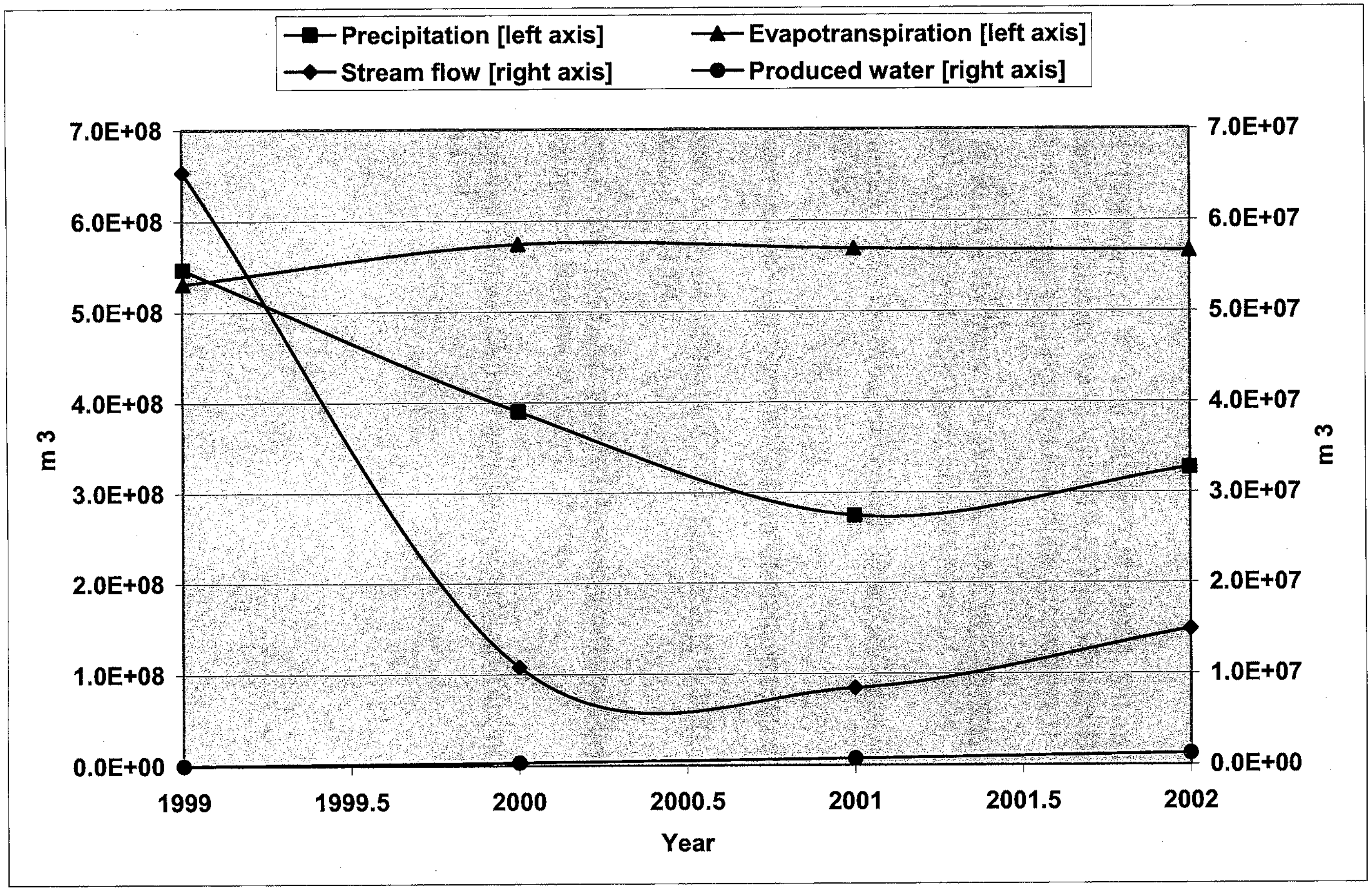

Figure 5. Estimated precipitation, evapotranspiration, stream flow, and produced water for the Vermejo River watershed from 1999-2002. Volumes are reported in m^3. Precipitation and evapotranspiration values are recorded on the right vertical axis while stream flow and produced water are recorded on the left vertical axis. While the volume of produced water is negligible compared to precipitation and evapotranspiration, it can equal as much as 9% of the stream flow volume.

