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Ground water of the Uncompahgre Valley Montrose County, Colorado

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GROUND WATER OF THE UNCOMPAHGRE VALLEY
MONTROSE COUNTY, COLORADO

BY

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ABSTRACT

Data from water quality tests of 50 wells and from general well information of 309 wells registered with the Colorado Division of Water Resources are presented for the area of Montrose County, Colorado, drained by the Uncompahgre River. This information, along with other pertinent information such as water laws and costs, is evaluated to determine the feasibility of increasing the use of ground water in the area.

The drainage basin of the Uncompahgre River within the Montrose area has three main geologic structures: the Uncompahgre uplift, the Montrose syncline, and the Gunnison uplift.

All formations exposed in the area are Mesozoic in age. The most important of them are the Morrison and Dakota formations and the Mancos shale. The Morrison and Dakota are the bedrock aquifers of the area. Overlying these consolidated materials are a series of Quaternary gravels that comprise the remainder of the ground-water sources.

The quality of the water from the 50 wells, chosen by random from a system of one-ninth township divisions, was fair to poor. High concentrations of dissolved solids, sulfate, fluoride, and iron tend to be the worst quality problems. Groundwater quality was usually suitable for most agricultural and domestic uses if the high mineral content and its resultant tastes, smells, and stains are not objectionable for a particular use. Limited quantities available tend to limit groundwater use for purposes such as irrigation.

Stock watering is the use for which the ground water of the area seems to be best suited. Stock prefer the ground water over surface water. If higher yields could be established, the wells would also be suitable for irrigation of most area crops.

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I. INTRODUCTION

A. Location of Area

The Uncompahgre River rises in the San Juan Mountains of southwest Colorado and flows approximately 75 miles in a northerly direction to its confluence with the Gunnison River just northwest of Delta, Colorado. The area to be examined in this thesis consists of the valley of the Uncompahgre in Montrose County, Colorado (Fig. 1).

B. Definition of Problems

The Uncompahgre River valley in Montrose County lacks a good water supply. There is less than ten inches of precipitation per year on the average with no one season receiving a large portion of that rainfall. Water that is available is often unusable either because of poor quality or prior appropriation to other users. The poor quality is found in both surface water and groundwater sources. Groundwater qualities will be discussed in a later chapter but can be classified generally as poor for most uses. Surface water is available from only one source located in the thesis area, the Uncompahgre River. Flow measurements are made of the river volume from gages located just south of the Montrose-Ouray County line at Colona. Records obtained from these gages show an average annual flow of 208,300 acre-feet (1903-1930) with as little as 102,200 acre-feet in one year. Not only is this volume too small to supply the thesis area but the quality is poor from this source also. It is contaminated by materials washed from agricultural sources, raw sewage, and, to a small extent, mines. Even if all of the waters of the Uncompahgre River were of a good quality, not all would be available because of the legal appropriation of much of this water for use downstream. This appropriation is also a limiting factor because of quality restrictions included in the legal appropriation. The water that leaves the thesis area must be at least of a certain quality which means that heavy use and the resultant increase in suspended and dissolved solids is not allowed.

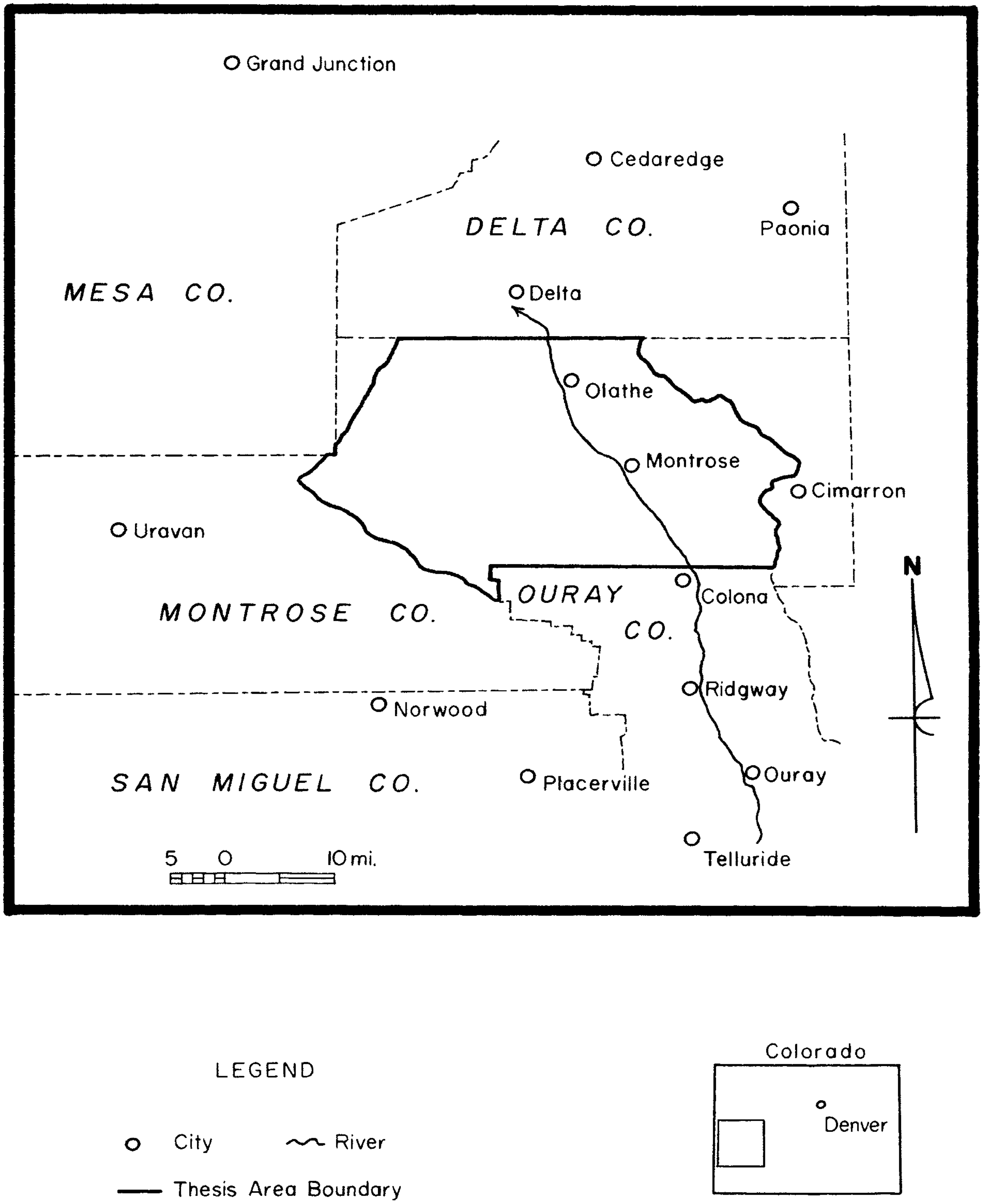

Figure 1. Map showing location of thesis area. The river shown is the Uncompahgre River.

The water supply problem is multiplied by the large per capita use of water in the thesis area. The city of Montrose through large-scale prior water development, which is described later, presently has no problems of water shortage. However, the city does use a large amount of water. The average use per capita is 400 gallons per day with this use going as high as 1,600 gallons per day during the summer months. The use per year by the city is 3,000 acre-feet [almost one billion gallons] (R. P. Hall, 1971, oral communication). The total use of water in the rural areas of the thesis area is not known because of the many sources used but is certainly quite high because of large scale irrigation in addition to domestic and stock use. Total amounts used in the future most certainly will be higher than the present use, and although the city of Montrose has sources available for almost twice the amount now in use, the rural areas are, at the present time, without adequate reserves of water.

The importance of an adequate water supply to the thesis area or to any area is an established fact. To the city of Montrose the abundant supply available makes growth possible. At the present time, the Montrose Chamber of Commerce is promoting the city's growth and its water supply is a definite plus. In the rural areas a dependable and usable water supply is even more important as agriculture is totally dependent on that. Because the largest single source of income for the city of Montrose is agriculture (34% [Montrose County Chamber of Commerce], 1971), the city itself has a definite if not direct interest in this rural water supply being obtainable. Because of the already adequate urban water supply and because of the importance to the area of the water supply for agricultural use, emphasis will be placed almost entirely on rural groundwater problems.

C. Selection of Problem

The selection of the ground water of the Uncompahgre River valley of Montrose County, Colorado, as a thesis problem was prompted by several things. One of these was the author's familiarity with the area. Another was that no detailed exploration of the problem had ever been made. The most important reason, however, was the problem being brought to the author's attention in December, 1970, by an article in the Montrose Daily Press. A study of the problem then brought to light the lack of previous groundwater research in the area. The fact that prominent persons and groups in the area were interested in such research being conducted was also a factor.

D. Objectives

The objectives of this thesis are first, to determine the groundwater resources available, and second, to examine present use of ground water in the thesis area to see if better or more efficient use of the water could be made. Under the study of available ground water, the aquifers now in use will be examined for quantity and quality of water and their locations determined. The possible presence of other usable aquifers will also be explored. The present efficiency of groundwater use will be studied on both administrative and individual levels. Groundwater law will also be reviewed and problems related to the laws will be examined.

E. Acknowledgements

The author wishes to extend thanks to Dr. J. C. Maxwell, University of Missouri-Rolla, who served as thesis advisor. Field expenses were partially defrayed by a grant from the V. H. McNutt Memorial Fund of the Department of Geology of the University of Missouri-Rolla.

The author is indebted to many persons in the state of Colorado for their help. In Denver, Richard H. Pearl of the Colorado Geological Survey provided much useful information and assisted the author in obtaining from the files of the Colorado Division of Water Resources data concerning wells located in the thesis area. In Montrose, Ralph V. Kelling, Jr. and staff of the District 4 office of the Division of Water Resources were especially generous in their help in supplying knowledge of the area and in criticisms of portions of this paper. Richard T. Edmondson of the Tri-County Water Conservancy District arranged the financing of the testing of the well water samples that make up an important part of this paper. Although special acknowledgement of each person is impossible, mention should also be made of the many residents of the thesis area who offered their cooperation.

My wife, Connie, who accompanied me on most of my field work, is deserving of special thanks for her help and encouragement.

II. REVIEW OF PREVIOUS LITERATURE

Because of the small amount of previous groundwater study on the Uncompahgre Valley in Montrose County, little information from previous literature is available. Material concerning nearby areas with similiar geologic conditions is included in this review.

Many of the previous geological studies of the area have neglected groundwater problems. Early studies of the area were more concerned with petroleum and mineral exploration or surface water development. The first published mention of ground water in the area (George *et al.*, 1920) concerns the well numbered 39 in this thesis numbering system. There, mention is made only of the mineral content of the water flowing from the well and its value as mineral water, so popular at that time.

H. J. Weeks (1925, p. 42), although limiting his work to Delta and Mesa counties located adjacent and to the north of Montrose county, presented the first geological evaluation of groundwater potential in the area. The study, made in 1922, concluded that the Dakota and Mancos formations could not be expected to produce usable ground water. Weeks did feel that the Gunnison (Morrison) formation would be a likely source of suitable ground water judging from the recharge areas being located in porous sandstone outcrops on the Uncompahgre Plateau, an area which receives enough precipitation to permit suitable recharge quantities. These sandstone beds are also considered by Weeks to be contained by impervious layers of shales of the same formation that prevents escape or contamination.

It was not until 1950 that any study was made of the Montrose area itself. T. O. Meeks, through the Soil Conservation Service of the United States Department of Agriculture, prepared a reconnaissance of the groundwater conditions in the Uncompahgre Valley (Meeks, 1950) which encompassed the whole of the thesis area. In his paper no water analyses are presented. It is stated that water obtained from alluvial wells is usually of better quality than water obtained from the lower confined aquifers. The general trend of water obtained from the Dakota to be of poorer quality as one proceeds northeast or down dip is brought forth. Specific data concerning quantity are not presented. Only relative comparison of the various sources and their recharge areas are mentioned.

In a study concerning the unsteady flow of wells of constant drawdown, C. E. Jacob and S. W. Lohman (1952, p. 563-569) examine the flow of 25 wells in the Grand Junction artesian basin of Mesa County, Colorado. A brief summary concerning their geologic character is given. The Salt Wash member of the Morrison formation is the stratigraphically highest aquifer mentioned, though.

Lohman (1965, p. 149) went on to do a more detailed study of the ground water of the Grand Junction basin. In that work the shallower formations are also considered. The Burro Canyon and Dakota formations are reported to yield small supplies of generally salty water, generally under an artesian head. The two formations are reported not to be readily separable in most drillers' logs (Lohman, 1965, p. 66) so differentiation is not made. The Mancos shale is listed as being essentially an unwatered formation with only meager amounts of unconfined, highly mineralized water. Other formations mentioned in the study are either not present in the Montrose area or are found only at great depth.

III. HISTORY

A. Settlement

The first white men to see the area around what is now Montrose were probably those of the Spanish expedition of Don Juan de Rivera of 1765. Leaving from Santa Fe, in what is now New Mexico, they explored the San Juan Mountain region for gold and eventually came northward down the Uncompahgre River valley. Several other groups of Spaniards also made trips through the area but no permanent settlement of the valley was ever attempted by them.

It was not until the Ute Indians were removed in 1880 and 1881 that the area was open to settlement. Prior to that time the Utes had held by treaty the whole of the western slope of Colorado except for the mineralized portion of the San Juan Mountains. They had given up the San Juan Mountain area in the San Juan Treaty of 1873 to try to stem the tide of prospectors and speculators who had been encroaching upon their territory. However, the pressure to open the entire area to settlement finally grew too great and in 1880 an uprising of some of the Indians against certain restrictions placed on them by their agent was used as an excuse to move them to Utah.

The area was quickly settled. In 1882 the city of Montrose was incorporated and in 1883 Montrose County was formed from a portion of Gunnison County. By 1890 the county had a population of almost 4,000 and by 1910 over 10,000. Since that time population growth has been slower but generally steady until now the county has a population of over 18,000 and the city of Montrose 6,500 (Table I).

B. Water Resource Development

Historical data concerning early water development and use in the Montrose area is scant. According to Monroe (1937), the Montrose water system pumping plant was built in 1888. One Robert Smith took charge of it in 1900 and the plant was connected with the Montrose Water Department most of the time from then until the

Table I

Statistics of Population in Thesis Area

	Montrose County		Thesis Area Towns: Montrose		Thesis Area Towns: Olathe	
Year	Population	Per Cent Change	Population	Per Cent Change	Population	Per Cent Change
1890	3,980		-		-	
1900	4,535	12.2%	1,217		-	
1910	10,391	56.4%	3,254	62.6%	458	
1920	11,852	12.3%	3,581	9.1%	491	6.7%
1930	11,742	-0.9%	3,566	-0.4%	593	17.2%
1940	15,418	23.8%	4,764	25.2%	705	15.9%
1950	15,220	-1.3%	4,964	4.0%	810	12.9%
1960	18,286	16.8%	5,044	1.6%	773	-4.8%
1970	18,366	0.4%	6,496	22.4%	756	-2.2%

from yearbooks of Colorado and
U. S. Bureau of Census

Cimarron Ditch was completed and a pipe line installed from the reservoir on Cerro Summit in 1905.

From the very first the present irrigational agriculture was the basic economy of the area with an adequate water supply being one of the main problems of the Uncompahgre River valley. The first decreed water right is that of the Reservation (U. S.) Ditch, Priority No. 1 for 2.69 cfs, for irrigation, appropriation date July 1, 1880, and decreed date November 14, 1888. Said water was used at the old Fort Crawford army post, about 8 miles south of Montrose (R. V. Kelling, 1971, personal correspondence). In the 1890's a diversion route from the Gunnison River, the Gunnison Tunnel, was proposed. The project was authorized by the federal government in 1903, and construction began the next year. The tunnel, a major engineering feat of its day, was completed in 1909, giving the city of Montrose an ample water supply. Since then improvements on the 5.8 mile long structure and associated dams and canals have been accomplished (U. S. Bur. of Reclamation, 1961, p. 761).

Large scale water development in the Montrose area has been limited to surface water and irrigation only. Early projects were privately financed and constructed. In 1903 the Uncompahgre Project of the Bureau of Reclamation was authorized by Congress and through these and other lesser projects an extensive irrigation system has been developed. Most of this is operated and maintained by the Uncompahgre Valley Water Users' Association. As of June 30, 1958, this agency operates 8 dams, 143 miles of canals, 425 miles of laterals, and 215 miles of drains serving 63,070 acres (U. S. Bur. of Reclamation, 1961, p. 763). Domestic water development has been slower in becoming established in the rural areas near Montrose. Domestic water was developed on an individual basis through the use of ground water or was hauled in from outside sources, a procedure still in use by a few people. Data concerning these earlier wells are either unknown or unavailable. Close to Montrose in the more heavily populated area, several cooperative water systems for domestic use have been available for several years but it has been only in the last few years that most of the area, through the Tri-County Water Conservancy District, has had a domestic water supply available. The development of these domestic water supplies on a large scale has also brought about changes in groundwater usage. Many wells previously used for domestic purposes have been either abandoned or put to different uses, the main one being the watering of lawns and gardens.

IV. GEOGRAPHY

A. Location and General Statistics

The thesis area consists of the Uncompahgre River drainage area in Montrose County, Colorado. It lies between latitudes 38° 40' 6½" N and 38° 19' 56" N. The longitudinal boundaries are variable as they lie on drainage divides but the whole of the area is encompassed between longitudes 107° 30' W and 108° 20' W. This places the area in the Canyon Lands section of the Colorado Plateau province (Thornbury, 1965, p. 405-441). The Canyon Lands section is bounded on the north by the Book Cliffs, on the east by the Southern Rockies, on the south by the San Juan River, and on the west by the High Plateaus section. This places the thesis area on the eastern edge of both the section and province.

