LARAMIE COUNTY
AQUIFER STUDY
FINAL REPORT

Prepared for:
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1.0 INTRODUCTION

On June 7, 2007, JR Engineering LLC entered into a contract with the Wyoming Water Development Commission (WWDC) to provide professional services for the Laramie County Aquifer Study, sponsored by the Board of Laramie County Commission. The purpose of this study is to characterize the hydro geologic state of the High Plains Aquifer in Laramie County, Wyoming. This effort resulted in the preparation of the “Water Resource Atlas of Laramie County, Wyoming” (Atlas). The Atlas has been prepared in paper and electronic GIS form. The GIS files reside at WWDC and the Laramie County, Department of GIS and Information Technology.

In addition to JR Engineering, the following sub-consultants participated in the study:

- HDR, Cheyenne, Wyoming.

This report contains background information, geology and hydrology of the Laramie County region, and aquifer management recommendations, in addition to a description of the interactive Decision Support System developed to be used as a planning and publication tool. It also includes a thorough discussion of the Water Resource Atlas of Laramie County, Wyoming, developed for the purpose of guiding future development in Laramie County.

2.0 BACKGROUND

In recent years, Laramie County has experienced unprecedented growth. Since 2000, the county has had a population growth 38% higher than the state wide average. This growth in Laramie County has focused attention on the long-term viability of water supplies. The primary source of water in the county is ground water. By understanding the impact that water development has had on the aquifers, we can begin to plan for future sustainability of the ground water supplies that are so vital to the county residents.

Ground water use in Laramie County dates back to the late 19th century. In 1909, migration into the eastern part of the county had begun with dry-land agriculture as the primary industry. When drought struck the area in the 1930s, farmers began to use ground water for irrigation. By 1964 there were 220 irrigation wells in the county and by 2004 there were 992 irrigation wells. Since domestic wells weren’t recorded prior to 1969, little early growth data exist. However by 1975, there were approximately 3000 existing and new permits issued. By the year 2004, there were slightly over 12,000 total permits issued for Laramie County.

Currently the County is experiencing growth in rural subdivisions that rely solely on ground water for domestic and irrigation supply. An understanding of the historic development and the present conditions of the aquifer will aid in planning for subdivision water development in the future.
3.0 SCOPE OF SERVICES

SCOPING MEETING AND PROJECT MEETINGS

Mr. Bruce Brinkman, Project Officer, WWDC; JR Engineering, LLC, project prime; and its sub consultants, Lidstone and Associates, and HDR Inc, held the initial scoping meeting on July 11, 2007. The meeting was held in the Laramie County Commissioners office with the sponsor, Laramie County Commissioners, WWDO, and others to review the scope, project goals and timetable. Subsequent meetings were held throughout the life of the project. The following is a tabulation of the more notable meetings held throughout the contract:

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3.1 STUDY AREA

3.1.1 System GIS

A GIS was developed to assemble all the data available on the water resources of Laramie County. The purpose of the GIS is to assist the County in planning, land use and zoning. The primary source of data was the WWDC Platte River Basin Plan. Other sources of GIS data included:

- Wyoming Department of Environmental Quality
- Wyoming Office of the State Engineer
- Wyoming State Geological Survey
- U.S. Environmental Protection Agency
- U.S. Geological Survey
- Cheyenne Board of Public Utilities
- Laramie County, Dave Sherrill, Gary Kranse, Joyce Pukash
- Laramie County Conservation District, Jim Cochran, Liberty Blain
- Source Water Assessment and Protection Program

The GIS, as developed for Laramie County, consists of the following files/layers, as listed in Table 1.
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3.1.2 Land Use and Zoning

The population of Laramie County in 2007 was estimated to be approximately 85,000. This number is expected to grow to 93,000 by the year 2020, bringing additional demands on the water resources of the County. In addition to the population growth the County is experiencing within the City of Cheyenne, it is also seeing significant increases in the population of rural subdivisions outside the City. These subdivisions presently, and in the foreseeable future, will rely solely on ground water for domestic needs. This population increase will require additional water for domestic use, as well as the industrial, commercial and agricultural needs to fuel this growth. The planned water source for these subdivisions will continue to be ground water, most of which is withdrawn from the High Plains Aquifer. Increased pressure will be put on this and other aquifers in the area to supply water to the growing subdivisions.

State and Federal lands also represent a significant portion of Laramie County. Historically, water development has occurred on these public lands as well as in privately owned areas. The Federal government utilizes ground water at military installations, and the State lands have been leased land for agricultural, industrial and municipal use, all relying on ground water. In the future it is expected that these uses will continue to increase, placing even greater pressure on the already heavily stressed aquifers.

Agricultural land in Laramie County is irrigated by both surface and ground water. The areas irrigated by surface water supplies are primarily located along the foothills, drawing water from minor tributaries, including Horse Creek and Chugwater Creek to the north, and Crow Creek in the southern part of the County. Though some wells are used for flood irrigation in the northern and western parts of the county, and the Terrace gravel aquifer is tapped for irrigation in the Carpenter area in the southern part of the county, most irrigation by water wells occurs on the eastern plains. These wells withdraw water from the High Plains Aquifer, the Terrace gravels, and alluvium. Estimates of actual use vary greatly from 80,000 to 200,000 acre-feet per year in the region. Center-pivot sprinklers are the primary irrigation method employed. In all, there are 992 wells permitted for irrigation in the county.

3.1.3 Statutes and Regulations

Water development in Laramie County is administered primarily by two state agencies. These agencies are the State Engineer’s Office (SEO) and the Wyoming Department of Environmental Quality/Water Quality Division (WQD). Subdivision developments, and its associated water issues, are administered jointly by WQD, Laramie County, and the City of Cheyenne Development Office where subdivisions will be within the city, in close proximity to the city boundaries, or where annexation will occur. Federal agencies have some oversight when water supply systems will be funded utilizing federal sources or if a system will be constructed on federal land.

Laws governing the SEO and the WWDC, and the establishment of water and sewer districts outside municipal boundaries, are included in Title 41 of the Wyoming Statutes. Laws governing WQD are included in Title 35, the Environmental Quality Act. These agencies have developed rules, regulations and guidelines to implement the Wyoming Statutes. County
responsibilities are addressed in Title 18 of the state statues. Chapter 5, Article 3 of Title 18 specifically applies to subdivisions.

3.1.3.1 Wyoming State Engineer’s Office (SEO)

The Wyoming State Engineer is charged by the Wyoming Constitution with the administration of all waters within the state (Chapter 1, Section 1, SEO Rules and Regulations). Title 41, Chapter 3 of the Wyoming Statutes addresses the administration and control of water rights. Prior to using any water in the state, the appropriator is required to obtain a permit. The permit is the first step in acquiring a water right and it defines the conditions of use as well as the priority date. Once a permit has been issued, the permit holder may begin construction of the facility (well, ditch, reservoir, etc.) and begin beneficial use of Wyoming water. Upon satisfying the conditions of the permit, the appropriator may file a notice of beneficial use and seek adjudication of the water right by the Board of Control (BOC).

Both surface and ground water rights are defined in Wyoming Statute 41-3-103 according to the following preferred uses:

- Drinking water for both humans and livestock;
- Water for municipal purposes;
- Water for steam engines, general railway use, cooking, laundering, bathing, refrigerating (including ice manufacturing), steam and hot-water heating plants, and steam power plants; and
- Water for industrial purposes

Appropriations of underground water for stock or domestic use, the latter being defined as household use and the watering of lawns and gardens for noncommercial family use where the area to be irrigated does not exceed one acre, where the yield or flow does not exceed .056 cubic feet per second or 25 gallons per minute, shall have a preferred right over rights for all other uses (W.S. 41-3-907).

All other water uses are considered non-preferred, although rights with a preferred use do not take precedence over a non-preferred use. The priority date of a water right determines who is entitled to water (Jacobs, Tyrell, and Brosz, 2003).

Since Wyoming became a state in 1890, the only way a water right can be acquired is by obtaining a permit from the state engineer. Water rights obtained before 1890 are termed territorial water rights. Wyoming water law requires that certain procedures be followed to obtain a valid water right. For both ground water and surface water rights, an application must be filed with the state engineer for a permit. The requirements for surface water and ground water permits are outlined in Rules and Regulations for the SEO.

Under W.S. 41-3-911, the State Engineer has the authority to order an interfering appropriator to cease withdrawal of water. This authority applies to situations where a well, withdrawing water for beneficial purposes, interferes unreasonably with an adequate well with a prior appropriation developed solely for domestic or stock uses.

When a complaint is filed, the SEO undertakes an investigation to determine if the alleged interference does exist. If interference is determined, the SEO can order the interfering
appropriator to cease or reduce withdrawals of underground water, or furnish at their own expense sufficient water to meet the need for domestic or stock use.

The state engineer has the authority and is directed to determine the area and boundaries of districts overlying the various aquifers yielding underground waters in the state, and to assign to each district a distinctive name or number. Ground water control areas can be established under W.S. 41-3-912. The Laramie County Control Area was established in 1981 by the BOC in Water Division No. 1 due to well interference between agricultural wells and declines in ground water levels in the southeastern portion of Laramie County. Currently the Laramie County Control Area Advisory Board reviews and makes recommendations to the SEO concerning any new development of high-production wells, enlargements of existing permitted wells, or placing new lands under irrigation within the control area if there are objections to the petitions or applications, or if requested by the State Engineer (TriHydro, 2006).

In June, 2006 the State Engineer issued a policy memo addressing *Dual Well Completions in the High Plains Aquifer and Lance Formation, Southeast Wyoming.* In general it has been the policy of the State Engineer to not allow wells to be completed in more than one aquifer. In Laramie County, the State Engineer considers the High Plains Aquifer and the Lance Aquifer to be two separate aquifers, and will not allow wells to be constructed dually in both aquifers. The High Plains Aquifer consists of the Ogallala Formation, Arikaree Formation, and the Tertiary White River Group including the Chadron and the Brule Formations. Numerous wells in the southeastern corner of Wyoming are completed with filter packs across several water bearing zones in the formations. Differences in heads and water chemistry have gradually diminished over time. Consequently the State Engineer’s position is that there are no reliable criteria for consistently distinguishing between the White River Group, Arikaree Formation, and Ogallala Formation stating, “Splitting the High Plains Aquifer into smaller hydrogeologic units is not currently feasible.” Water from the Lance Formation is chemically distinct from water of the High Plains Aquifer; therefore allowing wells to connect the two aquifers could have serious negative consequences.

The SEO has also established conditions and limitations for wells completed in either the High Plains Aquifer or the Lance Aquifer within the North Cheyenne Study Area. Wells within this designated area cannot be completed dually in both the High Plains Aquifer and the Lance Aquifer. Furthermore, all wells must be completed with at least 60 feet of perforated casing in the bottom portion of the well and at least 100 feet of water above the uppermost casing perforations. If special conditions are encountered, a waiver of this condition may be requested in writing from the State Engineer.

The State of Wyoming has entered into the Platte River Recovery Implementation Program (Program) with the Department of the Interior and the States of Colorado and Nebraska. The purpose of the Program is to provide compliance with the Endangered Species Act for certain historic and future uses in each state.

In areas of Laramie County that are potentially tributary to the North Platte River, the SEO will review applications for ground water permits for irrigation, municipal, industrial, and miscellaneous purposes for wells that may be hydrologically connected to the surrounding surface water streams to
determine if the depletions from the projects can be covered by the Program. Wells completed in the Horse Creek and Upper and Lower Laramie Basins are subject to review under the Program. A hydrologically connected ground water well is one so located and constructed that if water were intentionally withdrawn by the well continuously for 40 years, the cumulative stream depletion would be greater than or equal to 28% of the total ground water withdrawn from the well. Following the review, the State Engineer’s Office may place special conditions on ground water permits to document the actions required to obtain coverage by the Program.

Chapter 3, Article 7 of Title 41 addresses the establishment and operation of Water Conservancy districts. Article 8 addresses the establishment and operation of Flood Control Districts. Article 10 addresses In-Stream Flow. Chapter 7 addresses the establishment of Irrigation Districts. Chapter 8 addresses the establishment of Watershed Improvement Districts. Chapter 9 addresses Drainage Districts.

