GEOLOGIC AND HYDROLOGIC FACTORS GOVERNING IMPACTS OF DEVELOPMENT ON THE CRYSTAL RIVER NEAR MARBLE, GUNNISON COUNTY, COLORADO

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Wright Water Engineers, Inc.

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1.0   INTRODUCTION

This report provides an evaluation of the geologic, topographic, and hydrologic factors governing the impacts of development and presents a database for evaluating the propriety of future development in the Marble area of the Crystal River Valley. Spatial data established for the defined study area is compatible with the Gunnison County ARC/INFO geographic information system (GIS) database. The database and report provide a suitable basis to help establish appropriate land use and environmental policies and regulations for future development, including the appropriate use of individual sewage disposal systems (ISDSs).

The subject Marble Ski Area Filings are located in Sections 13, 14, 23, 24, 25, 26, 27, and 28 of Township 11 South, Range 88 West of the 6th P.M. in Gunnison County, Colorado as illustrated on Drawing 1.

The subject study area includes the Town of Marble and the following Planned Unit Developments (PUDs) in unincorporated lands: Marble Ski Area Filings 1, 2, 3, 4, 5, 7, MSA Condominium Filing, Hermits Hideaway, and the Crystal River Filing. Marble Ski Area Filings plotted during the early 1970s were projected to have approximately 2,400 single-family lots, 600 multi-family units, and a small ski area. A typical, single family lot size is approximately 0.3 acres. In the past two years, Gunnison County has noted a significant increase in development within these filings.

Planned central sewer and water facilities were thwarted by bankruptcy of the developer and never materialized. Water supply for this development must be satisfied by individual wells or hauling of water. Reliance on septic systems may impact groundwater and surface water quality. Investigations by the Colorado Geological Survey (CGS) (Rogers and Rold 1972) and Thorne Ecological Institute (Robinson and Cochran 1973), coupled with 1995 site inspections by the authors (Wright and

Rold), indicate that debris flows, landslides, avalanches, flooding, and potentially unstable steep slopes prevent or severely restrict construction in much of the platted area.

1.1   Goals of the Study

The goals of the study are to establish a topographic, geotechnical/water quality database compatible with ARC/INFO that can be used to aid the county in creating appropriate land use and environmental policies and regulations for future development, including the reasonable use of ISDSs. Available information pertaining to geotechnical factors associated with road construction, building site development, slope stability, and soil creep are summarized and the data incorporated into a special database. The study results are intended to aid the county in determining policies and decisions for defining conformable land use for specific areas, identifying primary density considerations, mapping non-developable areas, establishing a future buildout scenario, evaluating infrastructure design, and cataloging alternative construction techniques.

1.2   Scope of Work

The following summarizes the approved Scope of Work aimed at addressing and achieving the study goals:

Task 1.   Review existing published and unpublished geological, geotechnical, and hydrologic data relevant to the area.

Task 2.   Compile and review geotechnical data submitted to Gunnison County and/or CGS, local sanitarians, or Colorado Department of Public Health and Environment (CDPHE) by previous development proponents.

Task 3.   Meet with Gunnison County personnel and leaders of the Marble community to discuss the project.

Task 4.   Compilation of available water quality data from the Crystal River watershed.

Task 5.   Using computer technology compatible with ARC/INFO, prepare a digitized topographic map from the best available topographic source, and utilizing that data, prepare a slope map of the area.

Task 6.   A field inspection of the Marble Ski Area Filings by environmental geologist, Mr. John Rold, and civil engineer, Mr. Kenneth Wright.

Task 7.   Utilizing the assembled data, categorize those areas which are determined to be unsuitable for septic tank/leaching field systems and define those areas on the ARC/INFO map.

Task 8.   Evaluate the geotechnical characteristics that would relate to slope stability, natural hazards, road construction, building site development, and soil creep. This would result in a map showing areas that could be developed with minimal reviews and evaluation by the counties and those areas which could be developed only after careful detailed geotechnical and engineering studies of the site.

Task 9.   Consolidate the above data, evaluations and findings in regard to conformable land use, density considerations, non-developable areas; prepare a basis for future build-out scenarios, considerations for infrastructure design, and identification of alternative construction techniques.

Task 10.   Utilizing the above and available data, determine the accumulative impacts of septic systems on the water quality of the Crystal River.

1.3   Development History

Although the climate and the scenery have attracted many people to the Marble area since its earliest settlement, the first attempt to commercialize this resource occurred in 1956 when Mr. Wade Loudermilk assembled several hundred acres of land and formed the Crystal River Enterprises. The first recorded attempt to evaluate the area for commercial ski development occurred in 1967 when Crys-

tal Basin Outlife, Ltd., was formed and contracted with Sno-Engineering and Mr. Willie Schaeffler to evaluate the ski area potential.

