North Cheyenne Master Plan Plan
Level I Project

Final Report

Prepared for the
Wyoming Water Development Commission
Cheyenne, Wyoming

Prepared by
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Table of Contents

Contents

1. Introduction ............................................. 1-1
2. Project Setting ........................................... 2-1
3. Hydrogeologic Setting .................................... 3-1
4. Water Supply Needs ...................................... 4-1
5. Water Supply Alternatives .............................. 5-1
6. Water Quality ........................................... 6-1
7. Summary and Recommendations ....................... 7-1

Tables
Table 4a: Population projections - county. ............... 4-3
Table 4b: Water use projections - county. ............... 4-5
Table 5a: No action alternative. .......................... 5-2
Table 5b: Projected groundwater depletions. ............... 5-5
Table 5c: Groundwater recharge with raw water. ........... 5-11
Table 5d: Recharge from imported water supply systems. .... 5-12
Table 5e: Municipal system to city standards. .......... 5-23
Table 5f: Independent groundwater system cost summary. ... 5-42
Table 5g: Rural system with municipal supply. .......... 5-48
Table 5h: Water supply alternative comparison. ......... 5-50

Figures
Figure 1-1: Location map of the North Cheyenne Master Plan study area. 1-2
Figure 1-2: Source of water derived from wells. ............ 1-4
Figure 1-3: WWDC program levels. ........................ 1-7
Figure 1-4: North Cheyenne Master Plan Level I reconnaissance study planning process. 1-9
Figure 2-1: North Cheyenne Master Plan study area. ......... 2-2
Figure 2-2: Mean monthly temperature distribution at Cheyenne. 2-3
Figure 2-3: Long-term precipitation variation at Cheyenne. ... 2-4
Figure 2-4: Mean monthly precipitation distribution at Cheyenne. 2-5
<table>
<thead>
<tr>
<th>Figure</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>2-5</td>
<td>Mean monthly evapotranspiration distribution at Cheyenne.</td>
<td>2-6</td>
</tr>
<tr>
<td>2-6</td>
<td>Historic increase in the number of wells in the North Cheyenne study area</td>
<td>2-10</td>
</tr>
<tr>
<td>2-7</td>
<td>Location of all wells in the North Cheyenne study area as of July 1992.</td>
<td>2-10</td>
</tr>
<tr>
<td>3-1</td>
<td>Seasonal water-level fluctuations caused by lawn irrigation.</td>
<td>3-4</td>
</tr>
<tr>
<td>3-2</td>
<td>Potentiometric surface contours for the Tertiary aquifer in North Cheyenne in 1973, altitude in feet.</td>
<td>3-5</td>
</tr>
<tr>
<td>3-3</td>
<td>Long-term trend in water level in a well north of North Cheyenne that is occasionally affected by irrigation.</td>
<td>3-7</td>
</tr>
<tr>
<td>3-4</td>
<td>Long-term trend in water level in a well east of North Cheyenne affected by pumping of domestic wells.</td>
<td>3-7</td>
</tr>
<tr>
<td>3-5</td>
<td>Seasonal variation of selected wells on the west side of the study area.</td>
<td>3-8</td>
</tr>
<tr>
<td>3-6</td>
<td>Seasonal variation of selected wells on the west side of the study area.</td>
<td>3-8</td>
</tr>
<tr>
<td>3-7</td>
<td>Seasonal variation of selected well on the east side of the study area.</td>
<td>3-9</td>
</tr>
<tr>
<td>3-8</td>
<td>East-West cross section of wells of the 1989 potentiometric surface</td>
<td>3-9</td>
</tr>
<tr>
<td>3-9</td>
<td>1989 potentiometric surface North Cheyenne.</td>
<td>3-10</td>
</tr>
<tr>
<td>3-10</td>
<td>Hourly data for selected well - March through May 1992.</td>
<td>3-10</td>
</tr>
<tr>
<td>3-11</td>
<td>Detail of weekly water level fluctuations in well 14-66-10aba01, North Cheyenne.</td>
<td>3-11</td>
</tr>
<tr>
<td>3-12</td>
<td>Water level change in the Tertiary aquifer, North Cheyenne, 1973 to 1989, in feet.</td>
<td>3-12</td>
</tr>
<tr>
<td>4-1</td>
<td>Historic and projected population growth for the City of Cheyenne and Laramie County State of Wyoming projections.</td>
<td>4-3</td>
</tr>
<tr>
<td>4-2</td>
<td>Historic and projected increase in the number of wells in the North Cheyenne study area</td>
<td>4-5</td>
</tr>
<tr>
<td>5-1</td>
<td>North Cheyenne Recharge.</td>
<td>5-8</td>
</tr>
<tr>
<td>5-2</td>
<td>Main Distribution System Municipal System.</td>
<td>5-18</td>
</tr>
<tr>
<td>5-3</td>
<td>Peak demand pressures Municipal System.</td>
<td>5-20</td>
</tr>
<tr>
<td>5-4</td>
<td>Main Distribution System Municipal System - Local distribution network.</td>
<td>5-21</td>
</tr>
<tr>
<td>Figure 5-5:</td>
<td>Ogallala/Arikaree Formation well systems.</td>
<td>5-26</td>
</tr>
<tr>
<td>Figure 5-6:</td>
<td>Casper Formation well system.</td>
<td>5-31</td>
</tr>
<tr>
<td>Figure 5-7:</td>
<td>Main Distribution System Community groundwater system.</td>
<td>5-36</td>
</tr>
<tr>
<td>Figure 5-8:</td>
<td>Peak demand pressures Community groundwater system.</td>
<td>5-38</td>
</tr>
<tr>
<td>Figure 5-9:</td>
<td>Rural System Community groundwater system.</td>
<td>5-39</td>
</tr>
<tr>
<td>Figure 5-10:</td>
<td>Rural System Municipal Supply.</td>
<td>5-44</td>
</tr>
<tr>
<td>Figure 5-11:</td>
<td>Peak demand pressures Rural System with Municipal Supply.</td>
<td>5-46</td>
</tr>
</tbody>
</table>
1 Introduction
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This report presents the findings of a Level I reconnaissance investigation to develop a water supply master plan for the North Cheyenne area. This investigation was conducted for Laramie County under the direction and funding of the Wyoming Water Development Commission by States West Water Resources Corporation. This is the final report based upon the findings of the investigation.

A. Background

The North Cheyenne study area is a nearly 30 square mile area located immediately north of the city of Cheyenne (Figure 1-1). Prior to 1960, the area was essentially prairie land used for cattle grazing. An expansion of Wyoming’s economy brought an increase of population to the Cheyenne vicinity beginning in the 1970's. With that population growth, parts of the North Cheyenne area were subdivided and settled. The area is near enough to Cheyenne for a ten-minute commute to work, but far enough away to have a rural atmosphere. Lot sizes are much larger than in Cheyenne and there are fewer zoning rules and regulations than exist within the Cheyenne city limits. Many of the area residents raise horses or other livestock, and all enjoy the privacy and spaciousness of living in the country.

Along with the positive aspects of living in the country, there are some drawbacks. Most predominant among these drawbacks is that city services are not provided. Except for major county roads, which are asphalt, gravel roads are the norm. One major set of services not provided to the area residents is water and sewer. Each residence or commercial facility is required to provide these services independently. Water is obtained from wells drilled into the underlying aquifer. Sewage is disposed of through individual septic systems, which drain to the underlying aquifer. If enough houses are build together, each one having its own well and septic system, problems are bound to occur. As explained below, problems are occurring.

B. The Problems

There are three problems related to water supplies from wells in North Cheyenne. The problem that was the impetus for this investigation is that of declining of water levels in what is designated as the Tertiary aquifer by the Wyoming Department of the State Engineer. A second problem is possible degradation of the quality of water because of
Figure 1-1. Location of the North Cheyenne Master Plan study area.
the use of septic tanks. A third problem is the physical deterioration of wells. Deterio-
ration of a well is not a "groundwater supply" problem but is included herein because
decreased well yield that results from the deterioration could be mistakenly attributed to
a decline in water levels.

1. Declining Water Levels

Water levels are, and will continue to decline in most of North Cheyenne because the
source of water to a well is storage in an aquifer. In any aquifer, the water discharged
from a well initially comes from storage in the aquifer. This removal from storage forms a
cone of depression around the well that expands and deepens until the cone intercepts an
equal amount of natural recharge, induces an equal amount of additional recharge from
some other source, or some combination of the two.

This concept is illustrated by an example in Figure 1-2. Figure 1-2a represents the initial
condition where recharge and discharge are in equilibrium. Figure 1-2b shows that the
initial discharge from a well removes water from storage and there is no decrease in flow,
indicated by arrows, out of the area. With continued pumping (Figure 1-2c) part of the
flow out of the area is intercepted. Figure 1-2d shows that with continued discharge from
the well all the flow from the area is captured and recharge to the aquifer is increased by
flow from a stream.

In North Cheyenne, natural recharge is from precipitation, the same situation as shown in
the example in Figure 1-2. In the study area, precipitation averages approximately 15
inches per year. However, only 10 to 12 percent of that precipitation actually recharges
the aquifer. The remainder is lost to evapotranspiration. There are no discharge areas,
where water can be intercepted, nor any streams, where additional recharge can be
induced, close to the area. Therefore, the cone of depression in North Cheyenne can only
expand and deepen to supply water to wells.

For some residents of North Cheyenne a small decline in water level may decrease the
yield of their wells. The first water wells in the area obtained adequate quantities of water
for the domestic use by penetrating only part of the aquifer and the owners saw no need
of drilling deeper. Reportedly, some of these wells will no longer yield adequate supplies
for domestic purposes.
Figure 1-2. Source of water derived from wells.
2. Degradation of Water Quality

Degradation of water quality in the Tertiary aquifer has occurred in some of the areas of earliest urban development. Further degradation can be anticipated — in time — to occur throughout the area. Septic tanks and wells are both constructed in the Tertiary aquifer. Except for lawn watering, the only source of recharge to the aquifer is from precipitation and effluent from septic tanks. Whereas much of precipitation and runoff is evapotranspired before it percolates to the water table, effluent from septic tanks is discharged several feet below the surface and is less subject to evapotranspiration. This issue was not addressed in the original scope of work for this study. However, the potential for quality degradation became a major issue during the progress of the study. The potential degradation of water quality was investigated and has been included in this report.

3. Deterioration of Wells

A water well may deteriorate with time. Metal casing corrodes which causes sealing of the casing perforations. In addition, solids from the water are deposited near the casing because of decreases in pressure. When this occurs there is a decrease in yield of the well and this could be mistakenly attributed to declining water levels. Deterioration of wells with metal casings can necessitate a replacement well within 20 to 30 years. Many wells in the study area are this old or older and are likely showing signs of deterioration.

C. Purpose of This Study

The purpose of this study is to develop a water supply master plan for the North Cheyenne area. As part of its water resource planning program, the WWDC provides a service to municipalities, districts, and other entities to assist in planning for future water supply systems and improvements to existing systems. The master plans authorized by the WWDC serve as a framework for the entities to establish project priorities and perform financial planning to meet those priorities. Master plan investigations generally do not collect new primary-source data, but compile existing information, use the information to develop project alternatives, and make recommendations for a proposed course of action.

The North Cheyenne Master Plan is designed to be a working document that will provide the area residents with a summary of the area’s problems and potential solutions. As stated previously, a great deal of effort has been expended defining the problems and resources of the area, particularly by the State Engineer’s Office. However, no one planning document has consolidated all findings and provided a thorough comparison of potential alternatives. The goal of the Master Plan is to provide the citizens of the North
Cheyenne area a singular source to assist them in making choices regarding future water supply alternatives.

D. Overview of the Planning Process

1. The WWDC Program

The Wyoming Water Development Commission is the state agency responsible for the coordinated planning and development of the water resources of the state. The WWDC assembles and generates the data necessary to evaluate project feasibility, makes recommendations about project and program development, and provides development plans. In addition, the WWDC presents resultant data and recommendations to the Governor and Legislature.

WWDC projects evolve through a set of three levels, as shown in Figure 1-3. Level I projects are reconnaissance studies, which can be area- or basin-wide development plans, or preliminary analyses and comparisons of previously identified development alternatives. A promising alternative, based upon the Level I investigation, can be promoted to a Level II feasibility evaluation. If other agencies have performed analyses equivalent to WWDC Level I analyses, projects may begin at Level II. In general, Level I analyses provide a gross evaluation of project feasibility with a limited expenditure of funds.

Level II evaluations are conducted in two phases. A preliminary feasibility analysis of the proposed project occurs during Phase I. If the project appears feasible and meets criteria including water supply, constructability, and the sponsor’s ability to pay, then the project will continue to Phase II. Otherwise, if the project appears infeasible, the study can be abandoned without continuing to Phase II. During Phase II, development of a more detailed conceptual design allows an accurate appraisal of project cost. A detailed economic evaluation, based on the more accurate cost estimate, assesses the project sponsor’s ability to pay. If the project still appears feasible after this phase, and if a project sponsor is willing to commit financial resources to the project, the project can progress to Level III.

Level III projects also involve two phases. During the first phase, final designs for the project are generated. Additionally, this first phase produces an environmental assessment or environmental impact statement and secures permits required to build the project. Phase II is the actual construction of the project. Although the WWDC manages Level I and Level II investigations, the WWDC funds Level III projects but generally leaves management to the local project sponsor.
Level I
Reconnaissance Evaluation

Level II
Feasibility Evaluation

Phase I - Preliminary Analysis
Phase II - Conceptual Design

Level III
Design and Construction

Phase I - Final Design, Permitting, and EIS
Phase II - Construction

Figure 1-3. WWDC program levels.
2. The Level I Planning Study

The North Cheyenne Master Plan Level I reconnaissance study progressed through several steps (Figure 1-4). Although the WWDC’s scope of services defined objectives of the study, a scoping meeting held at the beginning of the project allowed public and sponsor input to add or modify project alternatives and goals. In addition, progress reports to the Laramie County Commissioners have insured participation in the study by the project sponsor.

The initial part of the study undertook several tasks simultaneously: 1) collection of background information and data, 2) review of previous planning studies, and 3) the gathering of public input. As a Level I study, little original source information was collected. Instead, secondary sources of published and unpublished information were used. Public input was gathered during the scoping meeting and subsequent public meetings.

The next step was to evaluate water supply alternatives that would address the problems. The alternatives evaluated would include: 1) no action, 2) groundwater management alternatives, 3) Cheyenne municipal system expansion, and 4) rural water supply systems. These alternatives were then screened to the most logical and constructible projects. Reconnaissance level alternative evaluations were performed to allow comparison of the alternatives. From the evaluations, a recommendation was made for the best alternative or combination of alternatives to solve the problems in the study area.

The issue of degradation of water quality was not addressed in the original scope of work. During the progress of the study, the potential for water quality degradation became an issue. Consequently, a water quality testing program was included in the second phase of the study. These results are presented in this report.
Collect Background Information

Review Previous Plans

Solicit Public Input

Alternative Formulation & Preliminary Evaluation

Screening Process

Reconnaissance Level Alternative Evaluation

Recommendations

Figure 1-4. North Cheyenne Master Plan Level I reconnaissance study planning process.
2 Project Setting
2 Project Setting

A. Physical Setting

1. Topography and Physiography

Topography in the North Cheyenne area is homogeneous, with rolling, undulating hills intersected by one ephemeral stream and its tributaries. Major residential development has occurred within and near the city limits in the southwest portion of the study area: Township 14, Range 66, Sections 18, 19, 21, and 22; and Township 14, Range 67, Sections 13 and 24 (Figure 2-1).

Maximum elevation is about 6,340 feet and decreases to the east and south to a minimum of about 5,970 feet. Only one distinct physiographic feature occurs in the study area — Buffalo Ridge. The ridge trends west-east and is located beginning in Section 16 and leaves the study area in Section 24. The elevation rise of the ridge varies from about 80 to 140 feet.

2. Drainage System

There are no major drainages in the study area, Childs Draw being the only channel. Childs Draw is an ephemeral stream with infrequent flow, with seven small tributaries joining it within the study area. The basin has its headwaters in Section 3 of Township 14 Range 67, just a section and a half from the western boundary of the study area. The main channel leaves the area in Section 12 (Figure 2-1). Dry Creek flows through the southwestern corner of the study area.

3. Climate

The climate of an area substantially affects how people live and what they do outdoors. Obviously, climate strongly influences residential water use (primarily lawn irrigation), mostly due to the amount and timing of precipitation and to temperatures during the growing season. If there is too little rainfall during the summer months, watering of lawns becomes necessary.
a. **Temperature**

Moderately warm summers and cold winters characterize the general climate of the North Cheyenne area. Figure 2-2 illustrates the variation of mean monthly temperature at Cheyenne. January is typically the coldest month of the year; July, the warmest. The highest recorded temperature at Cheyenne is 100 degrees Fahrenheit. This has occurred four times since recording began: July 14 and 15, 1881; July 11, 1939; and June 23, 1954. The lowest temperature recorded is -38 degrees on January 9, 1875.

![Figure 2-2. Mean monthly temperature distribution at Cheyenne.](image)

b. **Precipitation**

Moisture-laden air masses originating over the northern Pacific Ocean or over the Gulf of Mexico cause most of the precipitation occurring over Cheyenne. Significantly affecting the amount of moisture these air masses bring to Cheyenne is the area’s remoteness from the distant source areas of the moist air. Northward-moving gulf air masses may collide with cooler air masses. Thus, gulf air masses can lose much of their moisture over the Great Plains region of the country. Air masses from the Pacific must traverse many mountain ranges prior to reaching the basin. When forced to climb above a mountain range, an air mass loses much of its moisture as rain or snow. The many mountain ranges between the Pacific Ocean and the North Cheyenne area drain much of the moisture from these air masses before they reach Cheyenne.
Precipitation at Cheyenne averages about 15.3 inches a year, and has ranged from about 6 inches to nearly 24 inches during the past 93 years (Figure 2-3). Greatest precipitation occurs in May, averaging about 2.5 inches. July, the month in which consumptive water use of urban lawns is greatest, averages about 2.0 inches of precipitation. Mean precipitation depths fall to about one-half inch during the mid-winter months (Figure 2-4). Summertime rainfall occurs mostly from afternoon thunderstorms. As the ground surface is warmed by sunlight, so is the air just above it. As this unstable warm air rises into the cooler atmosphere, clouds are formed. Resulting storms can be quite violent, producing heavy rains, large hail, tornadoes, and damaging wind and lightning. The City of Cheyenne experienced a devastating flood on August 1, 1985, in which people died and over $60 million in damage was done. The maximum one-hour rainfall for that storm was 3.5 inches. This intensity, combined with large amounts of hail, produced significant flooding in the city.

Figure 2-3. Long-term precipitation variation at Cheyenne.
Evaporation describes the process of the return of moisture from the earth’s surface back to the atmosphere. Many climatological factors affect evaporation including solar radiation, temperature, and wind. In Wyoming, total annual evaporation tends to be much greater than precipitation. Evaporation is measured using specially constructed pans and adjustment factors which are used to estimate lake evaporation from pan evaporation. Mean annual pan evaporation in the Cheyenne area is estimated at 67 inches, with gross lake evaporation estimated at 47 inches using a 0.7 adjustment factor. Most evaporation occurs from May to September with only limited evaporation during the winter months. Water can also evaporate from soil surfaces, if conditions are favorable.
Water is also lost to the atmosphere through plants. This process is called transpiration, and like evaporation, is affected by solar radiation, temperature, and wind. In addition, plant species and soil type determine how much water is transpired. Lawn grasses require a great deal more water than native vegetation to maintain a desirable appearance; therefore, irrigation of lawns is a necessity in the study area.

Evapotranspiration is the combined process of evaporation from water surfaces and soils and transpiration by plants. Figure 2-5 illustrates the seasonal variation of evapotranspiration in the Cheyenne area.