3.1.3.2 County Regulations

Under Chapter 10 of Title 41, the board of county commissioners for any county in Wyoming is vested with the authority to establish water and sewer districts (W.S. 41-10-103) for the purposes of acquiring water and sewer services for entities within the county. The permitting of subdivisions within Laramie County is regulated by the Subdivision/Development Regulations, 2004, available on the Laramie County Planning Department Website. Prior to development, an application for a subdivision permit must be submitted to the Cheyenne/Laramie County Development Office. A subdivision permit checklist has been developed by the county to insure that a completed subdivision permit application meets the legal requirements of the state statutes and compliance with county regulations.

Among other requirements, the county regulations call for written certification by a Wyoming Licensed Engineer verifying the adequacy and safety of the proposed sewage disposal system, as well as certification from the City-County Health Unit that the proposed system meets its standards. This includes on-lot sewage systems as well as a centralized sewage collection and treatment system. The regulations also require written certification by a Wyoming Licensed Engineer confirming the adequacy and safety of the domestic water source and that the plan for the water supply meets the City-County Health Unit standards and the requirements of WQD. The applicant must demonstrate that the proposed sewage system is compatible with the proposed water supply system. If no public water supply or sewage disposal system is proposed by the subdivider/developer, the legend “NO PROPOSED PUBLIC SEWAGE DISPOSAL SYSTEM” and/or “NO PROPOSED DOMESTIC WATER SOURCE” in bold capital letters shall appear on the subdivision application and on offers, solicitations, advertisements, contracts, agreements and plats relating to the development.

If any changes to water rights within the subdivision are proposed, evidence must be provided that the developer has petitioned the Board of Control for any changes and provided a plan for the distribution of water appurtenant to the land to be subdivided if appropriate. Subdividers are required to submit three copies of the portions of their applications that pertain to the safety and adequacy of the proposed sewage system and water supply system to WQD for review. WQD may request assistance from the State Engineer and the Wyoming Water Development Office
(WWDO) in the review of the application. Applications are also reviewed by the City Engineer if the subdivision limits are within one mile of the city limits, and to the County Engineer for review and comment. The local conservation district will review the application for soil suitability, erosion control, sedimentation, and flooding problems.

After review of the permit application and plat for adequacy and completeness, the Development Office submits the application and plat to the Planning Commission along with findings and recommendations for approval or disapproval.

3.1.3.3 Wyoming Water Development Office

The Wyoming Water Development Commission (WWDC), comprised of 10 members appointed by the Governor, has authority over the Wyoming Water Development Program. The Wyoming Water Development Office (WWDO) administers the program. The authority and responsibilities of the WWDC are defined in Chapter 2—the planning and development portion of the Title 41 water laws. The WWDC is tasked with formulating, reviewing, and revising water and related land resources plans for the state of Wyoming and for appropriate regions and river basins (W.S. 41-2-107). Their responsibility includes recommending action or legislation needed to implement and carry out the plans.

The Wyoming water development program is established under W.S. 41-2-112 to foster, promote and encourage the optimal development of the state's human, industrial, mineral, agricultural, water and recreational resources. The program shall provide, through the commission, procedures and policies for the planning, selection, financing, construction, acquisition and operation of projects and facilities for the conservation, storage, distribution and use of water, necessary in the public interest to develop and preserve Wyoming's water and related land resources.

All laws of the state relating to the appropriation and use of water shall apply to any projects of the Wyoming Water Development Program (W.S. 41-2-116). The WWDO is required to obtain water rights for any project completed under their jurisdiction. The WWDC may grant funding up to $400,000 to incorporated cities and towns, water and sewer districts and improvement and service districts in Wyoming for exploration for, and feasibility studies of, the use of underground water for municipal and rural domestic purposes. Any entity receiving a grant is required to provide at least 25% of the cost of the exploration or study from its own funds. Proposed projects must serve 20 or more municipal/domestic water taps and have installed an individual water meter on each tap, 2,000 or more acres of irrigated cropland, or must rehabilitate watershed infrastructure, which will preserve the beneficial use of water in a watershed.

The WWDC may disqualify from consideration or give lower priority to a project proposed to correct problems identified in a review performed by the WQD under W.S. 18-5-306(c) where the Board of County Commissioners approved a subdivision application notwithstanding the Department's recommendation that the application be disapproved.
Water development projects are broken down into three levels. Project planning is performed in Levels I and II, and project construction is performed in Level III. Level I studies carry out necessary reconnaissance work, while Level II studies determine a project's feasibility. Levels I and II are 100% grant funded.

The Wyoming legislature must authorize each project and approve funding before a project proceeds. When Level III construction funding is authorized, the WWDO, with the project sponsor, establishes legal documentation required to make the state funds available, and ensures that the project constructed complies with the description, intent, and budget as specified in the enabling legislation. Current commission policy allows for grants of 67% of the eligible portions of new development and rehabilitation projects. The remainder of funding for eligible portions can be loaned at 4%. Sponsors may choose to fund the loan portion from other sources.

Authorization of the construction, operation and maintenance of the Stage II diversion of the Little Snake River to bring water supply in part to the City of Cheyenne is included in W.S. 41-2-204 through 211. These statutes also address financing of the project, and the ability of the City of Cheyenne and the WWDC to sell excess water from the project through the year 2036. The City may also recycle effluent from the city sewage treatment plant resulting from the treatment of Stage II water. The City and the WWDC may also sell a portion of the effluent from the sewage treatment plant resulting from the treatment of Stage II water.

The WWDC has funded numerous projects in Laramie County including studies for the municipalities of Albin, Cheyenne, Carpenter, Pine Bluffs and the Archer District. Studies of the feasibility of aquifer storage and retrieval of ground water were conducted in the vicinity of Crow Creek and Lodgepole Creek.

3.1.3.4 Wyoming Department of Environmental Quality/Water Quality Division

Title 35, Chapter 11 of the Wyoming Statutes comprises the “Wyoming Environmental Quality Act”. Article 3 addresses the Water Quality Division. Subdivision planning and the associated water supply and wastewater treatment requirements are regulated under the wastewater treatment program. Public water supplies defined as water for human consumption with at least 15 service connections or serving 25 individuals are also regulated by the WQD.

Under Chapter 3 of the WQD Rules and Regulations, a Permit to Construct is required for construction, installation, or modification of public water systems, sewerage systems, treatment works, or other disposal systems capable of causing or contributing to pollution. Chapter 8 addresses the classification of ground water and the types of use for each classification. Chapter 11 presents construction standards for wastewater treatment facilities. Chapter 12 includes construction standards for water supply wells. Chapter 22 presents Capacity Development Standards for Public Water Supplies. Chapter 23 establishes minimum standards for subdivision applications with respect to sewage systems, and water supply systems.

In Laramie County, WQD reviews proposed water supply and sewerage systems for adequacy and safety. WQD can request assistance in their review from the State Engineer’s Office. After review, WQD provides recommendations to the County Planning Commission, either Non-
Adverse of Adverse. Non-Adverse recommendations must be justified by the science presented by Wyoming licensed professionals in the application. The County Commissioners may approve or deny a subdivision application regardless of the WQD recommendations. If the commissioners approve a subdivision with an adverse WQD recommendation, the subdivider or developer must provide all purchasers with a copy of the WQD recommendation.

Subdividers have several options for providing a water supply system. If they propose connecting to an existing system, a statement must be provided from the existing system that it will provide service, and that the existing system has adequate capacity. If a centralized water supply is proposed utilizing ground water, a test well with extensive hydrologic analysis demonstrating long term dependability will be required to justify a non-adverse recommendation. In the case of on-lot water supplies, the WQD will require extensive hydrogeologic investigations to establish adequacy and safety of on-lot wells. Generally one well within the subdivision must be completed, pumped and the water quality tested prior to WQD approval.

Non-adverse recommendations may include recommended notes to be added to the plat and included in all other sales literature. Notes may restrict locations of leachfields or specify types of construction. If on-lot wells are proposed, the notes may restrict spacing, specify depths and well construction. If centralized sewerage or water supply systems are to be provided, a note restricting all lot owners to use the centralized system will be included.

Chapter 12, Section 9 (b) (iii) (b) (IX) of the WQD Rules and Regulations addresses wells that penetrate more than one aquifer. This section requires that wells be constructed with impervious seals to prevent migration of water from one aquifer or water bearing strata to another. In the case of the High Plains Aquifer WQD currently interprets this rule to allow wells to be screened across one water-bearing strata only. A definition of “water-bearing strata” is not provided in the regulations, so this interpretation is somewhat subjective. This policy contradicts the position of the State Engineer, who regards the High Plains Aquifer as a single hydrostratigraphic unit and permits wells to be screened across the entire saturated thickness of the High Plains Aquifer. In the North Cheyenne Study Area, the SEO requires that wells be screened over a minimum thickness of 60 feet within the High Plains Aquifer.

3.1.3.5 Federal Regulations

An environmental assessment (EA) must be completed for any water supply project that will be either constructed on federal land, or financed with federal funding. For water development projects in Laramie County, this typically applies to projects that are funded by the WWDC, where Level III construction will be financed all or in part with money from the State Revolving Fund. The EA process requires that a description of the proposed project be provided to the Natural Resources Conservation Service, the Federal Emergency Management Agency, The US Army Corps of Engineers, and the US Fish and Wildlife Service. The purpose of the consultation is to determine that the proposed project will result in no adverse impacts to the various resources administered by the federal agencies. A public meeting on the proposed project must be held, and a Finding of No Significant Impact determined before construction commences.
3.1.4 Environmental Issues

The selection of specific GIS layers covering important environmental issues affecting the High Plains Aquifer system included: Source Water Protection, Aquifer Sensitivity, Groundwater Vulnerability to Pesticides, Contaminated Sites, Permitted: Environmental Facilities, Septic Systems, and Oil and Gas Wells.

The Source Water Protection Area map, included in the Atlas, shows the locations of the Zone 3 source water protection areas that were identified through the SWAP program in 2004 in Laramie County. Aquifer Sensitivity and Groundwater Vulnerability to Pesticides maps, also included in the Atlas are the result of the Wyoming Ground Water Vulnerability Mapping Project. The Aquifer Sensitivity map demonstrates the relative sensitivity and vulnerability of the counties shallow ground water resources to potential contamination, while the Wyoming Ground Water Vulnerability to pesticides mapping presented areas where the ground water is vulnerable to contamination due to use of pesticides.

Sites of known ground water contamination in Laramie County are illustrated in the Atlas on the Contaminated Sites map. The Wyoming Department of Environmental Quality (DEQ) is the primary agency charged with protecting and preserving the surface and ground waters of the state, and with reducing or eliminating water pollution and contaminants. The DEQ works with the U.S. Environmental Protection Agency to this end. The DEQ is responsible for regulating the containment, cleanup, and disposal of oil or hazardous substances that have been released and which enter, or threaten to enter, waters of the state. The specific contaminants that have been released at these locations include a variety of regulated hazardous substances and depend upon the specific activities that were carried out at these sites. It should be noted that most of these contaminated sites lie within or immediately adjacent to the City of Cheyenne. The atlas map has been modified from information TriHydro Corporation (2004) acquired from databases of the Wyoming Department of Environmental Quality in 2003, and was updated in 2008 with information from the U.S. Environmental Protection Agency and DEQ.

3.2 SURFACE WATER INVESTIGATION FINDINGS

3.2.1 Laramie County Aquifer Study, Level I Amendment No.1 – Supplemental Supply

The purpose of the amendment was to examine supplemental water supply sources located inside and outside of Laramie County. The new tasking approved April 2008 also included a determination of source of supply, supply water rights if any, approximate quantities available, transmission options to get the water to users in Laramie County, and related costs.

On May 20, 2008, the JR project team conducted an interview with Messrs. Tim Wilson, Director of the City of Cheyenne Board of Public Utilities (BOPU) and Mike Purcell, Director, Wyoming Water Development Commission. During this interview, the following items were discussed:

- The BOPU potable water supply operations, including source, transmission and storage;
• Identification of available short term and long term excess water that could be delivered to portions of Laramie County
• Unappropriated supplies in the North Platte and Green River Basins and known raw water pipeline transmissions concepts

3.2.2 Summary of BOPU Surface Water Operations and Water Rights

The surface water rights map contained in the Atlas shows the location of rights on streams in Laramie County. Data related to diversion points are included in the Atlas Appendix. This data includes the stream name, facility name, appropriation date, appropriation amount, and irrigated acreage.