Although statistics limited to only the thesis area are not available, figures are available for the whole of Montrose County. The county is 33.6% under private ownership and 66.4% government owned (Goddard, 1967, p. 4). The population of both the county and the incorporated towns within the thesis area (Table 1) have for the past 60 years shown steady but not rapid growth. A large portion of the population has lived in the area for at least ten years. No exact figures are available but, except for a large Mexican-American population, no ethnic groups are in evidence. Almost all of the population of the thesis area is found within three miles of the Uncompahgre River.

Montrose, the largest town within over sixty miles distance, serves as a government and wholesale commercial center. Statistics from the Montrose County Chamber of Commerce (1971) give the town's major sources of income as agriculture (34%) and tourism (32%). The average income per capita (1970) is $1,985. The total assessed property value in Montrose County (1964 Colorado Yearbook) in the last year with available statistics was $32,983,585, a slight drop from the $33,026,355 of the previous year. The town's location at the junction of two federal highways and proximity to such attractions as Black Canyon of the Gunnison National Monument aides in making the town an attractive location to tourists. Freight transportation is available through eleven motor carriers and the Denver & Rio Grande Western Railroad. There are also regular commercial airline flights.

The area has been subdivided by the author into four sections: (1) the Uncompahgre Plateau, (2) the Mesa and Valley section, (3) the "Badlands," and (4) the Parks.

B. Uncompahgre Plateau

The Uncompahgre Plateau subdivision makes up the southwest half of the thesis area. It consists of the northeastward sloping homoclinal flank of the Uncompahgre Plateau. The plateau is relatively unbroken by canyons in comparison to most areas of the Colorado Plateau province. U. S. Army Map Service topographic maps, scale 1:250,000, contour interval 200 feet, are the only topographic maps available of this area which makes it difficult to estimate canyon depths. However, from these maps and from personal observation, canyons seem to reach a maximum depth of no more than 500 feet. The elevation of the plateau in the thesis area reaches a maximum of over 9,000 feet decreasing gradually to approximately 6,000 feet where the plateau reaches the mesa and valley subdivision. The surface formation, except for exposures of the Morrison in some of the canyons, is the Dakota (see Chapter V). The sloping terrain (Figs. 2 and 3) has a vegetation cover of scrub oak, juniper, cedar, pinyon pines, and sagebrush at the lower elevations, changing into forests of aspen, birch, and various conifers and grassy meadows at higher elevations (Fig. 4). Most of the Uncompahgre Plateau subdivision lies within the Uncompahgre National Forest, which is headquartered in Montrose. Few people live on the plateau although some ranches are found there. In addition to these permanent ranch operations, there is extensive summer grazing of sheep and cattle from farms and ranches from the lower elevations.

Figure 2. View to the southeast along strike of Uncompahgre Plateau at an elevation of 6850 feet. Scene shows typical lower elevation scrub vegetation of plateau.

Figure 3. Downdip view of lower portion of Uncompahgre Plateau. Foreground area shows scrub vegetation of the lower plateau. Background shows Uncompahgre River valley and Montrose with light colored Badlands area beyond. Horizon is the Gunnison uplift.

Figure 2.

Figure 3.

Figure 4. View of Uncompahgre Plateau at an elevation of approximately 8400 feet. Note the change in vegetation from Figs. 2 and 3 located only 1500 feet lower in elevation.

C. Mesa and Valley Section

The Mesa and Valley section consists of the Uncompahgre River valley, tributary valleys, and the flat-topped areas between these valleys. The area varies in width from only about one mile at the Ouray-Montrose County line on the south to approximately ten miles at the northern end of Montrose County at the Delta County line. The Mesa and Valley subdivision lies in the approximate center of the thesis area trending in a south-southeast to north-northwest direction. The terrain is flat or very gently rolling except at the edges of the mesas where a relatively abrupt drop is encountered. This drop is between 100 feet and 160 feet at most places. Elevation in the Mesa and Valley subdivision ranges from a maximum of approximately 6,400 feet in the south to less than 5,180 feet where the Uncompahgre River flows out of Montrose County. The elevation of tops of the mesas drops at approximately the same rate as the river grade with the river valley in the south being over 1,000 feet higher in elevation than the mesas in the north. The surface formation of the subdivision, except for Dakota outcrops along the western portion, is the Mancos shale. Over much of the area, these consolidated formations are covered with fluvial materials.

The Mesa and Valley section is the location of most of the population and agriculture other than ranching. Montrose and Olathe, the only towns in the thesis area, are found here on the east bank of the Uncompahgre River. Agriculture is practiced both in the valleys and on the tops of the mesas, but the mesas are the prime agricultural areas. This agriculture, the prime economic factor in the area, has as its main products for the outside market: feeder cattle, fruit (better grade apples and peaches), dry beans, sugar beets, truck vegetables, and Moravian barley (malting barley for beer). Values of products grown in Montrose County were led by hay with over $1,500,000 worth grown annually (1962). For amounts and values of other products see Table II. This agriculture employed 3,377 persons (1960 census) or 18.5% of the population. This percentage of the population with

Table II

Montrose County Agriculture Production (1962)
(listed in order of value)

	PRODUCT	PRODUCTION	VALUE
1.	Hay	68,870 tons	$1,515,140
2.	Dry Field Beans	119,680 100 lb. bags	742,541
3.	Sugar Beets	48,140 tons	601,750
4.	Barley	503,720 bushels	508,646
5.	Corn	189,800 bushels	248,638
6.	Oats	226,600 bushels	172,974
7.	Potatoes	92,250 100 lb. bags	155,880
8.	Spring Wheat	63,570 bushels	115,106
9.	Winter Wheat	24,240 bushels	44,844
10.	Grain Sorgum	7,580 bushels	9,096
11.	Rye	4,800 bushels	3,984
12.	Forage Sorgum	34 tons	527

from Colorado State Yearbook

agricultural employment has been steadily dropping with the mechanization of farming, but the importance of agriculture to the economy of the area has remained nearly the same. The average size of the farms has steadily increased until it is now 340 acres (1962). None of this agriculture would be possible without irrigation. Because of extensive development, the natural vegetation has been almost completely altered. Before irrigation the vegetation probably consisted of only a sparse cover of juniper, cedar, and sagebruch except for cottonwood along the Uncompahgre River. The Mesa and Valley section of the thesis area is the location of more than 90% of the water wells in the area (Fig. 5).

D. Badlands

The Badlands subdivision lies to the northeast of the Mesa and Valley subdivision. It consists of an area in which the Mancos shale is the sole surface formation. Much of the area is rough, with shale hills over 150 feet in relief not uncommon (Fig. 6). Elevation ranges from 5,300 feet in the north to almost 7,000 feet in the southeastern portion. Certain areas, mostly along dry stream courses, are rolling or even quite flat. There is a tendency for these more level areas to develop gypsiferous deposits (Fig. 7) resulting in the Badlands subdivision being made up of land that has very little commercial or economic value. There is little vegetation in the area with the steeper sloped portions being completely void of vegetation. This results in much erosion when rain occurs and adds to the already turbid flow of the Uncompahgre River. There are very few people living in the Badlands subdivision with those present farming the more level areas.

E. Parks

The Parks subdivision lies to the east of the Badlands subdivision. It consists of two park areas separated by the Cedar Creek valley. To the north of Cedar Creek is Bostwick Park and Upper Bostwick Park and on the south side is Shinn Park. These parks are flat or gently sloping areas. The elevations of the parks

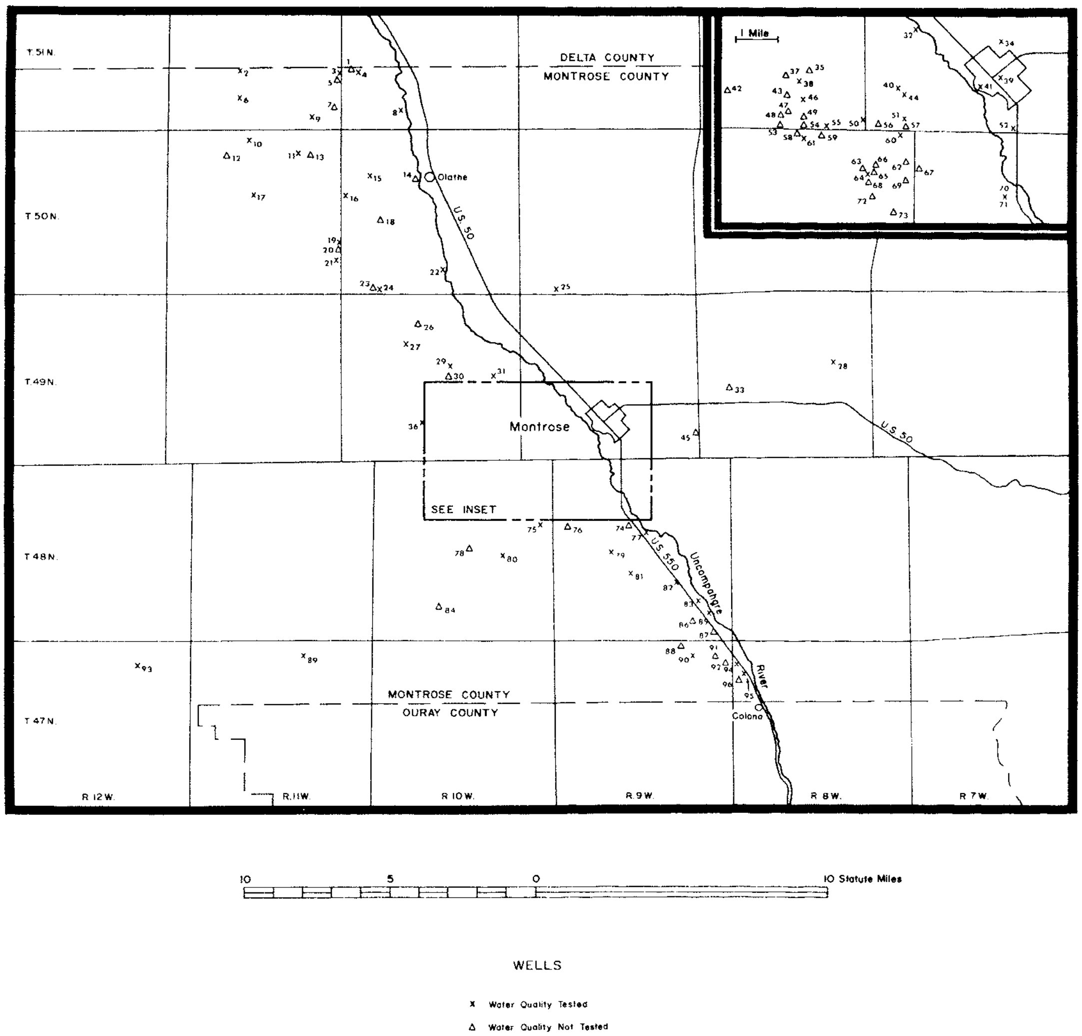

Figure 5. Map of thesis area showing the field checked locations of wells. Well numbers refer to those assigned by the author.

Figure 6. View of Badlands area to the northeast of Montrose. Area is made up of Mancos shale that has been eroded into series of steep hills and gullies. Note the cracked soil in the foreground and the irrigated flat area at middle distance. The darker area in the background is the Gunnison uplift.

Figure 7. Gypsiferous area in field that has become unusable for agriculture. Particular scene is on the north side of U. S. Highway 50 approximately four miles to the east of Montrose.

Figure 6.

Figure 7.

themselves ranges from less than 6,800 feet at the north end of Bostwick Park to over 7,500 feet in the northeast portion of Upper Bostwick Park. Relief in all the parks themselves is gentle. The surface material of these parks consists of unconsolidated clays, sands, and gravels. The natural vegetation has been completely altered, through irrigation, as the parks are now used for grazing or cultivation (Fig. 8). The natural vegetation was likely the same sagebrush and low altitude timber found on the steeply sloping bordering areas of the parks (Figs. 9 and 10). Population is sparse in the Parks subdivision also as consolidation of farming operations has led to the abandonment of many dwellings in the area.

F. Climate

The climate of the valley floor is arid with relatively moderate temperatures. Climatological data from the Montrose station shows a yearly mean temperature of 49.6° F. The highest temperature recorded in 71 years is 106° F and the lowest -23° F. The station receives a yearly average of 9.11 inches total melted precipitation. The most recorded in 82 years of records in one year is 13.97 inches total melted precipitation and the least in one year is 6.19 inches total melted precipitation. The most in one month ever recorded is 4.26 inches total melted precipitation and the least, recorded in several months, is none. The most total melted precipitation recorded in one day is 1.70 inches. August and September are the wettest months, with most of the precipitation falling in late afternoon showers and thunderstorms. The yearly evaporation rate, measured in the standard weather bureau type 4-foot diameter pan, is 58.06 inches. The average growing season in Montrose is 153 days; from May 7 to October 9 with the latest recorded killing frost on June 13 and the earliest recorded killing frost on September 14. Detailed climatological data for Montrose may be found in Appendix A.

The climate of the thesis area varies with altitude. In general, as the altitude increases, precipitation increases and

Figure 8. Bostwick Park. Note the relative flatness of ground and the intensive agricultural use. Gap in upland in the background is Red Rock Canyon. View is in northwesterly direction from Orchard Corner.

Figure 9. Montrose syncline from upland to the east. Horizon is Uncompahgre Plateau.

Figure 10. View to the southwest from a slightly lower elevation than Fig. 9. South Canal, which carries water diverted through the Gunnison Tunnel, is visible in the valley located in the area of lower elevation to the left in the photograph.

Figure 9.

Figure 10.

temperatures fall lower. The fact that the precipitation increases with altitude is an important factor in both the surface waters and the ground waters of the Uncompahgre Valley. Snowfalls at the higher elevations are the major source of supply for those waters. Snowfall data for Red Mountain Pass and Ironton Park (App. B), two stations within the Uncompahgre River drainage basin, show the relatively large amounts of snowfall at such elevations, 11,000 feet and 9,800 feet respectively.

G. Natural Resources

Natural resources of the thesis area include some coal measures in the Dakota formation, sands and gravels, and petroleum. The coal is sub-bituminous or lignitic and of a poor grade. At the present time, there is only one coal mine in the area, a small stripping operation in Deadman's Gulch. Evidence and records of earlier mines show a much larger coal mining industry in the early 1900's. Coal mining in the area is hampered not only by a lack of high grade coal but by high cost transportation, the lack of a large market nearby, and nearby coal mines with better quality coal.

Sand and gravel are quarried in small scale operations along the Uncompahgre River. Once again transportation costs and the lack of a market make this a limited operation.

In Montrose County there have been 58,092 million cubic feet of gas produced (1970 Oil and Gas Statistics), none of which came from the Uncompahgre River valley portion of the county. There are reports of water wells producing usable natural gas although not in quantities sufficient for commercial use. Some of these wells have, in fact, been connected to gas lines for farms and have supplied sufficient amounts of gas for their use. On one occasion Mr. Kelling and the author visited well 31 to check reports of gas from it. The well, drilled and cased into the Dakota formation, had enough gas leaking into it even after continual pumping of twelve hours to produce a flare when an open flame was held next to the well. A test sample of water taken after the twelve hour continual pumpage had a skim of oil present on its surface. The water from well 19 also had an oil skim present on its test sample. Several other wells were reported to have gas present and to show other evidences of oil or gas but the ones mentioned above were the only two observed by the author. There has been no oil produced in the county although at least eleven oil test wells have been drilled in the thesis area. Water well number 25 is, in fact, one of these dry oil wells. In 1970 only one oil test well was drilled in Montrose County. It was wildcat and dry and is now plugged and abandoned. The question of the source of the oil and gas has not yet been resolved. The possibility of it being leaks from a major reservoir has been enough to encourage wildcatting by some of the major oil companies of the nation. Other possible sources could be small lens traps or porous shale.

V. GEOLOGY

A. Structural Features

There are three major structural features affecting the geology of the Uncompahgre Valley in Montrose County. These are the Uncompahgre uplift, Montrose syncline, and the Gunnison uplift. The Uncompahgre uplift is a large homoclinal fault block dipping to the northeast at approximately 5° to 10°. The uplift forms the Uncompahgre Plateau. The main homoclinal tendency of the plateau is interrupted by local monoclinal steepenings of dip (Lohman, 1965, p. 80). No major monoclines are present in the thesis area itself although the Redlands monocline to the northwest and the San Juan monocline to the southeast are major features nearby (Kelley, 1955a, p. 796). The dip of the plateau is quite evident in secondary features also. Streams flowing off the plateau show a remarkable tendency to form a parallel drainage pattern until off the plateau. The widespread jointing and minor faulting concurrent with the dip may also be a factor in the drainage pattern. The aquifers of the area also are affected by the dip. It allows the aquifers to build up an artesian head because of the location of the recharge areas generally towards the higher parts of the plateau with the absence of any folds or faults that might tend to cut off such aquifers.

The Montrose syncline, featuring a northwesterly plunge, is located to the east of the Uncompahgre uplift. The axis of the syncline is located a few miles to the east of a line from Montrose to Delta (Kelley, 1955b, p. 23). The structural features of the syncline are not so well defined because river alluvium, glacial outwash, and the Mancos shale form the surface material where it is located. All of these tend to either conceal the structures present or to make them less obvious. A tendency for the dip to lessen to the east of the Uncompahgre River was noted by the author from measurements made using certain thin, resistant beds in the Mancos. The dip changes to westward or southwestward approximately midway between the Uncompahgre River and the upthrown area to the east of the thesis area, the Gunnison uplift.

The Gunnison uplift, included within the West Elk Mountains physiographic section by Fenneman (1931, p. 116-117), is made up of Precambrian basement rock with remains of Mesozoic strata on portions of it. The Gunnison fault, with a maximum throw of about 3,000 feet (Kelley, 1955b, p. 47), is the dividing line. The Mesozoic remnants have an anticlinal structure with axis parallel to that of the Montrose syncline. It is roughly five miles long and one mile wide with its axis roughly in a line from the Montrose airport to Olathe.

B. Paleozoic History

The geologic history of the thesis area prior to very Late Paleozoic time is not well known. There are no sedimentary rocks of age earlier than Mesozoic exposed in the area. It is because of this absence of evidence and the great length of elapsed time that early physiographic events are not very evident.