![Mean monthly evapotranspiration distribution at Cheyenne.](image)

d. Vegetation

Native vegetation type over the study area is rangeland short grass. Non-native vegetation consists of lawn grasses and various tree species.
B. Urbanization of the North Cheyenne Area

1. History of Development

The earliest plat in the North Cheyenne area was filed in 1929. The tract is located on Yellowstone Road outside the city limits in Township 14 Range 66 Section 19. Lots in this tract vary in size, some being less than 1 acre. There are other tracts along north Yellowstone that contain lots that are smaller than the county’s current 5-acre minimum. Filing dates for some plats are as early as 1946.

Other platted corridors as shown on Figure 2-1, occur along Ridge Road as far north as East Riding Club Road, and along Powerhouse Road north to Iron Mountain Road. Full development of these platted tracts has not yet occurred. The smallest lots along Ridge Road extend to the base of Buffalo Ridge. On top of Buffalo Ridge, lot size is much greater. There is development along Powderhouse Road north of Dell Range Boulevard on the west side of the road up to Storey Boulevard. Larger lots are found north of Storey on either side of Powderhouse.

Some of the largest lots can be found in Sections 33 and 35 of Township 15 Range 66 (Figure 2-1). These tracts were platted in 1970 and 1976, respectively. Well permits for Section 33 were filed as early as October 1970, while the last well permit was issued in December of 1990. Well permits in Section 35 range in date from June 1973 to March 1990. Many of these lots are currently developed.

2. Present Level of Development

As of July 1992 there were 1,444 households in the North Cheyenne area, based on tabulation of addresses and counting of residential zoning certificates issued. The current population of the study area is estimated to be 4,476 people, based on a density of 3.1 persons per household or address.

The popularity of the North Cheyenne area is evidenced by the number of residential zoning certificates issued in 1991 and the first half of 1992: 31 and 42, respectively. This growth rate is significantly higher than that estimated by the Wyoming Department of Administration and Information, Division of Economic Analysis. Because of the apparent low population projected by the State, additional study was conducted to estimate future population for the study area.
C. The North Cheyenne Water Supply Situation

1. Water Rights

Wyoming water law is based upon the Doctrine of Prior Appropriation. Under the Doctrine of Prior Appropriation the State owns all waters of the State. Anyone intending to beneficially utilize water in the State of Wyoming must first obtain an approved permit from the State Engineer. Upon approval of the permit by the State Engineer an appropriation is granted and the appropriator may proceed with construction of the project, the beneficial use of the water and the ultimate perfection of the water right.

The Doctrine of Prior Appropriation provides a mechanism for regulating and distributing the physically available water resource to the various appropriators who hold valid water rights. Under this system the regulating and distributing of the available water resource is accomplished by utilizing the priority date of the water right. The water right priority date is the date upon which the application for the water right permit was filed in the State Engineer's Office. Regulation and distribution of the available water supply proceeds by supplying water to the appropriation with the oldest water right priority date first and then proceeding through the list of younger priority dates until the water supply is either exhausted or all water rights from a particular water source are satisfied. It is by virtue of this system of water regulation and distribution that the phrase "First in time, first in right" comes to be.

Regulation and distribution of water resources by the water right priority date is a relatively straightforward task when surface water resources are involved. The use of priority regulation for groundwater rights becomes much more complex because the depths at which groundwater is found and the costs associated with its production are not as easily assessed as are surface water resources residing on the earth's surface. Two complex concepts prevail in Wyoming's groundwater statutes and while these concepts, maximizing beneficial use of the groundwater resource and priority regulation initially seem confusing and diametrically opposed to each other, they are not. Wyoming Statute 41-3-933 states "It is an express condition of each underground water permit that the right of the appropriator does not include the right to have the water level or artesian pressure at the appropriator's point of diversion maintained at any level or pressure higher than that required for maximum beneficial use of water in the source of supply. The state engineer may issue any permits subject to such conditions as he may find to be in the public interest." This statute would seem to contradict the concept of strict water right priority regulation. However, the interpretation of Wyoming Statute 41-3-933 says that until all appropriators of groundwater from the same aquifer are obtaining their water from the same depth within the aquifer, no priority regulation or distribution of the
groundwater resource will take place. The reason that no regulation or distribution will take place is because the first appropriator to have developed a well in the aquifer may have only just barely penetrated the water table.

Subsequent groundwater development without proper well spacing could draw the groundwater level down in the vicinity of the first well owner and cause injury to the first well owner. If the premise is accepted that the groundwater level or artesian pressure of the first appropriator in an aquifer is to be maintained, further development of the groundwater resource could not occur in that specific aquifer. Such an action would tend to "minimize" and not "maximize" the beneficial use of the groundwater contained in the aquifer which is inconsistent with Wyoming Statute 41-3-933. Thus all wells need to fully penetrate the aquifer, before a legitimate water right interference claim would exist. While seemingly harsh, such a concept serves to maximize the beneficial use of the states groundwater resources.

2. Groundwater Development

a. History of Groundwater Development

Figure 2-6 shows how the number of well permits issued has increased over time. Growth was slow during the first half of the century, with some increase after World War II. The greatest boom occurred during the mid to late 1970's, with about 750 permits issued in 7 years. Since 1985 the rate has leveled off to less than 50 permits each year. Figure 2-7 shows the location of all wells in the study area as of July 1992.

b. Present Status of Development

There are currently 1,464 valid well permits in the study area on file at the Wyoming State Engineer's Office. This does not mean that there are that many wells in operation, or even in existence. Some operating wells have more than one permit attached to them, while some permitted wells have not yet been constructed. In general, an applicant for a well permit must submit a certificate of completion within one year; however, extensions may be granted. If the well is not completed within one year and an extension is not granted, the permit may be canceled.
Figure 2-6. Historic increase in the number of wells in the North Cheyenne study area.

Figure 2-7. Location of all wells in the North Cheyenne study area as of July 1992.
3. **Cheyenne Municipal Water System**

a. **Present Service Area**

The Cheyenne Municipal Water System services the following areas: the City of Cheyenne, Warren Air Force Base, and the South Cheyenne Water and Sanitation District.

b. **Planned Service Area**

Future service areas are planned to the sewerable boundary shown on Figure 2-1. The sewerable boundary is based on elevation: on the north side of the boundary, flow of sewer lines is north away from the two existing sewer treatment plants, while sewer line flow on the south side of the boundary is toward the treatment plants.

c. **System Components**

**Capacity**

Current estimated yield for the Cheyenne Municipal Water System from both surface water sources and well fields is about 28,500 acre-feet per year. Surface water sources include Stage I, Stage II, and Crow Creek systems. Well production is from three well fields: Federal, Happy Jack, and Bell. Current demand is for approximately 15,000 acre-feet per year, which includes system losses of 3,500 acre-feet per year.

**Storage**

Water storage requirements consist of operational, emergency, and fire storage. In general, emergency storage is that amount that will be sufficient to supply the area in times of planned or unplanned equipment outage or in case of major disasters. Requirements for fire storage are determined by the Cheyenne Fire Administration Office. Combined water storage requirements in 1985 were about 33 million gallons. Projected requirements for the year 2010 are about 50 MG.

As of the writing of this report, total system storage is 23 MG: 13 MG at the Round Top water treatment facility, 5 MG in the King Reservoir near the Sherard water treatment plant, and 5 MG in the Buffalo Ridge tank. An additional 15 MG of storage will be available after the completion of the King II tank at the Sherard location.

**Pressure**

Elevation differences in the service area are one cause of pressure problems in the system. Round Top and King Reservoirs have high water levels of 6,369 and 6,365 feet.
respectively, and the lowest elevation in the service area is about 5,900 feet. This difference creates pressures that are too great for the lower areas, which makes installation of pressure reducing valves necessary.

Peak summertime usage, on the other hand, causes low pressure problems in some locations. Two higher elevation areas currently use booster pumps during peak flows: Monterey Heights, with a maximum elevation of about 6,260 feet; and Western Hills, with a maximum elevation of about 6,250 feet.

The 1985 Water System Master Plan (J.M. Montgomery, 1985) proposed the establishment of three pressure zones, of which Zones 1 and 2 included a small portion of the North Cheyenne study area. The northern boundary of Zones 1 and 2 correspond roughly to the sewerable boundary shown in Figure 2-1.

D. History of Groundwater Actions

The State Engineer's office recognized problems in the area at least as early as 1973 when measurement of water levels were made throughout the area. However, first mention of the problem in an Annual Report of the State Engineer was in 1984. The State Engineer's activity in the area beginning in 1984 has been described by Stockdale (1984, 1985, 1986, 1987, 1988, 1989, and 1990). The pages of these reports describing the activity are included in Appendix A. A summary follows.

In early December 1983, the Groundwater Division of the State Engineer's Office was contacted by the Cheyenne-Laramie County Regional Planning Office concerning the availability of groundwater in an area north and east of Cheyenne, an area which includes North Cheyenne. The division agreed to look into the situation by utilizing a computer model. The result of the model was a prediction that groundwater levels would decline by as much as 30 feet in North Cheyenne if all the platted lots were developed. A report was sent to the Planning Commission in January 1984.

On April 4, 1984 a public meeting was held to receive public input regarding the situation. A second meeting was held in June 1985 to present data that had been collected after the 1984 meeting. After this meeting, members of the Cheyenne-Laramie County Planning Commission decided that they should recommend to the Laramie County Commissioners that a committee be formed to look into various alternatives suggested in the two meetings.
The NCGWAC (North Cheyenne Groundwater Advisory Committee) had its organizational meeting August 28, 1985. During the year the committee met 9 times. Two reports were drafted and submitted to the Board of County Commissioners. The second report (June 3) provided the Commissioners with a list of solutions to groundwater-supply problems and contained the following recommendation:

"The North Cheyenne Groundwater Advisory Committee believes that the present residents of the area would prefer that any future development of the North Cheyenne Area preserve the area's low density, rural character, and therefore the residents would favor immediate implementation of the 11 solutions classified as 'low density'. (Motion made, seconded and passed at May 14, 1986 meeting)."

During fiscal year 1987 NCGWAC pursued two goals: (1) Education regarding the groundwater problem and (2) implementation of identified long and short term goals.

During fiscal year 1988, members of the State Engineer's Groundwater Division attended meetings held by NCGWAC and provided input to the committee's deliberations on the kind of a water district to be formed in the North Cheyenne area and the proposed boundaries of the District.

In fiscal year 1989, the members of NCGWAC felt that substantial progress had been made and the next step would be the formation of a water and sewer district. Because the goals for which the committee was created had been substantially achieved, it was recommended that the Committee be dissolved.
3 Hydrogeologic Setting
3 Hydrogeologic Setting

A. General

The Tertiary aquifer, as designated in Laramie County by the Wyoming Department of the State Engineer (WDSE), consists of the Ogallala Formation of Miocene and Pliocene age, the Arikaree Formation of Miocene age, and the White River Formation of Oligocene age. Within Laramie County, all three are major aquifers and, in places, yield in excess of 300 gallons per minute to local wells. The Ogallala Formation and the White River Formation are present in the subsurface in North Cheyenne. The Arikaree Formation is unknown because of its erosion prior to the deposition of the Ogallala. The Arikaree is included in this discussion because, where present, it is a possible source of water for a supply to North Cheyenne.

The three formations are considered a single, interconnected aquifer by the Wyoming Department of the State Engineer and in some reports of the U.S. Geological Survey (Crist 1980, p. 5; Luckey and others, 1986, p. 2). The formations cannot be distinguished in most logs of wells on file at the State Engineer’s Office. One well driller in the area (McRady’s Well Drilling, Inc.) indicates there is no change in water production with depth.

However, there are differences in the hydrologic properties of the formations in most areas. Therefore, the lithology and water-bearing properties of the formations are described both separately and in combination in the following sections.

B. Ogallala Formation

The Ogallala Formation is a water-laid deposit consisting of clay, silt, sand, gravel, cobbles — and less commonly — limestone. The clastic part of the formation was derived by erosion of older rocks, including the Arikaree and White River Formations — therefore complicating differentiation of the formations in the subsurface. Much of the coarse fraction consists of igneous and metamorphic rocks derived from the Laramie Mountains. Calcium carbonate cement, which decreases permeability, is common in the Ogallala. However, the cementation differs markedly both laterally and vertically. Large differences in cementation occur in the vertical within distances measured in inches.
The heterogeneity in the Ogallala formation is reflected in the aquifer properties. Theis (1941, p. 15) cited anomalies that were ascribed to irregularities in the aquifer; Morgan (1946, p. 12) noted that wells in Cheyenne's well field west of town appear to tap two or more locally separate lenses. Lowry and Crist (1967, p. 32), described four lenses tapped by city wells.

The average transmissivity determined from aquifer tests in the Ogallala in the Cheyenne well field was 16,000 gallons per day per ft (Lowry and Crist, 1967, p.36). Because of the heterogeneity and because the wells used in the tests were known to be in the strata with the largest transmissivity, Lowry and Crist (1967) used a regional method to analyze the transmissivity in the well field. They concluded that the transmissivity obtained by this method — 3,800 gpd per foot — was a more reasonable value in the well field.

C. Arikaree Formation

The Arikaree formation consists principally of very fine to fine-grained sandstone that contains massive siltstone and thin beds of volcanic ash. In places there is a conglomerate at the base (Lowry and Crist, 1967, p. 13). The formation is as much as 450 feet thick (Lowry and Crist, 1967, p. 8).

Aquifer tests have not been made in Laramie County to determine the transmissivity of the Arikaree. However, the permeability of the Arikaree is similar to that in the Ogallala Formation. This is indicated by the similarity in specific capacities, which is the ratio of yield to drawdown in the well. Large yields from the formation in the Lusk area have been ascribed to secondary permeability. Similar permeability has not been described in Laramie County.

Only the sandstone and conglomerate beds or zones of secondary permeability would yield water in sufficient quantities to be considered as a source of supply for North Cheyenne.

D. White River Formation

Lillegraven and Ostresh (1988, p. 320) described the earliest Oligocene as a period when "repetitious blanketings of airborne volcanic ash were washed off the highlands, reworked by fluvial and aeolian processes, and redeposited in the basins by periodic flooding of sediment-choked streams of all sizes." Lillegraven and Ostresh (1988, Figure 12) concluded that the drainage on the west side of the Laramie Range was northward and that the drainage on the east side was by streams flowing eastward.
In an area that includes Laramie County, Denson and Bergandahl (1961, p. C170) described the White River Formation as consisting of 65 to 85 percent silt and 5 to 25 percent very fine grained sand embedded in a matrix of clay-sized particles. Sandstone and conglomerate beds are present, and are more common near the mountains, but Crist (1980, p. 8) has identified the beds near the eastern edge of the county. However, because coarse grained material is a minor part of the White River, chances of obtaining a supply for any purpose are not as good as the chances in an equal saturated thickness of Ogallala/Arikaree.

Secondary permeability in the White River Formation has been ascribed to fractures (Rapp and others, 1953), piping (Lowry, 1966), and solution (Crist, 1972, p. 21). The reader is referred to these papers for additional discussion of the secondary permeability. Although the authors differ on cause of the secondary permeability, none have described the permeability as occurring where the White River is overlain by either the Ogallala or the Arikaree Formations. Secondary permeability in the White River in North Cheyenne has not been reported to the State Engineer as a source of water to wells (Richard G. Stockdale, personal communication, June 1992).

E. Tertiary Aquifer

The Ogallala and Arikaree, or the Ogallala, Arikaree, and White River Formations are considered as a single aquifer, the tertiary aquifer, in some reports. The use of this term is necessary to summarize those reports.

The Ogallala and Arikaree were considered as a single aquifer by Lowry and Crist (1976). Plate 2 of that report indicates the saturated thickness of the combined formations to be 150 to 250 feet in North Cheyenne. Crist (1980), in modeling the aquifer to determine the effect of pumpage on groundwater levels, considered the Ogallala, Arikaree, and White River to be a single aquifer. The combined saturated thickness of the three units in North Cheyenne, determined by subtracting the water level elevation from the bottom of the aquifer reported by Crist (1980 Plates 2 and 3), is about 500 feet. Measurements by the WDSE for 1989 show that water levels are about 10 feet higher than those of Crist (1980), so the saturated thickness of the Ogallala-Arikaree is about the same as the original estimate although there have been water level declines in the area. The bottom of the White River at two sites in the area (State Engineer groundwater permits UW83717 and UW8288) were 150 to 200 feet higher than mapped by Crist (1980). The difference probably is because of large relief on the pre-White River erosion surface.
1. Recharge, Discharge, and Movement of Water

Before the development in North Cheyenne, recharge to the Tertiary aquifer in North Cheyenne was from precipitation and from flow through the aquifer from the west. Natural discharge from the area was by flow to the east. With urban development, discharge by pumping and groundwater recharge from irrigation and effluent from septic tanks was imposed on the natural system. The recharge from septic tanks is estimated to be one-third of the total volume pumped. Recharge resulting from the irrigation of lawns is illustrated by water levels in a well that was located behind the State Capitol building as shown on Figure 3-1. Although some recharge from irrigation occurs, there is still a net loss in the groundwater reservoir in the area served primarily by groundwater. Water levels in areas bordering Cheyenne do show effects of lawn watering in the City.

![Figure 3-1. Seasonal water-level fluctuations caused by lawn irrigation.](image)

Water level data prior to that collected in North Cheyenne by the Wyoming Department of the State Engineer indicated an eastward gradient in the area. Analyses of data collected by the State Engineer in 1973 (Figure 3-2) support that the flow is generally eastward.
The time that is required for precipitation to reach the water table has been estimated by tritium analyses of water from two wells in the City well field. The samples were collected in 1966 by the U.S. Geological Survey. These tritium values indicate it was unlikely that there was any recent age water in samples from the two wells at that time and that the water was probably more than 30 years in age (written communication, Gordon L. Stewart, Tritium Lab, WRD, Washington D.C., July 1966).

2. **Water-Level Fluctuations**

Water-level changes in the Tertiary aquifer in observation wells in areas outside of the study area appear to be related to long-term trends in precipitation, rather than year to year changes or changes that can be attributed to specific rain storms, and to pumping in the area.
Water levels in a well four miles north of the North Cheyenne study area that is occasionally affected by irrigation (Figure 3-3) has risen about four feet since 1982. Water levels in a well five miles east of North Cheyenne is affected by pumping of domestic wells at Durham Estates (Figure 3-4) has also had a persistent upward trend during the same period. The rising water levels in these two wells are attributed to above normal precipitation during the past 10 years. Records obtained from National Oceanic and Atmospheric Administration for Cheyenne show that the mean annual precipitation for Cheyenne is 14.69 inches. The difference in the mean annual precipitation from 1982 to 1991 was +27.21 inches. Perhaps more significant, the difference between 1982-1992 and the 10 years immediately prior was +40.81 inches.

Long-term trends in water levels for the period of record in three observation wells in North Cheyenne were analyzed. Water levels in wells on the west side of the study area (Figures 3-5 and 3-6) have seasonal changes of 15 to 20 feet but the peaks were somewhat higher from the beginning of record through 1989. A rise in water levels during the period is also shown by water level measurements of the Wyoming State Engineer in 1973 and 1984 in the extreme northwest part of the study area. This contrasts with the well on the east side of the study area (Figure 3-7) which declined about 0.3 feet a year since the beginning of record to the present and has a seasonal change of 1.5 to 2.0 feet.

The difference in water level fluctuations of the wells on the west and east sides of the study area are, in part, explained by the position of the wells within the cone of depression caused by pumping in North Cheyenne. The position of the three wells are shown on an east-west section of the 1989 potentiometric surface on Figure 3-8. The 1989 potentiometric surface is shown on Figure 3-9. Because groundwater flow is related to gradient, it follows that the flow into the area of the two wells on the east side of the area would be greater than that of the observation well on the west side of the area.