Cheyenne’s Stage I/II Water System (also known as the Little Snake/Douglas Creek System) supplied between 2500 and 13,650 acre-feet of raw water to the City of Cheyenne from 1992 to 2004. This system includes several different components including source, storage and delivery.

One critical and complex component of Cheyenne’s water system involves the collection of water in the Sierra Madre Mountains on the western slope of the Continental Divide. Water collected in the Little Snake River Basin, located west of the Divide, is transferred across the Divide through a tunnel and is stored in Hog Park Reservoir on the eastern side of the Divide. The maximum storage capacity of Hog Park Reservoir is 22,600 acre-feet. Water collected and stored in Hog Park Reservoir belongs to Cheyenne, but the presence of several mountain ranges between Hog Park Reservoir and Cheyenne make the actual delivery of the water to Cheyenne cost prohibitive. To help mitigate the cost of delivery, an exchange arrangement was developed and approved by the Wyoming State Engineer. Per the exchange arrangement, Cheyenne’s trans-basin diversion water stored in Hog Park Reservoir and discharged to Hog Park Creek could be swapped for water from the much closer and more deliverable Douglas Creek drainage in the Snowy Range. Both Douglas Creek and Hog Park Creek are tributary to the North Platte River. Thus, when Cheyenne takes water out of the North Platte River Drainage via Douglas Creek, it can replace it with water from the Little Snake River Basin. The Little Snake River water is stored at Hog Park Reservoir and is delivered to the North Platte, whereas the Douglas Creek water is stored at Rob Roy Reservoir and is eventually delivered via a series of pipelines and additional storage facilities (Lake Owen, Granite, and Crystal Reservoirs) to the City of Cheyenne Sherard Water Treatment Plant and eventually to the consumer. To assist in maintaining the balance of flows within the North Platte River, the City of Cheyenne contracts with the US Bureau of Reclamation (USBR) for 10,000 acre-feet of storage in Seminoe Reservoir.

Under ideal conditions, Cheyenne would take water out of the North Platte River system at Douglas Creek (Rob Roy Reservoir) at exactly the same rate that it puts water into the North Platte River system from Hog Park Reservoir. This is not possible due to both physical and environmental constraints as dictated by their 1982 Special Use Agreement with the USDA Forest Service. The majority of the BOPU facilities lie on lands controlled by the Forest Service where the 1982 Agreement dictates both minimum and maximum flows and, in some cases, timing of the release of these flows to receiving natural stream courses. Of significant importance, Cheyenne is limited in the amount of water that can flow down Hog Park Creek (i.e.
flows cannot exceed 200 cfs or the natural flow, whichever is greater). During a typical spring runoff, Cheyenne is unable to release enough water from Hog Park Reservoir to match what can be collected at Rob Roy Reservoir. With all of the constraints, the true exchange capacity ranges from 12,000 to 13,000 acre-feet due to limited flows in Hog Park Creek. If natural flows in Hog Park Creek are greater that 200 cfs BOPU cannot operate an exchange.

If it were not for the water storage contract between the City of Cheyenne and the USBR, flow restriction in Hog Park Creek would limit Cheyenne’s ability to collect water in Rob Roy Reservoir to about 2,000 acre-feet each year. With the water storage account, during spring runoff each year, Cheyenne is able to trade for about 12,000 acre-feet of water, which can be stored in Rob Roy Reservoir for use in Cheyenne (2,000 acre-feet from releases to Hog Park Creek and 10,000 acre-feet from the Seminoe water account). These operational constraints include: (1) if the natural flow of the North Platte River above Seminoe Reservoir is not sufficient to meet the demands for natural flow, replacement releases must be made from Hog Park Reservoir rather than from Seminoe; (2) accounting for evaporation loss calculation at Seminoe Reservoir; and (3) accounting for conveyance losses and lag time for delivery to Seminoe.

Despite the limitations and as noted above, the Seminoe Reservoir water storage account is absolutely essential for the operations of the Cheyenne BOPU facilities. It allows Cheyenne to balance the limitations of their USDA Forest Service Special Use permit requirements while maximizing their water rights via storage allocation and release schedule. Steps are currently underway to increase the amount of water Cheyenne can store in Seminoe Reservoir and in return increase what can be collected in Rob Roy Reservoir. Both drainages (Little Snake River and Douglas Creek) depend heavily upon snow for runoff. When snow conditions are 100% of average, the Little Snake River yields about 21,000 acre-feet of water annually and the Douglas Creek drainage yields about 20,000 acre-feet.

The City’s storage capacity is another essential element in the BOPU’s ability to withstand drought and meet future demands. Typically the City maintains fairly high storage levels ranging from 53 to 100 percent of total storage (39,420 acre-feet). Each spring, the BOPU endeavors to store an average of 11,000 acre-feet of new water to meet demands throughout the year (Water and Waste Water Master Plan, Volume 3, April 2004).

In addition to the Seminoe Reservoir storage account, the WWDC leases 5,500 acre-feet of storage rights in Glendo Reservoir. Water stored in Glendo is transferred down the North Platte from Hog Park Reservoir via Seminoe and Pathfinder Reservoirs. The State of Wyoming can use this water to meet North Platte Compact demands or any other use.

In addition to surface water use, the BOPU relies on ground water from several sources including the Federal, Borie, Bell and Happy Jack well fields. They have also purchased and are engaged in a ground water exploration and development program at the Belvoir Ranch. From 1991 to 2002, the BOPU relied on ground water to provide approximately 30% of its total potable water demand. Ground water is blended with surface water to meet water quality needs. It is anticipated that in the future, the BOPU will rely on ground water sources to provide up to 25 percent of its total supply. As the City looks at its future demands, blending needs and source
development opportunities in an effort to maximize all of the water resources owned and leased by the BOPU, the BOPU has identified the need for additional water.

3.2.3 Potential Supplemental Supply

In consideration of Laramie County users, including the BOPU service area, Messrs. Wilson and Purcell addressed the possibility of additional, undeveloped water supplies. Such supplies include the continued development of the Belvoir Ranch ground water rights and supply and trans-basin supplies via a Colorado/Wyoming water supply project. The Belvoir Ranch water supply development project could include additional wells in the shallow Tertiary Aquifer and new wells in the deeper Paleozoic Aquifer. The trans-basin supply project targets unappropriated upper Colorado River Compact Water, which may include direct transmission from Flaming Gorge Reservoir or expansion and development from other reservoirs along the Green River including Fontenelle Reservoir. Should a project of this magnitude transpire, it could include the development and transfer of a portion of Wyoming’s share of the Green River Basin

3.2.4 Raw Water Transmission Pipeline Concepts

There have been several raw water transmission pipeline concepts proposed in the past several years, most notably the Million Conservation Resource Group (MCRG) pipeline and a similar pipeline configuration developed by municipal entities along the Front Range of Colorado.

MCRG proposes to construct a raw water pipeline to convey water from the Green River in Wyoming, east along Interstate 80 to a point east of Cheyenne. At this point the raw water transmission line would proceed south to its terminus near Pueblo, Colorado, following existing highway and utility corridors. The proposed pipeline will divert and convey up to 250,000 acre-feet from the Flaming Gorge Reservoir located along the Utah Wyoming border for use along the Front Range of Colorado. MCRG has been aggressively planning this pipeline and has requested assistance in mapping and defining all opportunities and constraints including geotechnical, hydrologic and political boundaries, which may exist along existing highway and utility corridors throughout the proposed pipeline alignment. The identification of potential end users is necessary in order to economically locate the final alignment of the pipeline. End users of the raw water potentially include agricultural users as well as municipalities and potable water districts. The ability for agricultural end uses such as mutual ditch companies, irrigation districts and water conservancy districts to benefit from a project of this magnitude will, for the most part, depend on the larger population demand and participation of the municipalities and potable water districts. Treated wastewater effluent (augmentation) from these municipalities and urban users may play an important part in the final agricultural use of this imported water.

According to Mike Purcell the State of Wyoming is not actively pursuing any of these raw water transmission pipeline concepts. However, should a raw water transmission pipeline were constructed along the I-80 corridor, it would provide additional water supply opportunities for the BOPU, as well as other rural and municipal users in Wyoming.
3.2.5 Surface Water Monitoring, Stream Gauges and Weather Stations

The USGS maintains gauging stations in Laramie County at the locations marked on Figure 1 and on the map located on page 4-2 of the Atlas. These stations can be accessed on the USGS website, where historic data is available for the stations. [http://waterdata.usgs.gov/wy/nwis/sw](http://waterdata.usgs.gov/wy/nwis/sw)
Figure 1 - River and Stream Gauging Station (Green Circles)
GROUND WATER

3.3.1 Water Rights

Ground water development began with the first wells dug in the late 1800’s. There are now over 12,000 permits issued for wells in the county. The Ground Water Division of the Wyoming State Engineer’s Office has been registering ground water rights for all uses except stock and domestic since 1947. In 1955, legislation was passed requiring that a permit be obtained from the State Engineer's Office prior to the drilling of all wells, except stock and domestic wells. Since May 24, 1969 a permit is required prior to drilling any water well. Ground water rights are issued for the same beneficial uses as for surface water rights (SEO). Table 1 shows the number of wells drilled in Laramie County for each specific use. It also displays the percentage of total water consumption comprised by each use.

Table 1

<table>
<thead>
<tr>
<th>Use</th>
<th>Number of Wells</th>
<th>Percent of Estimated Total Water Use</th>
</tr>
</thead>
<tbody>
<tr>
<td>Domestic</td>
<td>7244</td>
<td>2 – 5 %</td>
</tr>
<tr>
<td>Stock</td>
<td>1461</td>
<td>5 – 6 %</td>
</tr>
<tr>
<td>Irrigation</td>
<td>992</td>
<td>53 – 73 %</td>
</tr>
<tr>
<td>Municipal</td>
<td>70</td>
<td>2 – 3 %</td>
</tr>
<tr>
<td>Industrial</td>
<td>88</td>
<td>9 – 17 %</td>
</tr>
<tr>
<td>Miscellaneous</td>
<td>631</td>
<td>9 – 16 %</td>
</tr>
</tbody>
</table>

The map titled “Permitted Wells 2004” in the Water Resource Atlas shows the location of the permitted wells in Laramie County. As of 2004 there were 11081 wells in the county. The State Engineer’s Office maintains a database of all wells in Wyoming. The map layer contains data from the U.S. Geological Survey's (USGS) National Water Information System (NWIS), USGS reports, the Wyoming State Engineer's Office, consultant's reports, the Cheyenne Board of Public Utilities, the Laramie County Conservation District, the Town of Pine Bluffs, and Wyoming Geological Survey Reports.

The Wyoming State Engineer’s Office and the Ground Water Division of the U.S. Geological Survey maintain databases for ground water levels in the county. The data is used to monitor and assess the ground water resource. The data is also used by the SEO to investigate interference complaints. Most of the wells have continuous recordings of the water levels.

3.3.2 Ground Water Recharge

Laramie County is a semi-arid climate. Average annual precipitation ranges from approximately 14 inches in the central part of the county up to 24 inches in the Laramie Mountains on the west edge of the county. Precipitation, including snowmelt, is the source of recharge to the High Plains Aquifer.

3.3.3 Control Areas
To identify areas in Laramie County that are under more stringent water regulation, Lidstone and Associates contacted the SEO and obtained several Geographic Information System layers that show the boundaries and extents of the areas where new water development is currently more heavily regulated. A map of these areas is included in Figure 2 and the Atlas on page 5-9, and is titled “Areas of Special Ground Water Regulation.”

Figure 2- Areas of Ground Water Regulation
The Laramie County Control Area encompasses the eastern half of the county and affects most irrigation water rights. The Cheyenne and Federal Ground Water Districts cover most of the southwestern portion of the county in the vicinity of the Cheyenne well fields. The North Cheyenne Study Area lies along the northern boundary of the City of Cheyenne. The SEO has also identified areas around Chugwater, Horse, and Bear Creeks for special consideration, as these streams are all tributary to the North Platte River system.

Within the Horse and Lower Laramie Basins, the Wyoming SEO will review ground water permit applications for irrigation, municipal, industrial, and miscellaneous purposes for wells that may be hydrologically connected to the surrounding surface water streams. The purpose of the review process is to determine if the resulting depletions from the wells can be covered by the Platte River Recovery Implementation Program (Program). As previously described, a hydrologically connected ground water well in these areas is one so located and constructed that if water were intentionally withdrawn by the well continuously for 40 years, the cumulative stream depletion would be greater than or equal to 28% of the total ground water withdrawn from the well. Following the review, the SEO may place special conditions on ground water permits to document the actions required to obtain coverage by the Program.