The first Paleozoic event of consequence that probably occurred was the extension of the Late Cambrian Cordilleran trough into the area. This was followed by the invasion of the area by three successive Ordovician seas. No Silurian rock has be found in Colorado (Lohman, 1965, p. 21) and during both Silurian and Early and Middle Devonian time, the area was subjected to erosion sufficient to remove all of the previous deposits. After this extensive erosion the Late Devonian Colorado sag brought another period of sedimentation which continued into Mississippian time. In early Pennsylvanian time the ancestral Uncompahgre Plateau was uplifted with a corresponding deep geosyncline forming to the northeast. This emergent tendency of the Uncompahgre uplift continued well into Permian time and resulted in the removal of much of the Paleozoic deposits from the thesis area (Eardley, 1951, p. 16-20).

C. Mesozoic History

The peneplained area was a relatively stable continental area through the Triassic period. The area remained a continental area through the Jurassic period and until Late Cretaceous time.

It was during Late Jurassic time that the first formation with possible importance to the groundwater resources of the thesis area was deposited. This formation, the Entrada, although not exposed in the thesis area, yields good quality water with a sizable artesian head in the Grand Junction area. It consists of fine-grained sandstones (Lohman, 1965, p. 37-46). In the Montrose area the formation is probably at least 1,500 feet below ground level.

The Jurassic Morrison is stratigraphically the lowest formation that is exposed in the thesis area. The formation consists of varigated shales and crossbedded sandstones. The Morrison also contains thin beds and lenses of limestone and conglomerate. Rapid facies changes are dominant in the formation; few beds consist of the same sedimentary material for any great distance. The Morrison crops out in only a few of the canyons and valleys on the margins of the Uncompahgre Plateau. Nowhere is the entire thickness of the formation exposed in the thesis area. According to Meeks (1950, p. 4), the Morrison is tapped for water by a few of the deeper wells in the western margins of the Uncompahgre Valley. Confirmation of this is difficult because of the difficulty of separating the Morrison from overlying sedimentary rocks in drillers' logs. It is the author's opinion that much of the sedimentary rocks mentioned by Meeks and assigned to the Morrison are actually part of the overlying Burro Canyon formation. The Morrison is generally considered (Meeks, 1950, p. 8, and Lohman, 1965, p. 57) to contain moderate amounts of water of better quality than those of overlying aquifers. In the author's opinion, the possibility exists for untapped artesian aquifers to be in existence below the aquifers now in use within the thesis area.

The Cretaceous Period and its subsequent large sedimentation in the area began with the deposition of the Burro Canyon formation. The contact between the Burro Canyon and the Morrison formations is difficult to accurately establish. Both formations are made up of the same types of fluvial sandstones and shales. According to Craig and others (1955, p. 160), the contact is conspicuous only in areas with basal channel sandstones present.

The problem is further magnified by concealment by talus material from the overlying Dakota formation (Meeks, 1950, p. 4). The formation probably outcrops in the thesis area only in canyons and valleys on the western margin of the Uncompahgre Valley. The Shavano Valley is a likely location of such an outcrop. Because of the difficulty in establishing the contacts of the Burro Canyon with underlying and overlying beds especially in drillers' logs, its relative unimportance to the ground water of the area, the lack of acceptance of the Burro Canyon as a separate formation, and its previous inclusion with the Dakota formation in ground-water studies (Lohman, 1965, p. 66), no attempt will be made to separate the Burro Canyon formation in this study. It will be included with the Dakota formation in logs and aquifer locations.

Late Cretaceous time brought more deposits beginning with the Dakota formation. The Dakota is made up primarily of sandstones with various lenticular shales and coals. Various types of crossbedding are common in the sandstones. Figure 11 is a photograph of the formation showing the lenticular coals and shales with a massive sandstone bed above. Figure 12 shows this massive sandstone. The sandstones of the Dakota formation are resistant to erosion. Because of this the Dakota is the surface formation of the entire portion of the Uncompahgre Plateau within the thesis area except for some canyons which have cut into the underlying Morrison formation. Due to erosion, the thickness of the formation within the thesis area varies from 0 to about 200 feet. Because of the lack of fossils within the sandstone, Stokes (1952, p. 1345) considers the area to have had a semiarid paleoenvironment during deposition of the sand. However, Young (1960, p. 180-186) reports the findings of numerous fossils in the same stratigraphic sequence. The sandstones of the Dakota serve as the main bedrock aquifers of the thesis area with sufficient pressure to produce artesian flow present over portions of the area. Where they are not flowing, wells tapping the Dakota have a high artesian head.

Figure 11. Coal seam in Dakota formation. Total thickness of coal is approximately four feet although light streaks show clay lenses that tend to make the coal poor in quality.

Figure 12. View of contact between massive upper layer of Dakota sandstone and the underlying bed of shale. View is of the exposure on the east side of Shavano Valley. Note rock hammer in center for scale.

Figure 11.

Figure 12.

The following is a measured section of the Dakota on the east side of Shavano Valley (Meeks, 1950, p. 6):

	Thickness (feet)
Fine-grained, buff sandstone with some kaolin and small flecks of iron oxide. Cliff forming.	20
Hard, medium-grained, buff sandstone with streaks of yellow.	3
Hard, buff sandstone with streaks of light brown, and dark brown flecks of iron oxide.	2.5
Gray shale, mostly covered by talus.	17
Light gray to buff, cross-bedded sandstone with some kaolin and light brown flecks of iron oxide.	8
Gray shale with some black carbonaceous shale and coal.	35
Hard, buff, thin-bedded sandstone.	3
Gray shale.	15
Very hard, buff sandstone, with coarse grains of quartz, the stringers of small pebbles near base. Stained dark brown on weathered surface.	30
Soft, friable, white sandstone with streaks of kaolin. Contains some lime pebbles. Lower part concealed by talus.	5+
Total	138+

The end of Cretaceous time saw the entire area under subsidence. Sediments of over 5,000 feet were deposited in this time. This marine sediment is made up entirely of the Mancos shale. This shale, a dull gray in color, is the surface formation over most of the thesis area east of the Uncompahgre River and in certain outliers present to the west. The Mancos is quite fissile and weathers quickly to a gypsiferous soil that is poor in quality. Gypsum also tends to concentrate in areas to form what are locally known as alkali flats. Although the Mancos is made up almost completely of shale, there are thin beds and lenses of sandstones and limestones present also. The formation is highly fossiliferous. In road cuts where fresh outcrops of the formation may be observed, lenticular beds of highly carbonaceous material are evident. Among the numerous fossils observed by the author are Inoceramus labiatus von Schlotheim, at least four genera of foraminifera, ostracods, and fish scales and bones. Further evidence of the abundance of life is the bitumen present in the formation. Thickness of the Mancos in the thesis area varies from 0 to over 3,000 feet due to erosion. The Mancos, as a whole, contains no aquifers although a few producing wells are receiving their water from the formation. The close of the Cretaceous saw the renewed uplift of the area with a portion of the easily eroded shales removed.

D. Tertiary History

The Cenozoic Era opened with uplifts of the San Juan Mountain area and with the Ridgway glacial epoch (Atwood and Mather, 1932, p. 15-16, and Hunt, 1956, p. 64). No formations resultant of these Paleocene events are present in the thesis area. The Eocene saw a downwarping of the area to form Uinta or Green River Lake. The Uncompahgre arch was a peninsula extending into this lake (Hunt, 1956, p. 21). The remaining Tertiary events were a renewed uplift of the Uncompahgre Plateau and numerous volcanic epochs in the San Juan Mountains (Atwood and Mather, 1932, p. 17-21). There are no Tertiary deposits in the thesis area as it saw only the continued erosion of the Mancos and possible overlying formations from the area. There were structural changes during Tertiary time, though, especially during Miocene time.

E. Quaternary History

Quaternary history can be summed up as a period of uplift in the entire area and a series of glaciations and subsequent outwash gravel deposition. This general uplift brought a widespread increase in downcutting by area streams with the glaciations combining with the downcutting to produce the present day terrace gravels. The first of these downcuttings was the so called Florida cycle of erosion, after gravel deposits on Florida Mesa, located in Montezuma County, Colorado. Many portions of the Montrose area are capped by Florida gravels including Flat Top (Fig. 13), the Parks

Figure 13. Flat Top, a mesa located about two miles northeast of Montrose. The mesa, over 300 feet in height and made of the easily eroded Mancos shale, is capped by a resistant layer of gravel of Florida age.

area, and various other sites to the south and east of Montrose (Atwood and Mather, 1932, p. 112-114). According to the state geologic map of Colorado, Franklin Mesa, T. 49 N., R. 10 W. is also capped by Florida gravel. The Florida erosion stage was for a time interrupted by the Cerro glacial stage (Atwood and Mather, 1932, p. 28). This was named after the material in the vicinity of Cerro Summit (Atwood, 1915, p. 13-26). This has long been considered glacial till but a subsequent investigation by Dickinson (1965, p. 147-151) claimed this to actually be Mancos shale that had slumped and flowed from the steep slopes of the area. During Cerro time, piracy of the drainage of Shinn Park by Cedar Creek occurred (Atwood and Mather, 1932, p. 61, 114). Further uplift and river valley deepening continued until the Durango glacial stage. Its resultant outwash gravels brought new deposition. The next terrace below the Florida is covered with Durango outwash. Between the Durango glacial state and the final Wisconsin glaciation, further deposition of stream gravels occurred near Montrose. The largest area in which these non-glacial gravels were deposited is Spring Creek Mesa (Fig. 14) whose surface is 50 feet above the Wisconsin outwash and 40 feet below the Durango valley train (Atwood and Mather, 1932, p. 134). The final outwash deposit, the Wisconsin, is the material upon which the town of Montrose is located. This gravel is less than 20 feet above the modern alluvium at Montrose and continues in a downward trend which descends to the modern alluvium two to four miles north of Montrose (Atwood and Mather, 1932, p. 146).

Throughout Quaternary time the Uncompahgre River has been steadily moving its course in an easterly, downdip direction. Of the various gravels mentioned above only the Wisconsin and the modern alluvium are natural aquifers. However, due to extensive irrigation on the tops of the mesas, the gravels located there also provide a source of water. Wells with yields as high as 900 gpm tap these sources which become dry each winter with the close of the irrigation season.

Figure 14. Contact between Mancos shale and post-Durango gravels on the east side of Spring Creek Mesa. Gravels are remnants of an old Uncompahgre River floodplain (Atwood and Mather, 1932). View is of the north side of Colorado Highway 90 road cut.

F. Future Events

Future geologic events are difficult to forecast but the two most probable occurrences of any significance are the continued downcutting of the Uncompahgre River and erosion of the Mancos shale. The heavy use of the river's waters for irrigation and the resulting loss of flow will probably tend to slow the rate of downcutting by the Uncompahgre River.

VI. GROUNDWATER LAWS

Colorado groundwater laws are in a state of change. Their dynamic character, at the present time, has left certain loopholes in the laws but efforts are being made to correct them. In 1969 Colorado converted from the common-law doctrine of riparian rights to the doctrine of prior appropriation for all waters except small domestic wells and small livestock watering ponds (providing the dam is less than 15 feet high and holds less than 10 acre feet of water). Under this doctrine, now in use in eleven of the plains and mountain states, ownership of land does not include the ownership of the waters on and beneath the land. The basic intentions of this philosophy are to make better use of available water and to maintain groundwater supplies. The state has been using the right-of-prior-appropriation doctrine for many years with respect to most surface water rights and has one of the best systems in the nation concerning surface water rights and their administration. Ownership of water remains with the public until it is appropriated to someone. The basic philosophy of the right-of-prior-appropriation is stated in Section 5, Article XVI of the Colorado state constitution.

> The water of every natural stream, not heretofore appropriated, within the State of Colorado, is hereby declared to be the property of the public and the same is dedicated to the use of the people of the State, subject to appropriation as hereinafter provided.

In Section 6, Article XVI, the right-of-prior-appropriation is modified somewhat to give preference to domestic and agricultural uses.

> The right to divert the unappropriated waters of any natural stream to beneficial use shall never be denied. Priority of appropriation shall give the better right as between those using the stream for the same purpose: but when the waters of any natural stream are not sufficient for the service for all those desiring the use of the same, those using the water for domestic purposes shall have the preference over those claiming for any other purpose and those using the water for agricultural purposes shall have preference over those using the same for manufacturing purposes.

A system using state engineers and a groundwater commission to determine and maintain groundwater rights and priorities has been established. The state was recently divided into seven divisions, Montrose being the headquarters for Division 4. Each division has a division engineer and a staff under him for the administration and distribution of the waters of the state.

The present Colorado system of prior appropriation calls for the beginning of groundwater administration on July 1, 1972. All wells must then be registered. Wells put into operation after that date shall then go through a system of applications. The application procedure involves the acquiring of permission to sink the well (except for test wells). If no objections are raised, a conditional permit is issued and the well may be constructed. Within one year after the date of the permit, the well must be registered or the permit expires. Section 1 of Colorado House Bill 1160 provides for the exemption of certain wells.

> Designated ground water basins [none located on the western slope in Colorado]; Wells not exceeding fifteen gallons per minute of production and used for ordinary household purposes, fire protection, the watering of poultry, domestic animals, and livestock on farms and ranches, and the irrigation of not over one acre of home gardens and lawns, but not used for more than three single-family dwellings; Wells not exceeding fifteen gallons per minute of production and used for drinking and sanitary facilities in individual commercial businesses; Wells to be used exclusively for fire-fighting purposes if said wells are capped, locked, and available for use only in fighting fires; and Wells not exceeding fifty gallons per minute which are in production as of the effective date of this section, as amended, and were and are used for ordinary household purposes for not more than three single-family dwellings, fire protection, the watering of poultry, domestic animals, and livestock on farms and ranches, and the irrigation of not over one acre of gardens and lawns.

If the state determines the well is being put to beneficial use and the terms of the conditional permit have been complied with, a final permit may then be issued. The law gives the state much leeway on this issuance with full rights to restrictions as may be needed to insure the conservation of groundwater reservoirs. Any appeals to the state's decisions are dealt with as civil suits in the courts.

Due to increased groundwater use in the state, Colorado is reviewing any new wells carefully and is restricting new groundwater development in certain areas. The thesis area is not one of those restricted areas. A 600 foot minimum spacing between wells except for alluvial aquifers is one of several new regulations being enforced.

There are several problems that have been or might be encountered with the enforcement of the prior appropriation doctrine. One of these is acceptance of the doctrine by the people. The author, in interviewing well owners, found there was considerable opposition to the doctrine, especially from older residents and those with large real holdings. Another is the extensive records, investigations, and paperwork involved. To determine whether a new well is feasible or not, knowledge concerning the aquifer or aquifers involved is needed to determine whether the new well will cause overdraft. Some aquifers of the state are being overdrawn by wells already in existence. Another problem that may be encountered concerns old wells, whether in use or not. If in use, their exclusion from registration denies the state knowledge concerning the use being made of the various aquifers. Older wells that have been abandoned also present a problem in that they might allow pollution of aquifers. There is a need for further study to determine the extent of this problem. Finally, strict adherence to the prior appropriation doctrine would restrict the amount of groundwater use because a junior well will affect the yield of nearby senior wells in the same aquifer. The author believes legal action should be restricted to cases in which there are sizable reductions of well yields or the whole purpose of the law will be defeated. The final problem of defining a sizable reduction then arises.

VII. PROCEDURES

A. Gathering of Data

The first step in the gathering of information concerning the thesis area and subject was the compilation of notes from reference sources. Material available from publications and maps from sources at the University of Missouri-Rolla was the first source used. This was done in the spring of 1971. After sufficient background material had been gathered to supply an understanding of the area and its problems, a trip was made to the headquarters of the Colorado Geological Survey and the Colorado Division of Water Resources in Denver. Water well data were collected from the Division of Water Resources' files. This included the Colorado registration number, legal description of the location, owner, depth of well, static water level, yield, use of well, driller, drilling method, hole diameter, casing information, well log, test results, and date of drilling of all wells located in the thesis area. All of this information was recorded on 4" by 6" file cards. Approximately 300 wells were found to be located in the thesis area. Not all of the above information was found for each well, however. Information and advice from R. H. Pearl, the head of the water resources division of the Colorado Geological Survey, was obtained. A check of the Denver office of the Colorado Oil and Gas Commission for well logs from the thesis area was also made but no usable information was available there. While on this June trip to Denver, the Federal Center was also visited and maps of the thesis area obtained. A July visit to Denver was made to check on information obtained and to acquire additional material on certain wells and more maps.

After the first visit to Denver, other information concerning the thesis area and subject was gathered from various sources in the Montrose area. In Montrose, information was obtained from the District 4 offices of the Division of Water Resources both from their files and from the personal knowledge of staff members R. V. Kelling, R. I. Blewitt, and E. S. Hofmann. Other sources used included the files of the Tri-County Water Conservancy District, Uncompahgre Valley Water Users' Association, the County of Montrose, and the Montrose Daily Press plus personal interviews with people involved with matters concerning the thesis subject.

B. Information Used

The water quantity data used, for the most part, are the results of tests conducted just after the wells had been drilled. These results were those obtained from the Denver files of the Colorado Division of Water Resources. On certain wells where situations permitted new tests to be run on yield, the previously recorded yields were compared to field tests of the time required for the flow to fill containers of known sizes. Because of the type well or because of the need of the owner to have the well in use, no drawdown tests were run. Only the drawdown test results from the Denver files are used.

C. Field Work

During and after the obtaining of the information mentioned above, field work was carried out. First, a general reconnaissance of the area was performed for familiarization with landmarks, to compute the more efficient routes for travel while well testing and sampling, and to learn the geology of the area. While doing this reconnaissance, notes were taken of sites for good photographs and for structural, stratigraphic, and paleontological study. Investigation was also done into the best places to conduct water quality tests. All of the above was accomplished in June and July, 1971.