Daily highest water levels were used to summarize the long term trends described in the previous paragraphs. To illustrate the effects of pumping within the area, hourly data from March 1 to June 1, 1992 was obtained from the U.S. Geological Survey for well 14-66-10aba01. The data on Figure 3-10 shows weekly cycles and that yard irrigation work began the end of April. Detail of the cyclic change for two consecutive weeks, as shown on Figure 3-11, shows that use of water predominates in the mornings and evenings and that, at least in this area, Sunday is a day of rest and Monday is still wash day.
Figure 3-3. Long-term trend in water level in a well north of North Cheyenne that is occasionally affected by irrigation.

Figure 3-4. Long-term trend in water level in well east of North Cheyenne affected by pumping of domestic wells.
Figures 3-5 and 3-6. Seasonal variation of selected wells on the west side of study area.
Figure 3-7. Seasonal variation of selected well on the east side of study area.

Figure 3-8. East-West cross section of wells of the 1989 potentiometric surface.
Figure 3-9. 1989 potentiometric surface - North Cheyenne.

Figure 3-10. Hourly data for selected well - March through May, 1992.
Figure 3-11. Detail of weekly water level fluctuations in well 14-66-10aba01, North Cheyenne.

F. Effects of Groundwater Development

1. Declining Water Level

Decline of the water levels in most of North Cheyenne is documented in measurements made by the Wyoming Department of the State Engineer in 1973, 1984, and 1989. Whereas the total decline prior to 1973 can not be determined, the potentiometric surface for 1973 (Figure 3-2) shows a closed depression in the northeast part of the area and a steepening of the water table gradient on the west side of the area that are a result of pumping.

In 1973, development was concentrated more heavily in the western and eastern sides of the study area compared to that in the central part of the area, and the greatest decline would be anticipated in these areas. However, lawn irrigation within Cheyenne recharged the groundwater in some areas adjoining Cheyenne. Development since 1973 has occurred more heavily in the central part of the study area.
The eastern and the western parts of the study area, where they do not border the city, had the largest decline in water level between 1973 and 1989. The decline was at least 10 feet in most of the study area but it exceeded 30 feet in places (Figure 3-12). The figure indicates that the water level declines are extensive and affect approximately two-thirds of the study area to a considerable extent. The eastern most portions of the study area have not been affected as yet.

![Figure 3-12. Water level change in the Tertiary aquifer, North Cheyenne, 1973 to 1989, in feet.](image)

2. Degradation of Water Quality

There can be little doubt that effluent from septic tanks will seep into the aquifer and that the concentration of nitrates and other constituents will increase. The question is only one of time and concentration. The issue of degradation of water quality will be addressed in Chapter 6 of this report. This chapter includes a field testing program as well as a review of previous data.
3. **Deterioration of Wells**

A water well deteriorates in time. When this occurs, an associated decrease in yield can be mistakenly attributed to declining water levels. Some of the water wells supplying the City of Cheyenne have deteriorated and have been replaced by new wells at the same sites. The period between the original drilling and redrilling for two of the wells, City designations Bell 8 and Elkar 5, was 35 and 42 years, respectively. However, problems with the wells were noted in a report by the U.S. Geological Survey to the City of Cheyenne about 20 years prior to the time of redrilling.

Differences in the useful life of domestic and municipal wells would be expected because of differences in construction and the quantity of water pumped. However, it would be reasonable to assume some domestic wells in North Cheyenne would show effects of age in a similar period (about 20 to 30 years). Three wells in the study area that were being replaced by new wells were evaluated to determine if the problem was declining water levels, deterioration of wells, or both. It was determined that deterioration of the wells was the primary problem rather than decline of the aquifer.
4 Water Supply Needs
4 Water Supply Needs

A. General

A master plan requires estimates of population growth and water demands. This chapter develops the projections for the 50-year planning period. Several assumptions have been made when projecting the future development of the study area. One major assumption is that the City of Cheyenne will grow to the north to the limits of the sewerable boundary as shown on Figure 2-1. This assumption effectively eliminated the area south of the sewerable boundary from this study. This area has been previously studied in the Water Master Plan performed for the BPU in 1986. The Sponsor and the WWDC were in agreement to the assumption.

B. Projected Population Growth and Development

1. Current Population in the County

The population determination in the unincorporated area in the study area was approached using several different methods. The first approach was the tabulation of addresses (or residences) in the study area from the Laramie County Map and Address Book, dated November 1, 1991, published by the Laramie County Engineer’s Office. Forty-six (46) additional residential zoning certificates were issued from that date to July 7, 1992. The total number of residences in the study area was 1,444 as of July 7, 1992.

Information was also collected from the two electric utility companies serving the area (Cheyenne Light, Fuel and Power and Rural Electric Company). The total number of services was 1,443. This information was used to confirm the initial estimate discussed above.

There are an estimated 3.1 persons per residence or address. The average is based on the 1990 U.S. Census of Population and Housing available at the Wyoming State Librarian’s office. The current population of the study area is estimated to be 4,476.

2. Future Population

The Wyoming Department of Administration and Information, Division of Economic Analysis has prepared population forecasts using the 1990 Census data and the Wyoming
Economic Forecast for the years 1991 - 2002. The Division further extrapolated the State's populations for the years 2003 to 2012 for a total of 22 years of population projections.

The Division of Economic Analysis projected growth rate for the entire county is 0.7 percent. For the 22 years of forecasts, this translates to a total growth rate of 3,536 persons in the unincorporated parts of Laramie County. In the study area, this would mean a total population growth of 658 people for the 22 year period, about 30 persons per year or about 10 households, as shown on Figure 4-1. The figure also indicates the historical growth of Cheyenne and Laramie County. As indicated, the historic growth rates considerably exceed the State projections.

The Laramie County Engineer's Office issued 31 residential zoning certificates in 1991 and issued an additional 42 residential zoning certificates during the first half of 1992. The building "boom" in Laramie County and especially in the study area, has deviated from the forecasted growth. In addition, the historic growth of well permits for the study area exceed the State projections as shown in Figure 4-2. As shown, the projected growth of well permits based upon the most recent years is approximately 30 permits per year.

Consequently, the County Commissioners and the WWDC assumed that a growth rate of 30 houses per year in the unincorporated area of the study area should be used. The projected growth approximately equals the projected well growth, as shown on Figure 4-2. This projected rate of growth is also approximately equal to the long-term growth rate for Laramie County, as shown in Figure 4-1. Based on this assumption, population projections were made for the 50 year study period, as shown in Table 4a.

<table>
<thead>
<tr>
<th></th>
<th>Population projections - county.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Residences</td>
<td>1,444</td>
</tr>
<tr>
<td>Population</td>
<td>4,476</td>
</tr>
</tbody>
</table>

C. Future Development Patterns in the County

The breakdown of the existing occupied residences into a range of lot size is tabulated below:
At this time, the Laramie County subdivision regulations have set the minimum lot size at 5 acres. The County Health unit will not issue a waste treatment (septic) permit for less than one acre. This is for the previously platted, but undeveloped lots and tracts, which number 625 at the time of this report. Assumptions had to be made to allow projection of growth pattern. It has been assumed for study purposes that the minimum lot size would be reduced to 2.5 acres if water supply was available. Further assumptions are that all new development (the platting of land parcels currently greater than 10 acres) will occur within one-half mile of the following paved roads:
Two parcels of State of Wyoming land are located within the study area. The south half of Section 2 and the northeast quarter of Section 16 were excluded from the development projections.

These assumptions allowed projection of the number of lots available for development in the County. The number of lots available for development under the above assumptions would be 3,101 lots. At the rate of 30 houses per year, the development of the lots would take nearly 103 years. The detailed breakdown of the lot development projections are included in Appendix B, Table B-1.

D. Water Usage in the County

Water usage was estimated from a study performed at the University of Wyoming entitled "Water Requirements for Urban Lawns", 1979. A three year study of residential water use with emphasis on lawn water use was conducted. Lawn water application rates, potential evapotranspiration rates of lawn grass in an urban setting, and household use were monitored in Laramie and Wheatland, Wyoming.

Based on the study, the average water use for the study area has been estimated as 210 gallons per capita per day (gpcpd). Of this water use figure, 71 percent is for lawn irrigation or 150 gpcpd and only 60 gpcpd for in-house use. Based upon these water usages and the population projections, the water usage was projected for the 50-year study period. Both average demands and peak demands have been projected for the 50-year period. The projections are presented in Table 4b. The detailed breakdown of the water usages are included in Appendix B, Table B-1.
### Table 4b: Water use projections - county.

<table>
<thead>
<tr>
<th>Year</th>
<th>Average Demand - GPM</th>
<th>Average Demand - CFS</th>
<th>Average Demand - MGD</th>
<th>Average Demand - AF/Yr.</th>
<th>Peak Demand - GPM</th>
<th>Peak Demand - CFS</th>
<th>Peak Demand - MGD</th>
</tr>
</thead>
<tbody>
<tr>
<td>1992</td>
<td>651</td>
<td>1.45</td>
<td>0.94</td>
<td>1,048</td>
<td>1,634</td>
<td>3.64</td>
<td>2.35</td>
</tr>
<tr>
<td>1995</td>
<td>696</td>
<td>1.55</td>
<td>1.00</td>
<td>1,200</td>
<td>1,737</td>
<td>3.87</td>
<td>2.50</td>
</tr>
<tr>
<td>2005</td>
<td>830</td>
<td>1.85</td>
<td>1.20</td>
<td>1,337</td>
<td>2,083</td>
<td>4.64</td>
<td>3.00</td>
</tr>
<tr>
<td>2015</td>
<td>969</td>
<td>2.16</td>
<td>1.39</td>
<td>1,561</td>
<td>2,414</td>
<td>5.38</td>
<td>3.48</td>
</tr>
<tr>
<td>2025</td>
<td>1,104</td>
<td>2.46</td>
<td>1.59</td>
<td>1,778</td>
<td>2,760</td>
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<td>3.98</td>
</tr>
<tr>
<td>2035</td>
<td>1,238</td>
<td>2.76</td>
<td>1.78</td>
<td>1,995</td>
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<td>6.88</td>
<td>4.45</td>
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<tr>
<td>2045</td>
<td>1,374</td>
<td>3.06</td>
<td>1.98</td>
<td>2,213</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### E. Maximum Possible Development

To determine the maximum possible development in the unincorporated portions of the study area, the assumption was made that all undeveloped land would be developed regardless of location. This includes the areas located further from the existing paved roads. The lot size was reduced to 2.5 acres under the assumption that water supply would be available. The number of lots available for development under these assumptions was 5,504, an increase of 2,403 over the previous scenario. The water requirements for this scenario were also developed. The detailed breakdown of the lot development projections and water usage are included in Appendix B, Table B-2.

![Figure 4-2. Historic and projected increase in the number of wells in the North Cheyenne study area.](image)
5 Water Supply Alternatives
5 Water Supply Alternatives

A. General

This chapter analyzes the water supply alternatives for the North Cheyenne study area. The alternatives include the No Action alternative to serve as a comparison for the water supply alternatives. Several categories of Groundwater Management alternatives were investigated. These included moratoriums on well construction, lot size limitation, and irrigation controls as one category. The other category included recharge alternatives.

Alternatives involving water supply systems to replace groundwater use were investigated. These included systems constructed to City of Cheyenne standards with use of City water. Systems constructed to lower standards called rural systems were also investigated. The rural systems were analyzed with both water supply from the City and from groundwater sources.

B. The No Action Alternative

The No Action Alternative will occur if the existing patterns of development continue in the study area. As indicated in Chapter 4, approximately 30 additional housing units per year has been assumed as the expected growth rate. This section will evaluate the costs to the residents of the study area of the No Action Alternative. The long term effects of the alternative are also discussed.

1. New Development

It has been assumed that all new housing units would drill wells which would penetrate the entire aquifer. The average depth of the new wells has been estimated to be 600 feet. The wells would be constructed in accordance with DEQ and SEO regulations. The expected life of the new wells would be approximately 40 to 50 years. The longer expected life is due to improved technology and materials. The projected residence and associated well growth is shown in Table 5a.
Table 5a: No action alternative.

<table>
<thead>
<tr>
<th></th>
<th>1995</th>
<th>2005</th>
<th>2015</th>
<th>2025</th>
<th>2035</th>
<th>2045</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total residences</td>
<td>1,540</td>
<td>1,840</td>
<td>2,140</td>
<td>2,440</td>
<td>2,740</td>
<td>3,040</td>
</tr>
<tr>
<td>Failed wells/year</td>
<td>10</td>
<td>20</td>
<td>30</td>
<td>40</td>
<td>50</td>
<td>60</td>
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<tr>
<td>New development/year</td>
<td>30</td>
<td>30</td>
<td>30</td>
<td>30</td>
<td>30</td>
<td>30</td>
</tr>
</tbody>
</table>

New Development Costs

- Well construction -
  Inflated 150,000 222,000 328,600 486,500 720,200 1,066,100
- Pump & well maint. -
  Inflated 15,000 44,400 98,600 194,600 360,100 639,600
- Power costs -
  Inflated 15,000 53,300 138,000 311,300 648,100 1,279,300

Existing Well Costs

- Well reconstruction -
  Inflated 50,000 148,000 328,600 648,600 1,200,200 2,132,100
- Pump and well maint. -
  Inflated 75,000 111,000 164,300 243,200 360,100 533,000
- Power costs -
  Inflated 75,000 133,200 230,000 389,200 648,100 1,066,000

Total annual costs

- Inflated 380,000 711,900 1,288,100 2,273,400 3,936,800 6,716,100
- Present worth 380,000 481,000 587,900 700,900 820,000 945,000
- Cost/Residence/Yr. -
  Present worth 247 261 275 287 299 311

Total Present Worth for 50-year period = $32,523,000
2. Existing Development

The existing wells in North Cheyenne will continue to fail for two primary reasons. The declining water levels will render the shallower wells useless. In addition, most of the existing wells will reach the end of their expected life during the 50-year planning period. Many of the wells were constructed to much poorer standards than present day. The expected life of the existing wells is 20 to 30 years.

For purposes of this study, it has been assumed that at the beginning of the planning period 10 wells per year will fail and this number will increase at an annual rate of one per year. At this rate nearly all existing wells will have failed by the end of the planning period of 50 years. The estimated rate of well failures is shown in Table 5a. It was assumed that new wells averaging 600 feet in depth would be drilled.

3. Well Maintenance

All wells, whether old or new, require maintenance and well pumps require replacement or repair. For this study, it has been assumed that all wells would require maintenance every ten years. It has also been assumed that well pumps would be serviced or replaced every ten years.

4. Power Costs

Power costs were estimated based on average yearly usage rates as discussed in Chapter 4. Average aquifer water levels, well drawdown, and normal household discharge pressures were estimated. Present day power costs were estimated on the basis of power costs of 5 cents per kwh. Electrical power costs were estimated on the assumption that power costs would escalate at a rate of four percent per year. The pumping depths were increased to reflect the lowering of pumping levels in the future. The pumping depths were increased an average of two feet per year. The power costs were increased over time to account for lower pumping levels.

5. Economics

The costs of the No Action Alternative to the residents of North Cheyenne are summarized in Table 5a. The costs have been presented in present worth terms to be comparable to other alternatives. For purposes of this study, the rate of inflation and rate of interest have been assumed to be four percent.

The present day cost for well construction has been assumed at $5,000 per well. This cost was used for both new development and well replacement. Pump service and
replacement and well maintenance has been estimated at $500 per well, which would be performed every ten years for all wells.

The average, annual total costs to the residents of the study area have been estimated in ten year increments over the 50-year study period. The costs per residence have been totaled by ten year periods, as shown in Appendix C, Table C-1, which also includes the detailed cost estimates.

6. Effects of Alternative

The long-term effects of the No Action Alternative are not encouraging. The costs to the present and future residents has been estimated as approximately $32.5 million in present worth over the 50-year planning period. The average, annual cost per residence in 1995 dollars is estimated to be $280 for the 50-year period. The total cost per residence for a 50-year period is approximately $14,000. Those costs include initial drilling of the well, pump installation, well maintenance, pump maintenance and replacement, and power costs. The groundwater situation at the end of the planning period would also be of great concern. The water levels in the study area would continue to decline at increasing rates because of the increased pumpage. Eventually, the levels would decline to levels such that in many parts of the study area residents could not successfully get water. Presently, some wells that penetrate the entire aquifer obtain only marginal yields for domestic purposes. This problem will be greatly increased with decreasing water levels. In addition, pollution from septic systems could impact the groundwater to the extent that the resource could no longer be used for domestic purposes. The area would eventually have to import water or development would essentially cease.

C. Groundwater Management Alternatives

1. General

The alternatives for groundwater management fall into two general categories. One category limits groundwater usage to slow down the rate of groundwater decline and extend the life of the resource. The other category involves recharge to stabilize water levels.

The average yearly withdrawal of groundwater per residence has been estimated to be 0.73 acre-feet per year. Of this total, 0.23 acre-feet return to the groundwater through the leach field. In addition, it has been found that approximately 20 percent of irrigation water also escapes back to the aquifer. Consequently, the actual loss of groundwater is approximately 0.4 acre-feet per year per residence. Based on this loss figure and the population projections, the expected overdraft on the aquifer for the 50-year period is as
shown in Table 5b. This would be the projected groundwater effects of the No Action Alternative and give an indication of the magnitude of the projected deficits.

<table>
<thead>
<tr>
<th>Table 5b. Projected Groundwater Depletions.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1995</td>
</tr>
<tr>
<td>-------</td>
</tr>
<tr>
<td>Projected Residences</td>
</tr>
<tr>
<td>Deficit-AF/Yr.</td>
</tr>
</tbody>
</table>

2. **Water Use Limitations**

a. **Moratorium on New Well Construction**

The imposition of a moratorium on new well construction would stabilize the rate of decline of the water levels. However, the present rate of withdrawal is causing declines in excess of two feet per year in some areas. The extension of the moratorium to deepening or redrilling existing wells would eventually stop the decline when all wells were out of service.

The imposition of a moratorium on well drilling or well deepening in the study area would probably not be acceptable to either existing residents or the owners of undeveloped lots. A moratorium would probably have to be accompanied by some alternative water supply.

b. **Lot Size Limitation**

At the present time, a 5 acre minimum lot size limitation exists for new development in the study area. However, as indicated in Chapter 4, there are a great number of lots already platted that do not meet the criteria. These lots can be developed at the smaller sizes. Any lot size limitation, to be effective, would have to be extended to the already platted lots. A lot size limitation would serve to spread out groundwater development. The limitation would also decrease the total number of residences in the study area. However, the pattern of declining water levels would continue.

One philosophy that has been used in other states is to limit groundwater depletion from an individual lot to the recharge occurring on that property. In other words, groundwater depletions would be limited to the precipitation falling on that property that is recharged to the aquifer. In the Cheyenne area, recharge has been estimated to be approximately 0.75 inches per year. For the average depletion of 0.4 acre-feet per year per residence, a lot size of 6.4 acres would be required to balance the recharge with the depletions. A
fallacy of this philosophy is that the recharge on undeveloped areas contributes to the present situation and removal of the recharge will cause further declines. The philosophy was discussed in detail by Bredehoeft, Papadopulos, and Cooper (1982, pp. 51-57).

The primary benefit of the lot size limitation would be to spread out the development and not create additional areas of high concentrated withdrawals. However, the groundwater declines would continue due to the existing development and the additional wells. A lot size limitation would be most appropriate for more remote parts of the study area that cannot be served economically by some other alternative water supply.

c. Irrigation Controls

The area actually irrigated per residence varies greatly. The pumping rates used for this study are averages and reflect a wide range of irrigation practices. The average water usage will support an irrigated area of approximately 0.2 acre or 8,700 square feet. There are examples in other states of irrigation limitations being placed on irrigated area per residence or lot. To be effective, the limitations would have to be considerably more stringent than the present irrigation practices. The imposition of irrigation controls would serve to reduce the rate of increase of decline, but would not reverse the decline. The irrigation controls would be most effective if the controls were combined with lot size limitations in parts of the study area that could not be served economically by other alternative water supplies.