The SEO also closely monitors ground water permit applications for wells to be completed within the North Cheyenne Study Area and the Federal and Cheyenne Ground Water Districts. Wells completed within the North Cheyenne Study Area must be completed with at least 60 feet of perforated casing in the bottom portion of the well and at least 100 feet of water above the uppermost casing perforations. Wells within this designated area cannot be dually completed in both the High Plains Aquifer and the underlying Lance Aquifer. Additional conditions and limitations may be added depending upon whether a well will be completed in the Wyoming SEO's red or green areas shown on the map. While ground water districts are not specially regulated, they are areas where the SEO closely reviews new applications.

3.3.4 Monitoring Well Systems

The Wyoming State Engineer’s Office, the U.S. Geological Survey, and the Wyoming Water Science Center maintain databases for water levels in the County. The data are used to monitor and assess the ground water resource. The data are also used by the WYSEO to investigate interference complaints. Most of the wells have continuous recording of the water levels since 1977. Some are more recent.

3.3.5 Real Time Data

The City of Cheyenne BOPU maintains monitoring of its wellfields, while the Dyno –Nobel Chemical Plant (a.k.a. Coastal Chem & Wycon) also monitors it wells through totalizing flowmeters and low water level telemetry. The City of Cheyenne Belvoir Ranch maintains a series of Ogallala aquifer monitor wells (currently permitted under the WWDC/Cheyenne BOPU) each with water level transducer and recorder. Data from the aforementioned sites are catalogued and archived by each entity. Strategic sites from these sources could be integrated into a network representing the southwestern High Plains aquifer system.
3.4 WATER QUALITY

3.4.1 Ground Water Quality

Water quality data was collected from the U. S. Geological Survey, National Water Information System. There are 144 samples tested in Laramie County from 1911 to 2001. The Water Resource Atlas of Laramie County Appendix contains a summary of each water quality sample. The samples are located by Section, Township and Range. Additionally, a map was compiled displaying sites of known ground water contamination in Laramie County. The specific contaminants released at these locations include a variety of regulated hazardous substances and depend upon the specific activities that were carried out at these sites. A majority of these contaminated sites lie within or immediately adjacent to the City of Cheyenne.

3.4.2 Vulnerability and Sensitivity

Beginning in 1992, the State of Wyoming began an effort to assess the vulnerability of ground water to contamination. In 1998 the Wyoming Department of Environmental Quality completed the “Wyoming Ground Water Vulnerability Handbook.” The handbook included the results of the Wyoming Ground Water Vulnerability Mapping Project, which “developed a digital mapping product that could comprehensively assess the relative sensitivity, and vulnerability of the states shallow ground water resources to potential contamination.”

Maps of Ground Water Sensitivity and Vulnerability are presented in the Water Resource Atlas of Laramie County as: Aquifer Sensitivity, and Ground Water Vulnerability to Pesticides. Sensitivity, as it relates to ground water, is a measure of the ease with which contaminates can move from the surface downward to the ground water. The degree of sensitivity is based on the nature of the geology between the ground surface and the water table. The assessment of factors such as geology, depth to water, soil types, precipitation, and slope results in the Aquifer Sensitivity map. The Wyoming Ground Water Vulnerability Mapping Project used the base Aquifer Sensitivity map and overlaid the areas where the ground water is vulnerable to contamination from use of pesticides. The map legend for each shows a color range of red for high vulnerability, green for medium, and brown for low.

3.4.3 Source Water Protection

In 1996, the United States Congress passed Safe Drinking Water Act Amendments that required all states having the responsibility for administering the federal rules and regulations of this Act, or “primacy,” to develop a Source Water Assessment and Protection (SWAP) Program. Although Wyoming is the only state that does not have primacy, DEQ recognized the value and benefit of SWAP to help protect public water systems (PWS). During the 1998 legislative session, the Wyoming Legislature authorized DEQ to develop a SWAP program and to complete Source Water Assessments (TriHydro Corporation, 2004). As noted by Community Matters, Inc. (2001) in the Laramie County Comprehensive Plan, the County "should implement provisions concerning land use within recognized public, especially municipal, water wellhead protection and critical surface and ground water areas. In addition, the establishment of a wellhead protection program, for all other wells within the County, should be considered. Private
owners, municipalities, State and local environmental agencies could be brought together to spearhead such a program.”

The SWAP Program is a two-part program that consists of source water assessments and source water protection plans. The completion of a source water assessment involves determining a source water area for each Public Water System (PWS), assessing the sources of contamination within this area that have the potential to affect the drinking water supply, evaluating the susceptibility of the water supply to contamination by each of these potential sources of contamination, and finally, writing an assessment report that contains a summary of all the information gathered during the assessment. Due to Wyoming’s unique primacy status, the completion of source water assessments for all PWSs is voluntary (TriHydro Corporation, 2004).

Source water assessments for the systems that volunteered to participate were generally completed in 2004. Local governments, PWSs, and citizens can use these assessment reports to develop a source water protection plan that outlines the measures that the community or PWS believes are appropriate to protect their drinking water supply. These measures may include management plans, clean-up efforts, public education, or zoning changes among other options (TriHydro Corporation, 2004). The Source Water Assessment process delineates the source water area, or the area that contributes water to a well or surface water intake. This process identifies three separate Zones as follows: Zone 1 is called the “Accident Prevention” or “Sanitary Protection Zone” and is located within a 100 foot radius of the well or intake. This zone has the highest potential for released contaminants to affect the quality of the PWS. Zone 2 lies immediately beyond Zone 1, and is labeled the “Attenuation Zone.” Contaminants released within this zone are within close proximity of the well or intake and the chances of reaching the well or intake is still high. Zone 2 for ground water systems represents a 2-yr time of travel (TOT) that was determined using the best and most conservative hydrogeologic data available. Zone 3 is the area farthest from the well or intake. Contaminant sources within this zone are less likely to reach the well or intake in quantities that could affect water quality. Zone 3 for ground water sources extends from the edge of Zone 2 to the extent of the estimated 5-year TOT (TriHydro Corporation, 2004).

Another significant aspect of the SWAP program was the development of GIS data layers of potential sources of contamination that could affect water systems and water supplies throughout the state. Lidstone and Associates obtained the GIS layers from the DEQ that were developed for the SWAP program, showing potential sources of contamination. These datasets formed the base of the data that were used in the Laramie County project, and were classified as either permitted environmental facilities or contaminated sites. Permitted environmental facilities include those entities that are regulated by DEQ and/or EPA which use chemical compounds that have the potential to contaminate local surface or ground water supplies under specific circumstances. Contaminated sites, in contrast, are locations of known ground water contamination in Laramie County. The specific contaminants that have been released at these locations include a variety of regulated hazardous substances and depend upon the specific activities that were carried out at these sites.

The map titled “Source Water Protection Areas” shows the locations of the Zone 3 source water areas that were identified through the SWAP program in 2004 in Laramie County. PWSs that participated in and benefited from the SWAP program include the Cheyenne Board of Public Utilities, the Town of Pine Bluffs, Carpenter, Dyno Nobel, and Little America, among others.
3.4.3.1 Permitted Oil & Gas Wells

The map titled “Permitted Oil and Gas Wells” illustrate the locations of permitted oil and gas wells that have been drilled in Laramie County and are on file with the Wyoming Oil and Gas Conservation Commission (WOGCC) as of December 18, 2007, regardless of their current status. Each drilled location represents a potential source of contamination due to the environmentally hazardous nature of the materials sought from each well, the potential for cross contamination between aquifers bearing fresh water and hydrocarbons, and historic abandonment and cementing practices. The locations of these wells were acquired from the Wyoming Oil and Gas Conservation Commission.

The WOGCC regulates the drilling, testing, production, and abandonment of oil and gas wells in the state. By state law and a 1994 agreement between the WOGCC, the SEO, and the DEQ, the WOGCC has the authority over at least three areas directly related to oil and gas development.

First, the WOGCC is to require the drilling, casing, and plugging of oil and gas wells in order to prevent the pollution of fresh water supplies by oil, gas, or produced water and drilling fluids, and further to regulate the disposal of produced non-potable water, drilling fluids, and other oil field wastes.

To prevent waste or contamination of under ground sources of drinking water, the WOGCC is also responsible for permitting Class II injection wells, as defined under the federal Safe Drinking Water Act, used to inject gas and fluids for enhanced recovery and for noncommercial disposal of saltwater, non-potable water and oil field wastes related to primary oil and gas production.

Finally, the WOGCC is responsible for permitting the location, construction, operation and reclamation of noncommercial reserve pits and produced water retention and emergency pits used solely for the storage, treatment and disposal of drilling fluids, produced waters, emergency overflow wastes or other oil field wastes associated with the maintenance and operation of oil and gas exploration and production wells on a lease, unit, or communitized area.

3.5 AQUIFERS

3.5.1 Area Aquifers

The Laramie County Water Atlas provides a detailed overview of the aquifers that lie within Laramie County, as well as their stratigraphy. The stratigraphic relationships and physical extents of subaquifers of the High Plains Aquifer were identified through a reconfiguration of the fence diagram compiled by Cooley and Crist (1981). Data from this series of geologic cross sections were combined with data obtained from various drilling logs, and geologic and hydrogeologic reports to create contoured thickness maps of the White River Group, Arikaree Formation, Ogallala Formation, and the Quaternary Terrace Deposits. A generalized Three Dimensional Aquifer Model is shown on Figure 3 below. The bedrock geologic map of Wyoming was used where necessary to identify formation boundaries and limits.
Figure 3 - Three Dimensional Aquifer Model

3 Dimensional Aquifer Model
The High Plains Aquifer in Laramie County is generally comprised of the Ogallala, Arkaroe, and White River Formations. However, there are areas where one or more of these formations have eroded away. This 3-dimensional model shows how these three formations are situated within the County.

Model components have been vertically exaggerated for clarity.
The water resources of Laramie County consist primarily of ground water, trans-basin diversion and, to a minor extent, surface water. The primary water supply, and the focus of the Water Resource Atlas of Laramie County, Wyoming, is the Tertiary High Plains Aquifer.

The Tertiary High Plains Aquifer is comprised of three sub-aquifers which, listed from oldest to youngest, are the White River Group, Arikaree and the Ogallala aquifers. Underlying the High Plains Aquifer are the Lance, Fox Hills, Casper and Pre-Cambrian aquifers. Due to its depth, the Casper aquifer is only feasible as a water source in a narrow band along the Front Range, west of Cheyenne. The Lance, Fox Hills and Pre-Cambrian aquifers are only minor sources of water.

The White River Group, which consists of the Oligocene Chadron and Brule formations, overlies the erosional surface of the Lance Formation. The White River is an alluvial deposit with associated minor ash fall deposition. Unlike the overlying formations, the White River is relatively uniform across the county, consisting predominately of siltstone with sandstone, conglomerate and volcanic ash. Well yields range from 450 gallons per minute (gpm) west of Cheyenne, 1,000 gpm near La Grange, and 2,000 gpm in eastern Laramie County near Pine Bluffs.

The Arikaree Formation overlies the White River Group. The Arikaree is a coastal plain and alluvial deposit of fine-grained sandstone and silt. Well yields have attained 500-1,000 gpm in the Albin area.

The Ogallala Formation overlies the Arikaree and was deposited in alluvial fan complexes and braided streams. This depositional environment resulted in a heterogeneous formation of lenticular siltstones, sandstones and clay.

The Ogallala Aquifer is a major source of water for drinking and irrigation in an area covering seven states. The portion of the Ogallala in Wyoming is the western extent of the Ogallala aquifer, also referred to as the “Gangplank.” Well yields in the Cheyenne municipal wells range from 200 – 800 gpm, with irrigation wells near Albin yielding up to 1,000 gpm.

The “Bedrock Geology” map in the Atlas shows which formations are exposed at or near the surface (under the soil mantle). The bedrock geology of Laramie County from the Laramie Range mountain front on the west to the eastern border is comprised of primarily rocks of the High Plains Aquifer. Formations of older age are exposed on the Front Range and higher altitudes of the Laramie Range. Formations of Cretaceous age include the Lance and Fox Hills aquifers. The Casper Formation, which serves as an aquifer in the western part of the county, outcrops along the mountain front. The Precambrian rocks can provide water for small domestic homes.