In 1969, the Marble Ski Area, Inc., was formed and assembled 1,950 acres. They developed a master plan envisioning up to 8,800 dwelling units on private land and a major ski development utilizing 4,600 acres of federal lands covering the slopes of Mt. Daly, Arkansas Mountain, Sheep Mountain, and Buckskin and Coyote Basins. This plan would have resulted in a major ski complex as large as Vail, Aspen, or any now developed in the state.

In late 1970, the CGS became aware of this major development activity. Knowledge of the local geology and a cursory investigation indicated numerous serious geological constraints to the development and caused understandable serious concern. The CGS contacted the developer to determine his exact development plans and began a crash program of geological investigation. When the preliminary results outlining the serious geologic problems affecting the development were relayed to the developer, a confrontation arose. It became apparent that a readily available public document was needed to objectively portray the geologic problems of the area to the developer, state, and local decision-makers, investors, and the potential lot buying public. The CGS report, *Engineering Geologic Factors of the Marble Area,* was published in June 1972. It became a key document in a battle between the opponents and proponents of the Marble Ski Area. At that time, Senate Bill 35 had not been passed and Gunnison County did not have adequate subdivision regulations or staff to address such a major problem. Several of the early filings had already been approved. At that time, the CGS's only statutory authority for involvement was its enabling act which charged it to "delineate areas of natural geologic hazard which could affect the safety of or cause economic loss to the citizens of the state," and the charge, "to provide advice and counsel to all agencies of state and local government on geologic problems." In the early stages of the confrontation, Gunnison County was not aware they had a geologic problem and had not asked for the advice and counsel.

The basic concern arose from a comparison of the master plan document and geological conditions that would affect those activities. Particularly, the Slate Creek mudflow had been platted for residential development and an area of commercial development. Numerous lots had already been sold.

East of Carbonate Creek near the proposed ski area base facilities, numerous condominium sites were platted on or adjacent to active landslides, and on unstable slopes. In May 1973, when a catastrophic landslide took out a subdivision road and several condominium sites, the material ended up in Beaver Lake several hundred feet below. In the upper Slate Creek drainage, high density development was planned close to Gallo Bluff with little credence being given by the master plan to avalanches, mudflows, and potential landslides. Additionally, a school site was platted along the Crystal River and within the Carbonate Creek mudflow deposition zone. Condominium units were also master planned in the avalanche terrain south of the Marble town site.

On September 19, 1972, a mudflow on Slate Creek buried a subdivision road and covered numerous platted lots up to a depth of 3 to 4 feet. This event more than anything else demonstrated to the developer that geology was not an academic exercise and would be the paramount design consideration for planning this development. This event marked a change in dealings with the developer, who began to buy back lots that had been sold in the Slate Creek mudflow area and other hazardous areas. In an attempt to revise the development to conform to the serious geological problem areas, the total area was placed in a PUD with platting concentrated in the better areas, and with many of the hazard areas placed in an undisturbed or greenbelt status. Gunnison County became cognizant of geologic problems and refused to approve any plats or construction plans until they had been investigated and approved by the CGS. The ultimate plan to utilize some 4,600 acres of U.S. Forest Service (USFS) land for ski terrain and lift development was turned down by the USFS, and a more modest plan utilizing approximately 600 acres on the slopes of Mt. Daly was formally proposed. Earlier, a 4,200-foot chair lift and three ski trails had been constructed on private land. A study of environmental, ecological, and geological factors affecting the total development and the USFS's special use permit area was contracted to Thorne Ecological Institute of Boulder in 1973. Environmentalists, other opponents to the ski area, and governmental agencies raised questions of the impact on wildlife, particularly elk and deer winter range, proximity to the neighboring proposed Snowmass Wilderness area, air and water pollution, and numerous other factors. The State Land Use Commission conducted an investigation of the area. Numerous charges of improper and illegal sales techniques were leveled at the developer (Schneider 1974). Several lots were allegedly illegally sold from unplatted and unapproved filings. The state Real Estate Commission and the Securities Ex-

change Commission began investigations. Identified geologic hazards and other adverse publicity from many different angles exerted a serious drop in land sales and frightened away potential investors.

In 1973, the area was reorganized into the Marble Holding Company, Inc., with a change in management and an infusion of new personnel, new consultants, new enthusiasm, and new capital. The new corporation was not successful in overcoming the myriad problems and in September 1974, petitioned for bankruptcy. In 1977, the Federal Bankruptcy Court attempted to liquidate the land assets in order to satisfy the many creditors.