3. Recharge Alternatives

A general method to reverse the deficit and stop water level declines would be to develop recharge within the study area using imported water. The present and future deficits have been summarized in Table 5b. From 600 to 1,200 acre-feet of recharge per year would be needed to reverse the declines. Several alternatives exist for recharge. These alternatives include the use of imported city water for recharge, the use of city sewage effluent for recharge, and the use of leach field effluent for recharge.

a. Recharge with City Water

One alternative would be to import water to the study area and allow it to infiltrate to recharge the aquifer. A major stumbling block for this alternative is an economical, long-term water supply for the recharge program. The only realistic sources of water are from the City of Cheyenne system, which has excess water at the present time.
The requirements for recharge of groundwater are very rigorous. The significant permit required by the DEQ Water Quality Division for groundwater recharge would be an Underground Injection Control (UIC) permit. The primary purpose of the UIC permit is the protection of existing groundwater quality. In the project area, the groundwater is defined as Class I (suitable for domestic water supply). For artificial recharge projects, the Environmental Protection Agency (EPA) has stated that such "recharge projects should be designed, operated, and completed so as to be protective of human health and the environment and in compliance with UIC regulations". The intent of the UIC regulations is assurance that one of the following conditions exist:

- that the water available for recharge at the point of injection and/or recharge does not exceed National Primary Drinking Water Standards (i.e., maximum contaminant levels)

or

- that where the water quality standards are already exceeded due to activities or environmental reasons not related to the proposed recharge project, that recharge water not exceed the ambient concentrations that exist in the groundwater.

The applicant must monitor water quality for both the receiving aquifer and the surface water source used for recharge. To establish baseline water quality conditions, a multitude of constituents must be sampled from two to four consecutive quarters prior to project initiation. Then water quality monitoring must continue on a quarterly basis, unless a less frequent schedule can be justified. The large number of constituents that must be sampled — including locally used pesticides and herbicides — causes the water quality monitoring expense to be a substantial part of project costs. Recharge projects currently funded in the High Plains States Groundwater Demonstration Program (Bureau of Reclamation, 1989) have had cost increases in excess of 50 percent for water quality monitoring requirements imposed by the EPA.

Any groundwater recharge program would probably have to use good quality water. The logical source is the Roundtop Treatment Plant, which is located less than three miles from the study area. The proposed method of operation would be to purchase water during low demand periods so as not to require additional pipeline or treatment capacity. The system would be designed to deliver 1,200 acre-feet per year in a six month period. An 18-inch pipe would carry the water to the west portion of the study area. The water would be most effective being released near I-25 into Childs Basin. The water would flow east in the drainage in Sections 7, 8, 11, 12, 15, and 16, as shown on Figure 5-1. Approximately six miles of stream would be available for recharge. Small impoundments
and spreader dikes may be necessary to insure the infiltration. This drainage is located advantageously to recharge the areas showing the most impact of lowered water levels.

The response of water levels in the City to irrigation and the maintenance of a groundwater ridge east of the Buffalo Ridge Addition in spite of a large concentration of domestic wells in the area illustrates that artificial recharge is possible. Soils bordering Childs Draw, in North Cheyenne, correlate with the Asclon loam in the eastern part of the County and are described by the U.S. Department of Agriculture, Soil Conservation Service, as being unsuitable for facilities, such as sewage lagoons and reservoir because of severe seepage. Permeability ranges from 0.6 to 2.0 inches per hour. Therefore, artificial recharge to the groundwater in North Cheyenne using City water piped to Childs Draw and its tributaries, was considered feasible.

If permeability at the low end of the range (0.6 inches per hour) could be maintained without treatment and the average wetted channel perimeter was five feet, infiltration of approximately 164 gpm per mile could be expected. To offset the pumping of the quantity projected in 50 years would require nine miles of channel. The higher permeability (2.0 inches per hours) would reduce the channel lengths to approximately three miles.

The lower permeability would be more appropriate for minimally maintained channels because growth of biomass in the soil often decreases permeability with prolonged wetting. A higher infiltration could probably be maintained by periodic drying and disking of the stream channel but this would have undesirable consequences as the bare ground would be subject to wind and water erosion. The Soil Conservation Service rate the hazard of both wind and water erosion as moderate.

Liability for damage to structures in the drainage should also be considered. Childs Draw floods on occasion and any water for recharge being released into the drainage at the time of a flood would increase the magnitude of the flood. In addition, road crossings using small culverts with low embankments might result in backwater flooding of nearby dwellings and these crossings would be damaged more frequently if recharge water was in the channel at the time of storm runoff. Ice may be a problem in and near culverts if the recharge was attempted during the winter months.

If a recharge project is considered a viable alternative, a detailed study would be required to assure that most of the benefits accrued to the residents of North Cheyenne and not adjoining areas.
Two water sources were investigated for this alternative. One source would be raw water that could be diverted from the pipeline feeding the Roundtop water treatment plant. The construction costs for this system have been estimated at $2,750,000 in 1995 dollars, as shown in Appendix C, Table C-2. If the WWDC funds this construction at 1/3 loan and 2/3 grant, the annual loan costs would be approximately $42,700. Operation and maintenance has been estimated at $75,000 per year in 1995 dollars. The BPU has indicated that the cost of the raw water would be between the range of $100 to $300 per acre-foot. Purchase of the raw water was initially estimated at $100 per acre-foot for an annual cost of $60,000 for 600 acre-feet per year. The total estimated 1995 annual costs would be $177,700. The costs were also estimated at $300 per acre-foot for the raw water. The total estimated 1995 annual costs would be $297,700 for the higher raw water cost.

The yearly costs per residence for the system are shown in Table 5c for the 50-year study period. The 1995 costs per residence would have been $115 per year or $10 per month at the $100 per acre-foot water cost. This assumes that all residences in the study area would share in the costs. The 1995 costs per residence would be $193 per year or $16 per month at the $300 per acre-foot water cost. The detailed economic analysis is shown in Appendix C, Table C-3.

The other potential source of water would be treated water from the Roundtop Water Treatment Plant. Purchase of the treated water has been estimated as $2.19 per thousand gallons or $713 per acre-foot for an annual cost of $427,800 for 600 acre-feet per year. The cost of purchasing treated water from the BPU drives this alternative too high to be affordable. Even at municipal rates, the yearly cost to purchase 600 acre-feet of treated water would be $285,500.

The total cost of recharge systems would not be complete for comparison purposes without the inclusion of costs to construct, replace, and maintain individual well systems. These costs to the residents would be similar to those for the No Action Alternative previously discussed. The primary differences between this alternative and the No Action Alternative would be that at the end of the 50 year period the groundwater resource could be preserved and the residents could continue to depend upon individual wells.

The availability of city water for recharge could also potentially be a problem. The BPU has recently indicated that excess Stage II water availability would be 5,000 acre-feet per year for the next ten years. The availability beyond that time period is unknown. The recharge program would not require water on a firm basis and could use excess waters in varying amounts, depending upon availability. However, the possibility does exist that minimal or no water would be available in later years of the study period.
### Table 5c: Groundwater Recharge with Raw Water.

<table>
<thead>
<tr>
<th>Year</th>
<th>Water recharged AF/Yr.</th>
<th>1995</th>
<th>2005</th>
<th>2015</th>
<th>2025</th>
<th>2035</th>
<th>2045</th>
</tr>
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<tr>
<td></td>
<td></td>
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<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td></td>
<td>Estimated construction cost: $2,750,000 WWDC funding 2/3 grant-1/3 loan @ 4% interest</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Water purchase cost of $100/AF</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Construction loan cost</td>
<td>42,700</td>
<td>42,700</td>
<td>42,700</td>
<td>42,700</td>
<td>42,700</td>
<td>42,700</td>
</tr>
<tr>
<td></td>
<td>O &amp; M costs-inflated</td>
<td>75,000</td>
<td>111,000</td>
<td>164,300</td>
<td>243,300</td>
<td>360,100</td>
<td>533,000</td>
</tr>
<tr>
<td></td>
<td>Water Cost-$100/AF</td>
<td>60,000</td>
<td>72,000</td>
<td>84,000</td>
<td>96,000</td>
<td>108,000</td>
<td>120,000</td>
</tr>
<tr>
<td></td>
<td>Total Annual Cost - Inflated</td>
<td>177,700</td>
<td>225,700</td>
<td>291,000</td>
<td>382,000</td>
<td>510,800</td>
<td>695,700</td>
</tr>
<tr>
<td></td>
<td>Total Annual Cost - Present Worth</td>
<td>177,700</td>
<td>152,500</td>
<td>132,800</td>
<td>117,800</td>
<td>106,400</td>
<td>97,900</td>
</tr>
<tr>
<td></td>
<td>Residences</td>
<td>1,540</td>
<td>1,840</td>
<td>2,140</td>
<td>2,440</td>
<td>2,740</td>
<td>3,040</td>
</tr>
<tr>
<td></td>
<td>Cost/Residence/Yr - Present Worth</td>
<td>115</td>
<td>83</td>
<td>62</td>
<td>48</td>
<td>39</td>
<td>32</td>
</tr>
<tr>
<td></td>
<td>Total Present Worth for 50-year period = $6,473,000</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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### Table 5c (Continued)

<table>
<thead>
<tr>
<th>Year</th>
<th>Water recharged AF/Yr.</th>
<th>1995</th>
<th>2005</th>
<th>2015</th>
<th>2025</th>
<th>2035</th>
<th>2045</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Estimated construction cost: $2,750,000 WWDC funding 2/3 grant-1/3 loan @ 4% interest</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Water purchase cost of $300 A/F</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Construction loan cost</td>
<td>42,700</td>
<td>42,700</td>
<td>42,700</td>
<td>42,700</td>
<td>42,700</td>
<td>42,700</td>
</tr>
<tr>
<td></td>
<td>O &amp; M Costs-Inflated</td>
<td>75,000</td>
<td>111,000</td>
<td>164,300</td>
<td>243,300</td>
<td>360,100</td>
<td>533,000</td>
</tr>
<tr>
<td></td>
<td>Water Cost-$300/AF</td>
<td>180,000</td>
<td>216,000</td>
<td>252,000</td>
<td>288,000</td>
<td>324,000</td>
<td>360,000</td>
</tr>
<tr>
<td></td>
<td>Total Annual Cost - Inflated</td>
<td>297,700</td>
<td>369,700</td>
<td>459,000</td>
<td>574,000</td>
<td>726,800</td>
<td>935,700</td>
</tr>
<tr>
<td></td>
<td>Total Annual Cost - Present Worth</td>
<td>297,700</td>
<td>249,800</td>
<td>209,500</td>
<td>177,000</td>
<td>151,400</td>
<td>131,700</td>
</tr>
<tr>
<td></td>
<td>Residences</td>
<td>1,540</td>
<td>1,840</td>
<td>2,140</td>
<td>2,440</td>
<td>2,740</td>
<td>3,040</td>
</tr>
<tr>
<td></td>
<td>Cost/Residence/Yr - Present Worth</td>
<td>193</td>
<td>136</td>
<td>98</td>
<td>73</td>
<td>55</td>
<td>43</td>
</tr>
<tr>
<td></td>
<td>Total Present Worth for 50-year period = $10,024,000</td>
<td></td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>
b. Recharge with Sewage Effluent

Water for recharge could also be available from the City of Cheyenne in the form of sewage effluent. It is possible to purchase the effluent that results from the Stage I and II systems, which import water to the basin. A major drawback is the distance to the study area and the pumping necessary to deliver the water. The Dry Creek Sewage Treatment Plant is located approximately 11 miles from the west side of the study area. In addition, the plant is over 300 feet lower in elevation, thereby requiring considerable pumping. A more important constraint is the previously discussed requirements for quality of recharge water. The requirements virtually preclude the use of the sewage effluent without extensive additional treatment. However, if the degree of treatment at the Dry Creek plant must be upgraded, this alternative could be more attractive.

c. Recharge from Imported Water Supply Systems

Additional alternatives for recharge would involve any of the water supply alternatives investigated which import water. These systems would have the advantage of supplying recharge as long as the residents remain on septic tanks and leach fields. It is rather paradoxical that recharge of the groundwater can continue to take place using leach field effluent while it is probably not possible to use much higher quality secondary treatment effluent as recharge water. Based upon the previous projections of population growth, well failures, and water supply recharge, the well deficits and recharge have been evaluated for the 50-year study period in Table 5d.

<table>
<thead>
<tr>
<th>Table 5d: Recharge from Imported Water Supply Systems.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
</tr>
<tr>
<td><strong>1995</strong></td>
</tr>
<tr>
<td>-------------------------------</td>
</tr>
<tr>
<td>Total Residences</td>
</tr>
<tr>
<td>Residences on Water System</td>
</tr>
<tr>
<td>Recharge-AF/Yr</td>
</tr>
<tr>
<td>Well Deficit AF/Yr</td>
</tr>
<tr>
<td>Water Balance AF/Yr</td>
</tr>
</tbody>
</table>

As indicated, the aquifer would begin to recharge when in excess of 1,000 residences are on imported water. From that point forward, the recharge would exceed the demand on
the aquifer. The costs to furnish the water supply have been evaluated in other sections of Chapter 5. One concern of this method of recharge is the potential for pollution of the aquifer by leach field effluent. The aquifer could become unusable for domestic water supply. The issue has been addressed in Chapter 6.

d. Effects of Alternatives

The groundwater management alternatives such as moratoriums on well construction, lot size limitation, and irrigation controls would only serve to slow the rate of decline of the water levels. The existing wells and any new wells would continue the pattern of decline.

The alternatives that import water to the study area for recharge could reverse the pattern of water level decline. The recharge alternative using excess City water may not be a long term solution. The water supply alternatives that recharge through leach fields may cause pollution and render the aquifer unusable for domestic usage.

D. Municipal System to City Standards

This alternative would involve extension in North Cheyenne of a water supply system that is in full compliance with the BPU’s standards. The water supply would be from the City system and the operation and maintenance of the system would be performed by the City.

1. Water Purchase from BPU

The Cheyenne Board of Public Utilities has recently modified a long-standing policy of not serving water to properties outside the City limits. The Board has approved sale of water to areas outside the City limits at a rate of 1.5 times the in-town water rate. The conditions of such sales have not been formalized into a written policy at the time of this report. Consequently, the actual conditions of water sales may be different than those assumed herein.

At the 1992 in-town rate of $1.46 per thousand gallons, the rate for rural areas would be $2.19 per thousand gallons. A rate increase to $1.55 per thousand gallons was instituted in 1993 and additional increases are projected for the next two years. One of the big advantages of purchase of water from the BPU would be the BPU’s responsibility for treatment and testing of the water. The costs of testing for a community supply in accordance with EPA standards can be very significant.

Water needs were determined by utilizing the water needs identified in Chapter 4. In summary, the needs were based upon 210 gallons per capita per day (gpcd) and 3.1
people per residence. The cost of water usually affects usage rates. The purchase of water from the City could potentially decrease the usage. No reductions in usage have been assumed in the calculations, but a decrease might be reasonably expected. If water were available at 1.5 times the in-town rate, the average residence would expect to pay $520 per year or $43 per month for the purchase of water. If the water cost were at the present in-town rate, the average residence cost would be $346 per year.

2. Criteria

The BPU has developed a supply and distribution system which presently services over 42,000 residents in the City of Cheyenne. In addition, the Board provides water for over 8,000 residents of the South Cheyenne Sewer and Water District and over 5,000 customers on Francis E. Warren Air Force Base. The BPU supply system includes well fields, surface water diversion and storage structures. Source water is treated at two water treatment plants. The distribution system includes over 724 miles of pipeline. Domestic water and fire protection flows are carried in common mains.

Design and construction of water distribution mains is controlled by the BPU. Other authorities having jurisdiction or which impact design, include the Cheyenne Fire Department (CFD) and the Wyoming Department of Environmental Quality, Water Quality Division (DEQ). Each agency has published minimum standards for design. By applying the standards of each agency, a fairly defined picture of the proposed North Cheyenne System emerges. The requirements for water system construction for water sales outside the City were also undergoing changes at the time of this report. The characteristics of this system include:

1. All mains must be concrete lined, class 52, ductile iron pipe
2. The minimum main size will be 8 inches.
3. For 1 or 2 family occupancy, hydrant spacing must be 1,000 feet or less.
4. For 1 or 2 family occupancy, water valve spacing must be 800 feet or less.
5. The minimum Average Domestic Demand plus fire flow must result in a residual pressure of no less than 35 psi.
6. For residential areas, each hydrant must produce at least 1,000 gallons per minute. A minimum 1,500 gallons per minute must be available for fire fighting at a static pressure of at least 20 psi.
7. Fire demand is to be maintained for 2 hours.
8. Storage tanks up to 500,000 gallons capacity must provide for 2 hours of fire flow and 24 hours of an Average Daily Demand of 150 gallons per person per day.

9. Dead end mains are discouraged.

10. Once the mains and ancillary structures are accepted, the ownership and maintenance requirement passes to the Board of Public Utilities.

3. Approach

The approach has been to design a main water distribution system within the North Cheyenne project area that is in full compliance with the standards required within the City limits of Cheyenne. Local networks of eight-inch mains will connect to this basic system to provide domestic and fire flows to individual households.

Several objectives influenced the layout of the basic system. The first was to provide service to areas within North Cheyenne which were presently platted at very high density (less than 1 acre per lot) and which are experiencing significant drawdown of the water table. The second objective was to provide service to those areas which are expected to develop during the 50-year study period. This includes the areas bordering the paved roads. The third objective was to insure reliable, continuous service, even in the event of electrical or mechanical failure. The fourth objective was to minimize costs.

There are large areas in North Cheyenne which have been identified as having water level decline, as identified in Chapter 3. The areas are so widespread that the main distribution system was designed to cover a significant portion of the study area. It was not attempted to phase the system at this time due to widespread water level decline.

The North Cheyenne project area is located within Childs Draw. A ridgeline, Buffalo Ridge, separates the project area from the City of Cheyenne water system. Providing service north of the ridgeline requires relatively high pressure in existing mains, or pump stations. Pump stations are subject to electrical or mechanical failure, as well as high maintenance costs. For this reason every attempt was made to rely on gravity. In the final analysis, it proved impossible to provide water entirely by gravity. However, by providing adequately sized mains and one storage reservoir, at least basic domestic service can be maintained, even during total pump station failure.

The minimization of cost was addressed in several ways. First, increased sizing of pump stations was compared with increased and/or elevated storage and resizing mains. Use of computer simulation allowed evaluation of many different configurations. Also, the project area was divided into three pressure zones to optimize water main sizing. Finally,
the estimates of population growth and assumptions concerning location of future
development, discussed in Chapter 4 of this report, were utilized. This resulted in
elimination of distribution mains north of Iron Mountain Road and the undeveloped
lands in the east and northeast quadrant of the study area.

Following the design of the main distribution system, a typical or representative local
distribution system was designed which could be expected to connect to the main
distribution system. This system would be almost exclusively 8-inch mains connecting
homes and fire hydrants to the main distribution system. In reality, each local distribution
system must be individually designed to accommodate existing subdivisions. The
construction of these local systems will represent a one time cost to each resident of
North Cheyenne.

Finally, costs were developed for the main distribution system and for the representative
local distribution systems. Main distribution system costs were expressed in 1995 dollars.
Although the main distribution system was designed with phased construction potential,
the costs are presented for construction of the entire system. This approach was taken to
allow fair comparison of the city services extension system with other alternatives.

4. **Method of Analysis**

Design of the system was based upon future population projections and peak water
demands described in Chapter 4. Location of main distribution pipes was limited to
existing paved roadways. Initially, each north-south main was sized by treating it as a
stand alone, dead end main. This simplified assumption was then extended to the east­
west mains. Finally, a series of computer network evaluations were completed.

Since population projections were based upon quarter sections, the initial water main
sizing was based on half mile segments. Service areas were approximated for each north­
south main, and peak domestic flows were determined. A service node was established at
each half mile, where the demand for the surrounding area was withdrawn from the
system. Additionally, a fire flow of 1,500 gallons per minute was added and, using a
residual pressure of 20 psi, a main size was determined. Sizing progressed node by node,
moving the fire flow each time to simulate the worst case condition.