The “Aquifer Profile,” included in the Atlas, is a west to east cross-section that represents a generalized profile of the aquifers and stratigraphy in Laramie County. There are faults and other geologic details not shown, so this does not necessarily represent conditions at any specific location. The Saturated Thickness maps in the Atlas indicate that there are areas in Laramie County that appear to have relatively large saturated thicknesses. It should be kept in mind that potential water production varies significantly in different formations. The White River Formation is a part of the High Plains Aquifer and is the thickest member. However, it typically
has lower hydraulic conductivity than the overlying Ogallala and Arikaree aquifers. As the water level drops in the High Plains Aquifer, the higher producing Ogallala and Arikaree aquifers are depleted first, leaving a saturated, but often poorly producing, White River Formation.

3.5.2 Aquifer Properties

The hydrogeologic properties associated with the aquifers in Laramie County were derived from a variety of professional sources, including U.S. Geological Survey (USGS) reports, Wyoming Geological Survey reports, consultant’s reports prepared for the Wyoming Water Development Commission and various cities, DEQ subdivision water supply assessments, Laramie County Conservation District pump test reports, and unpublished University of Wyoming Master’s theses. The aquifer properties assembled included:

- Hydraulic Conductivity – A measure of how easily water moves through a unit of porous media, such as sand or gravel. It is largely governed by the size and shape of the pore spaces. Well sorted sands and gravels with large pore spaces that are interconnected have high hydraulic conductivities, while clays, silts, and mixed material with small, more isolated pore spaces have low hydraulic conductivities. Units are usually in meters/day, feet/day, or gallons per day per square foot (gpd/ft²). These last units are used in the Water Resource Atlas of Laramie County, Wyoming. Actual values for aquifer material can vary by many orders of magnitude, from 10⁻⁷ gpd/ft² for shale and unfractured rock, to 10⁵ gpd/ft² for coarse gravel.

- Transmissivity – The product of multiplying the hydraulic conductivity by the aquifer thickness. This is generally more useful than hydraulic conductivity, because it is a measure of how easily water moves through a specific section of aquifer. This can often be determined through well pumping tests. Units are usually in meters²/day, feet²/day or gallons per day per foot (gpd/ft). A small domestic well might be possible in areas with a transmissivity of only about 100 gpd/ft. Large municipal supply wells generally require a transmissivity of 10,000 gpd/ft or more.

- Specific Yield – A measure of how much stored water in an unconfined aquifer that is available for extraction, or the amount of water that would drain out of a unit of aquifer material as the aquifer is pumped down near a well. For sand and gravel aquifers, this is generally in the 10% to 30% range. For tighter material such as clay, it is generally less than 10%.

- Storage Coefficient – Similar to specific yield, but a measure of how much water is stored in a confined aquifer. This is much less than specific yield, because a confined aquifer is not drained during pumping, so water added to and released from storage is due to compression and expansion of the aquifer and water. Values for a confined aquifer storage coefficient usually range from 10⁻⁵ to 10⁻³.

More detailed definitions and explanations of these terms can be found in various texts on ground water. The aquifer-specific ranges of some of these parameters are shown on the stratigraphic column found in the Water Resource Atlas of Laramie County.
Potentiometric surface maps of the High Plains Aquifer in Laramie County were prepared for three separate time intervals, Predevelopment (~1942), 1994, and 2004. These maps were prepared from water level data gathered from the National Water Information System (NWIS) of the USGS, the Wyoming State Engineer’s Office, USGS reports, the Cheyenne Board of Public Utilities, the Town of Pine Bluffs, the Laramie County Conservation District, and unpublished University of Wyoming Master’s Theses. The 1977 potentiometric surface map for Laramie County that Crist (1980) developed was used as a guideline in developing these new maps in an effort to maintain consistency in contouring for the purpose of assessing areas of water level change through time.

3.5.3 Aquifer Water Demand

The USGS estimated Laramie County use in its 2006 publication, Estimated Water Use in Wyoming During 2000. Statewide withdrawals of ground water for irrigation, public supply, and industrial categories during 2000 totaled about 475 Mgal/day. The High Plains aquifer which underlies Platte, Niobrara, Goshen, and Laramie Counties was the source of about 62 percent (293 Mgal/day) of those withdrawals.

The USGS total estimated water use for Laramie County for irrigation and public water supply (surface and ground water withdrawals):

<table>
<thead>
<tr>
<th>Use</th>
<th>Est. total use in Mgal/day</th>
</tr>
</thead>
<tbody>
<tr>
<td>Irrigation</td>
<td>198</td>
</tr>
<tr>
<td>Public Water Supply Use</td>
<td>15.1</td>
</tr>
</tbody>
</table>

To assess current water demand in Laramie County, water usage information was compiled from the Platte River Basin Plan and several other sources. Because the Platte Basin Plan was done on a sub-basin basis and because Laramie County includes all or portions of several sub-basins, the amount of ground water that could be attributed to Laramie County had to be estimated. This particularly affected the estimate of ground water used for irrigation purposes in the county. Estimates of community water system usage were based on revised population numbers for the EPA for some of the water systems, and from Black and Veatch (2004) for the City of Cheyenne. For example the City of Cheyenne average demand from 1997 to 2001 was 14,861 acre-ft., of that total ground water from its well fields provided approximately 4100 acre-ft. Future planning calls for the development of 2000-4000 acre-ft of ground water over the next 10 to 50 years.

Areas of ground water mining were evaluated in two different ways. The first assessment involved the graphical subtraction of a later potentiometric surface from an earlier potentiometric surface. This technique yielded a shaded difference map that revealed areas where ground water levels had risen or declined. These maps had to be generalized due to local inconsistencies in water levels within the High Plains Aquifer. The second method involved a review of water level data for monitoring wells completed in a particular area. This technique is significantly limited by the lack of continuous historic water level data. Most of the wells that are used for monitoring purposes in Laramie County were installed after 1976, but many areas had already experienced significant declines by that time.
3.6 **WATER RESOURCE ATLAS OF LARAMIE COUNTY**

The Water Resource Atlas of Laramie County, prepared for this project as described in Task 7 of the Scope of Services and referred to throughout this report, provides a summary of the development of the water resources in the county, specifically the High Plains Aquifer. This atlas was developed using a Geographic Information System, which serves as the framework for the data and the maps. The GIS can be updated as information becomes available.

The Water Resource Atlas is organized to provide an overview of the geology, land use, development, regulations and surface water in Chapters 2 through 5. Chapters 5 through 7 describe the High Plains Aquifers in more detail the characteristics of the aquifers, impact of well development, and the water quality issues. The appendix contains references, water quality data and surface water rights.

3.7 **GROUND WATER DECISION SUPPORT SYSTEM**

3.7.1 **Introduction**

The Ground Water Decision Support System (GWDSS) is a modeling tool that was developed using GIS layers with the ESRI ArcGIS Spatial Analyst software. The purpose of this GWDSS is to allow the sponsor and other users to make informed decisions regarding current and future development within the County. Development and growth can be the lifeblood of a community, but such growth may be limited by the availability of the natural resources to sustain this growth. The GWDSS assessment tool can be used to address (1) the availability of water resources to supply development and growth; and/or (2) the anticipated impact of a proposed development on these water resources – both on a local and a regional basis.

The Ground Water Atlas (Task 7) provides an overview of the water resources of Laramie County including the geology, land use, development, surface water and ground water availability. While summarizing multiple aspects of water supply and use this GIS-based document specifically addresses the development of ground water resources through 2008. Integral to any GIS tool, maintaining and updating the database is essential. Although this atlas reflects information compiled through 2008, several data sets have not been amended or revised since 2004 and are therefore incomplete. As new information becomes available, the database and the GIS should be updated.

3.7.2 **Policy Rationale and Recommendations**

Local governments adopt programs that will protect natural resources, protect existing uses and preserve future uses. Governments are generally tasked with the conservation of scenic and open space resources, while preserving a healthy environment and a natural landscape that contributes to Wyoming’s livability. Developments are planned and directed to conserve the needed amount of open space. The conservation and preservation of ground and surface water resources and the physical limitations of the land should be used as the basis for determining the quantity, quality, location, rate and type of growth in a planning area. The efficient consumption of water
resources should be considered, while protecting water quantity, ground water levels and water quality.

From 2000 to 2008, Laramie County has seen unprecedented growth (38% higher than the statewide average) and much of this growth has included rural subdivisions. The development of rural subdivisions has generally included individual wells and septic. Since 1969 the Wyoming State Engineer has required the public to obtain permits for domestic and stock wells. Prior to that date ground water permits were only required for irrigation, municipal, industrial and miscellaneous use. Prior to 1970, there were less than 100 ground water permits issued by the Wyoming State Engineer each year. From 1970-1980, after well registration had passed, approximately 400 permits were issued each year. This post-1969 spike in wells included the registration of existing wells. From 1980 to 1995 well registration averaged approximately 250 wells per year. Since 1995, new well registration has averaged between 350 and 400 wells per year, coincidental with the increase in population and the growth of rural subdivisions. On a cumulative basis in 1975 there were approximately 3,000 permits issued. By the year 2004 there were slightly over 12,000 permits issued for Laramie County.

Several aquifers are present and utilized in Laramie County principally the Quaternary Alluvium, Quaternary Terrace, the Tertiary High Plains Aquifer and the pre-Tertiary Aquifer. The Tertiary High Plains Aquifer is the most developed and therefore the most impacted aquifer in Laramie County. It consists of the Ogallala, and Arikaree Formations and the White River Group. The multi-state Ogallala/High Plains Aquifer overuse and decline is well documented. Laramie County is adjacent to both the states of Nebraska and Colorado. The effect of un-bridled production and overdraft of the High Plains Aquifer by these states contributes to an edge effect within Wyoming. This edge effect and continued ground water mining has raised the question of the sustainability of the High Plains Aquifer in Laramie County.

Colorado addressed the issue of ground water mining in the 1960’s with the formation of designated basins in the “Northern High Plains Aquifer System” and recognized that local control could be accomplished through the formation of ground water management districts. More recently Colorado counties, in the 1990s created the 100, 200, and 300-year rules based upon a 100-year aquifer life in the expansive Denver Basin Aquifer system. The following is a synopsis of the “rules” and guidance of these management districts:

- **Aquifer Delineation**
  - Sub-units for management decisions in areas of similar aquifer characteristics
  - Identify areas of recharge and extraction
    - Quantify water use vs. replacement (water balance)
  - Identify hydrologically sensitive areas
    - Recharge areas
    - Small saturated thickness
  - Identify contaminated sites and their threat to ground water

- **Policy and Recommendations**
  - Land-use management
    - Restrictions/recommendations on land-use based on available water supply
    - Revisions to existing subdivision regulations
o Water acquisition
  ▪ Trans-basin
  ▪ Agriculture to municipal/domestic uses
o Irrigation management
  ▪ Education of water users within area
  ▪ Crop rotation, rotational fallowing
o Reductions in numbers of authorized water rights
  ▪ Seek funding for voluntary water rights purchases to retire water rights
  ▪ Identification of areas of possible water rights purchases
o Water Conservation Programs
  ▪ Set water conservation targets, including periscope
  ▪ Drip irrigation systems
o Well construction and abandonment procedures
  ▪ Protection of aquifers used for water supply
o Establish and maintain monitoring well network
  ▪ Water level/quality change
  ▪ Enforcement of accurate water use reports from users
  ▪ Action for over-pumping from state

Although unique in needs and demands, there is also commonality between Laramie County, Wyoming and the county development criteria of neighboring states. To a certain extent, the above rules and guidance are included in Laramie County and State of Wyoming rules and regulations. The Laramie County Ground Water Atlas and Decision Support System have been developed to serve as a mechanism to allow the County to (1) delineate the aquifers within the County and (2) adopt new policy as well as rules and regulations that protect and preserve the ground water resources of the County.