Well locating and testing was then done in August, 1971. Before this was undertaken, the following plan for choosing which well to consider for locating and testing was developed. First, only those wells registered in the files of the Denver office of the Colorado Division of Water Resources were considered. This was because insufficient data were available concerning the unregistered wells. After division of the note cards of each well according to legal location had been done, a preliminary plan of randomly picking one well per every quarter township was found to be unusable. Of the possible 63 quarter townships in the thesis area, only 33 of them had wells in them according to the Denver files. A check was next made of a plan using one well per section, but this plan showed 109 sections with wells; unacceptable both because the number was larger than desired and because of a heavy concentration of sections which the author felt would not only give too much repetition in field analysis but would also tend to cause medians and means computed from well data to be influenced too much by one relatively small area. The final plan chosen divided each township in 4-square-mile ninths consisting of four sections per division (Fig. 15). This plan had 56 areas with wells and seemed to offer a good group of representative locations without missing large areas or having unwanted repetition. Because only a limited number of wells penetrated into bedrock aquifers, all cards of deeper wells were then pulled from the 300 to have their filed location field confirmed and plotted on maps of the area so that the confined aquifers of the area could be better defined. From these cards of deeper wells, all wells found to be in divisions where no others were located were filed as wells to be tested for quality. If there was more than one of these deeper wells in a division, the well to be tested was determined on the basis of the amount and quality of information available concerning quantity tests and the drill hole. Finally, divisions containing shallower wells were represented using the same methods for choosing among wells as for the deeper ones.

The above set of well cards was reorganized by township for final field location. Prior to each day spent in the field, a group of these well locations was lightly marked on the map covering the area to minimize the time needed and for ease of location. However, due to errors in the Denver files on the actual location of over 35% of the wells eventually located, much time was spent asking help from residents of the area for clues as to the actual location. Through their help and from personal searching, all but

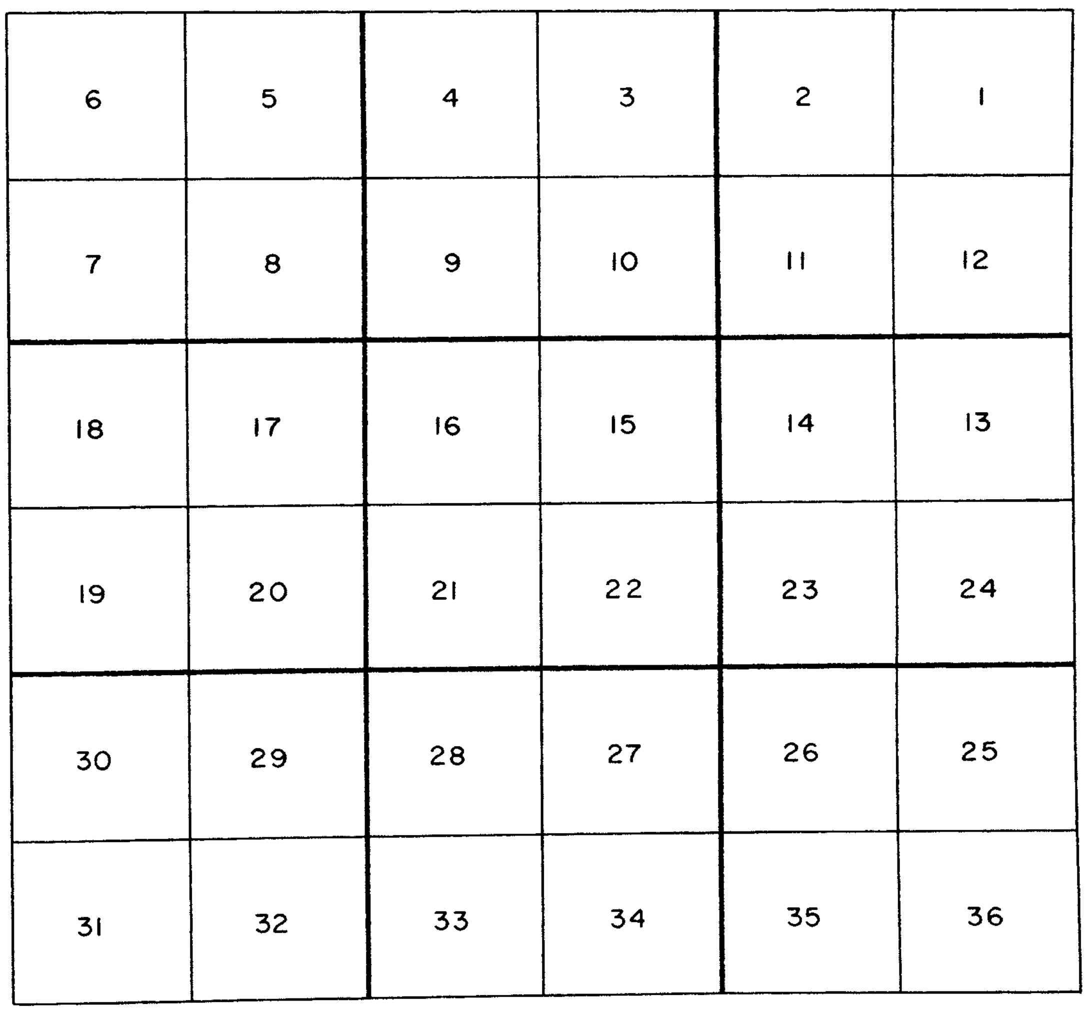

Figure 15. Diagram of a township showing method used for dividing it into four-square-mile ninths. Heavy lines indicate division boundaries.

some fifteen of the wells planned for locating or testing were found. A list of the wells with incorrect locations on file in Denver, and their locations as determined when field checked can be found in Appendix G.

Many revisions were necessary concerning which wells were to be tested. In addition to the wells never found, many wells originally picked for testing were unsuitable because of the location or their abandonment. In such cases, a substitute well was picked if any were available in the particular division of the unusable well.

After a well was tentatively located in the field, the owner or operator was questioned about the well. These questions were used for confirmation that the well was actually the one being sought. This avoided mistaking the well for one not listed. Questions were also asked concerning any special features of the well which were written on the note card of that well. After a well was specifically located in the field, the location was plotted on a map and the elevation determined and noted on the well's card. If the well was simply to be located, this ended work on it. If the well was to be tested, further work was done. If told by the owner or operator of the well that it had not been in use recently, the well was pumped to empty the well of any stagnant water. The water being pumped from the well was then observed for rust and other contaminants not native to the well's aquifer. When the water cleared and the temperature stabilized indicating true groundwater was flowing from the well, two samples were taken of it. One was put into a previously unused, one pint or one quart polyethylene bottle and immediately capped for later chemical analysis. The other sample was put into a wide mouth gallon jug that had been thoroughly rinsed with water flowing from the well to be tested. This jug of water was then tested for temperature with a mercury thermometer and for pH at the well site. The wells located were then given numbers by the author with the larger numbered wells to the south (Fig. 5).

D. Laboratory Work

Chemical analysis of the water was performed by the Grand Junction Laboratories in Grand Junction, Colorado, using the techniques found in Standard Methods for the Examination of Water and Wastewater, (1965). The laboratory was checked for its reliability through inquiry of area individuals and firms having had work done by it and by personal observation of their laboratory. Also three check samples were sent to them. One, from the city water system of Montrose, had been tested previously within a month of the author's test and the results were known. The other two were taken at the same time from the same well but were given separate test numbers to check if results would be the same. This checking and testing showed the laboratory to be reliable.

VIII. GROUNDWATER QUALITY

A. General Characteristics

General statistics of the water wells located in the thesis area show a mean depth of 104 feet and a median depth of 48 feet. This sizable difference can be attributed to the large number of shallow wells offset by a few wells of depths close to or greater than 1000 feet. The deepest well in the area reaches a depth of 1090 feet. It was not originally drilled for water but for oil. The mean depth of the 51 wells in the thesis area tested for quality if 192 feet with a median depth of 100 feet. The difference here is also because of a few deep wells and a larger number of shallow wells. The declared uses of the 309 wells in the thesis area registered with the Colorado Division of Water Resources in Denver are shown in Table III.

Table III

Well Uses

Registered Use	Tested Wells		Located Wells		All Registered Wells	
	No.	Pct.	No.	Pct.	No.	Pct.
Domestic	30	38.8%	53	55.2%	227	73.5%
Stock	10	19.6%	26	27.1%	41	13.3%
Domestic & Stock	7	13.7%	10	10.4%	16	5.2%
Irrigation	3	5.9%	6	6.3%	15	4.8%
Commercial	1	2.0%	1	1.0%	5	1.6%
Municipal	0		0		4	1.3%
Irrigation & Stock	0		0		1	0.3%

Water quality tends to become poorer as one follows an aquifer downdip with the general quality being better to the south and west. The extremes in characteristics in tested wells are shown in Appendix F. The reason for the mean being much higher than the medians for many substances is the extremely high values in a few wells.

Groundwater quality, in tests of water samples of 51 wells located within the thesis area, showed a quality from very poor to moderately good with most wells having water of a quality inferior to commonly used standards. Because wells 70 and 71 have combined discharges, only one sample was tested from those two wells. Tests were conducted for 24 quality characteristics (App. C).

B. Domestic Use Quality

Using drinking water standards of the Public Health Service (1962) (App. D), only 6 of the wells had samples with all chracteristics within the recommended limits. Of the water samples collected from wells registered with the Colorado Division of Water Resources for domestic or commercial use, only 5 out of 37, or 13.5% met the chemical characteristic standards recommended by the U. S. Public Health Service for water supplies where a more suitable supply can be made available. Thirteen of the domestic and commercial wells had fluoride concentrations high enough for rejection of their waters. Fluoride was the only substance of those used as grounds for rejection of water that was present in amounts in excess of Public Health Service standards. Of the tested wells, 28 are unsuitable by Public Health standards because of the amount of dissolved solids present, 13 from excessive amounts of sulfate, 15 from fluoride content, 4 each from high amounts of chloride or iron, and one from phenol alkalinity. Only 12 of the wells registered for possible drinking water fail in only one category. None of the wells registered for drinking water contain unsuitable amounts of arsenic, copper, zinc, lead, or nitrates. Averages are shown in Appendix E.

The dissolved solids, chloride, and sulfate concentrations limits of the Public Health Service are set because of taste and laxative effects of water exceeding those standards. As the factor of acclimatization is particularly important, a well with excessive amounts of dissolved solids, chloride, or sulfate is not necessarily unusable. Many of the natives of the area dislike waters not containing large concentrations of the three. Well 39, a public well, contains over three times the maximum value of dissolved solids recommended by the Public Health Service yet is used by many residents of the area for drinking water. The author found that except for an undesirably strong odor of H_2S, the water was not undesirable and seemed to contain a faintly sweet taste. The Public Health Service does conclude that water with excessive amounts of dissolved solids, chloride, or sulfate can be used without any obvious ill effects (U. S. Dept. of H. E. W., 1962, p. 34).

Iron is objectionable in domestic water for both its taste effects and tendencies of staining laundry and plumbing fixtures. Many who use well water for watering lawns and gardens in the thesis area also complained of the stain iron had imparted to such things as the siding on their houses from the lawn watering spray. Iron was, in fact, the mineral most often found objectionable among well users.

The average concentration of fluoride in the waters of the domestic wells of the thesis area is very near the optimum value for the area. Using the annual average maximum daily air temperature at Montrose [(64.3° F), App. A] the optimum concentration is 0.9 ppm and the upper limit is 1.2 ppm (U. S. Dept. of H. E. W., 1962, p. 8). More than 35% of the drinking water wells do contain concentrations at or above the upper limit, though. This fact is well known in the thesis area and well 46 was recommended by a Montrose dentist for testing because of its suspected high fluoride content. Its concentration of 1.3 ppm was, in fact, over the upper limit of the Public Health Service but was far from being the well with the highest fluoride content (App. F). The wells with concentrations of fluoride at rejectable levels are usable but tend to produce fluorosis in users (U. S. Dept. of H. E. W., 1962, p. 41). Fluorosis is present in many residents of the thesis area who had used well water for drinking purposes for a number of years during childhood. Concentrations in all test samples were well below levels causing acute health problems such as bone fluorosis.

Phenols are the only other substance found in samples from domestic wells in quantities objectionable by Public Health standards. Well 77, registered as domestic, was the only well tested with a detectable amount of phenols. The well was actually in use for stock watering only. Concentrations are objectionable in domestic water because carbolic acid, C_6H_5OH, the first of the phenols, is extremely destructive in its action on animal tissues (Keenan and Wood, 1957, p. 714). At the concentration found in the one well, there is little likelihood of danger because of its usual detoxification by other substances.

The other five substances mentioned by the Public Health Service, for which tests were conducted, are copper and zinc that are mentioned only because of the undesirable taste they may impart to water and arsenic, lead, and nitrates that are quite hazardous to health. The small portions of copper and zinc found in some samples are actually an asset as the two are essential in human metabolism. Of the other three, arsenic and lead are well known poisons while nitrates have been found to be extremely dangerous to infants in even very small amounts.

None of the other tests concerned quality factors that are of great importance in domestic use. Analysis was not made for bacterial content because laboratory facilities for this were not available. No instances of illness attributed to well water were reported in interviews with well owners. Ground water drawn from all aquifers tapped by the tested wells can be generally summarized as not having any prevalent mineral qualities that are unhealthful. The water does tend to possess mineral quantities producing odors, bad tastes, or staining tendencies.

C. Industrial Use Quality

The ground water of the thesis area is of a generally poor quality for industrial use. The excessive amounts of calcium and magnesium indicate most ground waters would produce scaling and corrosion (APHA, AWWA, and WPCF, 1960, p. 40). The silica content is such that crusting would be a problem. The iron and sulfate levels are also too high for most industrial uses. The amounts of sodium present would tend to cause foaming in boilers (Anderson, 1969, p. 45). In summation, little can be said in favor of thesis area ground water for industrial use.

D. Agricultural Use Quality

The quality of ground water for agricultural use is determined both by its dissolved constituents and the type of use. Ground water is suitable for the watering of stock in almost all cases while some wells produce water that has a poor rating for irrigation.

Stock watering is probably the use for which the ground water of the thesis area is best suited. The poisonous minerals such as lead and arsenic are nowhere present in dangerous concentrations. Stock seem to tolerate up to 5000 ppm of dissolved solids (Walton, 1970, p. 459). Only the sample from well 79 approaches that amount or exceeds it. Water from that well, registered for stock use, is not being used at the present time because the owner's cattle refuse to drink it. Whether the excessive amount of dissolved solids is their reason for refusal is open to debate because of the unusually high concentration of various other substances which might also tend to cause the stock to not drink it. Hem (1959, p. 243) states that water containing high concentrations of sodium or magnesium and sulfate are very undesirable for stock use. The high concentrations of these minerals in water from several of the wells makes them poor sources of stock water. According to a sizable number of sheep and cattle ranchers in the thesis area, stock prefer well water to the surface water of the area. The stable year-round temperature of water from the deeper wells is an asset for stock watering. Not only does it mean that the temperature of water stays above freezing, but this temperature makes the water more acceptable to the stock.

Use of ground water for irrigation deserves a study of the water to be used and the crops to be grown. For instance, beans and such fruits as apples have a low salt tolerance while barley and sugar beets have a high tolerance (Walton, 1970, p. 463-464). All are important crops in the area and salts are found in the area's ground water in varying amounts. Boron is an element that, in many areas of the West, may be present in amounts toxic to plants. In the ground water of the thesis area, no high concentrations of boron were found and as the element is essential to plant nutrition, the amounts of boron present may be an asset. Many metals are also needed for plant nutrition and are present in the area's ground water. While high concentrations of them will cause discoloration and abnormal plant shapes and sizes (Hawkes and Webb, 1962, p. 306), none of those metals such as copper, iron, or zinc are present in harmful amounts.

Ratios of certain minerals to one another is also an important factor in evaluating groundwater quality for irrigation. The most important of these is the sodium content in relation to the amounts of calcium and magnesium. When water with a high concentration of sodium is used for irrigation, some of the calcium and magnesium of the clays in the soil is exchanged for the sodium. This exchange of ions, called base exchange, causes the soil to become sticky and slick when wet and to be low in permeability. The soil shrinks into hard clods when dry (Johnson, 1966, p. 78-79). A high concentration of the sodium salts develops a highly saline soil. Figure 7 shows a field that has developed such a condition. The ground water of the thesis area has an acceptable ratio of the three minerals except that water from some of the deeper wells. A factor that must be kept in mind in the case of all minerals in the ground water is the tendency of mineral build-up in the soil as there is very little leaching in the area because of the low rainfall.

E. History of Quality

Groundwater quality has probably deteriorated in the bedrock aquifers since they were first tapped. Long time residents of the thesis area noted that in their opinions' water from older wells seemed to be poorer in quality than when first drilled. It is the author's opinion that this is the result of groundwater pollution through abandoned wells that have not been sealed and through poor well casing. Without some type of control on these pollution factors, the groundwater quality of the thesis area will probably continue to worsen.

IX. GROUNDWATER QUANTITY

Available groundwater quantities are a major limiting factor in the Uncompahgre Valley area. Only three wells known to tap bedrock aquifers have yields of fifty gallons per minute or more. Alluvial aquifers tend to have a higher yield but still have a median yield of only 30 gallons per minute. The average and median yields of all registered wells in the thesis area and of two sets of 73 wells each tapping bedrock and alluvial aquifers are as follows:

	All Wells	Bedrock Source Wells	Alluvial Source Wells
Mean	55 gpm	16 gpm	104 gpm
Median	30 gpm	12 gpm	30 gpm

Reasons for the difference between mean and median values include the presence of a few wells yielding in the order of 1000 gpm from alluvial aquifers whose only recharge is irrigation water which has leaked downward and the inclusion of registered wells which proved to be dry.