Two factors became apparent from this evaluation. The first was that the eastern part of
the project area was in a very high pressure zone. Static pressures of over 120 psi were
common. The second observation was that the present unassisted system could not
provide fire flow above elevation 6,200 M.S.L.
The next step involved the construction of a computer simulation, or model, of the proposed main distribution system. The program selected was Cybernet by Haestad Methods. Cybernet uses the KYPIPE model which is specifically designed for water system network analysis. The model of the main distribution system was then run with various modifications to the system. The cost for each modification was then compared to the effect on the system. In this way, the main distribution system was "optimized".

5. Main Distribution System

The main distribution system would be divided into three pressure zones. The system would consist of three pump stations, a 1.0 MG storage tank and 19.5 miles of ductile iron pipe, as shown on Figure 5-2. The system, as designed, would connect to the BPU system at four locations; Yellowstone Road, Powderhouse Road, Buffalo Ridge tank and Ridge Road.

The Buffalo Ridge tank and Ridge Road connections would provide water for the eastern pressure zone. On Ridge Road, the existing 12-inch main would be extended from Gregg Way north to Four Mile Road. Flow would then split into a 12-inch main to the west and north and a 12-inch main to the east. A pressure reducing valve would be needed. Pressure reducing valves would be installed between Ridge Road and Powderhouse Road on both the Four Mile Road and the Riding Club Road mains.

The connection to the Buffalo Ridge tank would be a 14-inch pipe located in Space Drive north to Four Mile Road. The pipe in Four Mile Road would be 12-inch. The eastern pressure zone would be fed primarily from the tank. The flows from the middle zone and the City system at Ridge Road would pass through the PRY’s only with large demands in the eastern zone or with low tank level. This eastern pressure zone would extensively use the Buffalo Ridge tank.

The middle zone would connect to the City system at Storey Boulevard. There are two existing 24-inch mains in Storey Boulevard which run to the Buffalo Ridge storage tank. Both the Yellowstone Road and the Powderhouse Road mains would be 14 inches from Storey Boulevard to Four Mile Road, and 12 inches to Riding Club Road. An 8-inch main would be extended on Powderhouse Road an additional half mile to the north. These mains would be connected with a 12-inch main along Riding Club Road and a 10-inch main along Four Mile. The pressure from the city system could provide peak hour flows and fire flows to residences in this zone below elevation 6,200 M.S.L. In addition, domestic flows could be supplied to all residences in this zone. To provide peak hour flow plus fire flow to all residences in this zone, pump stations on both Yellowstone Road and
Powderhouse Road would be needed. These pump stations would be 30 horsepower systems located in close proximity to the Storey Boulevard 24-inch mains for best operation. Finally, the previously mentioned pressure reducing valves east of Powderhouse Road on Four Mile and Riding Club Road would insure optimum productivity from the pump stations. An additional function of the pump stations would be to provide water for the pressure zone north of Riding Club Road, in the vicinity of Yellowstone Road and west of I-25.

Because some areas have elevations above 6,200 M.S.L., the city system would be unable to provide even peak hour flows to the north and west portion of the project area. Water should be pumped up to a storage tank located half a mile north of Riding Club Road on Yellowstone Road. The peak demand pressures of the proposed system are shown on Figure 5-3. To provide 24 hours of domestic flow plus two hours of fire flow at 1,500 gpm, the storage tank should be at least 1,000,000 gallons in size. Water would be pumped out of the storage tank using a 15 horsepower pump station. The pump station sizing would be needed for the development of Murray Hills Estates, much of which is located between 6,250 and 6,300 M.S.L. The area east of the storage tank would be supplied by local networks. An eight-inch distribution main would be located immediately west of I-25, from one half mile north of Riding Club Road to Western Hills 12th Filing.

6. Local Distribution System

The local distribution systems for typical patterns of development were analyzed. The systems to meet City standards would consist of minimum eight-inch ductile iron pipe, appropriately spaced fire hydrants, adequate valving, and individual house connections to City standards, as shown on Figure 5-4. The local distribution system would be different for other sections, but general layouts and sizing would be similar.

7. Cost Estimates and Economics

The cost of the main distribution system was estimated using the WWDC standard procedure. The estimated construction costs were $6,000,000 as shown in Appendix C, Table C-4. The annual payments assuming a 2/3 grant and 1/3 loan at four percent interest would be $853,000 per year. Operation and maintenance costs were estimated for the main distribution system. The costs for operation and maintenance were escalated at four percent per year. The cost of purchase of water from the City has been analyzed at both 1.0 and 1.5 times the in-town rate.

The costs for typical local distribution systems were developed. The local distribution systems included ductile iron piping, fire hydrants, valves, and house connections. The
costs for the local distribution and house connections were developed for an average lot. The average cost per lot to install the local distribution system and house connection was estimated to be $10,000. The BPU is also proposing to impose a tap fee which would increase the hook-up cost to approximately $14,000. The cost for any individual lot will vary depending upon lot size, location of house on the lot, configuration of the subdivision, and other factors. The actual cost to a lot owner could vary widely depending how costs are assessed for the local distribution system. It is also possible that other funding sources could be available such as Farmer’s Home Administration or Farm Loan Board. The WWDC will not participate in the local distribution systems. The detailed cost summaries are shown in Appendix C, Tables C-5 and C-6.

The total costs of the municipal system to City standards are summarized in Table 5e. The number of system users was analyzed for two scenarios. The first scenario includes all new residences and all residences with failed wells on the system. The second scenario is an accelerated schedule whereby 450 users are on the system at start-up. The analyses indicated that the first scenario was not economically feasible. Therefore, only the second scenario is presented herein. The costs are presented on the basis of present worth annual costs and cost per user for the main distribution system. The costs of the local distribution system were estimated as a one time per user cost of $14,000 in present worth. The total cost to the user would be the one time cost of the local distribution system plus the annual user cost for the rest of the system. As shown in Table 5e, the costs in the first years of operation are high due to lack of a sufficient number of users. With 450 users on the system, the estimated yearly cost is $710 for the early years of operation. The $14,000 hook-up cost is in addition to the yearly costs.

E. Independent Groundwater System

1. Groundwater Supply Sources
   a. General

Seventeen sedimentary geologic units occur in Laramie County. Seven of the units are presently sources for municipal water supplies in Laramie County or elsewhere in the State. From oldest to youngest, these are:
Table 5e: Municipal System to City Standards.

<table>
<thead>
<tr>
<th></th>
<th>1995</th>
<th>2005</th>
<th>2015</th>
<th>2025</th>
<th>2035</th>
<th>2045</th>
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<tr>
<td>System users</td>
<td>450</td>
<td>1,000</td>
<td>1,650</td>
<td>2,400</td>
<td>2,950</td>
<td>2,950</td>
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<tr>
<td><strong>Main Distribution System</strong></td>
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<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Estimated Construction Cost</td>
<td>$6,000,000</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>WWDC funding 2/3 grant-1/3 loan @ 4% interest</td>
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<td></td>
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</tr>
<tr>
<td>Total Annual Cost -</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inflated</td>
<td>85,300</td>
<td>85,300</td>
<td>85,300</td>
<td>85,300</td>
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<td>85,300</td>
</tr>
<tr>
<td>Total Annual Cost -</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Present Worth</td>
<td>85,300</td>
<td>57,600</td>
<td>38,900</td>
<td>26,300</td>
<td>17,800</td>
<td>12,000</td>
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<tr>
<td>Cost/User/Yr.</td>
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<td></td>
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<tr>
<td>Present Worth</td>
<td>190</td>
<td>58</td>
<td>24</td>
<td>11</td>
<td>6</td>
<td>4</td>
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<tr>
<td>Water Purchase Costs -</td>
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<td>1.0 In-Town Rates</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Present Worth</td>
<td>346</td>
<td>297</td>
<td>259</td>
<td>223</td>
<td>194</td>
<td>185</td>
</tr>
<tr>
<td>1.5 In-Town Rates</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Present Worth</td>
<td>520</td>
<td>445</td>
<td>389</td>
<td>335</td>
<td>291</td>
<td>278</td>
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<tr>
<td>Total Cost/User/Yr.</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>1.0 In-Town Rates</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Present Worth</td>
<td>536</td>
<td>355</td>
<td>283</td>
<td>234</td>
<td>200</td>
<td>189</td>
</tr>
<tr>
<td>1.5 In-Town Rates</td>
<td></td>
<td></td>
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<td></td>
<td></td>
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<tr>
<td>Present Worth</td>
<td>710</td>
<td>503</td>
<td>413</td>
<td>346</td>
<td>297</td>
<td>282</td>
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<tr>
<td>Local Distribution System</td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cost per New User</td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Present Worth</td>
<td>14,000</td>
<td>14,000</td>
<td>14,000</td>
<td>14,000</td>
<td>14,000</td>
<td>14,000</td>
</tr>
</tbody>
</table>
(1) Casper Formation of Pennsylvanian and Permian age.
(2 & 3) Lance Formation and Fox Hills Sandstone both of Upper Cretaceous age.
(5) Arikaree Formation of Miocene age.
(6) Ogallala Formation of Miocene and Pliocene age.
(7) Alluvium of Pleistocene and Recent age.

Of these aquifers, only the Casper Formation and a combination of Ogallala and Arikaree are considered as possible sources for a community supply for North Cheyenne. The other aquifers are dismissed from further consideration because:

- (2 & 3) Lance-Fox Hills: The Lance-Fox Hills were eliminated from consideration because of the undesirable water quality and because of the number of wells that would be required to provide the peak demand estimated to be required in 50 years. The most probable development of the aquifer would be as part of a "do-nothing" alternative. Some wells in Laramie County that did not obtain adequate yields for domestic uses from the tertiary aquifer have been completed in both the tertiary and the Lance-Fox Hills.

In North Cheyenne, no wells are reported as obtaining water from the Lance-Fox Hills, but several have been drilled to the top of the Lance-Fox Hills and have obtained marginal yields. It is anticipated that with additional development in the study area, it will be necessary to utilize water from the Lance-Fox Hills if an alternative supply is not developed.

- (4) White River Formation: The White River Formation consists predominantly of massive brittle argillaceous siltstone containing a few beds of sandstone, conglomerate, and volcanic ash. Denson and Bergandahl (1961, p. C170) described the formation in an area that includes Laramie County as consisting of 65 to 80 percent silt and 5 to 25 percent very fine-grained sand embedded in a matrix of clay-sized particles.

Only the sandstone and conglomerate beds or places with secondary permeability would yield water in sufficient quantities to be considered as a source of supply for North Cheyenne.

The sandstone and conglomerate beds are most common near the mountains, but do extend eastward across the county. (See Crist 1980, p. 8). As emphasized in the description of the lithology, sand and larger material are a minor part of the White
River. Therefore, exploration for water in them can be expected to meet with a low probability of success, even near the mountains. In development of the Cheyenne well field supply near Federal, yields of about 100 to 500 gallons per minute were developed, but more than half of the test wells were not developed because of small yields.

Authors differ on cause of the secondary permeability, and none have described the permeability as occurring where the White River is overlain by either the Ogallala or the Arikaree Formations. Secondary permeability in the White River in North Cheyenne has not been reported to the Office of the State Engineer as a source of water to wells (Richard G. Stockdale, personal communication, June 1992).

Exploration for water in the White River as a source for North Cheyenne is not recommended because of the poor chance of finding zones of secondary permeability in the areas closest to North Cheyenne and because of the number of wells that would be required without the secondary permeability.

(7) Alluvium: The nearest source of water from the alluvium that would be adequate for a community supply for North Cheyenne is in the Pine Bluffs/Carpenter area. Pine Bluffs/Carpenter is in a control area where groundwater development is restricted. In addition, the quality of the water is being affected adversely by irrigation. The area is 30 miles from North Cheyenne and 800 feet lower than North Cheyenne.

2. Ogallala/Arikaree Formations Groundwater Source
   a. General

   A potential well field located approximately 15 miles north of the study area was selected for analysis. Detailed investigations of the area would have to precede a decision to develop a well field. The field would be located on State of Wyoming lands as shown on Figure 5-5. The field would require a pipeline approximately 15 miles long to deliver water to the northwest portion of the study area. The pipeline would primarily follow the right-of-way of Highway 85.

   b. Arikaree Formation

   The Arikaree Formation consists of very fine to fine-grained sandstone that contains massive siltstone, and thin beds of volcanic ash. (Lowry and Crist, 1967, p. 13). The formation is as much as 450 feet thick in places (Lowry and Crist, 1967, p. 8) but it has probably been removed by erosion in North Cheyenne.
The permeability of the Arikaree is small such that yields suitable for North Cheyenne could only be obtained from areas where there is a large thickness or areas with secondary permeability. Large yields from the formation in the Lusk area have been ascribed to secondary permeability. Similar permeability has not been described in Laramie County.

The Arikaree Formation is considered as a potential source of community supply for North Cheyenne. However, it would not be a single source but developed in conjunction with the Ogallala Formation. Therefore, discussion of development is included in the section describing the Ogallala. The quality of water from the Arikaree Formation was summarized with water from the underlying White River Formation (Table 5f).

c. Ogallala Formation

The Ogallala Formation consists of lenticular beds of sand and gravel deposited by braided streams and of silt, clay, and thin limestone beds deposited in temporary lakes. (Lowry and Crist, 1967, p. 16). The formation is as much as 330 feet thick (Lowry and Crist, 1967 p. 8).

The Ogallala and the Arikaree Formations are similar and the differences in heavy minerals is the reliable method to identification. Generally, this is not possible in wells because of the difficulty in obtaining representative samples. Because of the difficulty in distinguishing between the two formations in wells, they are considered as a single aquifer in this report. However, there are differences in the hydrologic properties as evidenced by a line of springs at the contact of the two formations in the Horse Creek drainage.

Specific capacities for the Ogallala in Laramie County range from less than 1 to 229 gpm per foot of drawdown and, for large thickness of Arikaree in the state, up to 40 gpm per foot of drawdown. (Libra and others 1981, p. 65).

An area north of North Cheyenne has the largest saturated thickness of the combined Arikaree and Ogallala Formations in the county (Lowry and Crist, plate 2) and a well field could be developed to supply the water estimated to be required in 50 years for North Cheyenne.

Advantages of this groundwater alternative are:

- Yields of Ogallala-Arikaree are more predictable than those of the Casper and success of wells would be more certain.
The long-term effects of pumping would be more easily predicted. They would, at least in part, intercept natural discharge along the valley of Horse Creek.

Disadvantages of this groundwater alternative are:

- The area is in a groundwater control area. In a control area, after an application to appropriate is filed and processed, it is (1) advertised in a local newspaper for three consecutive weeks to provide notice to other appropriators that groundwater development is proposed, (2) consideration of the application by the Control Area Advisory Board and any objections filed to the granting of the permit follows the advertising. If the Control Area Advisory Board desires additional information, the applicant, and if a protest has been filed, the protestant, will be invited to appear and discuss the matter before the Board. The Board will submit its recommendation to the State Engineer, and (3) the State Engineer will then take the application under consideration. If valid protests have been filed, the State Engineer must hold public meetings. The application to appropriate can be rejected or severely limited.

- Whereas there is no concern about the quality of water with respect to total dissolved solids content, in places water from the formation contains radon in excess of the 300 pCi/L proposed for drinking water beginning in 1996. Treatment of the water would be possible but would increase the cost.

- The area is lower in elevation than North Cheyenne, which would increase pumping costs.

The demands have been estimated to increase from a yearly demand of 328 acre-feet in the first 10 years of operation to 2,154 acre-feet per year in 50 years. The peak demands from the field would increase from 500 gpm to 3,340 gpm over the study period. A well field with two or three wells would be sufficient for the initial years of the project. The probable yield of the wells is expected to be 500 gpm. Additional wells would be added at approximate 10 year intervals as demand increases. The wells would probably be drilled to depths of 500 to 600 feet. The wells would be spaced at approximate 2,500 feet centers to optimize yield and construction costs. The pumping depths of the wells would be expected to be approximately 250 feet.

The well field is approximately 500 feet lower in elevation than the proposed storage tank elevation in the study area. Consequently, pumping heads will be large to deliver the water to the study area. The possibility of radon gas may require aeration and chlorination of the water would be required.
c. Pipeline and Storage

An 18-inch pipeline would conduct up to 3,340 gpm from the well field to a storage tank in Section 1 of the study area. The pipeline would follow Highway 85 for most of the length. The pipeline would be a steel pipeline because of the high pressures involved. Total pumping heads could exceed 1,000 feet at the well field at high pumping rates.

The storage tank would be located on a hill in the northwest portion of the study area. A one million gallon storage tank would be sufficient to serve the expected users for approximately 25 years, as discussed later in this report.

d. Cost Estimates and Economics

The costs for the well field, pipeline to the study area, and storage tank were estimated using the WWDC standard methods. The estimated construction costs were $9,000,000 as shown in Appendix C, Table C-7. The annual payments assuming a 2/3 grant and 1/3 loan at four percent interest would be $140,000 per year.

Power costs were estimated at 5 cents per kwh, which was assumed to increase at a rate of four percent per year. In addition, the amount of power used would increase with the increased pumpage. As indicated previously, the amount of water pumped could increase from 328 acre-feet per year to 2,154 acre-feet in 50 years.

Operation, maintenance, and replacement costs were estimated for the system. Operational costs would include personnel, equipment, treatment (chlorination), and testing. The costs of operating even a groundwater system can be very substantial. Maintenance costs were estimated assuming that all wells and pumps would require servicing or replacement on 10 year frequencies. The costs for operation and maintenance were escalated at four percent per year. The costs of additional wells to be constructed were estimated in present day costs and escalated at four percent per year.

The costs for the project over the 50-year study period have been summarized in Appendix C, Table C-8. The costs were also converted to present worth to allow comparison with other alternatives. The present worth of this alternative for the 50-year study period would be $12,660,000.
3. **Casper Formation Groundwater Source**

a. **General**

A Casper formation well field was selected for analysis. Detailed investigations of the area would have to precede a decision to develop a well field. The proposed well field would be located in the south half of Section 35 and the north half of Section 2, as shown on Figure 5-6. The field would require a pipeline approximately 23 miles long to deliver water to the study area. As shown, the pipeline is proposed to be located along Horse Creek Road for most of its length.

b. **Casper Formation**

The combination of the prohibitive cost of drilling, probably in excess of 10,000 feet, and probable poor quality of water from the formation at large depths preclude drilling a well to the Casper Formation in the North Cheyenne area. Exploration should be near the outcrop.

In the area between Crow Creek and Federal and for a distance north of Federal, folding has turned the formation to a near vertical or overturned position and in some areas there are thrust faults. This structure makes the prediction of the depth to the formation, even near the outcrop, speculative without the aid of geophysical surveys.

A reconnaissance study of the potential for groundwater development from the aquifer by Eisen and others (1980) indicates the formation is as much as 1,100 feet thick in the area. The southern edge of this report area was Township 17, but within the area north of Township 17 in Laramie County, two sites were designated as having potential for groundwater exploration.

There have been more extensive studies of the aquifer on the west side of the Laramie Range, and in that area specific capacities range from less than 1 to more than 100 gpm per foot of drawdown (Eisen and others 1980, plate 2). The higher specific capacities are associated with secondary permeability that has resulted from faulting and/or folding of the formation.

The specific capacities of wells on the east side of the Laramie Range could be expected to have higher specific capacities because the formation on the east side of the range is about twice that on the west side (Eisen and others, 1980 Figure 3).

The chemical quality of the water from the Casper Formation near the outcrop generally contains less than 500 ppm total dissolved solids.
An area in Section 2, Township 15 north, Range 70 west and adjoining Section 35, (Figure 5-6), is considered as a possible source of community supply for North Cheyenne. Wells with a specific capacity of 25 gpm per foot of drawdown, the mid-range of that reported on the east side of the Laramie Range, could be developed. The 3,340 gpm projected requirement for North Cheyenne could possibly be obtained from one well with 140 feet of drawdown.