A major factor in the problems facing potential land development in the Marble area is the situation that most of the tracts did not go through the Senate Bill 35 subdivision process. That statutory system of geologic investigation by the developer's consultant, review by the CGS, evaluation by the county staff and approval by the County Commissioners was detoured when upon bankruptcy of the developer, separate tracts of land were sold by the bankruptcy court. Lots and tracts were sold without warranty to land speculators, out-of-state buyers, retirees, summer home candidates, and people just wanting a beautiful piece of Colorado. Many lots have been bought and sold several times with no thought or concern for geologic hazards, access, physical water availability and quality, or septic tank suitability. Although developable lots exist in the area, many parcels present significant risks and even insurmountable problems for a home builder.

2.0   GEOLOGIC SETTING

To fully understand the problems of the Marble area, one must understand the geologic setting. Diastrophism (mountain building) and geomorphic processes have shaped the area's topography and, in combination, control the movement of fluids. Geologic formations of the area control its topographic shape and the movement of fluids as certainly as the muscles and bone structure of the human body determine its anatomy and the movement of the fluids within it.

Regionally, the area lies between the southern edge of the Piceance Creek Basin to the west and the Sawatch Uplift to the east. Locally, the study area lies on the northeast flank of a northwesterly-plunging gentle syncline. The syncline itself has been modified by the Treasure Mountain Stock, the Ragged Mountain Laccolith, and the associated Raspberry Creek Phacolith, as well as the Snowmass Stock and the major Elk Range thrust fault to the east. These intrusions have intensely metamorphosed the sedimentary rocks around them and have mildly metamorphosed the Mesaverde and Mancos sediments in the study area. The underlying bedrock formations of Mesaverde and Mancos Formations in the study area dip gently some 18 to 25 degrees to the southwest and to the west.

Most of the underlying bedrock formations are covered to varying thickness with surficial deposits of the glacial moraine, landslides, mudflows, talus, colluvium, and alluvium (Drawing 4). The morainal deposits form a varying thickness of material blanketing the valley walls, particularly on the gentler, south-facing slopes. Colluvium, which is formed from the weathering and downward gravitational movement of other surficial deposits and bedrock, blankets the area in many locations. Debris flow and mudflow deposits occur several places.

The Cretaceous Mancos Shale bedrock can be seen where it is exposed in the canyon of Carbonate Creek, the lower slopes of Gallo Bluff, and the steep slopes northeast of the town site. The Mancos consists of fairly massive, dark gray, laminated, silty shale. The Cretaceous Mesaverde Formation, exposed in the upper portions of Gallo Bluff, extends to the west to the town site of Placita, and consists of interbedded sandstone, shale and thin to thick coal beds. Coal beds were mined in the historic past, but no coal mines are known in the study area.

To the southeast, the Treasure Mountain Dome exposes a full section of Mesozoic and Paleozoic formations down to the Precambrian gneiss and Tertiary granite-porphyry core. Although the Yule Marble does not crop out in the study area, it is important historically for it gave the town its name and provided its first industry. The Yule Marble, which is metamorphosed Leadville Limestone crops out high on the southwest and the northwest flanks of the Treasure Mountain Dome. Marble was produced commercially from the late 1800s until approximately the mid-1940s when the town and mill were damaged by a major mudflow. The quarry re-opened for commercial production in 1990, and is currently shipping marble.

Numerous avalanche tracks exist along the Gallo Bluff and the steep slopes to the south of the Crystal River (Drawing 6). Mears (1975) describes the Crystal River paths as medium-sized with starting zones of 10 to 30 acres and having vertical drops of less than 3,000 feet. Accumulation zones, however, are oriented on the lee side of ridges and avalanches occur relatively often. A second group of much larger avalanches occurs in the vicinity of Elk Mountain and Mount Daly to the east and north of Marble.

2.1   *Geologic History*

The classical, complete geologic history of the area has been discussed previously by Rogers and Rold (1972), Robinson and Cochran (1973), and Rold (1977), as well as Gaskill and Godwin (1966). Therefore, only those geologic processes which relate directly to the problems of the study area will be discussed. The pertinent geologic history began approximately 100 million years ago in Cretaceous time. A wide-spread sea covered the area with the deposition consisting mostly of dark gray mud approximately 4,000 feet in thickness. This mud later lithified and became the shales of the Mancos Formation which are well-exposed in the lower part of Gallo Bluff, along the canyon of Carbonate Creek and the steep slopes to the northeast of Marble.