Yields as low as the above tend to limit possible uses. Available quantities alone make industrial use of ground water impractical. For agricultural and domestic use, ground water of the thesis area is usually available in suitable amounts. Yields of wells tapping groundwater sources are usually larger to the west or nearer the probable recharge areas. In recent alluviums of the Uncompahgre River, yields are better upstream. This is probably due to depletion of stream waters by irrigation canals. A third set of aquifers, those atop the various mesas to the west of the Uncompahgre River, yield substantial amounts of water during the irrigation season with the yield approaching 900 gpm from several wells on Ash Mesa near the Montrose-Delta County line. During the winter months this source is dry. For lawn watering and field crop irrigation, this makes a fine source as during the months that it is dry or low in yield, the requirements are also small. For stock watering, household use, and other year-round water uses, bedrock aquifers should be utilized.

Although testing of the yield of wells is required by Colorado groundwater law, only about one third of the wells in the thesis area have test results which give the length of time the well was tested, the yield, and the drawdown. Most of those that have been tested were tested for not over two hours with a bailer so a good set of test results of well yields in the area is not available.

Using the test result records that are available, the specific capacity of wells from alluvial aquifers averages between 10 and 15 gpm/ft. of drawdown. A set of five wells, drawing from Recent alluvium, field location unconfirmed, located just to the west of the Uncompahgre River about three miles south of Montrose, were pumped at rates of over 300 gpm for from 18 to 24 hours. These 42 inch diameter wells showed specific capacities of from 72 to 89 gpm/ft. of drawdown.

Wells with bedrock sources showed very low specific capacities. Several of them are less than 0.1 gpm/ft. of drawdown. The median and mean specific capacities are 0.24 and 0.49 gpm/ft. of drawdown respectively. An aquifer listed on many well logs as a white sandstone 40 to 50 feet thick seems to be the best aquifer in quantity. It is about 200 feet below the surface in the areas most heavily used for ground water and probably makes up the Burro Canyon formation or the base of the Dakota formation.

There are many flowing artesian wells in the thesis area, although yields are generally small. Of the wells upon which water quality tests were performed, over one half of those tapping confined aquifers are flowing. Almost all of the wells into confined aquifers do have a sizable artesian head even if they are not flowing. Not one of the flowing artesian wells is also pumped. An increase in water quantity might be accomplished if flowing artesian wells were also pumped to increase flow.

The logs of the 96 wells with locations that were field checked are listed in Appendix H. Where the information is available, the aquifer or aquifers are indicated.

X. COMPARISON OF GROUND WATER TO SURFACE WATER

A. Factors Involved

Three factors must be taken into account when comparing the practicality of groundwater use to surface water use in the thesis area. These factors are the quantity available, the quality of the available water, and the comparative costs of these waters.

B. Industrial Use

The undesirability of ground water for industrial use because of the small amounts available is further compounded by the high amounts of certain minerals and dissolved solids. Although better in quality than most ground waters, the surface water supplies are also inferior to the standards set for many industries. The sulfate content is especially bad. In summary, the entire water supply of the area is not very conducive to industrial development.

C. Agricultural Use

For agricultural use, surface water seems to be a better source of supply for irrigation, while ground water is usually superior for stock watering. Ground water is a poorer source of water for irrigation not because of quality but, once again, because of quantity. The extensive Uncompahgre Project, mentioned earlier in the paper, offers a source of supply for irrigation that is of a volume large enough to meet crop needs. Ground water is not completely dominated in irrigation, however. Near the Uncompahgre River, adequate supplies are available for irrigation. On the gravel-topped mesas the surplus irrigation water that has percolated downward also makes a sizable irrigation water supply. With these groundwater supplies, the largest problem is obtaining legal rights to the amounts of water needed.

It is in the watering of stock that ground water holds the firmest edge over surface water. Ground water for stock watering purposes is probably more abundant than surface water available for that purpose. Ground water is actually preferred by the animals themselves over surface waters, but ground water, assuming its source is a bedrock aquifer, is especially desirable in the winter because of its constant year-round temperature. The relative warmth of the water eliminates the need to maintain ice-free watering locations; as long as the ground water is allowed to maintain some sort of flow once it reaches the surface. The warmer water is, once again, preferred by stock. Watering troughs supplied directly by ground water also keeps water losses from evaporation lower than do stock watering ponds.

D. Domestic Use

Domestic water use is much less clearly an area of superiority for either ground water or surface water. The preferences of each individual is the factor that clouds the choosing between the two more than anything. With the coming of the rural domestic water systems, many residents of the newly served areas abandoned their old domestic water wells to use the less highly mineralized water being piped in. Yet many people, with water coming from the same aquifer, refused the new water because of the lack of minerals to which they had become accustomed. More people dislike ground water for domestic use because of its usual staining effects than for any other reason. Except for the more remote areas not served by the rural water system, adequate supplies of water are available from both surface and subsurface sources. In these areas, ground water of very good quality is available with the exception of the Badlands subdivision, where possible groundwater sources are very far below the surface. The cost factor also enters into the picture in the determination of which source to use. Using the rates of the Tri-County Water Conservancy District, one pays $6.00 if use is less than 2000 gallons a month; $1.50 per 1000 gallons for the next 3000 gallons, up to 5000 gallons; $.80 per 1000 gallons for the next 30,000 gallons, up to 35,000 gallons; $.60 per 1000 gallons for the next 65,000 gallons, up to 100,000 gallons; $.50 per 1000 gallons for the next 100,000 gallons, up to 200,000 gallons; and $.40 per 1000 gallons for all water used above

200,000 gallons. This is the general rate for rural users of domestic water systems in the thesis area if one disregards any system membership dues or assesments and the initial cost of connecting onto the system. If we disregard possible maintenance expenses, the only cost of ground water is the power supply for pumping the water and even this cost is eliminated if the well supplying the water is of the flowing artesian variety. This cost difference is the main reason why most well users have continued to use the ground water as their source of domestic supply. In most cases where the well owner has connected onto a domestic water system, the well is not completely abandoned but is used for the watering of gardens and lawns and other outside uses with the new supply connected to inside plumbing only.

The factor of cost tends to tip the scales the other way for someone wanting a new domestic system. The usual cost of well drilling in the thesis area is about $3.00 per foot (including casing) and the average well depth is about 100 feet when shallow wells used to tap the summer sources are not included. A domestic well not tapping an aquifer supplying good quality water at rates that might be needed is probably a poor choice for a water supply. These costs naturally differ somewhat depending on many factors so each location is actually a new situation.

XI. CONCLUSIONS

The results of this study can be summarized as follows:

1). Two major groundwater sources are located in the area. The alluvial aquifers consist of the Holocene deposits of the Uncompahgre River and the Quaternary terrace gravels. The bedrock aquifers tapped in the area are the Dakota and the Morrison.

2). Investigations into possible other, deeper sources such as the Jurassic Entrada formation should be made.

3). Groundwater quality is generally poor. The major problems are high concentrations of dissolved solids, sulfate, chloride, fluoride, iron, and sodium. Although no well has objectionable quantities of all of these minerals, only a few wells do not have at least one problem in chemical content.

4). Although the water quality is not good, there are no health hazards prevalant in the ground water of the area.

5). The prevalent use of ground water in the area is for domestic purposes, with stock watering next in importance. Little irrigation water comes from groundwater sources.

6). Sources outside the area are used for urban supplies and much of the irrigation water. The rest of the irrigation water is from the Uncompahgre River.

7). The quantity of ground water present in the bedrock aquifers is too low for uses other than stock watering and domestic uses. Precisely how much water is available has not been determined.

8). More groundwater knowledge is needed. Specifically, more wells need to be under the law so that better knowledge of the sources of supply can be established to avoid possible overdrafting of the aquifers.

9). Controls need to be established on abandoned wells so that possible pollution of aquifers by them can be avoided.

10). Stricter attention to well registrations is needed. Without accurate data on wells, the correct controls are impossible.

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VITA

Ted William Craig was born on September 6, 1947, in Springfield, Missouri. He received his primary and secondary education in Mountain Grove, Missouri. He has received his college education from Drury College, in Springfield, Missouri; the University of Missouri-Columbia, in Columbia, Missouri; Southwest Missouri State College, in Springfield, Missouri; and the University of Missouri-Rolla, in Rolla, Missouri. He received a Bachelor of Arts degree in Biology and in Geology from Drury College, in Springfield, Missouri, in June, 1969. He married the former Connie Jean Sims of Montrose, Colorado, on June 4, 1970. He has been enrolled in the Graduate School of the University of Missouri-Rolla since August 1969.

APPENDICES

Appendix A

Climatological Data
Montrose No. 2 Reporting Station

Precipitation and Evaporation
[reading in inches]

	Averages		Extremes[2]	
	Evaporation Rate[3]	Total Melted Precipitation[1]	Most	Least
Jan.	1.34	.65	1.94	.05
Feb.	1.53	.60	1.49	T
Mar.	3.37	.65	2.24	T
Apr.	5.89	.98	2.80	T
May	8.05	.74	2.73	.07
Jun.	9.31	.49	2.51	0
Jul.	9.14	.70	2.27	.02
Aug.	7.75	1.25	3.42	.06
Sep.	5.35	.96	4.26	.03
Oct.	3.38	.93	3.13	0
Nov.	1.70	.57	1.73	.03
Dec.	1.25	.59	1.62	.10
Year	58.06	9.11	13.97	6.19

(1) based on standard thirty year weather bureau averages

(2) from Uncompahgre Water Users' Assoc. files, 1958-1970; and Montrose Daily Press files, 1924-1970.

(3) compiled from readings 1958-1970

Appendix A

Climatological Data
Montrose No. 2 Reporting Station

Temperature [Fahrenheit]

	Averages[1]			Extremes[2]	
	Average Maximum	Average Minimum	Average	Highest	Lowest
Jan.	38.6°	14.3°	26.5°	63°	-23°
Feb.	43.3°	19.3°	31.3°	72°	-23°
Mar.	52.2°	26.0°	39.1°	75°	- 3°
Apr.	63.0°	34.5°	48.8°	89°	2°
May	73.3°	42.4°	57.9°	91°	23°
Jun.	84.6°	50.0°	67.3°	102°	32°
Jul.	90.6°	56.0°	73.3°	103°	35°
Aug.	87.3°	54.2°	70.8°	106°	37°
Sep.	80.1°	46.5°	63.3°	95°	27°
Oct.	67.1°	35.8°	51.5°	87°	14°
Nov.	50.4°	23.2°	36.8°	77°	- 8°
Dec.	40.9°	16.3°	28.6°	68°	-21°
Year	64.3°	34.9°	49.6°		

(1) based on standard thirty year weather bureau averages

(2) from Uncompahgre Water Users' Assoc. files, 1958-1970; and Montrose Daily Press files, 1924-1970.

Appendix B

Average Snowdepth Measurements at Two Higher Altitudes in Uncompahgre River Drainage Basin (measurements in inches)

Ironton Park
Sec. 29, T. 43 N., R. 7 W.
altitude - 9,800 feet

Date	Snow Depth	Water Content
Feb. 1	31.1	7.66
Mar. 1	39.9	11.14
Apr. 1	42.5	13.48
May 1	19.6	7.42

Red Mountain Pass
Sec. 13, T. 42 N., R. 8 W.
altitude - 11,000 feet

Date	Snow Depth	Water Content
Jan. 1	48.0	11.40
Feb. 1	65.2	18.27
Mar. 1	81.6	24.90
Apr. 1	89.7	31.22
May 1	77.6	31.065
May 15	61.3	27.175
Jun. 1	24.7	12.16

from Washichek, Stockwell, and Evans, 1963;
Washichek and McAndrew, 1967;
and Washichek and Moreland, 1967-1971.

Appendix C

Chemical Analyses of Individual Well Water Samples [a]

Well Number	2	3	4	6
Owner or Operator	Byers	Bailey	Blackstone	Wright
Use*	S	I	I	D
Depth (in feet)	48	36	40	38
Temperature (Centigrade)	19°	13°	13°	13°
pH [b]	7.2	7.3	7.4	7.2
Conductivity [c]	1340	1380	1300	1700
Phenol Alkalinity [d]	0	0	0	0
Total Alkalinity [d]	265	320	285	490
Suspended Solids	14.0	6.8	0.5	6.4
Dissolved Solids	1102	922	840	1272
Total Solids	1116	928	840	1278
Phosphate (PO_4)	0.03	0.07	0.04	0.05
Nitrate (NO_3)	6.6	7.48	6.60	17.6
Sulfate (SO_4)	530	370	385	450
Chloride (Cl)	145	40	52.5	27.5
Fluoride (F)	1.2	1.0	1.15	1.9
Arsenic (As)	0.00	0.00	0.00	0.00
Lead (Pb)	0.0	0.0	0.0	0.0
Iron (Fe)	0.04	0.02	0.10	0.02
Copper (Cu)	0.0	0.0	0.0	0.0
Zinc (Zn)	0.0	0.08	0.01	0.0
Magnesium (Mg)	47.2	46.22	39.9	23.84
Silica (SiO_2)	37.5	25.0	27.5	35
Potassium (K)	1.5	1.0	2.0	1.2
Sodium (Na)	74	112	112	116
Calcium (Ca)	253.6	190	193.6	132.8
Boron (B)	0.06	0.05	0.15	0.06

*C-Commercial; D-Domestic; I-Irrigation; S-Stock.

[a] results in parts per million unless noted otherwise

[b] logarithm of reciprocal of hydrogen ion concentration

[c] in micromhos per centimeter

[d] as $CaCO_3$

Individual Well Test Results

Number	8	9	10	11	15
Owner	Anderson	Boyer	Clubb	McIntire	Webb
Use	S	D	D	D	D
Depth	933	25	230	30	55
Temp.	13°	18°	17°	13°	13°
pH	6.9	7.2	7.8	7.4	7.7
Conduct.	3800	1800	1700	1200	2200
Phenol	0	0	0	0	0
Tot. Alk.	2575	300	650	310	180
Sus. Sol.	27.0	30.4	4.0	4.4	2.0
Dis. Sol.	2566	1692	936	784	2338
Tot. Sol.	2593	1722	940	788	2340
PO_4	0.1	0.06	0.03	0.03	0.05
NO_3	0.26	4.8	0.22	5.72	3.9
SO_4	10	640	145	260	1120
Cl	12.5	17.5	362.5	10.0	12.5
F	1.1	2.5	1.30	1.7	.15
As	0.00	0.00	0.00	0.00	0.00
Pb	0.0	0.0	0.0	0.0	0.0
Fe	0.03	0.05	0.03	0.03	0.06
Cu	0.0	0.0	0.0	0.0	0.0
Zn	0.0	0.0	0.0	0.0	0.0
Mg	14.11	39.9	7.2	54.50	64.23
SiO_2	16.25	42.0	20	31.25	40
K	9.0	1.8	4.0	1.5	2.2
Na	1200	108	508	60	111
Ca	42.4	403.2	20	202.4	526.4
B	0.35	0.06	0.05	0.06	0.10

Individual Well Test Results

Number	16	17	19	21	22
Owner	Distel	Burch	Carrico	Distel	Keep
Use	D&S	D	D	D&S	S
Depth.	420	75	237	195	17
Temp.	19°	14°	15°	15°	13°
pH	7.2	6.9	7.3	7.1	7.1
Conduct.	3700	4100	1700	2000	1800
Phenol	0	0	0	0	0
Tot. Alk.	1995	580	710	1030	320
Sus. Sol.	4.5	186.5	1.5	95.6	7.27
Dis. Sol.	2090	4534	776	1156	1344
Tot. Sol.	2094	4720	777	1251	1351
PO_4	0.03	0.04	0.01	0.07	0.04
NO_3	0.3	0.22	0.26	0.22	6.6
SO_4	110	2600	145	120	710
Cl	82.5	52.5	95	42.5	15.0
F	1.12	0.95	1.30	4.3	1.0
As	0.00	0.00	0.00	0.00	0.00
Pb	0.0	0.0	0.0	0.0	0.0
Fe	0.05	0.1	0.05	0.12	0.03
Cu	0.0	0.0	0.0	0.0	0.0
Zn	0.01	0.0	0.0	0.0	0.01
Mg	9.24	344.2	6.32	18.97	83.21
SiO_2	18.75	18.75	13.75	18.75	27.5
K	7.0	2.5	4.5	6.0	3.0
Na	1025	215	540	650	152
Ca	20.8	524	15.0	40.8	167.2
B	0.06	0.05	0.06	0.30	0.06

Individual Well Test Results

Number	24	25	27	28	29
Owner	Homewood	Meaker	Lechleiter	Deines	Wright
Use	D&S	S	D	D&S	S
Depth	268	1090	100	171	245
Temp.	19°	21.5°	13°	17°	15.5°
pH	7.2	6.4	7.3	7.5	6.8
Conduct.	980	3300	1500	700	1280
Phenol	0	0	0	0	0
Tot. Alk.	330	2040	490	505	610
Sus. Sol.	6.4	31.2	11.6	0.2	6.4
Dis. Sol.	562	2180	932	506	654
Tot. Sol.	568	2211	943	506	660
PO_4	0.04	0.04	0.04	0.06	0.04
NO_3	0.08	0.3	0.39	3.96	0.26
SO_4	120	130	260	10	90
Cl	20.0	167.5	22.5	7.5	300
F	2.5	1.1	0.95	0.35	1.15
As	0.00	0.00	0.00	0.00	0.00
Pb	0.0	0.0	0.0	0.01	0.0
Fe	0.49	0.02	0.02	0.03	0.01
Cu	0.0	0.0	0.0	0.02	0.0
Zn	0.0	0.0	0.0	0.65	0.07
Mg	25.79	16.54	49.63	34.06	27.73
SiO_2	20	37.5	21.25	28.7	13.75
K	3.5	9.5	2.2	0.09	4.5
Na	215	1010	275	68	305
Ca	54.4	49.6	107.2	116	54.4
B	0.06	0.30	0.10	0.10	0.03