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APPENDIX 8. GAS COMPOSITION DATA FOR VERMEJO PARK RANCH

The following gas composition data was obtained from the Oil Conservation Division (OCD) of the New Mexico for wells on the Vermejo Park Ranch.

Well	Valdez Canyon 2919 071	Valdez Canyon 2918 012J	Van Bremmer Canyon 3019 322	Van Bremmer Canyon 3019 311G	Van Bremmer Canyon 3018 241M	VPR B 25	VPR B 13	VPR B 26
Date	1/30/1990	1/5/1990	1/5/1990	1/5/1990	1/5/1990	1/5/1990	1/5/1990	1/30/1990
Component (% Mol)								
Nitrogen	0.3	0.36	0.07	0.1	4.04	0.14	0.13	0.06
Carbon Dioxide	0.44	0.79	0.57	0.83	0.17	0.57	0.42	0.7
Methane	90.43	96.36	99.31	98.67	97.81	99.26	98.26	99.14
Ethane	5.28	1.58	0.05	0.22	1.07	0.03	0.47	0.1
Propane	2.2	0.55	0	0.09	0.75	0	0.26	0
I-Butane	0.41	0.15	0	0.04	0.14	0	0.08	0
N-Butane	0.47	0.09	0	0.03	0.03	0	0.1	0
I-Pentane	0.18	0.04	0	0.02	0.02	0	0.06	0
N-Pentane	0.15	0.02	0	0	0	0	0.06	0
Hexanes	0.14	0.06	0	0	0	0	0.16	0
Gasoline Content								
Pentanes + Heavier	0.188	0.05	0	0.008	0	0	0.117	0
Butanes + Heavier	0.479	0.13	0	0.031	0.017	0	0.177	0
Propanes + Heavier	1.094	0.284	0	0.056	0.056	0	0.25	0
Ethane + Heavier	2.51	0.708	0.013	0.115	0.257	0.008	0.376	0.027
26 Gasoline	0.275	0.076	0	0.01	0	0	0.169	0
Heating (BTU/ft^3)								
Water Saturated	1095	1010	985	987	988	984	1009	984
Dry Gas	1114	1028	1003	1055	1005	1002	1027	1002
Specific Gravity								
Water Saturated	0.633	0.585	0.562	0.562	0.573	0.562	0.575	0.564
Dry Gas	0.633	0.584	0.561	0.567	0.572	0.561	0.575	0.563
Pressure	14.65 psia							
Temperature	60 F							

Well		VPR A 1	VPR A 8	VPR A 9	VPR A 10	VPR A 11	VPR A 12	VPR A 14
Date		11/26/1999	11/26/1999	11/26/1999	11/26/1999	11/26/1999	11/26/1999	11/26/1999
Component (% Mol)								
Methane		97.26	94.15	95.86	98.54	97.53	98.26	98.34
Ethane		0.05	0.03	0.02	0.02	0.01	0.03	0.02
Propane		0	0	0	0	0	0	0
Isobutane		0	0	0	0	0	0	0
Normal Butane		0	0	0	0	0	0	0
Isopentane		0	0	0	0	0	0	0
Normal Pentane		0	0	0	0	0	0	0
Hexanes		0	0	0	0	0	0	0
Nitrogen		2.21	4.82	3.99	1.33	2.33	1.16	1.54
Oxygen		0	0.8	0.02	0	0	0	0
Carbon Dioxide		0.48	0.2	0.11	0.11	0.13	0.55	0.1
Helium		0	0	0	0	0	0	0
Hydrogen		0	0	0	0	0	0	0
Ideal								
Dry	BTU/ft^3	980.1	948.5	965.5	992.5	982.2	989.9	990.5
Wet	BTU/ft^3	963.86	932.75	951.3	976	965.84	973.41	974.03
Real								
Dry	BTU/ft^3	982	950.2	967.3	994.4	984.1	991.8	992.4
Wet	BTU/ft^3	965.7	934.5	951.3	977.9	967.7	975.3	975.9
Specific Gravity		0.5679	0.5802	0.5717	0.5606	0.5648	0.5642	0.5613
Compressibility		0.9981	0.9982	0.9981	0.9981	0.9981	0.9981	0.9981
Pressure	14.65 psia							
Temperature	60 F							