During one of the retreats of this Cretaceous sea, the shoreline advanced northeastward across the area. Widespread forest and swamp conditions existed on the landward side of the ancient shoreline. As these forests and swamp deposits were later buried and lithified, they became the coal beds of the Mesaverde Formation. Both the Mesaverde Formation, and especially the Mancos Shale are argilla-

ceous (made of clay). As such, they are easily eroded because their properties are severely weakened by the presence of water. These underlying geologic characteristics contribute significantly to the slope instability and provide much of the material for the numerous landslides and mudflows in the area.

Some 70 million years ago, mountain-building forces formed the basic geologic framework of basins and mountain uplifts for the entire Rocky Mountains and the underlying structural blueprint of the Marble area.

Later, several igneous rock masses, particularly the Treasure Mountain Stock, the Snowmass Stock, the Ragged Mountain Laccolith, and the Raspberry Creek Phacolith intruded the area. These large, molten masses of rock provided the heat and pressure to metamorphose or alter the thick limestone beds of the Leadville Formation into the Yule Marble, and, to a certain extent, change Mesaverde coals from moderate grade bituminous to high grade coking coals, and even in some cases anthracite. This metamorphism likewise hardened the Mancos Shale and Mesaverde Formation in many parts of the study area.

During the Pleistocene or Ice Age, from approximately 1 million years ago to 10 thousand years ago, the mountain ranges of the area contained large ice caps from which major glaciers moved down the major high mountain valleys. Four major glacial episodes occurred in the Rockies during that period. Glaciers coming down the Crystal River Valley carved the valley into its present general shape. These glaciers, in many places, formed the oversteepened, unstable valley walls in the soft bedrock of the Mancos and Mesaverde Formations and left a thin veneer of morainal material. This set the stage for the post-glacial slope instability and mass wasting problems that plague the area yet today. In the last 10 thousand years, the processes of erosion and mass wasting by landslides and debris flows have combined to form the present topography of the Marble area.

3.0   GEOLOGIC CONSTRAINTS TO DEVELOPMENT

Geologic constraints affecting development in the Marble area are tied directly to the basic processes of material weathering, erosion, transportation, and deposition. The effects of these processes are magnified because of the unique geologic setting of the Crystal River valley. These basic processes have seriously constrained development since the first human activities in the Marble area. Such processes may be referred to as geologic hazards when catastrophic events devastate facilities and infrastructure and/or present human safety implications. The geologic setting and associated morphological processes, perhaps more than any other components, influence development locations, infrastructure alignments, and maintenance needs, and significantly add to the total development cost.

Engineering geologic factors have seriously constrained development since man's first activities in the valley. Although these factors have become significant geologic hazards when they interacted with man's activities, they have also definitely affected the location, construction costs, and maintenance costs of transportation and development facilities, and exert strong, constant, and economic pressures on all development activities. Such engineering geology terms as shear strength, angle of repose, excavatibility and erodibility, though unknown words to early workers, have continually affected the cost and safety of all of man's construction activities.

Several specific engineering geologic factors have been evaluated and mapped by the CGS (Rogers and Rold 1972), and Robinson & Cochran as consultants for the ski area developers (Drawing 4). These studies have been reevaluated for this investigation. These geologic factors which constitute geologic hazards are discussed under three major categories: (1) mudflows and debris flows, (2) slope instability, and (3) avalanches.

3.1   *Mudflows and Debris Flows*

Rogers and Rold (1972) described the origin and mechanics of Marble's alpine-type mudflows as follows:

> "With a torrential or cloudburst type rainstorm, rapid water runoff occurs, generally accompanied by debris avalanching of the upper slopes. The water and debris obtained high velocities . . . incorporating the coarse lag deposits which accumulate at very steep angles of repose in the steep intermittent stream beds of the lower parts of the high slopes. The mixing of storm runoff, soil and rock debris forms a viscous slurry of the approximate consistency of a wet concrete mix . . . A rather high velocity is maintained by the channeling effect, the steep gradient and the pressure of the moving mass from above and behind. When this stream of mud reaches the lower slopes, it spreads out, loses velocity and deposits much of its coarse load."