Individual Well Test Results

Number	31	32	34	36	38
Owner	Carmichael	Price	Drake	Lutz	English
Use	D	D	D	D	D
Depth	565	40	55	50	195
Temp.	17.5°	15°	15°	12°	13°
pH	6.7	7.2	7.3	7.5	7.2
Conduct.	2700	960	2700	760	960
Phenol	0	0	0	0	0
Tot. Alk.	1530	280	280	375	410
Sus. Sol.	8.6	3.0	5.8	5.2	2.8
Dis. Sol.	1594	800	2392	490	684
Tot. Sol.	1602	803	2397	495	686
PO_4	0.03	0.03	0.04	0.03	0.02
NO_3	0.22	2.64	2.68	5.28	0.22
SO_4	110	210	1420	30	81
Cl	75	17.5	287.5	7.5	17.5
F	1.13	0.4	0.92	0.35	1.25
As	0.00	0.00	0.00	0.00	0.00
Pb	0.0	0.01	0.0	0.0	0.01
Fe	0.06	0.35	0.11	0.03	1.0
Cu	0.0	0.01	0.0	0.0	0.02
Zn	0.0	0.0	0.02	0.0	0.0
Mg	40.87	32.8	104.62	35.03	24.3
SiO_2	18.75	37.7	17.5	31.25	28.7
K	4.5	1.0	4.0	1.0	11
Na	880	105	108	83	350
Ca	77.6	160	577.6	106.4	50
B	0.14	0.025	0.25	0.25	0.04

Individual Well Test Results

Number	39	40	41	44	46
Owner	Montrose	Feed Lot	Carper	Smith	Johnston
Use	D	S	C	D	S
Depth	900	47	26	40	120
Temp.	23	15	15	16	13
pH	6.8	7.5	7.8	7.3	7.5
Conduct.	2950	770	340	800	520
Phenol	0	0	0	0	0
Tot. Alk.	15.05	260	95	250	305
Sus. Sol.	26.6	5.2	1.2	1.6	5.0
Dis. Sol.	1805	520	250	426	372
Tot. Sol.	1831	525	251	427	377
PO_4	0.065	0.05	0.04	0.04	0.05
NO_3	0.22	3.9	0.13	4.18	1.1
SO_4	252	75	65	160	30
Cl	62.6	140	12.5	12.5	10
F	1.925	0.4	0.66	0.12	1.3
As	0.00	0.00	0.00	0.00	0.00
Pb	0.00	0.01	0.0	0.0	0.0
Fe	0.095	0.07	0.05	0.04	0.28
Cu	0.0	0.0	0.02	0.0	0.01
Zn	0.045	0.04	0.0	0.016	0.25
Mg	15.75	18.49	23.1	14.59	15.8
SiO_2	16.6	27.5	35	28.75	32.5
K	40.5	2.0	1.0	1.5	2.0
Na	622	65	35	49	135
Ca	116	132.8	46	126.4	30
B	0.14	0.05	0.0	0.06	0.10

Individual Well Test Results

Number	50	51	52	55	60
Owner	Hance	Jackson	Colorado	Bush	Peak
Use	D	D	D	D	D
Depth	310	50	38	148	297
Temp.	15°	14°	14°	11°	15.5°
pH	6.9	7.4	7.2	7.1	7.6
Conduct.	1220	640	2500	1700	950
Phenol	0	0	0	0	0
Tot. Alk.	590	270	385	250	670
Sus. Sol.	5.0	5.65	37.2	33.2	2.6
Dis. Sol.	664	456	1748	1250	758
Tot. Sol.	669	461	1785	1283	760
PO_4	0.02	0.03	0.03	0.03	0.03
NO_3	0.17	1.32	2.11	0.22	0.13
SO_4	20	0.30	2000	440	30
Cl	32.5	267.5	20.0	400	12.5
F	1.15	0.70	0.5	0.85	1.25
As	0.00	0.00	0.00	0.00	0.00
Pb	0.0	0.0	0.0	0.0	0.0
Fe	0.08	0.01	0.02	0.2	0.12
Cu	0.0	0.0	0.0	0.0	0.01
Zn	0.01	0.0	0.0	0.0	0.0
Mg	23.1	18	85.15	78.34	14.5
SiO_2	16.25	23.75	32.51	16.25	28.7
K	6.0	1.1	2.2	9.0	2.5
Na	337	57	216	145	390
Ca	28.0	92	600	194	10
B	0.06	0.16	0.14	0.06	0.06

Individual Well Test Results

Number	61	64	70/71	75	77
Owner	Hotchkiss	Benedict	Chipeta	Corman	Jones
Use	D	D	D&S	D	D
Depth	165	168	22/21	140	542
Temp.	14.5°	14°	11.5°	15.5°	19°
pH	7.4	7.2	7.4	7.3	6.4
Conduct.	520	770	860	1060	2800
Phenol	0	0	0	0	100
Tot. Alk.	203	190	295	300	1440
Sus. Sol.	4.8	3.8	3.4	14.0	3.4
Dis. Sol.	262	462	578	620	2028
Tot. Sol.	266	465	581	634	2031
PO_4	0.04	0.04	0.03	0.02	0.25
NO_3	0.39	0.35	3.9	0.22	0.132
SO_4	70	110	110	225	225
Cl	10.0	17.5	130	22.5	110
F	1.5	0.33	0.70	0.40	1.3
As	0.00	0.00	0.00	0.00	0.00
Pb	0.0	0.0	0.0	0.0	0.01
Fe	0.01	0.06	0.06	0.15	0.35
Cu	0.0	0.0	0.0	0.0	0.01
Zn	0.02	0.0	0.01	0.0	0.0
Mg	10.7	47.20	87.1	25.3	32.8
SiO_2	18.75	33.75	26.25	23.75	32.75
K	3.0	1.5	2.0	2.5	18
Na	74	65	57	92	1020
Ca	41.6	85.6	144.8	112.8	62
B	0.05	0.04	0.05	0.10	0.17

Individual Well Test Results

Number	79	80	81	82	83
Owner	Collins	Cooper	Twombly	Weiscamp	Luttrell
Use	S	I	D&S	D	D
Depth	255	250	140	50	50
Temp.	15.5°	14.5°	16.5°	14.5°	16°
pH	6.7	7.1	7.0	7.0	7.2
Conduct.	8000	4800	960	960	860
Phenol	0	0	0	0	0
Tot. Alk.	355	1980	240	325	290
Sus. Sol.	8.6	10.0	8.0	14.4	1.8
Dis. Sol.	11494	2728	772	658	728
Tot. Sol.	11502	2738	780	672	729
PO_4	0.08	0.07	0.02	0.02	0.04
NO_3	360.8	0.3	3.34	4.4	4.4
SO_4	7550	860	305	211	200
Cl	70	262.5	25	12.5	12.5
F	1.12	1.0	0.92	0.35	0.4
As	0.00	0.00	0.00	0.00	0.00
Pb	0.01	0.0	0.0	0.0	0.0
Fe	2.47	0.02	0.63	0.05	0.08
Cu	0.02	0.0	0.01	0.0	0.03
Zn	0.0	0.0	0.0	0.0	0.0
Mg	1047	8.5	30.4	25.3	32.8
SiO_2	28.7	18.75	28.7	32.5	47.5
K	10	6.0	2.0	2.9	1.0
Na	1800	1430	105	72	52
Ca	968	20	60	180.8	130
B	0.0	0.05	0.0	0.06	0.01

Individual Well Test Results

Number	85	89	90	93	94	95
Owner	Flowers	Donley	Sanders	Shaver	Shott	Colby
Use	D	S	D	D	S	D
Depth	48	100	224	60	341	60
Temp.	13°	7.5°	13°	6°	14°	16.5°
pH	7.5	7.3	6.8	-	6.6	7.2
Conduct.	620	660	620	225	3100	1180
Phenol	0	0	0	0	0	0
Tot. Alk.	250	260	250	130	1430	425
Sus. Sol.	1.4	9.56	3.4	1.0	2.2	2.0
Dis. Sol.	580	288	474	132	1474	988
Tot. Sol.	581	297	477	133	2476	990
PO_4	0.05	0.02	0.03	0.03	0.02	0.03
NO_3	1.84	0.17	0.35	0.22	0.13	4.4
SO_4	165	30	66	30	510	425
Cl	10	90	12.5	7.5	130	17.5
F	0.45	0.20	0.91	0.0	1.15	0.5
As	0.00	0.00	0.00	0.00	0.00	0.00
Pb	0.0	0.0	0.03	0.01	0.0	0.0
Fe	0.01	0.2	1.08	0.06	0.65	0.05
Cu	0.02	0.0	0.01	0.01	0.01	0.03
Zn	0.33	0.01	0.31	0.7	0.0	0.0
Mg	45	28.22	29.1	15.8	15.8	6.0
SiO_2	45	13.75	30	28.7	43.2	47.2
K	1.0	1.5	1.9	0.0	15.0	1.0
Na	49	25	100	2.3	1134	82
Ca	116	76.0	48	28	126	266
B	0.01	0.04	0.05	0.0	0.11	0.05

Appendix D

Drinking Water Standards of
the U.S. Public Health Service

Substance	Recommended Limits	Limits of Rejection[1]
Arsenic (As)	0.01	0.05
Chloride (Cl)	250.	-
Copper (Cu)	1.	-
Fluoride (F)[2]	1.2	1.8
Iron (Fe)	0.3	-
Lead (Pb)	-	0.05
Nitrate (NO_3)	45.	-
Phenols	0.001	-
Sulfate (SO_4)	250.	-
Total Dissolved Solids	500.	-
Zinc (Zn)	5.	-

(1) concentrations in mg/l

(2) concentrations allowed at annual average of maximum daily air temperatures of Montrose.

from Public Health Service,
Drinking Water Standards,
1962, p. 7-8.

Appendix E

Well Water Quality Averages and City Water Quality

	Well Water Averages Mean	Median	Montrose City Water (after treatment)
Temperature	14.7°	14.5°	-
pH	7.2	7.2	-
Conductivity	1720	1250	350
Phenol Alkalinity	2	0	0
Total Alkalinity	561.	315	65.0
Suspended Solids	13.7	5.2	14.8
Dissolved Solids	1333	792	228
Total Solids	1347	796	242
Phosphate (PO_4)	0.04	0.04	0.01
Nitrate (NO_3)	9.5	0.39	0.20
Sulfate (SO_4)	484	163	125
Chloride (Cl)	76	25	7.5
Fluoride (F)	1.0	1.0	0.085
Arsenic (As)	not detected - less than 0.001 in all samples		
Lead (Pb)	0	0	0.00
Iron (Fe)	0.19	0.055	0.01
Copper (Cu)	0	0	0.0
Zinc (Zn)	0.04	0	0.02
Magnesium (Mg)	59.7	28.0	4.8
Silica (SiO_2)	27.7	28.7	19
Potassium (K)	4.5	2.2	3.0
Sodium (Na)	332.	112	26.3
Calcium (Ca)	160.5	110.0	64
Boron (B)	0.08	0.06	0.05

Appendix F

Water Quality Extremes
(well no. in parenthesis)

Temperature	23^{o}	(39)	6^{o}	(93)
pH	7.8	(10, 41)	6.4	(25, 77)
Conductivity	8000	(79)	225	(93)
Phenol Alkalinity	100	(77)	0	(49 samples)
Total Alkalinity	2575	(8)	15.05	(39)
Suspended Solids	186.5	(17)	0.2	(28)
Dissolved Solids	11494	(79)	132	(93)
Total Solids	11502	(79)	133	(93)
Phosphate (PO_4)	25	(77)	0.01	(19)
Nitrate (NO_3)	360.8	(79)	0.08	(24, 60)
Sulfate (SO_4)	7550	(79)	0.30	(51)
Chloride (Cl)	400	(55)	7.5	(28, 36, 93)
Fluoride (F)	4.3	(21)	0.0	(93)
Arsenic (As)	not detected - less than 0.001 in all samples			
Lead (Pb)	0.03	(90)	0.0	(40 samples)
Iron (Fe)	2.47	(79)	0.01	(5 samples)
Copper (Cu)	0.03	(83, 96)	0.005	(35 samples)
Zinc (Zn)	0.65	(28)	0.01	(32 samples)
Magnesium (Mg)	1047	(79)	6.0	(95)
Silica (SiO_2)	47.5	(83)	13.75	(19, 29, 89)
Potassium (K)	40.5	(39)	0.0	(93)
Sodium (Na)	1800	(79)	2.3	(93)
Calcium (Ca)	968	(79)	10	(60)
Boron (B)	0.35	(8)	0.0	(4 samples)

Appendix G

List of Corrected Well Locations

In the process of locating the wells of the thesis area, the author found that many wells had been given inaccurate locations in their filing with the Colorado Division of Water Resources. Below is a list of these wells with the incorrect location given above the correct location. The number of wells with locations incorrectly given in their registration is undoubtably higher as this list contains only those wells with the location field checked by the author and found to be at least a ¼ section in error. The Colorado registration number is given with the number of the well as used in the thesis below in parenthesis.

Number	Location
750	NW¼, NW¼, Sec. 12, T. 47 N., R. 9 W.
(96)	NW¼, NW¼, Sec. 7, T. 47 N., R. 8 W.
2035	SE¼, NE¼, Sec. 36, T. 48 N., R. 10 W.
(50)	NE¼, SE¼, Sec. 36, T. 49 N., R. 10 W.
2212	SE¼, SE¼, Sec. 21, T. 51 N., R. 11 W.
(3)	SE¼, SE¼, Sec. 24, T. 51 N., R. 11 W.
4507	SE¼, SE¼, Sec. 24, T. 50 N., R. 11 W.
(19)	NE¼, NE¼, Sec. 25, T. 50 N., R. 11 W.
8525	SE¼, SE¼, Sec. 20, T. 51 N., R. 11 W.
(2)	SE¼, SW¼, Sec. 21, T. 51 N., R. 11 W.
9462	NE¼, SE¼, Sec. 26, T. 49 N., R. 10 W.
(38)	NE¼, SW¼, Sec. 26, T. 49 N., R. 10 W.
9511	SW¼, NE¼, Sec. 34, T. 49 N., R. 9 W.
(41)	SE¼, SW¼, Sec. 28, T. 49 N., R. 9 W.
11079	NE¼, SE¼, Sec. 11, T. 48 N., R. 10 W.
(72)	NE¼, NE¼, Sec. 11, T. 48 N., R. 10 W.

Number	Location
13881	NW¼, NE¼, Sec. 1, T. 48 N., R. 9 W.
(60)	NW¼, NE¼, Sec. 1, T. 48 N., R. 10 W.
14742	SE¼, SE¼, Sec. 15, T. 49 N., R. 10 W.
(29)	SW¼, SE¼, Sec. 15, T. 49 N., R. 10 W.
17244	SW¼, SW¼, Sec. 36, T. 49 N., R. 9 W.
(55)	SW¼, SW¼, Sec. 36, T. 49 N., R. 10 W.
19144	NW¼, NW¼, Sec. 35, T. 49 N., R. 9 W.
(43)	NW¼, NW¼, Sec. 35, T. 49 N., R. 10 W.
19489	NE¼, NW¼, Sec. 1, T. 47 N., R. 9 W.
(91)	NE¼, SW¼, Sec. 1, T. 47 N., R. 9 W.
22315	SW¼, SW¼, Sec. 6, T. 47 N., R. 9 W.
(95)	SE¼, NW¼, Sec. 7, T. 47 N., R. 8 W.
22647	NW¼, NW¼, Sec. 7, T. 48 N., R. 9 W.
(67)	NW¼, NW¼, Sec. 6, T. 48 N., R. 9 W.
23361	SE¼, NW¼, Sec. 35, T. 49 N., R. 10 W.
(47)	NW¼, SW¼, Sec. 35, T. 49 N., R. 10 W.
24541	SE¼, NE¼, Sec. 34, T. 49 N., R. 10 W.
(48)	NE¼, SE¼, Sec. 34, T. 49 N., R. 10 W.
26721	NW¼, SE¼, Sec. 32, T. 48 N., R. 9 W.
(83)	NW¼, SE¼, Sec. 26, T. 48 N., R. 9 W.
28773	SE¼, SE¼, Sec. 19, T. 49 N., R. 8 W.
(33)	NW¼, SW¼, Sec. 20, T. 49 N., R. 8 W.
29303	SE¼, SE¼, Sec. 22, T. 49 N., R. 9 W.
(82)	SW¼, SW¼, Sec. 23, T. 48 N., R. 9 W.
29384	NE¼, SW¼, Sec. 35, T. 49 N., R. 9 W.
(49)	NE¼, SW¼, Sec. 35, T. 49 N., R. 10 W.
31887	NW¼, NE¼, Sec. 26, T. 48 N., R. 9 W.
(85)	NW¼, NW¼, Sec. 36, T. 48 N., R. 9 W.

Number	Location
32404	NE¼, NW¼, Sec. 34, T. 50 N., R. 10 W.
(22)	NW¼, NE¼, Sec. 34, T. 50 N., R. 10 W.
33490	NW¼, NW¼, Sec. 3, T. 48 N., R. 9 W.
(58)	NW¼, NW¼, Sec. 3, T. 48 N., R. 10 W.
34769	NE¼, SE¼, Sec. 35, T. 49 N., R. 10 W.
(35)	SW¼, NE¼, Sec. 26, T. 49 N., R. 10 W.

Appendix H

Logs of Wells with Field Checked Locations

Listed below are the 96 wells whose locations were field checked. The numbering system of the wells is that of Fig. 5. The Colorado Well Registration number follows the assigned number in parenthesis. The owner or operator, location, elevation, depth, static water level, yield, use, and the well's log are also given as registered in the files of the Colorado Division of Water Resources in Denver. No corrections, changes, or additions are made except for the elevations, which were determined by the author in the field, and corrected locations. An "X" indicates an aquifer.