Advantages of this alternative are:

- An altitude about 600 feet higher than North Cheyenne.
- It is not in a groundwater control area.

Disadvantages of this alternative are:

- Uncertainty of penetrating a zone of high secondary permeability to obtain desired yield.
- Uncertainty of predicting response to long-term withdrawal of water because of proximity to aquifer boundary (edge of outcrop and faulting).
- Limited area for spacing wells in the event more wells would be required.

The water needs for the study area have previously been estimated to increase from a yearly demand of 328 acre-feet in the first 10 years of operation to 2,154 acre-feet per year in 50 years. The peak demands from the well field would increase from 500 gpm to 3,340 gpm over the study period.

A field with two or three wells would be sufficient for the early years of the project. The probable yield of the wells is expected to be quite large. A well would need to be added approximately every 10 to 20 years to meet the expected demands. The wells would be approximately 800 to 1,000 feet deep with 12-inch casing. The water producing portions of the well would be unscreened. The wells would be spaced approximately 1,500 feet apart at a minimum. The wells would probably be artesian with water rising to near the ground surface.

The well field is approximately 600 feet higher than the proposed water storage facility. Consequently, minimal pumping head is required to operate the system. The pipeline would flow by gravity and the well pumps would serve to lift the water only to the surface.
The possibility of radon gas in the water may require aeration of the water which could be done at the well head or at the tank in the study area. If treated for radon, water would have to be chlorinated and furnished sufficient chlorine contact time.

c. Pipeline and Storage

An 18-inch pipeline would conduct the 50-year peak flow of 3,340 gpm essentially using the drop from the well to the study area. The pipeline would be routed east from the well field along section lines to Horse Creek Road. The pipeline would parallel the road to the study area, cross I-25 and transport water to a storage tank located either in Section 1. The pipeline would probably be ductile iron, although other pipe materials should be considered. A storage tank would be located on a hill to eliminate the need for elevated storage.

d. Cost Estimates and Economics

The costs for the well field, pipeline to the North Cheyenne study area, and storage tank were estimated using the WWDC standard methods. The estimated construction costs were $12,400,000 as shown in Appendix C, Table C-9. The annual payments assuming a 2/3 grant and 1/3 loan at four percent interest would be $192,400 per year.

Power costs were estimated at 5 cents per kwh, which was assumed to increase at a rate of four percent per year. In addition, the amount of power used would increase with the increased pumpage. As indicated previously, the amount of water pumped could increase from 328 acre-feet per year to 2,154 acre-feet per year in 50 years.

Operation, maintenance, and replacement costs were estimated for the system. Operational costs would include personnel, equipment, treatment (chlorination), and testing. The costs of operating even a groundwater system can be very substantial. Maintenance costs were estimated assuming that all wells and pumps would require servicing or replacement on 10 year frequencies. The costs for operation and maintenance were escalated at four percent per year. The costs of additional wells to be constructed were estimated in present day costs and escalated at four percent per year.

The costs for the project over the 50-year study period have been summarized in Appendix C, Table C-10. The costs were also converted to present worth to allow comparison with other alternatives. The present worth of this alternative for the 50-year study period would be $9,435,000.
4. **Groundwater Source Comparison**

The results of the cost estimates and economic analysis of the groundwater sources leads to several conclusions. The Casper well field with a total estimated construction cost of $12.4 million is more economical over the 50-year study period than the $9.0 million Ogallala well field. This is due to the much lower pumping costs for the Casper well field. The second major conclusion is that the well field project would be difficult to finance in the early years of the period unless there are a large number of expected users. The costs per user lower dramatically as more users are on the system.

5. **Independent Groundwater Distribution System**

a. **General**

An Independent Groundwater System would consist of a Casper well field and delivery pipeline as previously discussed and analyzed in this chapter, and a rural distribution system. The rural distribution system would not be constructed to City of Cheyenne standards. The primary difference would be the limited fire-flow capacity with rural distribution systems being designed for domestic and irrigation purposes only. The system would also utilize more economical pipe materials than a system built to city standards. With the rural systems having limited fire fighting capabilities, the major components of the distribution network can be greatly reduced. These reductions include pipe size, pumping rates, storage requirements, and material specifications.

b. **Design Method**

The criteria, approach, and methods of analysis are similar to that for the Municipal System to City Standards previously discussed. The same domestic and irrigation demands were used for the computer simulation. The primary difference from the municipal system is the absence of fire demand. The pipe was assumed to be PVC to minimize costs of the system. Other procedures were essentially the same.

The design and analysis of the distribution networks was aided by the use of Cybernet, Version 2.0 software. Cybernet is an add-in program to Autocad release 12, which allows for network design and analysis within the Autocad graphical environment. With the use of Cybernet, a mathematical model of the proposed distribution network was developed. The model accommodates the network configuration and various hydraulic components which would produce significant effects on the proposed network. Extended period simulation (EPS), also referred to as operation-over-time-capabilities of Cybernet, were also used to obtain a better understanding of the time varying performance of the network.
A diurnal demand curve, which is a water demand verses time curve for a 24-hour summer day, was developed for the study area. This allowed for the daily demand fluctuation of the network to be modeled. EPS is particularly useful in determining the performance of time varying features such as tank levels, pressure regulating valves, and pump status over a wide range of operating conditions.

Certain limitations on the distribution network complexity were needed. This is appropriate for a network model of this nature and Phase I level of study. The most widely accepted method of reducing a model's complexity is to subdivide the network into fragment models that can be analyzed independently. The result is a skeleton model of the main network, which is a more manageable model without losing overall accuracy. For the study area, pipes of eight-inch diameter or larger were modeled as the main skeleton network. Pipes of diameter less than eight inches were modeled independently as fragment models. Flow demands from the fragment models were included within the main skeleton network and the resulting pressures used as input for the fragment models.

c. Pressure Zones

Due to the topographical relief of approximately 250 feet across the study area, three pressure zones would be proposed for the system. The pressure zones would eliminate the high pressure in the lower areas and allow for the entire network to operate within more acceptable pressures. The lower operating pressures would allow the use of more economical pipe.

The three pressure zones would be controlled by four pressure regulating valves (PRV's), as shown on Figure 5-7. The PRV's may be either electrically or hydraulically actuated to maintain the desired pressure in the downstream zone.

d. Main Distribution System

Historic development patterns within the study area show that the majority of development has occurred within a half mile of the paved roads in the study area. As indicated in Chapter 4, it has been assumed that growth will continue to occur along the paved roads.

In consideration of this trend, water mains would be proposed when possible, along paved roads, as shown on Figure 5-7. Once the water mains are installed, it would be anticipated that local distribution systems would be installed to meet local demands. As this process continues, dead-end lines would be connected to form a more reliable and efficient looped distribution system.
The proposed main distribution system (Figure 5-7) would consist of 8-inch, 10-inch, 12-inch, and 16-inch diameter supply lines. The four proposed PRV's would be located with two allowing for flow to enter zone 2 from zone 1 and two allowing for flow from zone 2 to zone 3. The PRV's would operate in the throttled position, allowing for minimum flow necessary to pass while maintaining design pressure in the downstream zone.

The main distribution system for the highest zone would include the 18-inch pipeline from the well field which would be located along Horse Creek Road. The 18-inch pipe would be routed in Iron Mountain Road from I-25 to Yellowstone and thence south on Yellowstone to the proposed tank location. A 16-inch pipe would conduct water south on Yellowstone to Riding Club Road where a PRV would separate this zone from zone 2. An 8-inch pipe would be routed on the west side of I-25 from Horse Creek Road to Four Mile Road. The 8-inch pipe is then routed east across I-25 along Four Mile Road to Yellowstone to loop the system.

The intermediate zone, zone 2, consists of 12-inch pipe on Riding Club Road and Four Mile Road between Yellowstone Road and Powderhouse Road. The portions of Yellowstone Road and Powderhouse Road between Riding Club and Four Mile are also 12-inch pipe. Extensions north and south on Powderhouse are 8-inch pipe.

The lower zone, zone 3, consists of 10-inch pipe located in Riding Club and Four Mile between Powderhouse and Braehill Roads. A 10-inch loop south on Ridge Road and Braehill from Four Mile Road completes the system.

Figure 5-8 would represent, with the use of 3D-bars, the pressure in the network at the peak hour demand. The two PRV's between zones 1 and 2 would be wide open and the other two PRV's would be throttled.

The portion of the system west of I-25 in zone 1 operates at minimal acceptable pressures. This is due to the high ground elevations relative to the standpipe elevation. There are a few, buildable lots in this area that have ground elevation at or above the standpipe elevations that were not modeled. These particular sites would require a pump station to obtain acceptable pressures.

e. Standpipe Operation

Using the diurnal demand curve (Figure 5-9), the inflow rate and equalization volume of the 1.0 million gallon (MG) standpipe was determined. Points A & B would represent times during the day when the flow into the storage tank would equal that of the average
maximum day demand. Point C would equal the peak hour demand and point D would be the minimum hour demand.

The area above the horizontal average maximum day demand line in Figure 5-9 would be the amount of storage volume (approximately 0.5 MG) required to meet the difference between inflow and peak hour demand. The area below the average maximum day demand line would represent the required volume of storage needed to fill the tank during periods of low demand. The 0.5 MG emergency storage would be used in the event of higher than expected demand or down time on the supply service from the well field. The local distribution system emergency storage would be capable of network demands for approximately six hours.

f. Local Distribution Systems

For a rural system, it was determined that the local distribution network within individual sections works efficiently if the network follows the generalized layout shown in Figure 5-6 for Section 7, Township 14 N., Range 66 W. Six-inch lines would run between individual sections and four-inch lines would divide the section into quarters. Two-inch feeder lines would supply local areas. The local distribution system would be different for other sections, but general layouts and sizing would be similar.

The local distribution system for a rural system offers significant cost savings over a municipal system. Because fire demands are not present, the local system is made up of smaller pipe from 2-inch to 6-inch. The pipes would be PVC to minimize costs as well.

g. Cost Estimates and Economics

The cost estimates and economic analyses of the Casper well field and the delivery pipeline to the study area have been presented previously in this chapter. That information has been brought forward to analyze the entire system.

The main distribution system was cost estimated using the WWDC standard procedure. The estimated construction costs were $3,250,000 as shown in Appendix C, Table C-11. The annual payments assuming a 2/3 grant and 1/3 loan at four percent interest for 50 years would be $50,400 per year. Operation and maintenance costs were estimated for the main distribution system. The costs for operation and maintenance were escalated at four percent per year. The costs for the main distribution system over the 50-year study period have been summarized in Appendix C, Table C-12. The costs were also converted to present worth for comparison purposes.
The costs for typical local distribution systems were developed. The local distribution systems included PVC piping, valves, and house connections. The costs for the local distribution system and house connections were developed for an average lot. The average cost per lot to install the local distribution system and house connection was estimated to be $3,250. The cost for any individual lot will vary depending upon lot size, location of house on the lot, configuration of the subdivision, and other factors. The actual cost to a lot owner could vary widely, depending how costs are assessed for the local distribution system. It is also possible that other funding sources could be available, such as Farm Home Administration or Farm Loan Board. The WWDC will not participate in the local distribution systems.

The total costs of the Independent Groundwater System are summarized in Table 5f. The detailed cost summaries are shown in Appendix C, Tables C-13 and C-14. The number of system users was analyzed for two scenarios. The first scenario is the previously developed scenario of all new residences and all residences with failed wells on the system. The second scenario is an accelerated schedule whereby 450 users would be on the system at start-up. The first scenario was found to be economically infeasible. Therefore, only the second scenario is presented herein. The costs are presented on the basis of present worth annual costs and cost per user for the Casper formation well field and the main distribution system. The costs of the local distribution system were estimated as a one-time per user cost of $3,250 in present worth.

The total cost to the user would be the one-time cost of the local distribution system plus the annual user cost for the rest of the system. As shown in Table 5f, the costs in the first years, particularly in the first scenario, are high due to lack of a sufficient number of users. The costs for the accelerated schedule are still high in the early years, but are considerably more favorable.

F. Rural System with Municipal Supply

1. General

This alternative would combine a rural distribution system similar to that discussed in the Independent Groundwater System Alternative with a water supply from the City of Cheyenne. Water would be purchased from the City of Cheyenne at several selected points. The distribution system would be owned, operated, and maintained by an entity representing the North Cheyenne users.
Table 5f: Independent Groundwater System Cost Summary.

<table>
<thead>
<tr>
<th></th>
<th>System users</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1995</td>
<td>2005</td>
<td>2015</td>
<td>2025</td>
<td>2035</td>
<td>2045</td>
</tr>
<tr>
<td>System users</td>
<td>450</td>
<td>1,000</td>
<td>1,650</td>
<td>2,400</td>
<td>2,950</td>
<td>2,950</td>
</tr>
</tbody>
</table>

Casper Formation Well Field
Estimated Construction Cost - $12,400,000
WWDC funding 2/3 grant-1/3 loan @ 4% interest

|                  |               |       |       |       |       |       |
| Construction loan cost | 192,400       | 192,400 | 192,400 | 192,400 | 192,400 | 192,400 |
| Upgrade costs-inflated | 0              | 44,400  | 65,700  | 421,600 | 144,000 | 213,200 |
| Power costs - inflated | 1,000          | 5,000   | 11,200  | 18,400  | 26,900  | 36,600  |
| O & M costs - inflated | 50,000         | 70,300  | 109,500 | 170,200 | 264,000 | 408,700 |
| Total annual cost - Inflated | 243,400       | 312,100 | 378,800 | 802,600 | 627,300 | 850,900 |
| Total annual cost - Present worth | 243,400       | 210,900 | 172,900 | 247,400 | 130,700 | 119,700 |

Main Distribution System
Estimated Construction Cost - $3,250,000
WWDC funding 2/3 grant-1/3 loan @ 4% interest

|                  |               |       |       |       |       |       |
| Construction Loan - Main System | 50,400         | 50,400  | 50,400  | 50,400  | 50,400  | 50,400  |
| O & M Cost-Inflated | 50,000         | 111,000 | 219,100 | 405,400 | 720,200 | 1,243,700 |
| Total Annual Cost - Inflated | 100,400        | 161,400 | 269,500 | 455,800 | 770,600 | 1,294,100 |
| Total Annual Cost - Present Worth | 100,400        | 109,000 | 123,000 | 140,500 | 160,500 | 182,100 |
| Total Annual Cost Present Worth | 343,800        | 319,900 | 295,900 | 387,900 | 391,200 | 301,800 |
| Cost/User/Yr. Present Worth | 764            | 320     | 179    | 162    | 133    | 102    |

Local Distribution System Hook-Up Cost

|                  |               |       |       |       |       |       |
| Cost per new user - Present Worth | 3,250         | 3,250  | 3,250  | 3,250  | 3,250  | 3,250  |
2. Analysis

The Rural System with City Supply was analyzed in a manner very similar to the Independent Groundwater System. The difference is the water supply from the City versus a groundwater supply. The location of the main distribution system, methods of analyses, assumptions, and local distribution systems were similar to the previous analyses. Consequently, the information has not been repeated. The main distribution system (Figure 5-10) would be supplied by two water main extensions from a water main along Storey Blvd., one water main extension from the existing Buffalo Ridge 5.0 MG storage tank, and one main extension in Ridge Road. All four of the proposed connections are under the BPU ownership.

Pressure zones 2 and 3 would operate directly off the BPU's system, while pressure zone 1 would operate off a 1.0 MG standpipe which would be supplied by a pump station from zone 2.

3. Main Distribution System

The main distribution system (Figure 5-10) would be supplied by four 12-inch diameter water mains. Two water mains would connect with an existing 24-inch water main along Western Hills Blvd. and Storey Blvd. A third connects with the existing 5.0 MG Buffalo Ridge storage tank, and the fourth connects to an existing 12" water main in Ridge Road. Four flowmeters and check valve assemblies are proposed to meter flows from BPU's system and to prevent metered flows from re-entering BPU's system.

The distribution system in zone 1 would consist primarily of 8-inch mains. The area west of I-25 would be served by a main in Bishop Blvd. The interstate highway would be crossed at Iron Mountain Road and Four Mile Road extended. Zone 2 would be served by 12-inch mains from Western Hills Blvd. — Storey Blvd. in Yellowstone Road and Powderhouse Road. Mains in Four Mile Road and Riding club Road would be 12-inch. An 8-inch main would be extended up Powderhouse Road north of Riding Club Road. Zone 3 would be served by 12-inch mains from the Buffalo Ridge tank and a main in Ridge Road. The tank elevation would cause the area to be served from the tank in most instances. The zone would be served by 10-inch mains in Ridge Road and Braehill Road with other mains in Riding Club Road and Four Mile Road.

The five proposed PRV's would operate in the closed position under normal operation of the system. The PRV's would operate in the open/throttled position only in the event of higher than design demand or reduced pressure at the four supply points.
Figure 5-11 represents, with the use of 3-D bars, the pressure in the system at peak hour demand. The pressures shown represent the system with the PRV's closed as discussed above. The portion of the system west of I-25 in zone 1 operates at minimal acceptable pressures. This is due to the high ground elevations relative to the standpipe elevation. There are a few, buildable lots in this area that have ground elevation at or above the standpipes elevation that were not modeled. These particular sites would require individual pump stations to obtain acceptable pressures.

4. **Standpipe Operation**

Under normal operation the standpipe would only supply the demand needs of zone 1. Supply from the standpipe to zones 2 and 3 would only occur if pressure drops due to high demand or interruption in the supply from BPU's system. Under normal conditions the water level in the standpipe would lower by ten feet in a 24-hour period to meet the needs of zone 1. Supply to the standpipe would consist of a 1,200 gpm pump that is located in zone 2. Pressure switches would turn the pump on and off as governed by the standpipe water level.

5. **Local Distribution System**

The local distribution systems would be essentially the same as developed for the Independent Groundwater System. The costs for typical local distribution systems were developed. The local distribution systems included PVC piping, valves, and individual house connections. The costs for the local distribution and individual house connections were developed for an average lot. It has been assumed that no tap fees would be assessed by the BPU for this alternative.

6. **Buffalo Ridge Storage Tank**

Currently the existing Buffalo Ridge storage tank's high water elevation is below the hydraulic grade line of BPU's system. This has resulted in the tank only partially draining during periods of high demand, causing insufficient water turn-over within the tank to be a problem. A pump system has recently been installed to force turn-over in the tank. The proposed connection of the study area to the 5.0 MG Buffalo Ridge storage tank would eliminate the problem. With zone 3's primary source of supply being Buffalo Ridge storage tank, approximately 1.0 MG of daily water turn-over would eventually be expected.
7. **Cost Estimates and Economics**

The main distribution system was estimated using the WWDC standard procedure. The estimated construction costs were $5,000,000 as shown in Appendix C, Table C-15. The annual payments assuming a 2/3 grant and 1/3 loan at four percent interest would be $77,600 per year. Operation and maintenance costs were estimated for the main distribution system. The costs for operation and maintenance were escalated at four percent per year. The cost of purchase of water from the City has been analyzed at both 1.5 times the in-town rate and at the in-town rate. The actual purchase price would need to be negotiated since the BPU would have no responsibility for operation and maintenance of the system. The total costs of the system are summarized in Table 5g. The detailed cost summaries are shown in Appendix C, Tables C-16 and C-17. The number of system users was analyzed for two scenarios. The first scenario was the previously developed scenario of all new residences and all residences with failed wells on the system. The second scenario is an accelerated schedule whereby 450 users are on the system start-up. Because the first scenario was not economically feasible, only the second scenario is presented herein. The costs are presented on the basis of present worth annual costs and cost per user for the main distribution system.

The costs of the local distribution system were estimated as a one time per user cost of $3,250 in present worth. The total cost to the user would be the one time cost of the local distribution system plus the annual user cost for the rest of the system. As shown in the table, the costs in the first years are high due to lack of a sufficient number of users.