3.7.3 Development of a Laramie County Ground Water Decision Support System

There are at least five types of decisions related to ground water development that may potentially arise within the county. For developments that are proposing ground water supply as a source, decision makers must consider:

- Water availability – “new wells.” Is adequate ground water available? If so, will the proposal consume already appropriated ground water?
- Water availability – “relocation of existing wells.” Will the proposal impact neighboring wells at its new location?
- Water availability – “enlargement of existing wells.” Will the proposal impact the aquifer at the same location, but in a different fashion?
- Water availability – “change in use.” Will the proposal impact the aquifer due to its change in use (i.e., timing, application efficiency) or return flow to the aquifer?

For all types of development, decision makers must consider:

- Water quality–“contamination of ground water”. Will the proposal lead to an adverse impact on subsurface water quality?

In making decisions about the viability of land development in a particular area, the availability of water of sufficient quality and quantity is near the top of the list of considerations. In the
course of this study, large amounts of water resource data were examined, and gathered together into a GIS database. A pilot level GWDSS has been developed to utilize this information to judge the suitability of a site for development.

Barring additional trans-basin diversions and an expanded delivery system to the rural portions of the county, the primary source of domestic water supply outside of the Cheyenne municipal service area will continue to be ground water. Historically, subdivisions have relied on either a single large volume well, or individual small volume (< 25 gpm) wells for each lot. The Laramie County Aquifer Study (LCAS) has confirmed that the ground water potentiometric surface has declined in recent years over most of Laramie County. Aquifer sustainability as a continuing resource must be balanced against the need for continued growth.

The GWDSS that accompanies the Ground Water Atlas provides a basis for balancing the questions of aquifer sustainability versus growth. Such decisions are not always clear and no system can give a complete answer about whether or not a site should be developed. The GWDSS is a tool addressing the many factors that should be considered as one evaluates the potential water supply for a particular development location.

Factors that should be considered when evaluating a potential water supply or development project include the following:

- The aquifers that underlie the parcel.
- The characteristics of the aquifers, including
  - Transmissivity/Hydraulic Conductivity;
  - Saturated Thickness;
  - Specific Yield/Storage Coefficient.
- Proximity to other high-production wells, what is the likelihood of interference with other water rights?
- The historical decline in the potentiometric surface in the area.
- Have other wells in the area experienced declining production?
- Proximity to large irrigation wells.
- Any special ground water regulations at the site.
- Potential aquifer vulnerability/sensitivity to environmental factors.
- Nearby sources of contamination, such as oil/gas wells, or feed lots.

In order to directly compare and contrast all of these factors within the GWDSS, a numerical quantity is assigned to describe these factors at a particular site. Each factor can be weighted to allow the user to balance the type of decision which must be made with the criteria, being used to make that decision. For example when evaluating a development which will require a ground water source, the question of what aquifers underlies the parcel and their respective saturated thickness may be more heavily weighted than other factors. When considering a development which could contaminate the aquifer, potential vulnerability/sensitivity and nearby sources of contamination may be more heavily weighted.

The proposed GWDSS utilizes a ranking scale from 1 to 5 for the various factors under consideration, with the number 1 reflecting the lowest rank (or worst situation) and the number 5
reflecting the best situation. As an example, in Laramie County the following rank could be assigned to the aquifers present under a site:

5 – Ogallala, Arikaree, and White River Aquifers Present
4 – Ogallala and White River Aquifers Present
3 – Arikaree and White River Aquifers Present
2 – Terrace and White River Aquifers Present
1 – White River Aquifer only

Using these rankings, a site with an Aquifer Present factor that rates a 5 would be a better choice for locating a well than a site with an Aquifer Present factor that rates a 2. Other factors (hydraulic conductivity, saturated thickness, distance to large irrigation wells etc.) can each be ranked in a similar fashion. The more factors considered in support of a decision, the more informed the decision will become. The weighting of each factor within the GWDSS is important in addressing the type of decision.

One problem with this type of system is in dealing with discrete data points, and how to use that data for areas some distance away from any data point. There are several ways to approach this problem. For instance, the aquifer transmissivity data are based on pump tests conducted on individual wells. It could be assumed that areas within some distance say 0.5 mile have the same value as the data point. Some type of averaging or interpolation is generally performed between two data points for an area between them. As variable as the geology of the High Plains Aquifer is, either of these techniques may result in an erroneous answer. For some parameters, there may not be sufficient data to determine a quantitative value for every site. Sensitivity analysis is important when developing the GWDSS.

3.7.4 Pilot Study Decision Support System

As a demonstration of how a numerical decision support system could work for Laramie County, 12 factors were selected from the GIS database in this project, to serve as a pilot study. The 12 factors are shown in the GWDSS table (Table 3.7.5 a). For each of these factors, a numerical scale was produced that ranked the countywide data on a scale of 1 to 5, with 5 being the highest rank.

For each factor, a series of countywide rasters were produced utilizing the GIS that spatially represent the 12 factors. These rasters are composed of 500 foot x 500 foot resolution pixels. Each pixel has a value of 1 to 5, representing the value of the data in that area. If there are no data for a given factor in that area, the pixel has a “no data” value. Appendix A includes maps generated from the rasters that graphically portray the ranking of the 12 demonstration factors.
### 3.7.5 Table

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<tr>
<th>Rank</th>
<th>Aquifers Present</th>
<th>Hydraulic Conductivity (gpd/ft)</th>
<th>Aquifer Specific Yield (%)</th>
<th>Saturated Thickness (Feet)</th>
<th>Distance to Large Irrigation Wells (Miles)</th>
<th>Special Ground Water Regulations</th>
<th>Distance to Oil &amp; Gas Well (Miles)</th>
<th>Distance to Confined Feeding Lot (Miles)</th>
<th>Distance to DOD CERCLA Site (Miles)</th>
<th>Distance to Contamination Site (Miles)</th>
<th>Aquifer Sensitivity</th>
<th>Aquifer Vulnerability to Pesticides</th>
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<td>&gt; 20</td>
<td>&gt; 600</td>
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#### Weighting Factor Scenarios

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Total: 100

**Comments on Scenarios**

1. Heavy weight on Aquifers Present. All Parameters Used.
2. Saturated Thickness left out to increase County coverage.
3. Equal weight on all parameters.
4. Heavy on environmental factors - avoiding contamination. Saturated Thickness left out.
5. Equal weight, excluding sensitivity & vulnerability.
Once the rasters were produced, each one was weighted, relative to the other rasters. In this way more significance could be placed on data that are considered to be more important. These rasters were then combined in a weighted overlay, using the ESRI ArcGIS Spatial Analyst software, resulting in a composite suitability map. Each pixel in the weighted overlay is also ranked from 1 to 5, based on the weighted data.

Depending on the type of decision, the weighting for each raster can be easily changed. This allows for a number of “what if” scenarios. Five example scenarios are presented in the GWDSS table. Each of these scenarios represents a different way to combine the GIS data into an overall suitability map. The assumptions for each scenario are presented below, and resultant maps for the five scenarios are presented in Appendix B.

- Run 1 simulates a decision in which available water supply is most important, so factors reflecting aquifer parameters are weighted more heavily.
- Run 2 modifies run 1 to reflect limited saturated thickness data available for some areas of the county.
- Run 3 assigns equal weight for all ranking factors.
- Run 4 emphasizes environmental factors involved with siting a water well.
- Run 5 is similar to run 4 but excludes aquifer sensitivity and vulnerability.

While the results maps for each scenario are somewhat different from each other, there are some consistencies throughout all five. Considering a development that will require a water supply source, there are some areas of the County that rank consistently low, based on availability of water, opportunity for well interference and aquifer sensitivity among other factors. These areas include the Pine Bluffs and Carpenter areas, and in the northeastern part of the county adjacent to Goshen County. In the example analyses, these areas typically rank a two on the scale. The 10-15 mile wide Cheyenne area typically rates a 3. The area surrounding Cheyenne and extending northeast toward Albin and north-northwest consistently rates a 4.

Any GWDSS and its accompanying GIS database is a living document. This pilot project is intended to show the capabilities of such a system, while recognizing that additional factors, different ranks of these factors and the weight of each factor within the GWDSS can and should be customized by the user.

Additional considerations should be taken into account as a more refined system is developed for Laramie County. Ground water predominantly flows from the west to the east across Laramie County. In addition there is a vertical component of leakage from the overlying Ogallala to the Arikaree to the Brule within the High Plains Aquifer. Development within the western part of Laramie County will affect not only water quality but also water quantity within the eastern part of the County. This should be taken into account when one considers the proliferation of rural subdivisions (domestic wells and septic) near Cheyenne as well as other development in the western portion of the County.
3.8 MODELING CONSIDERATIONS

3.8.1 Modeling Requirements for the Aquifers

A number of studies have been conducted in the southeastern Wyoming area in an effort to model the effects of ground water utilization on aquifers, streams and reservoirs in the region. The model employed in most of the studies was developed by Peter C. Trescott, George Francis Pinder, and S. P. Larson for the US Geological Survey in 1976. For more information on the derivation of the model, formulas utilized, or other specific details see Trescott, Pinder, and Larson’s USGS Publication titled “Finite-Difference Model for Aquifer Simulation in Two Dimensions with Results of Numerical Experiments.” The study titled “Digital Model of the Bates Creek Alluvial Aquifer near Casper, Wyoming” employed a different variation of a model, developed for USGS by Kent C. Glover in 1988, and titled “A Finite-Element Model for Simulating Hydraulic Interchange of Surface and Ground Water.” The following pages summarize previously conducted ground water modeling efforts in southeastern Wyoming.

Modeling Considerations

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<th>Model</th>
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<th>Area Size (square miles)</th>
<th>Model Type</th>
<th>Aquifer</th>
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<td>USGS</td>
<td>400</td>
<td>ModFlow</td>
<td>Arikaree</td>
<td>Effects of Irrigation &amp; Industrial Ground water use on aquifer levels &amp; streamflow</td>
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<td>Effect of Pumpage on Ground Water levels as Modeled in Laramie County, Wyoming</td>
<td>1980</td>
<td>USGS</td>
<td>2320</td>
<td>ModFlow</td>
<td>Tertiary &amp; Alluvium</td>
<td>County-wide model to predict aquifer drawdown through 1987</td>
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<td>USGS</td>
<td>55</td>
<td>ModFlow</td>
<td>Bates Creek Alluvium</td>
<td>Relatively small model to predict pumping effects on Bates Creek Alluvial Aquifer</td>
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3.8.1.1 “Digital Model of the Arikaree Aquifer near Wheatland, Southeastern Wyoming”

Year: 1977

By: US Geological Survey (USGS)

For: State Water Administrators

A mathematical simulation of the flow of ground water was applied to predict the long-term effects of irrigation and proposed industrial pumping from the unconfined Arikaree aquifer. The study involved a 400 square mile area near Wheatland, in Southeastern Wyoming, containing portions of central Platte County and extreme western Goshen County. The area boundaries, as described in the report, are comprised:

“on the west by outcrops of rocks of pre-Tertiary age in the Laramie Mountains, on the north by a ground water divide north of Cottonwood Creek, on the northeast by the North Platte River, and on the southeast by the Wheatland fault system. The southern boundary has been chosen arbitrarily and passes through the town of Wheatland, Wyoming, about 4 miles south of the confluence of the Laramie and North Laramie Rivers.” (Hoxie, 1977)

The mathematical model was specifically used to predict the long-term effects of irrigation and industrial ground water withdrawals on aquifer levels and streamflow. It was assumed that the system was in a steady-state condition at the beginning of the model. The study considered three cases: maximum, mean, and minimum proposed levels of ground water utilization for irrigation and industry within the area.

3.8.1.1.1 Case I – Maximum Utilization

In Case I, it was assumed that all 42 irrigation wells under permit by the State of Wyoming at the time of the study were in production and that each well consumptively applied 1.4 feet of ground water annually to each acre assigned to the well, including all enlargements to the assigned acreages. The net annual rate of ground water consumption for irrigation in this case was 10,066 acre-feet. For industrial use, the annual rate of ground water withdrawal was set at 6110 acre-feet, which was the maximum rate of annual withdrawal projected to be required by the Missouri Basin Power Project.

Considering Case I, the model predicted that aquifer levels would drop more than 5 feet over an area of 124 square miles, and more than 50 feet over a 38 square mile area by the end of the 40-year simulation period. Additionally, the model indicated depletion in streamflow of 6400 acre-feet per year for the Laramie River and 4100 acre-feet per year for the North Laramie River.
3.8.1.1.2 Case II – Mean Utilization

It was again assumed that the 42 irrigation wells under permit were in production. The same pumping rate assumed in Case I were applied in Case II, with the exception of those wells that applied water to lands having both surface water and ground water rights. Those wells were assumed to pump at one-half of the rate of the Case I rates. The net annual rate of ground water consumption in this case was 9718 acre-feet. The annual industrial consumption of ground water was set at 1450 acre-feet, which was the annual average withdrawal rate projected to be required by the Missouri Basin Power Project.