1 (2951) Holden NE¼, NW¼, Sec. 19, T. 51 N., R. 10 W. elev. 5228
depth 40' water level 21' yield 900 gpm use-irrigation

0- 1	top soil
1- 7	clay subsoil
7-29	Rock and gravel
29-34	Hard conglomerate
34-36	loose gravel
36-37	clay
37-	brown shale

2 (8525) Byers SE¼, SW¼, Sec. 21, T. 51 N., R. 11 W. elev. 5248
depth 48' water level 14' yield 20 gpm use- stock

0-15	adobe
15-19	gravel
19-30	clay
30-48	clay and sand

3 (2212) Bailey SE¼, SE¼, Sec. 24, T. 51 N., R. 11 W. elev. 5231
depth 36' water level 36' yield 750 gpm use-irrigation

0- 2	top soil
2- 5	clay
5-10	clay and rocks
10-16	boulders and gravel
16-36	rocks and gravel
36-	shale

4 (2213) Blackstone SE¼, SW¼, Sec. 19, T. 51 N., R. 10 W. elev. 5236

depth 40' water level 40' yield 900 gpm use-irrigation

0- 2	top soil
2- 5	clay
5-12	clay and rocks
12-27	boulders and gravel
27-29	clay
29-40	boulders and gravel
40-	shale

5 (3054) Holden NE¼, NE¼, Sec. 25, T. 51 N., R. 11 W. elev. 5237

depth 35' water level 20' yield 450 gpm use-irrigation

rock and gravel all

6 (41324) Wright SE¼, SW¼, Sec. 28, T. 51 N., R. 11 W. elev. 5296

depth 38' water level 23' yield 30 gpm use-domestic

0-10	soil	
10-28	sand and gravel	
28-32	boulders	X
32-38	sand and gravel	X

7 (13685) Kramer NW¼, NE¼, Sec. 36, T. 51 N., R. 11 W. elev. 5265

depth 693' water level-flow yield 5 gpm use-stock

0-642	old well
642-645	sand
645-679	shale
679-693	white sand

8 (2034) Anderson SE¼, NW¼, Sec. 32, T. 51 N., R. 10 W. elev. 5276

depth 933' water level 845' yield 3 gpm use-stock

0- 6	soil
6- 51	yellow shale
51-396	Mancos shale
396-490	small stratas rock and shale
490-494	gray rock
494-764	sandy shale
764-781	grey rock
781-810	hard sandrock and shale
810-817	brown sand
817-824	stratas sand and shale
824-845	brownish sand
845-863	white sand and water
863-894	stratas rock and shale
894-925	white sandstone
925-933	green shale and rock

9 (30941) Boyer NE¼, SE¼, Sec. 35, T. 51 N., R. 11 W. elev. 5331

depth 25' water level 9' yield 20 gpm use-domestic

0-15	gravel, boulders and sand	X
15-25	yellow clay	

10 (16861) Clubb SE¼, NE¼, Sec. 4, T. 50 N., R. 11 W. elev. 5401

depth 230' water level-flow yield 2 gpm use—domestic

0- 15	soil-sandy	
15- 19	gravel	
19- 36	clay and gravel	
36- 55	gravel and boulders	
55- 63	adobe	
63-130	shale	
130-146	shale and rock	
146-170	grey sandstone	
170-185	hard grey rock	
185-230	stratas sand and shale	X

11 (26451) McIntire SW¼, SE¼, Sec. 2, T. 50 N., R. 11 W. elev. 5402

depth 30' water level 5' yield 20 gpm use-domestic

0- 2	top soil	
2- 6	sand	
6- 7	clay	
7-28	small gravel and sand	X
28-30	yellow clay	

12 (18596) Luelf NW¼, NW¼, Sec. 9, T. 50 N., R. 11 W. elev. 5490

depth 260' water level 215' yield 5 gpm use-domestic

0-17	top soil	
17-25	sand stone	
25-30	sand and shale	
30-40	sandstone	
40-45	shale and bentonite	
45-53	shale and coal	X
53-62	sandstone	
62-75	coal	X
75-106	sandstone	X
106-117	green shale	
117-130	sand-some black shale	X
130-137	green shale	
137-139	sands	X
139-142	green shale	
142-145	white sand	X
145-164	red shale	
164-260	sand, ranging in color from tan to white	
260-262	black shale	

13 (22736) Silver NE¼, NE¼, Sec. 11, T. 50 N., R. 11 W. elev. 5405

depth 390' water level 370' yield 7 gpm use-domestic

0- 15	sand and clay
15- 35	sand and gravel
35-370	shale
370-390	sandstone

14 (11866) Horn SW¼, SE¼, Sec. 9, T. 50 N., R. 10 W. elev. 5327

depth 24' water level 5' yield 200 gpm use-irrigation

0- 9	top soil
9-23	cobble gravel sand
23-24	shale

15 (33696) Webb SE¼, SE¼, Sec. 7, T. 50 N., R. 10 W. elev. 5413

depth 55' water level 13' yield 30 gpm use-domestic

0-22	clay	
22-25	sand	X
25-32	clay	
32-34	gravel	X
34-42	clay	
42-55	shale	

16 (3099) Distel SW¼, NW¼, Sec. 18, T. 50 N., R. 10 W. elev. 5447

depth 420' no flow use-domestic and stock

0- 20	clay and gravel
20- 60	yellow shale
60-270	Mancos shale
270-300	stratas sand and shale
300-320	grey rock
320-354	sandrock and water
354-393	stratas sand and shale
393-420	white sandstone

17 (22737) Burch NE¼, SE¼, Sec. 16, T. 50 N., R. 11 W. elev. 5615

depth 75' water level 11' yield 10 gpm use-domestic

0- 9	sand and clay
9-40	shale
40-67	water bearing sand
67-75	shale

18 (17088) Pierson NW¼, SW¼, Sec. 20, T. 50 N., R. 10 W. elev. 5500

depth 407' no water level given yield-dry use-stock

0- 20	clay and boulders
20-330	shale
330-407	sand with shale streaks

19 (4507) Carrico NE¼, NE¼, Sec. 25, T. 50 N., R. 11 W. elev. 5485

depth 237' water level-flow use-domestic yield 15 gpm

0- 8	soil
8- 27	gravel
27-173	shale
173-180	stratas sand and shale
180-194	sandstone
194-226	stratas sand and shale
226-237	sandstone

20 (3809) Carrico SE¼, NE¼, Sec. 25, T. 50 N., R. 11 W. elev. 5495

depth 175' water level-flow yield 50 gpm use-domestic

0- 10	soil
10- 20	yellow shale
20-150	black shale
150-168	sandy shale
168-175	sandstone

21 (41231) Distel SE¼, SE¼, Sec. 25, T. 50 N., R. 11 W. elev. 5524

depth 195' water level-flow yield 30 gpm use-domestic and stock

0- 4	sandy soil	
4- 13	gravel	
13- 50	shale	
50- 81	stratas shale and sandstone	
81-105	sandstone	X
105-123	sandrock and shale	
123-136	sandrock	X
136-145	shale	
145-160	shale coal and rock	
160-193	sandstone	X
193-195	white shale and rock	

22 (32404) Keep NW¼, NE¼, Sec. 34, T. 50 N., R. 10 W. elev. 5458

depth 17' water level 8' yield 30 gpm use-stock

0- 8	adobe	
8-17	gravel	X

23 (36462) Homewood SW¼, SW¼, Sec. 32, T. 50 N., R. 10 W. elev. 5637

depth 340' water level-flow yield 10 gpm use-stock

0- 22	soil gravel and boulders
22- 53	yellow shale
53-225	black shale
225-232	sandstone X
232-275	sandstone stratas of shale
275-287	sandstone X
287-300	shale, rock and coal
300-340	sandrock

24 (36720) Homewood SW¼, SW¼, Sec. 32, T. 50 N., R. 10 W. elev. 5639

depth 268' water level-flow yield 5 gpm use-domestic and stock

0- 4	soil
4- 18	gravel and boulders
18- 53	yellow shale
53-200	black shale
200-241	sandstone
241-246	shale
246-265	sandstone
265-268	shale

25 (9993) Meaker SW¼, SW¼, Sec. 32, T. 50 N., R. 9 W. elev. 5701

depth 1090' water level-flow yield 2 gpm use-stock

0-950	Mancos
950-	Dakota

26 (6476) Coal Crk. Sch. Dist. NW¼, NE¼, Sec. 9, T. 49 N., R. 10 W. elev. 5708

depth 340' water level 6' yield 12 gpm use-domestic

0- 20	clay and gravel
20- 31	gravel
31-285	shale
285-340	sandstone

27 (41440) Lechleiter SW¼, SW¼, Sec. 9, T. 49 N., R. 10 W. elev. 5720

depth 100' water level 6' yield 30 gpm use-domestic

0-18	soil
18-33	gravel and boulders
33-35	shale
35-100	shadstone X

28 (35592) Deines NW¼, SE¼, Sec. 14, T. 49 N., R. 8 W. elev. 7068

depth 171' water level 105' yield 30 gpm use-domestic and stock

0- 6	soil	
6-105	stratas sand and clay	
105-121	red clay	X
121-132	sandy clay	X
132-147	black clay	X
147-159	yellow clay and sand	X
159-171	stratas clay and sand	X

29 (14742) Wright SW¼, SE¼, Sec. 15, T. 49 N., R. 10 W. elev. 5740

depth 245' water level-flow yield 12 gpm use-stock

0- 26	clay and gravel	
26- 34	gravel and boulders	
34-147	shale	
147-153	sandstone	
153-174	shale	
174-192	sandstone	
192-196	shale and rock	
196-237	sandstone	X
237-245	rock and shale	

30 (1243) Pulver NE¼, NW¼, Sec. 22, T. 49 N., R. 10 W. elev. 5820

depth 240' water level 92' yield 20 gpm use-domestic

0- 43	yellow shale
43- 92	Mancos shale
92-128	stratas sand and shale
128-143	sandstone
143-196	stratas sand, coal and shale
196-240	white sandstone

31 (19148) Carmichael NW¼, NW¼, Sec. 24, T. 49 N., R. 10 W. elev. 5800

depth 565' water level 15' yield 10 gpm use-domestic

0- 20	topsoil and clay	
20-370	shale, Mancos	
370-378	sandstone	
378-382	shale	
382-384	clay	
384-388	shale	
388-480	broken sandstone, Dakota	
480-483	clay	
483-488	coal	
488-530	limestone	
530-540	white clay	
540-555	white limestone	X
555-565	red clay	

32 (7280) Price SE¼, NW¼, Sec. 20, T. 49 N., R. 9 W. elev. 5701

depth 40' water level 10' yield 30 gpm use-domestic

0-20	clay and gravel
20-40½	sand and gravel

33 (28773) Del Tonto NW¼, SW¼, Sec. 20, T. 49 N., R. 8 W. elev. 6143

depth 50' water level 32' yield 30 gpm use-stock

0-32	yellow shale	X
32-50	black shale	

34 (14275) Drake SW¼, SW¼, Sec. 22, T. 49 N., R. 9 W. elev. 5798

depth 55' water level 18' yield 15 gpm use-domestic

0-22	shale
22-55	shale

35 (34769) Frigetto SW¼, NE¼, Sec. 26, T. 49 N., R. 10 W. elev. 5810

depth 168' water level-flow yield 30 gpm use-domestic

0- 10	soil	
10- 26	shale and sandstone	
26- 48	yellow sandstone	X
48- 54	stesks black shale and rock	
54- 76	grey sandstone	X
76- 93	shale and rock	
93-105	sandrock	X
105-112	shale, coal and rock	
112-138	grey sandrock	X
138-168	white sandstone	X

36 (29098) Lutz NE¼, SE¼, Sec. 28, T. 49 N., R. 10 W. elev. 5875

depth 50' water level 20' yield 30 gpm use-domestic

0-20	clay and sand	
20-50½	sand and stratas gravel	X

37 (18803) Holman NW¼, SW¼, Sec. 26, T. 49 N., R. 10 W. elev. 5844

depth 182' water level-flow yield 4 gpm use-stock

0- 6	soil	
6- 24	yellow shale and rock	
24- 40	brown sandstone	
40- 46	stratas rock and shale	
46- 73	sandstone	X (bad)
73- 97	shale and sandstone	
97-107	coal and shale	
107-112	rock and shale	
112-118	sandrock	X
118-134	stratas rock and shale	
134-140	sandrock	
140-158	shale and rock	
158-168	sandrock	X
168-172	red shale	
172-182	grey shale	

38 (9462) English NE¼, SW¼, Sec. 26, T. 49 N., R. 10 W. elev. 5837

depth 195' water level-flow yield 6 gpm use-domestic

0- 23	clay and gravel
23- 36	gravel
36- 72	shale and sandrock
72-120	white sandstone - sour water
120-160	shale and rock
160-196	white sandstone

39 City of Montrose NE¼, SW¼, Sec. 28, T. 49 N., R. 9 W. elev. 5801

depth 900'? water level-flow yield 9 gpm? use-domestic

0- 28	surface materials
28-600	shale
600-608	coking coal
608-900	shale

40 (5602) Montrose Feed Lot SE¼, SE¼, Sec. 29, T. 49 N., R. 9 W. elev. 5775

depth 47' water level 12' yield 30 gpm use-stock

0- 9	clay and gravel
9-46½	sand and gravel

41 (9511) Carper SE¼, SW¼, Sec. 28, T. 49 N., R. 9 W. elev. 5780

depth 26' water level 10' yield 30 gpm use-commercial

0-10	adobe
10-26	sand and gravel

42 (23075) Schell NW¼, NE¼, Sec. 33, T. 49 N., R. 10 W. elev. 6081

depth 245' yield-dry use-domestic

0- 3	top soil
3- 20	tan sandstone, fractured
20- 62	tan sandstone, consolidated
62- 64	carbonaceous shale
64- 70	streaks of light grey clay with sandstone stringers
70- 80	coal with clay layers
80- 90	coal with sandstone layers
90-100	grey sandy clay
100-105	very dense sandstone - light grey
105-107	dark grey shale
107-114	very dense sandstone with dark grey shale
114-140	dense white sandstone
140-175	porous white sandstone
175-190	sandstone and chert
190-192	hard tan sandstone
192-205	red sandstone with clay
205-245	green shale with anhydrite stringers

43 (19144)McPheeters NW¼, NW¼, Sec. 35, T. 49 N., R. 10 W. elev. 5904

depth 310' water level-flow yield 3 gpm use-domestic

0- 3	soil	
3- 17	yellow sandstone	
17- 69	sandstone	X (bad)
69- 90	shale and rock	
90-100	coal and shale	
100-108	rock and shale	
108-115	sandstone	
115-123	shale and rock	
123-144	sandstone	X (bad)
144-150	shale and rock	
150-160	white sandstone	
160-166	red shale	
166-173	sandstone	
173-176	brown shale	
176-185	pink shale	
185-241	white shale and rock	
241-244	red shale and rock	
244-265	hard sandstone	
265-270	red and white shale and rock	
270-276	white shale	
276-285	hard sandstone	
285-297	white shale and rock	
297-308	red shale	
308-310	red and white shale rock	

44 (26918) Smith NE¼, NE¼, Sec. 32, T. 49 N., R. 9 W. elev. 5781
depth 40' water level 7' yield 20 gpm use-domestic

0-17	cobble	
17-40	sand and gravel	X

45 (16674) Dicamillo NE¼, NE¼, Sec. 36, T. 49 N., R. 9 W. elev. 6025
depth 60' water level 16' yield 15 gpm use-stock

46 (32540) Johnston SW¼, NE¼, Sec. 35, T. 49 N., R. 10 W. elev. 5889
depth 120' water level-flow yield 5 gpm use-stock

0- 17	sandy soil	
17- 49	yellow sand	
49- 53	stratas sand and shale	
53- 82	sandstone	X (bad)
82-110	white shale rock and coal	
110-115	sandstone	X
115-120	stratas sand and shale	X

47 (23361) Packard NW¼, SW¼, Sec. 35, T. 49 N., R. 10 W. elev. 5980
depth 169' water level 20' yield 6 gpm use—domestic

0- 6	soil and sandstone	
6- 12	clay and sandstone	
12- 45	stratas shale and sandstone	
45- 70	yellow sandstone	X (bad)
70- 79	black shale and sandstone	
79- 97	sandstone	
97-110	shale coal and rock	
110-135	sandstone and shale	
135-169	sandstone	X

48 (24541) Sanders NE¼, SE¼, Sec. 34, T. 49 N., R. 10 W. elev. 6020
depth 170' water level 20' yield 10 gpm use-domestic and stock

0- 2	soil	
2- 14	rotten sandrock and shale	
14- 21	yellow shale	
21- 68	yellow sandstone	X
68- 81	black shale and sandstone	
81- 93	sandstone	
93-114	shale, coal and rock	
114-125	sandrock and shale	
125-134	sandrock	
134-142	shale and rock	
142-170	sandrock	

49 (29384) Weir NE¼, SW¼, Sec. 35, T. 49 N., R. 10 W. elev. 5967

depth 175' no water level given yield 30 gpm use-domestic

0- 2	soil	
2- 40	yellow shale and sandstone	
40- 85	yellow sandstone	
85-100	black shale and rock	
100-112	coal shale and rock	
112-118	sandrock and shale	
118-136	sandrock	X
136-146	shale and rock	
146-175	sandstone	X

50 (2035) Hance NE¼, SE¼, Sec. 36, T. 49 N., R. 10 W. elev. 5908

depth 310' no water level given yield 6 gpm use-domestic

0- 6	soil
6- 30	gravel and boulders
30-200	shale
200-210	stratas sand and shale
210-223	sandstone
223-290	stratas sand coal and shale
290-310	white sandstone

51 (1242) Jackson NE¼, SE¼, Sec. 31, T. 49 N., R. 9 W. elev. 5924

depth 50' no water level given yield 30 gpm use-domestic

0- 7	topsoil
7-36	gravel and boulders
36-50	sand and gravel

52 (27692) Colo. Fish, SE¼, SW¼, Sec. 34, T. 49 N., R. 9 W. elev. 5849
Game & Parks Dept.

depth 38' water level 27' yield 10 gpm use-domestic

0-27	adobe
27-38	gravel

53 (15346) Young SE¼, SE¼, Sec. 34, T. 49 N., R. 10 W. elev. 6062

depth 157' water level 40' yield 30gpm use-stock

0- 4	soil	
4-30	sandstone and shale	
30-56	sandstone	
56-73	stratas of sand and shale	
73- 87	sandstone	
87-102	sand and shale	
102-118	stratas of coal and shale	
118-157	sandstone	X