8. **Phased Construction**

In most major water distribution projects, it is advantageous to phase construction to lessen costs per user at the front end of the project. In the case of North Cheyenne, the existing patterns of development are not in an orderly manner. In addition, the groundwater declines are widespread in the study area. Consequently, it is very difficult to target areas that would have the most potential users in the early years of the project.

Another factor is the potential funding by the WWDC. The standard WWDC funding package entails a 2/3 grant and 1/3 loan at four percent for 50 years. The WWDC would fund the main distribution systems and supply systems.

The potential for phasing of the construction should be re-evaluated when more accurate information is available on the location and numbers of potential users of a supply system.
Table 5g: Rural System with Municipal Supply.

<table>
<thead>
<tr>
<th></th>
<th>1995</th>
<th>2005</th>
<th>2015</th>
<th>2025</th>
<th>2035</th>
<th>2045</th>
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<tr>
<td>System users</td>
<td>450</td>
<td>1,000</td>
<td>1,650</td>
<td>2,400</td>
<td>2,950</td>
<td>2,950</td>
</tr>
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Main Distribution System

Estimated Construction Cost - $5,000,000

WWDC funding 2/3 grant - 1/3 loan @ 4% interest

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<table>
<thead>
<tr>
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<th></th>
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<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Construction Loan Cost</td>
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<td>77,600</td>
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<td>O &amp; M Costs</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inflated</td>
<td>50,000</td>
<td>111,000</td>
<td>219,100</td>
<td>405,400</td>
<td>720,200</td>
<td>1,243,700</td>
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<tr>
<td>Total Annual Cost</td>
<td>127,600</td>
<td>188,600</td>
<td>296,700</td>
<td>483,000</td>
<td>797,800</td>
<td>1,321,300</td>
</tr>
<tr>
<td>Inflated</td>
<td>127,600</td>
<td>127,400</td>
<td>135,400</td>
<td>148,900</td>
<td>166,200</td>
<td>185,900</td>
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<tr>
<td>Present Worth</td>
<td>284</td>
<td>127</td>
<td>82</td>
<td>62</td>
<td>56</td>
<td>63</td>
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<tr>
<td>Water Purchase Costs</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.5 In-Town Rates</td>
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<td></td>
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<td></td>
</tr>
<tr>
<td>Present Worth</td>
<td>520</td>
<td>445</td>
<td>389</td>
<td>335</td>
<td>291</td>
<td>278</td>
</tr>
<tr>
<td>1.0 In-Town Rates</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Present Worth</td>
<td>346</td>
<td>297</td>
<td>259</td>
<td>223</td>
<td>194</td>
<td>185</td>
</tr>
<tr>
<td>Total Cost/User/Yr.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>1.5 In-Town Rate</td>
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<td></td>
<td></td>
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<tr>
<td>Present Worth</td>
<td>804</td>
<td>572</td>
<td>471</td>
<td>397</td>
<td>347</td>
<td>341</td>
</tr>
<tr>
<td>1.0 In-Town Rate</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Present Worth</td>
<td>630</td>
<td>424</td>
<td>341</td>
<td>285</td>
<td>250</td>
<td>248</td>
</tr>
</tbody>
</table>

Local Distribution System Hook-Up Costs

<p>| | | | | | | |</p>
<table>
<thead>
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<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Cost per New User</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Present Worth</td>
<td>3,250</td>
<td>3,250</td>
<td>3,250</td>
<td>3,250</td>
<td>3,250</td>
<td>3,250</td>
</tr>
</tbody>
</table>

5-48
The water quality issue could cause phasing of construction to be attractive. If water quality degradation is found to be a major problem in certain areas, the construction of portions of the main distribution system may be economical.

G. Comparison of Water Supply Alternatives

The analysis resulted in three water supply alternatives that were investigated in depth. These included an alternative to construct a Municipal System to City Standards, which would deliver fire flow as well as domestic and irrigation flows. This system would be supplied from the City of Cheyenne system.

The second alternative would be an Independent Groundwater System, which would deliver domestic and irrigation flows, but not fire flows. The water source would be a Casper formation well field located approximately 23 miles west of the study area.

The third alternative would involve a Rural System with City Supply that would deliver domestic and irrigation water, but not fire flows. The water source would be from the City of Cheyenne.

To compare the alternatives, Table 5h was developed. The table compares yearly costs over the study period as well as other user costs. The scenario used was one with 450 users on the system, initially. It was assumed that the WWDC would participate financially on supply and main distribution, but not on the local distribution systems.

As indicated in Table 5h, the most costly alternative for construction is the Independent Groundwater System at $15,650,000. The Municipal System to City Standards has a construction cost of $6,000,000, while the Rural System with City Supply costs $5,000,000. These costs include the main distribution system and water supply components for each alternative.

The annual costs, however, indicate that the alternatives are relatively equal in the early years, while the Independent Groundwater System costs less in the more distant future. This is due to the need to purchase water from the City of Cheyenne for the other two alternatives.

The hook-up costs heavily favor the Independent Groundwater System and Rural System with City Supply due to the smaller and cheaper system. The $14,000 per hook-up cost for the Municipal System is quite high.
### Table 5h: Water Supply Alternative Comparison.

<table>
<thead>
<tr>
<th></th>
<th>1995</th>
<th>2005</th>
<th>2015</th>
<th>2025</th>
<th>2035</th>
<th>2045</th>
</tr>
</thead>
<tbody>
<tr>
<td>System users</td>
<td>450</td>
<td>1,000</td>
<td>1,650</td>
<td>2,400</td>
<td>2,950</td>
<td>2,950</td>
</tr>
</tbody>
</table>

#### Municipal System to City Standards

<table>
<thead>
<tr>
<th>Cost/User/Yr.</th>
<th>190</th>
<th>58</th>
<th>24</th>
<th>11</th>
<th>6</th>
<th>4</th>
</tr>
</thead>
</table>
| Water Purchase Costs - 1.5 In-Town Rate
| Cost/User/Yr. | 520 | 445 | 389 | 335 | 291 | 278 |
| Total Cost/User/Yr. | 710 | 503 | 413 | 346 | 297 | 282 |

#### Local Distribution System Costs Per New User

| Cost/User | 14,000 | 14,000 | 14,000 | 14,000 | 14,000 | 14,000 |

#### Independent Groundwater System

| Casper Well Field and Delivery System Construction Cost - $12,400,000
| Main Distribution System Construction Cost - $3,250,000
| WWDC Funding 2/3 grant - 1/3 loan @ 4% interest
| Cost/User/Yr. | 764 | 320 | 179 | 162 | 133 | 102 |
| Local Distribution System Costs Per New User

#### Rural System with City Water Supply

| Main Distribution System Construction Cost - $5,000,000
| WWDC Funding 2/3 grant - 1/3 loan @ 4% interest
| Cost/User/Yr. | 284 | 127 | 82  | 62  | 56  | 63  |
| Water Purchase Costs - 1.0 In-Town Rate
| Cost/User | 346 | 297 | 259 | 223 | 194 | 185 |
| Total Cost/User/Yr. | 630 | 424 | 341 | 285 | 250 | 248 |
| Local Distribution System Costs Per New User
6 Water Quality
6 Water Quality

A. General

The original Level I Contract did not include an investigation to determine if urban development had impacted the chemical quality of groundwater in the North Cheyenne area. However, a water quality investigation of groundwater was included in the study because possible deterioration in groundwater quality was a concern of the public. In the 1960's urban development had resulted in increased nitrate concentrations in groundwater in some areas in the Dry Creek and Crow Creek drainages near the City of Cheyenne. Most of the problem areas have since been incorporated into the City and now use City water and sewer services.

In response to the concerns about groundwater quality, the Wyoming Water Development Commission requested a cursory investigation of groundwater quality in the North Cheyenne area. The primary objective of this study was to determine if increased urban development had caused changes in the quality of groundwater in the Tertiary aquifer north of Cheyenne. The secondary objective was to determine if radon concentrations in the Tertiary aquifer in the North Cheyenne area were similar to the radon levels in the parts of the aquifer that provide water to the City of Cheyenne's municipal well fields.

Three chemical constituents of groundwater were sampled and analyzed; nitrates, chlorides, and radon. Chlorides and nitrates naturally occur in small concentrations in the Tertiary aquifer and increase as the result of human activity. Nitrate was selected for analyses because it is the major indicator of pollution from septic systems and fertilizer application. Chloride concentrations were analyzed to supplement the information on nitrates and was selected because it is present in household and other wastes, but is not used as fertilizer. Radon was selected because during the course of the study it was pointed out by the Cheyenne Board of Public Utilities that the radon exceeded the proposed EPA standards in many wells in the Tertiary aquifer.

Sections B, C, D, & E of this chapter describe the SWWRC investigation of water quality in the North Cheyenne area. A detailed discussion of the statistical analysis of the data used in this study is presented in Appendix D. Fact sheets on nitrates and radon published by the U.S. Environmental Protection Agency (EPA) are also enclosed in Appendix D.
The aquifer in the North Cheyenne area is called the Tertiary aquifer by the Wyoming State Engineer’s Office. The aquifer includes the White River Formation, the Ogallala Formation, and the Arikaree Formation (where it is present). The term "Tertiary aquifer" is used in this context throughout this Chapter. The Tertiary aquifer is described in Chapter 3 of this report.

B. Health Concerns

Of the three constituents sampled, only nitrates and radon are health concerns. The EPA limit on nitrates in public water supplies is 45 milligrams per liter (mg/l) when reported as nitrates (NO3). The EPA is in the process of establishing limits for radon; however as of April 1993, the limit had not been formally adopted. The proposed limit is 300 pico Curies per liter (pCi/l). The EPA has no mandatory limit on chlorides. A suggested limit of 250 mg/l for chloride is recommended for taste rather than health considerations.

1. Nitrates

Nitrates occur in both surface and groundwater. Nitrates originate from many sources such as animal and human wastes, soil, fertilizers and crop residues. The presence of nitrates in water may indicate pollution from fertilizers or septic tank leakage and further investigation should be made to find the source of the nitrates.

Information on nitrates is contained in an EPA fact sheet reproduced in Appendix D. This fact sheet states, in part, that nitrates are not harmful. However, through a chemical process in the digestive system, they are converted to harmful nitrites.

Nitrates/nitrites in drinking water are not normally a problem for adults. However, they are a particular concern for children under six months of age because their digestive systems are more likely to allow conversion of nitrates to nitrites. The nitrite is absorbed into the blood stream and prevents the blood from carrying oxygen and the child could suffocate. This disease is called methemoglobinemia or "blue baby" disease.

The EPA recommends testing for bacteria when nitrates are present because nitrates may indicate recent pollution by human or animal wastes. Testing for bacteria was not part of the water sampling in North Cheyenne. Fecal coliform bacteria live only a matter of weeks after they leave a septic environment and it will take much longer for water to travel from sources of bacteria to the aquifer under normal conditions. Bacteria could reach the aquifer if wells were not constructed according to State standards, as the bacteria could move down to the water table along the casing of a well.
In order to have water checked for nitrates, contact your local or State Health Department. A sample can be analyzed at minimal cost. Testing for bacteria should also be requested. Additional information can be obtained from your State Health Department or the EPA.

2. **Radon**

Radon is a naturally occurring radioactive gas and is carcinogenic. The principal health hazard of radon in water is that it is released into the air within the home. Showers, aerators on faucets, and other devices serve to release the radon from water and into the air causing an increase in the concentration of the gas within the home.

The EPA suggests that the concentration of radon in the air in the living space of a home should be less than 4 pCi/l. The EPA estimates that radon levels in the air in a home will increase approximately 1 pCi/l for every 10,000 pCi/l of radon in the water that is used in the home. The EPA fact sheet on radon is included in Appendix D.

Testing of radon in water is expensive, costing approximately $200 per sample. Testing for radon in the air in a home is much more economical and can be done by the homeowner. Test kits are available from the Laramie County Health Department as well as other sources.

C. **Approach**

Samples of groundwater were collected in the North Cheyenne area on March 10, 1993. The samples were taken from wells located in the area drained by Child’s Draw and in areas where there was early concentrated housing development. These areas were chosen for sampling, because the samples had to be obtained where development has been present long enough for its effects to appear in the aquifer. It is estimated that it takes 20 to 30 years for water to travel from the surface to the water table in the Tertiary aquifer. The area sampled was developed before 1973, so it was felt that any changes to groundwater quality caused by development would be present in this area.

Fifteen samples were collected for nitrates and chlorides. Four samples were collected for radon. Samples were preserved to prevent change in the concentration of the constituents between the time of collection and analysis. All samples were analyzed by Accu-Labs Research, Inc. of Golden, Colorado.

The concentration of nitrates and chlorides in the March 10, 1993 water samples were compared with control data obtained from computer files of the U.S. Geological Survey.
Results of the analyses for radon were compared with results of analyses in the City well field to determine if similar concentrations of radon occur in the aquifer in North Cheyenne.

D. Quality of Water

Pre-development groundwater quality from the Tertiary aquifer in most locations is excellent as shown by the control data, which was obtained from USGS computer files. These data are shown in Appendix D. The control data is from wells completed in the Tertiary aquifer in Laramie County in an area including Townships 14 through 17 north and Ranges 64 through 69 west, exclusive of Francis E. Warren Air Force Base. The well locations are shown on Figure 6-1.

Analyses of water from wells east of Range 64 and North of Township 17 were excluded from sampling because irrigation for agriculture has affected the quality of water in some areas. Samples of water that might be in part from alluvium, which is more susceptible to pollution, were also eliminated. Analyses of water from wells on Francis E. Warren Air Force Base were not included because of the long period of activity at the base which may have affected the quality of water.

Most of the U.S.G.S. control data are from undeveloped areas, but at least three of the samples are from subdivisions located near Cheyenne. The samples were collected between 1949 and 1984. The samples from the subdivisions provide some of the most recent data, but were collected at about the time development began in the area. Although the samples are from areas of recent development, they are believed to be representative of pre-development conditions because it takes 20 to 30 years for water to move through the soil to the water table.

Table 6a gives the results of the analyses for nitrates and chlorides. Both the groundwater samples collected from North Cheyenne on March 10, 1993 for this study and the control data are presented in this table.

Analyses are presented in Table 6a in order of increasing chloride concentration. The averages of the chlorides and nitrates for the two sets of data are shown. The average concentrations of chlorides and nitrates are higher for the North Cheyenne samples. The average nitrate concentration in the North Cheyenne samples is 12.7 mg/l compared to 6.0 mg/l for the control data. The average chloride concentration in the North Cheyenne samples is 8.4 mg/l compared to 5.1 mg/l in the control sample.
Figure 6-1. Location of wells for which analysis is given in Appendix D (filled circle) and the location of the North Cheyenne Area (shaded).

Table 6b presents the results of the radon analyses for the groundwater samples from North Cheyenne and from the City of Cheyenne well fields. The analyses indicate that three of four samples from North Cheyenne exceed the EPA proposed standard for radon concentration. The average radon concentration in both the North Cheyenne samples and the City's well fields exceed the proposed EPA standards. The City of Cheyenne presently eliminates radon by aeration and ventilation before discharge to the City system. Aeration and ventilation options are also available to local homeowners.

Although the average concentration of radon in water samples from the North Cheyenne area exceed the proposed EPA standards, the water would cause only a small increase in the concentration of radon in the home. Using EPA's estimate that radon in air increases 1 pCi/l for every 10000 pCi/l in water; the concentration of radon in the air would increase 0.078 pCi/l if one used the water that has the highest concentration of radon (780 pCi/l).
Table 6a. Results of analyses for chloride and nitrate in North Cheyenne and in adjoining areas.

<table>
<thead>
<tr>
<th>Chloride (mg/l)</th>
<th>Nitrate (mg/l)</th>
<th>Chloride (mg/l)</th>
<th>Nitrate (mg/l)</th>
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<tbody>
<tr>
<td>&lt;3</td>
<td>11.1</td>
<td>1</td>
<td>8.3</td>
</tr>
<tr>
<td>&lt;3</td>
<td>23.5</td>
<td>1.5</td>
<td>1.8</td>
</tr>
<tr>
<td>4</td>
<td>7.1</td>
<td>1.6</td>
<td>3.9</td>
</tr>
<tr>
<td>4</td>
<td>11.1</td>
<td>2</td>
<td>5.8</td>
</tr>
<tr>
<td>4</td>
<td>12.4</td>
<td>2</td>
<td>8.4</td>
</tr>
<tr>
<td>5</td>
<td>10.6</td>
<td>2</td>
<td>6.2</td>
</tr>
<tr>
<td>5</td>
<td>13.3</td>
<td>2.1</td>
<td>7.5</td>
</tr>
<tr>
<td>6</td>
<td>27.4</td>
<td>2.2</td>
<td>---</td>
</tr>
<tr>
<td>8</td>
<td>11.9</td>
<td>2.3</td>
<td>7.7</td>
</tr>
<tr>
<td>8</td>
<td>23.9</td>
<td>2.3</td>
<td>3.2</td>
</tr>
<tr>
<td>9</td>
<td>36.7</td>
<td>2.5</td>
<td>6.8</td>
</tr>
<tr>
<td>10</td>
<td>27.4</td>
<td>2.6</td>
<td>6.9</td>
</tr>
<tr>
<td>11</td>
<td>9.7</td>
<td>2.7</td>
<td>7.6</td>
</tr>
<tr>
<td>22</td>
<td>19.5</td>
<td>2.7</td>
<td>4.9</td>
</tr>
<tr>
<td>28</td>
<td>19.5</td>
<td>2.8</td>
<td>4.3</td>
</tr>
<tr>
<td>Avg.</td>
<td>8.4</td>
<td>2.8</td>
<td>7.3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3.3</td>
<td>5.3</td>
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<td></td>
<td></td>
<td>3.6</td>
<td>3.2</td>
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<td></td>
<td></td>
<td>3.8</td>
<td>5.7</td>
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<td></td>
<td></td>
<td>3.9</td>
<td>3.9</td>
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<tr>
<td></td>
<td></td>
<td>3.9</td>
<td>8.7</td>
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<tr>
<td></td>
<td></td>
<td>4</td>
<td>16.5</td>
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<tr>
<td></td>
<td></td>
<td>4.3</td>
<td>3.7</td>
</tr>
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<td></td>
<td></td>
<td>4.9</td>
<td>3.4</td>
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<tr>
<td></td>
<td></td>
<td>5.4</td>
<td>0.4</td>
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<td></td>
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<td>5.6</td>
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<td>5.7</td>
<td>1.3</td>
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<td>6</td>
<td>1.6</td>
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<td></td>
<td></td>
<td>17</td>
<td>8.3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>38</td>
<td>9.7</td>
</tr>
<tr>
<td>Avg.</td>
<td>5.1</td>
<td>9.7</td>
<td>6.0</td>
</tr>
</tbody>
</table>
Table 6b. Radon concentration (pC/l) in water from the Tertiary Aquifer in the City well fields and North Cheyenne.