The Case II model forecasted an aquifer level decline of more than 5 feet for an area of 120 square miles, and more than 50 feet for a 21 square mile area after 40 years. The study also predicted that streamflow would be reduced by 2500 acre-feet per year in the Laramie River and 4000 acre-feet per year in the North Laramie River.

3.8.1.1.3 Case III – Minimum Utilization

In Case III, only the 26 irrigation wells whose ground water rights were senior to the rights of the industrial wells were assumed to be in production. Case I pumping rates were again applied, but any enlargements to the originally assigned acreages were excluded. Total annual consumption of ground water for irrigation in this case was 5299 acre-feet. As with Case II, industrial withdrawals were set at the projected annual average rate of 1450 acre-feet.

Case III predicted aquifer level declines to be less than 50 feet throughout the study area and greater than 5 feet over an area of 98 square miles. Streamflow depletion was forecasted to be 1700 acre-feet per year in the Laramie River and 3500 acre-feet per year in the North Laramie River. Perhaps most significant of the predictions was that a system of steady-state flow would approximately be achieved at the end of 40 years.

Hoxie additionally notes:

“Initially, most of the water that would be discharged from the aquifer by the pumping wells would be derived from water held in storage within the aquifer, and the withdrawal of this water would be accompanied by the development and growth of coalescing cones of depression around the pumping wells. As the resultant cone of depression migrates along reaches of the Laramie and North Laramie Rivers, an increasing fraction of the water discharged by the wells would be derived from streamflow, either from the direct infiltration of surface flow to the aquifer or by the interception of ground water that would otherwise have discharged from the aquifer to the streams. Eventually most or all of the water that is discharged by the wells may be supplied by water lost from the streams, and a new system of steady-state flow would be established.”
3.8.1.2 “Effect of Pumpage on Ground Water Levels as Modeled in Laramie County, Wyoming”

Year: 1980

By: US Geological Survey (USGS)

For: State Water Administrators

A digital hydrologic system model was developed to investigate ground water level changes resulting from withdrawals at the time of the study (1977) and to provide a means of predicting the future effects of ground water development in Laramie County, Wyoming. The study focused on “a 2320 square mile area in Laramie County bounded approximately by Horse Creek on the north, Nebraska on the east, Colorado on the south, and pre-Tertiary outcrops on the west.” The actual modeled area is further defined as extending “from the pre-Tertiary outcrops on the west to about 11 miles into Nebraska on the east and from 3 to 7 miles north of Horse Creek on the north to the pre-Tertiary outcrops about 9 miles into Colorado on the south.” (Crist, 1980)

The digital model was used to predict the results of pumping through 1987. All pumping rates were assumed to be equal to the rates estimated for 1977, with no additional wells added during the 10-year span of the model. The model calculated changes in ground water level by 1987 to be as much as 30-40 feet lower than 1920 levels, when agricultural use of ground water in the area began.

A second simulation was created to show the result of irrigating approximately 16,400 additional acres, which represented requests for permits, received by the Wyoming State Engineer, to drill additional irrigation or other wells exceeding 50 gallons per minute.

In 1977, at the time of the study, approximately 47,300 acres were irrigated in Laramie County, and ground water levels were declining by as much as 4 feet per year in some areas. In February of that year, the Wyoming State Engineer, upon recommendation of the Wyoming State Board of Control, imposed a moratorium on additional ground water development by large capacity (greater than 50 gallons per minute) wells in approximately the eastern one-half of the county.

The conclusions of the report do not specifically quantify the acreages with predicted water level declines, but the effects are illustrated in Figures 1 and 2 below. As one would expect, Figure 2 shows much larger affected regions resulting from increased pumping.

Crist also notes that the case of increased pumpage simulated by the model was hypothetical, and that resulting water level changes were mapped to illustrate how the model might be used as a guide by water administrators in making management decisions.
Figure 4. Water Level Changes - Current Pumping Rates
Figure 12.—Water-level changes calculated for 1920-87 assuming increased pumpage after 1977.
3.8.1.3 “The Ground water System in the LaGrange Aquifer near LaGrange, Southeastern Wyoming”

Year: 1983

By: US Geological Survey (USGS)

For: State Water Administrators

At the time of the study, ground water from the LaGrange Aquifer was being increasingly utilized for irrigation purposes. From 1973 to 1978, ground water pumpage increased in the region east of Horse Creek, which was the area of principal interest in the study. That area contained Hawk Springs Reservoir and 14 adjacent wells used to supplement surface-water supply in the reservoir. The reservoir and adjacent wells are located in a natural discharge area. Up-gradient from Hawk Springs Reservoir there were 28 irrigation wells in an approximately 6 square mile area. From 1973 to 1978, water levels dropped 3 to 12 feet in this region, causing concern about the effects of pumping the wells on the hydrologic system.

The study area specifically consisted of approximately 130 square miles mostly contained in southeastern Goshen County, Wyoming. Small parts of the area extend into Laramie County, Wyoming, as well as into Nebraska. The boundaries were drawn in such a manner as to “maintain continuity of the boundaries used in the model developed for the LaGrange area.” (Borchert, 1983)

A digital model was created and used to simulate the ground water flow system in the unconfined LaGrange Aquifer. The model was used to simulate four 6-month pumping alternatives, including three hypothetical alternatives, for the area east of Horse Creek. The altitude of Hawk Springs Reservoir was held constant, approximating a reservoir volume of 7000 acre-feet, for all four pumping alternatives.

3.8.1.3.1 Pumping Alternative 1

Alternative 1 simulated historic conditions for 1973-1978, including monthly recharge from precipitation, so none of the wells were considered to be active. The first 6-month simulation indicated a discharge from the aquifer to the reservoir at a rate of 5.2 cubic feet per second (cfs). As the system was considered to be at steady-state, the aquifer displayed no decrease in ground water level.

3.8.1.3.2 Pumping Alternative 2

The second alternative considered a scenario in which only the 14 wells adjacent to the reservoir were pumped. At the end of the first 6-month simulation, the model showed an average drawdown of 3.2 feet in the aquifer. Calculated rate of discharge to the reservoir from the aquifer decreased from 5.2 cfs to 0.4 cfs.
3.8.1.3.3 Pumping Alternative 3

For pumping alternative 3, the model simulated only the 28 up-gradient irrigation wells to be in use. The results of this scenario indicated an average decrease in the aquifer water level of 4.8 feet, and a decrease in the aquifer discharge rate from 5.2 cfs to 3.8 cfs at the end of the 6-month pumping period.

3.8.1.3.4 Pumping Alternative 4

In the fourth and final case, the study assumed all 42 wells to be active. The model showed an average drawdown in the aquifer of 8.2 feet and reversed the discharge from the aquifer to the reservoir after 6 months. In this instance, the reservoir showed a discharge to the aquifer of 1.0 cfs.

3.8.1.4 “Computer Modeling of the Ground Water System, North Cheyenne Area”

Year: 1984

By: Wyoming State Engineer’s Office

For: Cheyenne-Laramie County Regional Planning Office

The Cheyenne-Laramie County Regional Planning Office became concerned about the adequacy of the water supply for proposed subdivisions north of the City of Cheyenne while reviewing preliminary plats for development of the area. At the time of the study, there were more than 1350 wells in the 150 square mile area and more than 1500 undeveloped lots without wells. It was determined that if all the existing lots were developed, the required ground water withdrawals would be equivalent to the quantity of water necessary to operate 14 center-pivot irrigation systems. Previous development of irrigation wells at this magnitude in eastern Laramie County had caused a “general decline” of the water table level. Therefore, it was inferred that the development of the lots north of Cheyenne would cause similar decline in ground water levels.

In December 1983 the Cheyenne-Laramie County Regional Planning Office requested that the State Engineer’s Office (SEO) conduct an investigation of the ground water situation in the study area north of Cheyenne. The Regional Planning Office asked the SEO to evaluate the impacts of both present levels of development and potential future development.

Three major assumptions were made with respect to the computer model. First, withdrawal rates were assumed to be 900 gallons per day, or 1 acre-foot per year. That quantity was considered a reasonable amount of water to support a family of four, as well as to water lawns, gardens, trees and animals commonly found in the study area. Second, two growth rates for future well development in the area were projected over a period from 1984-1998 to illustrate impacts for both high and low rates of development. Finally, ground water pumping rates were modeled as constant throughout the year, rather than spiking during summer months. Consequently, the model results only show the general decline of ground water levels and do not accurately...
illustrate seasonal variations. It is likely that during the summer months when demand is greatest, water levels were several feet lower than the model results indicate. The model was set up to simulate four scenarios.

3.8.1.4.1 Scenario I

The first simulation considered only existing wells, and was run through 2009. After the 25-year period, the model projected a maximum drawdown between 15 and 20 feet in the area of Cowboy Country, Riding Club Estates, and All American Subdivision. There were also significant areas that would experience drawdown of 15 feet or less. See Figure 3 for map indicating total area affected in Scenario I.

3.8.1.4.2 Scenario II

The second model was run assuming 33 new wells per year from 1984-1998, in addition to existing wells. The new wells were added at locations proportionate to the number of vacant lots. The simulation was again run through 2009, and again it resulted in a maximum drawdown of 15-20 feet. This time, however, the area in which that amount of drawdown can be expected is approximately three times as large as in Scenario I. The areas displaying drawdown of 5-10 feet and 10-15 feet did not change significantly. See Figure 4 for map indicating total area affected in Scenario II.

3.8.1.4.3 Scenario III

The third computer simulation was conducted assuming every vacant lot in the study area had a house and well on it by 1999. This resulted in a constant development rate of 101 wells per year. After 2009, the results of the model indicate that the most intensely developed areas will experience ground water level decline of over 20 feet. The 5-10 feet drawdown area increased significantly along Horse Creek Road and in the vicinity of the Yellowstone North Subdivision. See Figure 5 for map indicating total area affected in Scenario III.

3.8.1.4.4 Scenario IV

The final simulation was conducted under the same assumptions as Scenario III, but projected for an additional 10 years to 2019. At that time, it is expected that maximum drawdown would have increased to more than 30 feet in the vicinity of Cowboy Country, Riding Club Estates, and All American Subdivision. Most of the study area would be included in the area experiencing at least a 5-10 feet decline in ground water levels. See Figure 6 for map indicating total area affected in Scenario IV.
The study concluded that, at the level of development experienced in the area at the time of the study, residents could expect declines of 15-20 feet in the water table. The authors further note:

“All indications are that the area bounded by Dell Range Boulevard on the south, Warren AFB on the west, the Zoned Area boundary on the north, and Christensen Road on the east will be affected by water level declines in the next 25 years regardless of whether additional homes are built in the area. A worst case prediction, in which the number of homes and dwellings in the study area are more than doubled in the next 15 years, results in a water level decline of slightly more than 30 feet, 35 years in the future.” (Stockdale and Martin, 1984)
Figure 6. Scenario 1 Results

SCENARIO 1
Predicted Drawdown in 2010 with no additional development after 1983:
- Less than 5 ft
- 5 to 10 ft
- 10 to 15 ft
- 15 to 20 ft
Figure 9. Scenario IV Results
Bates Creek, located southwest of Casper, Wyoming and the surrounding area has been utilized for cattle and sheep ranching since the 1880s. Rancher’s plant large fields of alfalfa and other hay crops to feed livestock in the area, and they irrigate the fields with water diverted from Bates Creek and its tributaries. To supplement the surface water supply in the area, a number of irrigation wells have been drilled near the creek and, at the time of the study, more wells were planned in the near future.

In order to better understand the effects of ground water pumping, a computer model was used to simulate ground water flow within the Bates Creek alluvial aquifer. The model considered three scenarios. The first model assumed no ground water pumping; the second looked at pumping the existing wells; and the last scenario modeled the pumping of all existing and proposed wells.