54 (33486) Wilson SE¼, SW¼, Sec. 35, T. 49 N., R. 10 W. elev. 6017

depth 175' water level 60' yield 8 gpm use-domestic and stock

0- 1	soil	
1- 3	sandrock	
3- 19	shale and sandrock	
19- 63	yellow sandrock	
63- 72	black shale and rock	
72- 93	hard rock into sandrock	
93-113	shale rock and coal	
113-116	sandrock and shale	
116-160	sandrock	X
160-163	red shale	
163-167	blue shale and rock	
167-175	red shale and rock	

55 (17244) Bush SW¼, SW¼, Sec. 36, T. 49 N., R. 10 W. elev. 5934

depth 148' water level-flow yield 45 gpm use-domestic

0- 18	soil	
18- 42	yellow sand	X
42- 63	white sand	X
63- 69	rock and shale stratas	
69- 91	white sandstone	
91-110	stratas shale rock and coal	
110-148	white sandstone	X

56 (30484) Love SW¼, SW¼, Sec. 31, T. 49 N., R. 9 W. elev. 5920

depth 245 water level-flow yield 2 gpm use-domestic

0- 4	soil	
4- 18	gravel	
18- 30	clay and gravel	
30-140	shale	
140-200	stratas shale and rock	
200-245	sandstone	X

57 (479) Brethouwer SE¼, SE¼, Sec. 31, T. 49 N., R. 9 W. elev. 5940

depth 460' no water level given yield 30 gpm use-domestic

0- 6	soil and gravel
6- 29	gravel and boulders
29- 40	sand and gravel
40-290	Mancos shale
290-306	stratas sand and shale
306-322	sandstone
322-350	stratas shale and sand
350-368	sandstone
368-440	stratas sandstone, shale and coal
440-460	white sandstone

58 (33490) Miller NW¼, NW¼, Sec. 3, T. 48 N., R. 10 W. elev. 6045

depth 168' water level 40' yield 15 gpm use-domestic

0- 2	soil	
2- 7	yellow clay	
7- 58	yellow sandrock	
58- 66	black shale and sandrock	
66- 78	sandstone	X
78- 83	shale	
83- 97	sandrock	X
97-119	shale coal and rock	
119-168	sandrock	X

59 (38545) Rowser NE¼, NE¼, Sec. 3, T. 48 N., R. 10 W. elev. 5961

depth 175' water level-flow yield 30 gpm use-domestic

0- 4	soil	
4- 23	yellow shale and sandrock	X
23- 68	yellow sandrock	X
68- 72	black shale and rock	
72-114	sandrock shale and coal	X
114-175	sandrock	X

60 (13881) Peak NW¼, NE¼, Sec. 1, T. 48 N., R. 10 W. elev. 5941

depth 297' water level 30' yield 6 gpm use-domestic

0- 41	gravel and boulders	
41-110	shale	
110-114	gray rock	
114-277	shale	
227-297	stratas sand and shale	X

61 (33540) Hotchkiss SW¼, NW¼, Sec. 3, T. 48 N., R. 10 W. elev. 6063

depth 165' water level 20' yield 16 gpm use-domestic

0- 14	stratas yellow clay and sandrock	
14- 76	yellow sandstone and shale	
76- 84	stratas black sandstone and shale	
84- 98	grey sandstone	
98-121	stratas shale and rock	
121-165	sandrock	X

62 (19281) Bugas SE¼, NE¼, Sec. 1, T. 48 N., R. 10 W. elev. 5976

depth 262' water level 4' yield 12 gpm use-domestic

0- 11	gravel	X
11- 28	yellow clay	
28-200	Mancos shale	
200-261	white sandstone with streaks shale	X
261-262	shale	

63 (26642) Smith NW¼, SE¼, Sec. 2, T. 48 N., R. 10 W. elev. 6007

depth 185' water level-flow yield 15 gpm use-stock

0- 28	yellow shale and sandstone	
28- 47	yellow sandstone	
47- 53	black shale and rock	
53- 72	sandstone	
72- 97	rock and shale	
97-100	sandrock	X
100-110	shale rock and coal	
110-115	sandrock	X
115-140	rock and shale	
140-185	white sandstone	X

64 (27992) Benedict SE¼, SE¼, Sec. 2, T. 48 N., R. 10 W. elev. 6029

depth 168' water level-flow yield 30 gpm use-domestic

0- 8	soil	
8- 27	yellow shale and sandrock	
27- 42	yellow sandrock	X
42- 46	black shale	
46- 72	brown sandrock	
72- 76	black shale	
76- 79	hard sandstone	
79-104	shale and rock	
104-118	stratas coal, rock and shale	
118-136	sandrock and shale	
136-145	hard sandrock	
145-168	sandrock	X

65 (2039) Smith SE¼, SE¼, Sec. 2, T. 48 N., R. 10 W. elev. 6009

depth 180' no water level given yield 20 gpm use-domestic

0- 21	gravel and soil
21- 42	shale
42- 92	stratas sand and shale
92-127	sandstone
127-168	stratas sand coal and shale
168-180	white sandstone

66 (26383) Brady NW¼, SW¼, Sec. 1, T. 48 N., R. 10 W. elev. 5991
depth 214' water level-flow yield 15 gpm use-domestic and stock

0- 6	soil	
6- 20	yellow shale	
20- 35	yellow shale and rock	
35- 42	sandrock	X (bad)
42- 48	shale and sandrock	X (bad)
48- 60	sandrock	X (bad)
60- 69	shale and rock	
69- 93	sandrock	X (bad)
93-102	shale	
102-120	sandrock	X
120-128	shale and rock	
128-145	sandrock, coal, shale	X
145-208	white sandrock	X
208-214	red and white shale	

67 (22647) Loss NW¼, NW¼, Sec. 6, T. 48 N., R. 9 W. elev. 5989
depth 245' water level 30' yield 30 gpm use-domestic

0- 12	clay and gravel	
12- 19	boulders	
19- 32	sand and gravel	
32- 48	yellow shale	
48-108	stratas black shale and rock	
108-122	sandrock	
122-128	shale and rock	
128-160	sandrock	X (bad)
160-182	shale and rock	
182-196	coal shale and rock	
196-205	shale and rock	
205-245	white sandrock	X

68 (18663) Gary SE¼, SE¼, Sec. 2, T. 48 N., R. 10 W. elev. 6047
depth 194' water level-flow yield 8 gpm use-domestic

0- 2	soil	
2-20	yellow sand and shale	
20-41	hard sand	
41-76	stratas sand and shale	
76-90	white sand	
90- 96	stratas sand and shale	
96-127	white sand	
127-136	coal, shale and rock	
136-144	hard sand	
144-150	stratas shale and rock	
150-194	white sandstone	X

69 (21884) Monson NE¼, SE¼, Sec. 1, T. 48 N., R. 10 W. elev. 6002

depth 180' water level 20' yield 12 gpm use-domestic

0- 6	topsoil and clay	
6- 35	gravel, sand, boulders	
35- 38	yellow clay	
38-118	Mancos shale	
118-135	broken sandstone with streaks of shale	
135-160	tan sandstone, slight porosity	X
160-161	shale	
161-180	white, porous sandstone	X
180-	shale	

70 (4935) Chipeta Water Co. SE¼, SE¼, Sec. 5, T. 48 N., R. 9 W. elev. 5916

depth 22' water level 10' yield 60 gpm use-domestic and stock

0-10	adobe
10-22	gravel

71 (4936) Chipeta Water Co. SE¼, SE¼, Sec. 5, T. 48 N., R. 9 W. elev. 5916

depth 21' water level 10' yield 60 gpm use-domestic and stock

0-10	adobe
10-21	gravel

72 (11079) Gaunt NE¼, NE¼, Sec. 11, T. 48 N., R. 10 W. elev. 6103

depth 198' water level 15' yield 30 gpm use-domestic

0- 3	soil
3- 18	shale
18- 80	dry sandstone
80- 96	stratas sand and shale
96-107	water sandstone
107-141	stratas rock and shale
141-163	sandstone
163-198	white sandstone

73 (2038) Cornforth SW¼, NE¼, Sec. 12, T. 48 N., R. 10 W. elev. 6059

depth 180' no water level given yield 20 gpm use-domestic

0- 6	soil
6- 24	gravel
24- 61	shale
61- 96	stratas shale and sand
96-121	sandstone
121-163	stratas coal sand and shale
163-180	white sandstone

74 (7802) Sampson SW¼, NW¼, Sec. 9, T. 48 N., R. 9 W. elev. 5960

depth 480' water level-flow yield 3 gpm use-stock

0- 36	gravel
36-320	shale
320-350	sandstone
350-358	stratas sand and shale
358-370	sandstone
370-405	stratas sand and shale
405-412	coal and sandstone
412-416	hard sand
416-440	sandstone
440-480	white sand and shale

75 (23690) Corman SE¼, SW¼, Sec. 12, T. 48 N., R. 10 W. elev. 6136

depth 140' water level 60' yield 30 gpm use-domestic

0- 2	soil
2- 26	yellow shale and sandrock
26- 38	yellow sandstone
38- 43	black shale
43- 56	shale and sandrock
56- 63	sandrock
63- 87	rock and shale
87- 96	coal shale and rock
96-108	rock and shale
108-116	gray sandstone
116-140	white sandstone X

76 (10630) Caddy SE¼, SW¼, Sec. 7, T. 48 N., R. 9 W. elev. 6116

depth 370' water level 20' yield 20 gpm use-domestic

0- 40	yellow shale
40- 70	black shale
70-100	stratas shale and rock
100-153	gray sandstone
153-170	stratas shale and rock
170-184	stratas coal and shale
184-196	gray rock
196-237	sandstone
237-315	white shale and rock
315-360	red shale and rock
360-370	sandstone

77 (6332) Jones SW¼, SW¼, Sec. 10, T. 48 N., R. 9 W. elev. 5984

depth 542' water level-flow yield 30 gpm use-domestic

0- 4	soil	
4- 20	gravel	
20-320	shale	
320-380	stratas rock and shale	
380-385	grey rock	
385-430	white sand	
430-455	stratas rock and shale	
455-463	sandrock	
463-470	coal	
470-479	sandrock	
479-486	stratas sand and shale	
486-542	white sandstone	

78 (19623) Garrison NW¼, SW¼, Sec. 15, T. 48 N., R. 10 W. elev. 6395

depth 80' water level 35' yield 5 gpm use-stock

0-15	clay with sandstone boulders and gravel	
15-55	clay with streaks of sandstone	
55-65	white sandstone, porous, shattered	X
65-80	clay	

79 (22534) Collins NW¼, SE¼, Sec. 17, T. 48 N., R. 9 W. elev. 6057

depth 255' water level 6' yield 30 gpm use-stock

0- 6	clay	
6- 18	gravel and boulders	
18- 52	yellow shale	X (bad)
52-112	black shale	
112-145	sand	
145-155	rock and shale	
155-163	sand	
163-172	rock and shale	
172-180	sand	X
180-186	rock and shale	
186-198	sand	
198-204	shale rock and coal	
204-215	rock and shale	
215-220	hard rock	
220-225	sandstone	X

80 (10680) Cooper NE¼, NW¼, Sec. 23, T. 48 N., R. 10 W. elev. 6250

depth 250' water level 248' yield 62 gpm use-irrigation

0- 15	top soil
15- 25	sandstone boulders
25- 35	sandstone
35- 55	red and blue shale
56- 65	sand
66-150	red and blue shale
151-165	sandstone
166-245	red and blue shale
246-250	sand

81 (26477) Twombly SW¼, NE¼, Sec. 21, T. 48 N., R. 9 W. elev. 6104

depth 140' water level 25' yield 30 gpm use-domestic and stock

0- 38	clay and boulders	X (bad)
38- 50	shale	
50- 58	shale and rock stratas	
58- 63	hard sandstone	
63- 75	shale and sandstone	
75-112	sandstone	
112-128	shale and rock	
128-140	sandstone	X

82 (29303) Weiscamp SW¼, SW¼, Sec. 23, T. 48 N., R. 9 W. elev. 6097

depth 50' water level 25' yield 30 gpm use-domestic

4- 30	gravel and boulders	
30-50½	sand and gravel	X

83 (26721) Luttrell NW¼, SE¼, Sec. 26, T. 48 N., R. 9 W. elev. 6143

depth 50' water level 36' yield 30 gpm use-domestic

0-40	grave, clay and boulders
40-50	sand and gravel

84 (19232) Garrison SW¼, SW¼, Sec. 28, T. 48 N., R. 10 W. elev. 7188

depth 262' water level 120' yield 2 gpm use—stock

0- 2	topsoil	
2- 60	sandstone	
60- 61	coal	
61- 80	sandstone	
80- 89	brown shale	
89-150	sandstone	
150-180	sandstone with streaks of clay	
180-185	green shale	
185-200	grey sandstone	X
200-224	green shale	
224-250	red and green shale	
250-262	red sandstone	

85 (31887) Flowers NW¼, NW¼, Sec. 36, T. 48 N., R. 9 W. elev. 6165

depth 48' water level 22' yield 30 gpm use-domestic

0- 3	soil	
3-22	clay and boulders	
22-48	sand and gravel	X

86 (11335) Mills NW¼, SE¼, Sec. 35, T. 48 N., R. 9 W. elev. 6174

depth 375' no water level given yiels 15 gpm use-domestic

0- 20	clay and gravel
20- 40	boulders
40- 46	soft shale
46-222	black shale
222-255	rock and shale
255-275	sandstone
275-328	stratas shale and sandstone
328-375	sandstone

87 (16001) White SE¼, SW¼, Sec. 36, T. 48 N., R. 9 W. elev. 6210

depth 420' water level-flow yield 6 gpm use-stock

0- 56	gravel and boulders	
56-256	shale	
256-261	hard rock	
261-302	sandstone	
302-305	shale	
305-317	sandstone	X
317-338	shale and rock	
338-346	sandstone	X
346-357	shale, coal and rock	
357-360	hard sandstone	X
360-366	sandstone	X
366-378	shale and rock	
378-420	white sandstone	X

88 (25585) Mills NW¼, NW¼, Sec. 2, T. 47 N., R. 9 W. elev. 6390

depth 330' water level-flow yield 10 gpm use-stock

0- 8	soil and boulders	
8- 35	yellow shale	
35-130	black shale	
130-147	sand rock	
147-163	shale and rock	
163-187	sandrock	X
187-207	shale and rock	
207-218	sandstone	
218-223	shale and rock	
223-235	sandstone	
235-270	shale, rock and coal	
270-297	sandstone	X
297-307	white shale and rock	
307-312	pink shale and rock	
312-330	white shale and rock	

89 (4505) Donley NW¼, SE¼, Sec. 3, T. 47 N., R. 11 W. elev. 8300

depth 100' water level-flow yield 50 gpm use-stock

0- 6	soil	
6- 12	shale	
12- 30	sand and shale	
30- 50	sandstone	
50- 63	stratas sand and shale	
63- 70	shale	
70- 86	sand and shale	
86-100	sandstone	

90 (42328) Sanders NW¼, SE¼, Sec. 2, T. 47 N., R. 9 W. elev. 6324

depth 224' water level-flow yield 30 gpm use-domestic

0- 53	sandy soil	
53- 74	soft sandstone and shale	X (bad)
74- 93	sandstone	
93-147	shale and rock	
147-156	shale, coal and rock	
156-163	sandrock	X
163-175	sandrock and shale	
175-224	white sandstone	X

91 (19489) Holman NE¼, SW¼, Sec. 1, T. 47 N., R. 9 W. elev. 6380

depth 405' water level 25' yield 30 gpm use-stock

0- 20	soil and gravel	
20- 38	gravel and boulders	
38- 50	yellow shale	
50-102	black shale	
102-106	sandstone	X (bad)
106-204	black shale	
204-244	thin stratas shale and rock	
244-257	gray sandrock	
257-275	stratas shale and sand	
275-282	gray sandrock	
282-286	hard rock	
286-297	stratas sand and shale	
297-312	sandrock	
312-320	rock and shale	
320-332	sandrock	
332-355	stratas sand rock and shale	
355-361	coal and shale	
361-384	stratas sand and shale	
384-405	white sandstone	X

92 (29588) Linscott NE¼, SE¼, Sec. 1, T. 47 N., R. 9 W. elev. 6280

depth 338' water level-flow yield 3 gpm use-stock

0- 18	clay	
18- 48	gravel and boulders	
48-135	shale	X (bad)
135-163	sand, shale and rock	
163-175	sandrock	
175-184	shale and sandstone	
184-223	sandstone	X
223-244	shale and rock	
244-255	sandrock	X
255-293	shale coal and rock	
293-325	shale and sandrock	X
325-338	white shale and rock	

93 (31802) Shaver SW¼, SW¼, Sec. 2, T. 47 N., R. 12 W. elev. 9000

depth 60' water level 35' yield 1 gpm use-domestic

0- 3	soil	
3-30	yellow shale	
30-60	white sand and shale	X

94 (13993) Shott SW¼, SW¼, Sec. 6, T. 47 N., R. 8 W. elev. 6290

depth 341' water level 70' yield 10 gpm use-stock

0- 7	heavy loam	
7-110	river gravel	
110-170	black shale	
200-230	shale	
230-341	white sandrock	X

95 (22315) Colby SE¼, NW¼, Sec. 7, T. 47 N., R. 8 W. elev. 6302

depth 60' water level 42' yield 30 gpm use-domestic

0-12	soil	
12-35	gravel, clay and boulders	
35-42	large boulders	
42-60	sand and gravel	X

96 (750) Jutten NW¼, NW¼, Sec. 7, T. 47 N., R. 8 W. elev. 6383

depth 360' no water level given yield 10 gpm use-stock

0- 20	adobe
20- 39	boulders
39-203	Mancos shale
203-260	stratas shale and sand
260-283	sandstone
283-316	stratas sand and shale
316-332	sandstone
332-348	stratas shale and coal
348-360	white sandstone