<table>
<thead>
<tr>
<th>Test Data Radon in Water from the Tertiary Aquifer</th>
<th>Control Data City Well Radon (pCi/l)</th>
</tr>
</thead>
<tbody>
<tr>
<td>230 ± 30</td>
<td>Bell #6</td>
</tr>
<tr>
<td>370 ± 40</td>
<td>Bell #10</td>
</tr>
<tr>
<td>480 ± 40</td>
<td>Bell #12</td>
</tr>
<tr>
<td>780 ± 50</td>
<td>Bell #16</td>
</tr>
<tr>
<td>Avg. 465</td>
<td>Bell #17</td>
</tr>
<tr>
<td></td>
<td>Borie</td>
</tr>
<tr>
<td></td>
<td>Coastal #17</td>
</tr>
<tr>
<td></td>
<td>(proxy Weber)</td>
</tr>
<tr>
<td></td>
<td>Conrey #1</td>
</tr>
<tr>
<td></td>
<td>Eddy well</td>
</tr>
<tr>
<td></td>
<td>Elkar #1</td>
</tr>
<tr>
<td></td>
<td>Elkar #5</td>
</tr>
<tr>
<td></td>
<td>Elkar #7</td>
</tr>
<tr>
<td></td>
<td>Federal #24</td>
</tr>
<tr>
<td></td>
<td>Federal #25</td>
</tr>
<tr>
<td></td>
<td>Finnerty</td>
</tr>
<tr>
<td></td>
<td>Happy Jack #3</td>
</tr>
<tr>
<td></td>
<td>King #2</td>
</tr>
<tr>
<td></td>
<td>King #4</td>
</tr>
<tr>
<td></td>
<td>King #5</td>
</tr>
<tr>
<td></td>
<td>Koppes #1</td>
</tr>
<tr>
<td></td>
<td>Koppes #3</td>
</tr>
<tr>
<td></td>
<td>Koppes #6</td>
</tr>
<tr>
<td></td>
<td>Merritt #5</td>
</tr>
<tr>
<td></td>
<td>Merritt #6</td>
</tr>
<tr>
<td></td>
<td>Merritt #8</td>
</tr>
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<td></td>
<td>Merritt #9</td>
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<tr>
<td></td>
<td>Merritt #15</td>
</tr>
<tr>
<td></td>
<td>State #1</td>
</tr>
<tr>
<td></td>
<td>State #2</td>
</tr>
<tr>
<td></td>
<td>Avg. 668</td>
</tr>
</tbody>
</table>

There is an increased emphasis on statistics in environmental work. Major uses of statistics in environmental studies include the extraction of the maximum information from the data and the formulation and objective testing of hypotheses about the data. States West Water Resources Corporation obtained the assistance of Dr. John F. Busby to prepare a statistical analyses of the data used in this study. This analysis is presented in Appendix D.
E. Conclusions

Development has affected the chemical quality of water in North Cheyenne. Both chloride and nitrate concentrations in the North Cheyenne samples are significantly higher than the control data. Because concentrations of both chloride and nitrates are elevated, the change can not be attributed solely to fertilizer.

None of the samples from North Cheyenne exceeded the limit for nitrates established by EPA for public supplies. The chloride concentrations in the North Cheyenne samples are well below the EPA suggested limit on chloride. Radon occurs naturally in the water from the Tertiary aquifer in North Cheyenne. The proposed EPA standard of 300 pC/l for radon in public water supplies is exceeded in three of the four wells sampled in North Cheyenne.
7 Summary and Recommendations
7 Summary and Recommendations

A. The Problems

There are three problems related to water supplies from wells in North Cheyenne. The problem that was the impetus for this investigation is declining of water levels in what is designated as the Tertiary aquifer by the Wyoming Department of the State Engineer. A second problem is possible degradation of the quality of water because of the use of septic tanks. A third problem is the physical deterioration of wells. Deterioration of a well is not a "groundwater supply" problem, but is included herein because decreased well yield that results from the deterioration could be mistakenly attributed to a decline in water levels.

B. Existing Groundwater Supply

The source of groundwater for urban development in North Cheyenne is designated the Tertiary aquifer by the Wyoming State Engineer. This aquifer consists of two and possibly three geologic units. Permeable zones in the aquifer are sands and gravels which differ in thickness and areal extent within the aquifer. Under natural conditions, the groundwater flow in the area was from west to east. Recharge to the area occurs by flow through the aquifer from the west and by infiltration of precipitation. Discharge occurs by flow out of the area to the east. Discharge through wells was added with urban development. As much as 30 percent of the quantity pumped will, in time, return through septic tanks as recharge. Water-level changes reflect long term variation in precipitation, annual changes caused by lawn watering, and diurnal changes related to use within the North Cheyenne homes.

By 1973, the quantity of water pumped was enough to reverse the eastward direction of groundwater flow in one area. A decline of water level of at least 10 feet in most of the area, and more than 30 feet in parts of the area, occurred from 1973 to 1989. Areas near the City had little or no decline because lawn watering in the City contributed to recharge.

Some wells in the Tertiary aquifer began to deteriorate in 20 to 30 years and many of the wells in North Cheyenne are this old. Therefore some decreases in well yield that have been attributed to declining water levels may be all, or in part, because of well deterioration.
C. Water Supply Needs

Future population growth and water demands were estimated for the North Cheyenne area. The number of residences as of July, 1992 in the North Cheyenne study area was determined to be 1,444, which was equal to a population of approximately 4,476. A population growth rate of 30 residences per year was assumed for the unincorporated portion of the study area. This is an approximate annual growth rate of two percent.

The pattern of development was estimated by assuming that the minimum lot size would be 2.5 acres if water supply was available. It was also assumed that all new development would occur within one-half mile of a paved road.

Water usage was estimated as 210 gallons per capita per day based on studies of similar areas. Future water usage was estimated for each quarter section in the study area.

D. Alternatives

The alternatives investigated included the No Action Alternative, Groundwater Management Alternatives, and Water Supply Systems Alternatives. Within the broad categories are more specific alternatives which are discussed.

1. No Action Alternative

The No Action Alternative would result in a long term decline of water levels such that water supplies could no longer be obtained from the aquifer. Pollution from septic tanks could possibly degrade the quality of the aquifer so that water could eventually be rendered unusable for human consumption.

2. Groundwater Management Alternatives

The Groundwater Management Alternatives fall into two general categories. The first category includes alternatives such as a moratorium on new well construction, lot size limitation, and irrigation controls. These alternatives would not stop the decline of water levels but would slow the rate of decline. They could be appropriate for areas which could not be reasonably or economically served by other alternatives.

The other category of Groundwater Management Alternatives involve recharge of the aquifer by importation of water. One method of accomplishing this would involve utilization of raw water from the City of Cheyenne for recharge in the Childs drainage. The construction costs for this alternative were estimated at $2,750,000. Water would
have to be purchased from the City and might not be available long term. One advantage of this alternative is that all residents of North Cheyenne would be beneficiaries of the project and would share the costs. The 1995 costs per residence would be $10 to $16 per month and would decrease in future years.

The second method of recharge would occur if water supply systems with imported water supply were constructed. The septic tank effluent and excess lawn water would recharge the aquifer. When a sufficient number of residents are on a water system, the aquifer could begin to recharge. One of the negative impacts of recharge using septic systems is the possible pollution of the aquifer. The aquifer could become unusable for domestic purposes.

3. Water Supply Alternatives

This category of alternatives has three types of systems that were investigated. These included a Municipal System to City Standards, an Independent Groundwater System, and a Rural System with Municipal Source. Each system is discussed in more detail.

a. Municipal System to City Standards

This alternative would involve extension of the City of Cheyenne municipal system to serve rural users. The system would be constructed to City standards and then would be operated and maintained by the City. The users would purchase water from the City, but would be responsible for loan payments for the main distribution system. Each user would also be responsible for the cost of the local distribution system to serve the individual residence.

The main distribution system was designed to primarily follow the paved roads in the study area. The existing development is concentrated along the roads. A network analysis using Cybernet was used to size the main distribution system. The analysis resulted in pipe sizes from 8 to 16 inches in diameter. A total of 18.5 miles of ductile iron pipe, valves, hydrants, storage tank, reducing valves, and pump stations would be required. The project would cost an estimated $6,000,000.

The local distribution system would consist of 8-inch ductile iron pipe with appropriate hydrants, valves, and connections. The average cost per lot would be $10,000 just for the local distribution system. In addition, a tap fee would be charged by the BPU. The large size of lots in North Cheyenne is the reason for the high costs.
The economic analyses was performed and assumed that the WWDC would participate in the main distribution system. The participation would be in the form of a 2/3 grant and 1/3 loan at 4 percent interest for 50 years. The local distribution systems would be financed by the users.

The economic analysis indicates that the system would be very expensive for the users. The $14,000 cost to hook-up to the system is probably too expensive for most potential users. In addition, the costs for loan payment for the main distribution system and purchase of water from the City are quite high in the early years of the project. A range of users from 100 to 450 residences at the project start-up were analyzed. At a water purchase rate of 1.5 times the in-town rate, the costs to the users would be approximately $60 per month with 450 users on the system.

b. Independent Groundwater System

An Independent Groundwater System would have two components. A source of groundwater would have to be developed and delivered to the study area. A distribution system would be needed to deliver water to the users. This type of system would be owned, operated, and maintained by the users.

Two potential well fields were investigated and compared. A potential Ogallala/Arikaree Formation well field was identified approximately 15 miles north of the study area. Additional investigation would have to be done to develop more accurate information on yields. The well field and delivery pipeline to the study area has an estimated cost of $9,000,000. The well field is approximately 500 feet lower than the study area so pumping costs are appreciable.

The second potential groundwater source is a Casper Formation well field located approximately 23 miles west of the study area. Little is known about the area, but potentially large production wells are possible. The well field and delivery pipeline to the study area have an estimated cost of $12,400,000. The well field is approximately 600 feet higher than the study area so pumping costs are nominal.

An economic comparison of the two potential sources indicates that the Casper Well Field is more economical over the 50-year study period. Consequently, this source was assumed for the system.

The main distribution system was designed to primarily follow the paved roads in the study area. The system would furnish domestic and irrigation water, but not fire
protection flows. The existing development is concentrated along these roads. A network analysis with Cybernet was used to size the main distribution system. The system resulted in a total of 19 miles of pipes from 8 inches to 16 inches in diameter. The pipes would probably be PVC pipe. The system would also include valves, a storage tank, pressure reducing valves, and pump station. The main distribution system would cost an estimated $3,250,000. The local distribution systems would consist of PVC pipe from two inches to six inches in size. The average cost for the local distribution system would be $3,250 per user.

The economic analysis was performed for a period of 50 years and assumed that the WWDC would participate in the well field, delivery pipeline, and the main distribution system. The participation would be in the form of a 2/3 grant and 1/3 loan at 4 percent interest for 50 years. The local distribution system would be paid or financed entirely by the users.

The economic analysis indicates that a considerable number of users would be necessary to make the project affordable in the early years of the project. Two scenarios with a range of start-up users of 100 and 450 were analyzed. Even with 450 users on the system, the costs per user exceed $60 per month in the early years of the project. The hook-up cost of $3,250 per year is more nominal.

c. Rural System with Municipal Supply

This alternative would involve a rural type distribution system with purchase of water from the City. The system would furnish domestic and irrigation water but not fire protection flows. The system would be owned, operated, and maintained by the users. Water would be purchased from the City at the connection points to the City system. The users would have to pay for loan payments, operation and maintenance, and purchase of water.

The economic analysis was performed for a period of 50 years and assumed that the WWDC would participate in the main distribution system. The participation would be in the form of a 2/3 grant and 1/3 loan at 4 percent interest for 50 years. The main distribution system would consist of 22.0 miles of pipe from 8 inches to 16 inches in diameter. The system would also incorporate valving, storage tank, pressure reducing valves, mainline meters, and pump station. The estimated cost is $5,000,000.

The local distribution systems would consist of PVC pipe from two inches to six inches in size. The average cost for the local distribution system would be $3,250 per lot. This does
not include any tap fee to the BPU. The local distribution systems would be paid or financed by the users. The cost of water purchase from the City was analyzed at the in-town rate. The lower water cost would seem appropriate in view of the fact that the users would operate and maintain their own system.

The economic analysis indicates that a considerable number of users would be necessary to make the project affordable in the early years of the project. Two scenarios with a range of 100 and 450 users at start-up were analyzed. With 450 users on the system and assuming a water cost equal to the in-town rate, the costs would be $52 per month in the first years of the project.

d. Comparison of Water Supply Alternatives

The analysis resulted in three water supply alternatives that were investigated in depth. These included an alternative to construct a Municipal System to City Standards, which would deliver fire flow as well as domestic and irrigation flows. This system would be supplied from the City of Cheyenne system. The second alternative would be an Independent Groundwater System, which would deliver domestic and irrigation flows, but not fire flows. The water source would be a Casper formation well field located approximately 23 miles west of the study area. The third alternative would involve a Rural System with City Supply that would deliver domestic and irrigation water, but not fire flows. The water source would be from the City of Cheyenne.

To compare the alternatives, Table 7a was developed in Chapter 5 (Table 5h) and is repeated herein. The table compares yearly costs over the study period as well as other user costs. The scenario used was one with 450 users on the system, initially. It was assumed that the WWDC would participate financially on supply and main distribution, but not on the local distribution systems. As indicated in Table 7a, the most costly alternative for construction is the Independent Groundwater System at $15,650,000. The Municipal System to City Standards has a construction cost of $6,000,000, while the Rural System with City Supply costs $5,000,000. These costs include the main distribution system and water supply components for each alternative. The annual costs, however, indicate that the alternatives are relatively equal in the early years, while the Independent Groundwater System costs less in the more distant future. This is due to the need to purchase water from the City of Cheyenne for the other two alternatives. The hook-up costs heavily favor the Independent Groundwater System and Rural System with City Supply due to the smaller and cheaper system. The $14,000 per hook-up cost for the Municipal System is quite high.
Table 7a: Water Supply Alternative Comparison.

<table>
<thead>
<tr>
<th></th>
<th>1995</th>
<th>2005</th>
<th>2015</th>
<th>2025</th>
<th>2035</th>
<th>2045</th>
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</thead>
<tbody>
<tr>
<td>System users</td>
<td>450</td>
<td>1,000</td>
<td>1,650</td>
<td>2,400</td>
<td>2,950</td>
<td>2,950</td>
</tr>
</tbody>
</table>

**Municipal System to City Standards**

Main Distribution System Construction Cost - $6,000,000
WWDC Funding 2/3 grant - 1/3 loan @ 4% interest

Cost/User/Yr. 190 58 24 11 6 4

Water Purchase Costs - 1.5 In-Town Rate

Cost/User/Yr. 520 445 389 335 291 278

Total Cost/User/Yr. 710 503 413 346 297 282

**Local Distribution System Costs Per New User**

Cost/User 14,000 14,000 14,000 14,000 14,000 14,000

**Independent Groundwater System**

Casper Well Field and Delivery System Construction Cost - $12,400,000
Main Distribution System Construction Cost - $3,250,000
WWDC Funding 2/3 grant - 1/3 loan @ 4% interest

Cost/User/Yr. 764 320 179 162 133 102

**Local Distribution System Costs Per New User**


**Rural System with City Water Supply**

Main Distribution System Construction Cost - $5,000,000
WWDC Funding 2/3 grant - 1/3 loan @ 4% interest

Cost/User/Yr. 284 127 82 62 56 63

Water Purchase Costs - 1.0 In-Town Rate

Cost/User 346 297 259 223 194 185

Total Cost/User/Yr. 630 424 341 285 250 248

**Local Distribution System Costs Per New User**

The most desirable water supply alternative for the North Cheyenne area is the Rural System with City Supply. The monthly costs are the lowest initially, and the system would be rather easily phased. The initial hook-up costs of $3,250 per user are more affordable. In addition, it would be advantageous for a district to purchase treated water rather than be responsible for operation and maintenance of a treatment system. The main distribution system is shown on Figure 5-10.

e. Phased Construction

Phased construction of the main distribution system was investigated. The advantages of phased construction would be the potential for service of large numbers of users in certain areas at affordable prices. There are several problems with phasing at this time. First, the potential users have not been identified or located so the most economical segments have not been identified. Secondly, the WWDC funding available for the main distribution system is very attractive and might not be available in the future. Thirdly, the lack of water supply for large portions of the study area would continue the pattern of new well development.

E. Water Quality

1. General

The original Level I Contract did not include an investigation to determine if urban development had impacted the chemical quality of groundwater in the North Cheyenne area. However, a water quality investigation of groundwater was included in the study because possible deterioration in groundwater quality was a concern of the public. In the 1960's urban development had resulted in increased nitrate concentrations in groundwater in some areas in the Dry Creek and Crow Creek drainages near the City of Cheyenne. Most of the problem areas have since been incorporated into the City and now use City water and sewer services.

In response to the concerns about groundwater quality, the Wyoming Water Development Commission requested a cursory investigation of groundwater quality in the North Cheyenne area. The primary objective of this study was to determine if increased urban development had caused changes in the quality of groundwater in the Tertiary aquifer north of Cheyenne. The secondary objective was to determine if radon concentrations in the Tertiary aquifer in the North Cheyenne area were similar to the radon levels in the parts of the aquifer that provide water to the City of Cheyenne's municipal well fields.
Three chemical constituents of groundwater were sampled and analyzed; nitrates, chlorides, and radon. Chlorides and nitrates naturally occur in small concentrations in the Tertiary aquifer and increase as the result of human activity. Nitrate was selected for analyses because it is the major indicator of pollution from septic systems and fertilizer application. Chloride concentrations were analyzed to supplement the information on nitrates and was selected because it is present in household and other wastes, but is not used as fertilizer. Radon was selected because during the course of the study it was pointed out by the Cheyenne Board of Public Utilities that the radon exceeded the proposed EPA standards in many wells in the Tertiary aquifer.

2. Approach

Samples of groundwater were collected in the North Cheyenne area on March 10, 1993. The samples were taken from wells located in the area drained by Child’s Draw and in areas where there was early concentrated housing development. These areas were chosen for sampling, because the samples had to be obtained where development has been present long enough for its effects to appear in the aquifer. It is estimated that it takes 20 to 30 years for water to travel from the surface to the water table in the Tertiary aquifer. The area sampled was developed before 1973, so it was felt that any changes to groundwater quality caused by development would be present in this area.

Fifteen samples were collected for nitrates and chlorides. Four samples were collected for radon. Samples were preserved to prevent change in the concentration of the constituents between the time of collection and analysis. All samples were analyzed by Accu-Labs Research, Inc. of Golden, Colorado.

The concentration of nitrates and chlorides in the March 10, 1993 water samples were compared with control data obtained from computer files of the U.S. Geological Survey. Results of the analyses for radon were compared with results of analyses in the City well field to determine if similar concentrations of radon occur in the aquifer in North Cheyenne.

3. Conclusions

Development has affected the chemical quality of water in North Cheyenne. Both chloride and nitrate concentrations in the North Cheyenne samples are significantly higher than the control data. Because concentrations of both chloride and nitrates are elevated, the change can not be attributed solely to fertilizer.
None of the samples from North Cheyenne exceeded the limit for nitrates established by EPA for public supplies. The chloride concentrations in the North Cheyenne samples are well below the EPA suggested limit on chloride. Radon occurs naturally in the water from the Tertiary aquifer in North Cheyenne. The proposed EPA standard of 300 pC/l for radon in public water supplies is exceeded in three of the four wells sampled in North Cheyenne.

F. Recommendations

The following recommendations are made for the North Cheyenne Master Plan project:

1. A rural distribution system with a water supply from the City of Cheyenne is the best water supply system. The system would be the most affordable and lends itself to phasing of construction. The estimated cost for the entire main distribution system is $5,000,000, which the WWDC could participate in financially. The local distribution systems would have to be financed separately or paid directly by the users. If a water supply system is constructed, a moratorium on well construction within one-half mile of the main distribution system should be imposed. The moratorium should include new well construction as well as existing well deepening or re-drilling.

2. Determine the interest of the residents in forming a legal entity to represent the North Cheyenne area. Any solutions to the groundwater problems that involve funding and expenditures would require some entity with authority. That authority would have to include authority to incur debt and assess members. It would also be of great benefit to determine if only limited areas of North Cheyenne are interested in formation of an entity or entities. It may be feasible to phase construction of a water supply system to serve critical areas.

3. Continue and expand groundwater management requirements for new developments not on water supply systems. These should include lot size limitations and irrigation controls. The large number of existing platted lots should be included in the limitation. Irrigation controls should be imposed to limit irrigated area.

4. If a water supply system is not determined to be feasible or affordable, a recharge program utilizing excess water from the City of Cheyenne should be investigated. A pipeline from the Roundtop Water Treatment Plant to the upper end of Childs Draw in the study area could be used for delivery of water for recharge. The
construction costs for the system were estimated at $2,750,000. The project could benefit essentially all residents of the North Cheyenne area. One potential problem would be the long-term availability of water.
References


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