The area of interest in this study was comprised of “approximately 55 square miles in southeast Natrona County. The area is bounded on the west by the North Platte River and on the north and south by relatively impermeable shale of Cretaceous age. The eastern boundary was chosen to be far enough upstream to be outside the influence of present and proposed ground water development.” (Glover, 1983)

The models’ results showed a decrease in ground water discharge to Bates Creek of 3.5 cfs after 10 years if only existing wells were pumped and a decrease of 4.9 cfs after 10 years if all existing wells and 7 proposed wells were pumped.
4.0 RECOMENDATIONS

4.1 Decision Support System (GWDSS)

When this project began, there was some question about whether a ground water flow model might be required to provide adequate information about the availability of ground water at a particular site. Traditional ground water flow models, such as might be constructed with ModFlow, are cumbersome. Special skills are required to construct, operate, and interpret results from such a model. Even with the special skills, this approach is only as good as the data, which supports the model and the modeling assumptions which govern the model. Typically such numeric models address aquifer head, or potentiometric surface elevation as the final output.

As an alternative, it was decided to explore a decision support system based on the Geographic Information System (GIS) database, which was constructed as part of this project. The GWDSS is discussed in detail in Section 3.7. of this report. A GWDSS allows many parameters to be considered in a simplified but often comprehensive fashion. In the case of the Laramie County Aquifer Management GWDSS the following parameters were derived from the Water Resources Atlas of Laramie County, Wyoming:

- Aquifers Present
- Hydraulic Conductivity
- Aquifer Specific Yield
- Saturated Thickness
- Distance to Large Irrigation Wells
- Special Ground Water Regulations
- Distance to Oil & Gas Wells
- Distance to Confined Feeding Lots
- Distance to CERCLA Sites
- Distance to WDEQ Contamination Sites
- Aquifer Sensitivity
- Aquifer Vulnerability

4.1.1 Parameter Scaling

The current pilot GWDSS includes all of these parameters and has quantified the value of each parameter on 1 to 5 scale, with the scale indicative of the quality of that parameter at a particular site. A value of 1 indicates a low quality or negative value, whereas a value of 5 is a higher quality or positive value. For example, a site close to an environmental contamination would be a low score, such as a one out of five, while a site far enough away that the contamination would not be a concern would be a high score, such as a five out of five. Once all of the parameters have been scaled, some type of overlay may be constructed to compare values of all of the parameters at a particular site. In this way, all of the parameters can be considered together.

Given the complexity of each parameter and their interrelationships with each other, there are opportunities for a myriad of scaling approaches. As the user operates the GWDSS, parameter scaling should be adjusted.
4.1.2 Parameter Weighting
Some parameters may be considered to be more important than others in evaluating a particular site. For example, one might consider the aquifer present under a parcel to be more important than other parameters. Weighting factors may be applied to reflect this relative importance. In this way different scenarios may be evaluated by using different combinations of parameters and weighting factors prior to using this system for decision making.

4.1.3 Further GWDSS Development

Recognizing that the GWDSS is a pilot study and is intended to demonstrate a conceptual decision making model, there are several possible refinements as discussed below:

- Ground water flow is ignored. The ideal shape for an exclusion zone around a particular ground water contamination site is likely not a circle. The zone of influence would likely extend further down gradient than up gradient.
- Contamination sites vary with regard to the amount of pollutant, toxicity of the pollutant, solubility of the pollutant. Distances from a contamination source should be site specific.
- Changes in potentiometric surface over time should be included in this evaluation and can be evaluated with aquifers present;
- Losses in nearby well production should also be considered. A scale of 1 to 5 may not be the most appropriate scale.

4.2 GIS updates and Quality Assurance and Quality Control

A GIS is a living document and requires periodic updates to ensure that not only is the information system up to current standards, but even more importantly that each data base is as accurate as possible. The current data bases are undergoing constant refinement and improvements. The Ground Water Atlas and the Ground Water DSS should be regularly be upgraded.

4.3 Additional Monitor Wells

The Wyoming State Engineer has constructed a network of monitor wells throughout Laramie County. Additional monitor wells are needed and could improve both spatial and vertical (per aquifer) distribution. Traditional aquifer demand has focused on the Arikaree, Ogallala and Brule (High Plains Aquifer). New demand is being placed on the Lance, Fox Hills, Terrace Aquifer and Paleozoic Aquifers. Monitor wells will be required to quantify available water and long term aquifer response to pumping for these non-traditional aquifers. Monitor well placement can also focus on new areas of increased water demand such as rural subdivisions and growth areas around the City of Cheyenne.

4.4 Irrigation Withdrawals

Irrigation use produces significant demands on ground water within Laramie County. The Atlas estimates that ground water use for irrigation ranges from 51 to 73% of the total, yet there is very
little actual metering or quantification of irrigation withdrawals. Reporting of annual irrigation water use via either meters or power records would greatly improve the data base. If power records are used, irrigators would need to provide some information on pumps and pump efficiency. Such information could be used later to help calibrate ground water models or establish long term sustainability of the aquifers.

4.4 Aquifer Sustainability

The Ground Water Atlas and GWDSS focuses on the long term availability of ground water as a water supply source. The documents address both water quantity and water quality and past modeling efforts have addressed the long term drawdown of the regional aquifer given certain water withdrawal conditions. Additional research is necessary to address aquifer sustainability—both near term and long term. The previous headings including the placement of additional monitor wells and quantification of demand will assist in this regard.
5.0 ACKNOWLEDGEMENTS

The Water Resource Atlas of Laramie County, Wyoming was prepared by JR Engineering LLC, Lidstone and Associates and HDR with funding from the Wyoming Water Development Commission, at the request of the Commissioners of Laramie County, Wyoming. We are grateful to all the people and agencies that provided data, time and advice. The preparation of the atlas required an immense amount of time in data gathering and development of a Geographic Information System. All the maps you see in the atlas are also in GIS format at Laramie County.

The following people and agencies helped provide data and advice:

Laramie County Conservation District, Liberty Blain, Jim Cochran
Wyoming Department of Environmental Quality, Jane Francis
Laramie County, Dave Sherrill, Gary Kranse, Joyce Pokash
Wyoming Office of the State Engineer, Jeremy Manley
U.S. Environmental Protection Agency, Mike Wireman
U.S. Geological Survey
Cheyenne Board of Public Utilities

Much of the information contained herein was derived directly from two significant prior studies; The Platte River Basin Plan, and the Wyoming Ground Water Vulnerability Assessment Handbook. We thank all of those who were instrumental in the preparation of these documents.

Finally, special thanks goes to Bruce Brinkman of the Wyoming Water Development Commission and especially to Marvin Crist who took of his own time to educate those of us less knowledgeable.
6.0 APPENDIX A - DEMONSTRATION FACTORS
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<th>Special Ground Water Regulations</th>
<th>Distance to Oil &amp; Gas Well (Miles)</th>
<th>Distance to Confined Feeding Lot (Miles)</th>
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<th>Distance to DEQ Contamination Site (Miles)</th>
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**Weighting Factor Scenarios**

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**Total**

0 100

**Comments on Scenarios**

1 - Heavy weight on Aquifers Present. All Parameters Used.
2 - Saturated Thickness left out to increase County coverage.
3 - Equal weight on all parameters.
4 - Heavier on environmental factors - avoiding contamination. Saturated Thickness left out.
5 - Equal weight, excluding sensitivity & vulnerability.
Aquifer Hydraulic Conductivity

Legend
- 1 - 0 to 25 GPD/SQFT
- 2 - 25 to 50
- 3 - 50 to 100
- 4 - 100 to 200
Aquifer Saturated Thickness

Legend

1 - < 200 Feet
2 - 200 to 400
3 - 400 to 500
4 - 500 to 600
5 - > 600

0 10
Miles
Distance to Large Irrigation Wells

Legend
1 - < 0.25 Miles
2 - 0.25 to 0.5
3 - 0.5 to 1.0
4 - 1.0 to 2.0
5 - > 2.0
Distance to Oil and/or Gas Wells

Legend

1 - < 0.25 Miles
2 - 0.25 - 0.5
3 - 0.5 to 1.0
4 - 1.0 to 2.0
5 - > 2.0

0 10 Miles
Distance to Confined Feeding Lot
Distance to DEQ Ground Water Contamination Sites

Legend
- 1 - < 2 Miles
- 2 - 2 to 3
- 3 - 3 to 4
- 4 - 4 to 5
- 5 - > 5

Directions:
- 0 10 Miles
Aquifer Sensitivity

Legend
1 - High
2 - Medium High
3 - Medium
4 - Medium Low
5 - Low

0 10 Miles

J.R. Engineering
A Western Company
Ground Water Vulnerability to Pesticides

Legend

1 - High
2 - Medium High
3 - Medium
4 - Medium Low
5 - Low

0 10 Miles
7.0 APPENDIX B – RESULT SCENARIOS
Laramie County Aquifer Study - Ground Water Decision Support System

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<thead>
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<th>Rank</th>
<th>Aquifers Present</th>
<th>Hydraulic Conductivity (gpd/ft²)</th>
<th>Aquifer Specific Yield (%)</th>
<th>Saturated Thickness (Feet)</th>
<th>Distance to Large Irrigation Wells (Miles)</th>
<th>Special Ground Water Regulations</th>
<th>Distance to Oil &amp; Gas Well (Miles)</th>
<th>Distance to Confined Feeding Lot (Miles)</th>
<th>Distance to DOD CERCLA Site (Miles)</th>
<th>Distance to DEQ Contamination Site (Miles)</th>
<th>Aquifer Sensitivity</th>
<th>Aquifer Vulnerability to Pesticides</th>
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**Weighting Factor Scenarios**

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**Total**: 100

**Comments on Scenarios**
1. Heavy weight on Aquifers Present. All Parameters Used.
2. Saturated Thickness left out to increase County coverage.
3. Equal weight on all parameters.
4. Heavier on environmental factors - avoiding contamination. Saturated Thickness left out.
5. Equal weight, excluding sensitivity & vulnerability.
Result No. 2
The Decision Support System (GWDSS) is based on using weighted overlays of spatial data. This is done with the ESRI ArcGIS Spatial Analyst Extension. This quick guide is intended to give a brief overview of how these weighted overlays are constructed. More detailed information about Spatial Analyst is available in the User’s Guide and help files that are provided with the software.

I. Create Rasters
Spatial Analyst generally works only with rasters. Other spatial datasets such as point, line, and polygon shape files must first be converted to rasters. This can be done with the Spatial Analyst Toolbar Menu: Spatial Analyst>>Convert>>Features to Rasters. It can also be done in Arc Toolbox: Conversion Tools>>To Raster. This ArcToolbox menu is shown in Figure 1.
II. Add Spatial Analyst Extension
Spatial Analyst is an extension to the “normal” ArcGIS software. Once it has been installed, it must be enabled, or added in before any Spatial Analyst tools will work. Go to the Tools menu: Tools>>Extensions. A window will open to allow you to check Spatial Analyst to enable it (Figure 2).

![Image of Extensions window](image)

Figure 2 – Enable Spatial Analyst Extension.

After checking the Spatial Analyst box, click on close and Spatial Analyst will be enabled.

III. Reclassify Rasters

After the rasters have been created, they should be reclassified, so that the pixel values fall within the desired scale, such as the one to five scale used in the GWDSS pilot study. This reclassification may be done through ArcToolbox: Spatial Analyst Tools>>Reclass>Reclassify. This opens the Reclassify window (Figure 2).
When the input raster is selected, the current pixel values show up under the Old Values list. A corresponding new value to replace the existing values may be added under the New Values list. A name and location for the new reclassified raster should be picked in the Output Raster space. All of the rasters that will be combined in the weighted overlay should be reclassified to the same scale.

IV. Run Spatial Analyst Weighted Overlay

The weighted overlays are created through ArcToolbox, using Spatial Analyst Tools>>Overlay>>Weighted Overlay (Figure 3). This opens the Weighted Overlay Window (Figure 4). Each raster is added to the list by clicking on the plus button and browsing to the raster file.

When the first raster is added, the % influence will automatically be set to 100%. As additional rasters are added, they will initially be given a % influence value of zero. After all of the rasters are added, the % influence will need to be manually set for each raster. The total % influence for all of the rasters must add up to 100%.

The resulting weighted overlay will be written as a new raster. The name and location of that raster should be set in the Output Raster section of the window.
Figure 3 – Starting Weighted Overlay

Figure 4 – Weighted Overlay Window.
9.0 REFERENCES


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