Well	Castle Rock 3017 31F	Castle Rock 3117 271G	Castle Rock 3117 271G	VPR D 21	VPR D 21	VPR D 21	VPR D 24	VPR D 20
Date	10/13/1990	9/25/1990	10/13/1990	10/13/1990	5/5/1991	5/23/1991	5/3/1991	5/8/1991
Component (% Mol)								
Nitrogen	1.93	2.61	1.77	0.08	0.67	0.18	0.7	0.07
Carbon Dioxide	0.42	0.4	0.27	0.36	1.08	0	0.08	0.13
Methane	97.07	96.98	97.95	99.41	90.64	99.79	98.49	99.42
Ethane	0.12	0.01	0.01	0.10	0.09	0.03	0.39	0.22
Propane	0.16	0	0	0.03	0.02	0	0.15	0.09
I-Butane	0.08	0	0	0.01	0.01	0	0.03	0.01
N-Butane	0.08	0	0	0.01	0	0	0.05	0.02
I-Pentane	0.05	0	0	0	0.01	0	0.03	0.01
N-Pentane	0.05	0	0	0	0.02	0	0.02	0.01
Hexanes	0.04	0	0	0	7.46	0	0.06	0.02
Gasoline Content								
Pentanes + Heavier	0.056	0	0	0	3.308	0	0.047	0.017
Butanes + Heavier	0.109	0	0	0.006	3.311	0	0.073	0.027
Propanes + Heavier	0.154	0	0	0.014	3.317	0	0.115	0.052
Ethane + Heavier	0.186	0.003	0.003	0.041	3.341	0.008	0.22	0.111
Heating (BTU/ft^3)								
Water Saturated	980	961	971	989	1329	990	995	995
Dry Gas	997	979	988	1006	1352	1007	1013	1012
Specific Gravity								
Water Saturated	0.576	0.571	0.566	0.561	0.789	0.557	0.567	0.561
Dry Gas	0.575	0.57	0.565	0.56	0.792	0.556	0.566	0.56
Pressure	14.65 psia							
Temp	60 F							

Well	Castle Rock 3017 161H	Castle Rock 3017 161H	VPR D 18	VPR D 18	Castle Rock 3117 141G	Castle Rock 3117 141G
Date	5/2/1991	5/23/1991	10/13/1990	5/8/1991	5/2/1991	9/24/1990
Component (% Mol)						
Nitrogen	0.78	0.04	24.76	40.28	1.22	4.04
Carbon Dioxide	1.01	0.24	0.37	0.01	0.01	0.16
Methane	92.29	99.63	58.65	43.43	98.52	95.66
Ethane	0.08	0.09	6.07	5.98	0.02	0.05
Propane	0.01	0	4.89	4.96	0	0.03
I-Butane	0	0	1.24	1.26	0	0.01
N-Butane	0	0	1.71	1.71	0.01	0.02
I-Pentane	0	0	0.79	0.74	0.01	0.01
N-Pentane	0	0	0.77	0.69	0.02	0.01
Hexanes	5.83	0	0.79	0.71	0.19	0.01
Gasoline Content						
Pentanes + Heavier	2.576	0	0.928	0.862	0.096	0.012
Butanes + Heavier	2.576	0	1.902	1.842	0.099	0.022
Propanes + Heavier	2.579	0	3.268	3.228	0.099	0.03
Ethane + Heavier	2.6	0.024	1.371	1.2774	0.104	0.043
Heating (BTU/ft^3)						
Water Saturated	1250	989	1016	858	989	952
Dry Gas	1272	1007	1034	878	1007	969
Specific Gravity						
Water Saturated	0.74	0.559	0.835	0.893	0.568	0.576
Dry Gas	0.742	0.558	0.839	0.898	0.567	0.575
Pressure	14.65 psia					
Temp	60 F					