The major Marble mudflow or debris flow fan (frequently called an alluvial fan and shown as such on several maps) is one of the more apparent features to the geologist or layman visiting the area, and has figured prominently in its history. The major composite flow (Appendix A, Figures 2 and 4) was first mapped by Gaskill (1966) and is readily apparent on aerial photographs (Appendix A, Figure 5). The fan-shaped mudflow deposit which is approximately a mile long, spreads out into the Crystal River Valley to a width of approximately a mile and a half. Rogers and Rold (1970) calculated the maximum thickness of the mudflow complex as approximately 175 feet. Field observations indicate the older part of the fan was deposited by debris flows from the ancestral Carbonate Creek at a location somewhere between the present locations of Carbonate Creek and Slate Creek. Next, probable major landslide activity originating from Gallo Bluff (Appendix A, Figure 7), or possibly a glacier, diverted Carbonate Creek eastward to its present channel. Thereafter, the younger Slate Creek drainage developed on the western edge of the upper reaches of the fan. In order to protect the town from mudflows, the townspeople in 1920 diverted the main Slate Creek channel to the western extremities of the fan.

The major mudflow fan postdates the glacial retreat and, therefore, is no older than approximately 10,000 years. The deposition of the fan has deflected the Crystal River southward and caused the upstream damming that was later modified by the development of Beaver Lake. Erosion of the south canyon wall by the deflected stream has triggered a landslide.

3.1.1 Carbonate Creek Mudflow (Appendix A, Figure 4, Location 2b)

Carbonate Creek descends from a steep and sizable drainage basin (approximately 3,700 acres) on the slopes of Mt. Daly and Elk Mountain to the north. The upper channel is entrenched and actively

eroding a steep, incised canyon in the Mancos Shale. As it emerges from the steep canyon and its gradient flattens, coarse debris carried by the water is first deposited in a fan. Devastating mud floods have been recorded in 1936, 1941, and 1945. The "undeveloped" area in the center of the town represents the area devastated by the 1941 and 1945 mudflows (Appendix A, Figure 8). Some of the more recent floods caused little or no damage because this central area had not been rebuilt. The lighter color of the Carbonate Creek mudflow reflects an additional provenance of igneous and Pennsylvanian sedimentary rocks not available to the Slate Creek drainage which drains only Mancos and Mesaverde terrain.

3.1.2 Slate Creek Mudflow (Appendix A, Figure 4, Location 2a)

Slate Creek heads along the base of Gallo Bluff and follows an entrenched course along the western edge of the major mudflow deposits. This highly erosive channel (Appendix A, Figure 9) with over-steepened banks of old landslide and mudflow debris from the Mesaverde and Mancos is potentially very unstable. Both the rapidly wasting Gallo Bluff and the channel banks provide abundant sources for mudflow debris during strong runoff and periods of thunderstorms. Where the channel emerges from its entrenched course, some 2,000 feet north of the Crystal River, the gradient decreases and the mudflow debris is deposited with the coarsest material being deposited closest to the mouth of the channel. Blocks in excess of 6 feet in diameter are common (Appendix A, Figure 10). Fine muds are deposited all the way to the Crystal River. Studies by Rogers and Rold (1972) of aerial photographs of different ages, vegetation, topography, and the mudflow deposits, indicated a Slate Creek debris flow frequency on an average of approximately one every two years. Historic events have borne out those predictions. A debris flow on Slate Creek in September of 1972 which buried many platted lots and two subdivision roads was a major factor in convincing the developer that geologic factors were predictable and should be taken into account in development.

Many developers or home builders see the apparent channel of mudflows such as Slate Creek and Carbonate Creek as permanent features and feel that by avoiding that channel with a reasonable right-of-way, the remainder of the fan could be built upon with impunity. In the Ski Area Filings, for example, residential lots were originally platted and sold at a density of 3 to 4 per acre across much of the Slate Creek mudflow (Appendix A, Figure 10). The history of this and other fans indi-

cate, however, that over time these channels migrate back and forth across the entire fan surface much like a fire hose gone wild. The channel of Slate Creek has changed its course over the fan several times since the 1972 study. Inspection of early photographs and detailed topography and our field evaluation of the Marble fan show numerous old channels throughout the fan.

Debris flows of lesser magnitude but with the capability of considerable damage also occur at the mouths of Raspberry and Milton Creeks south of the landing strip. Serious flooding and debris deposition have been noted since development began.

Most of the drainages into the Crystal River downstream from Marble show strong mudflow and debris fan deposition, and have exerted considerable adverse impact on the roads and potential building sites.

3.2   Slope Instability Problems

Slope instability problems include deep soil creep, old landslides in various stages of instability which could easily be reactivated by construction, active moving landslide masses and potential unstable slopes where new slides could be activated by construction activity. Active landslides are relatively easily mapped. Old landslides which have undergone erosion and varying degrees of modification are more difficult to define. Precise delineation and prediction of the future behavior of potentially unstable slopes so common at Marble can be very difficult. Comparisons with similar geologic, topographic, and moisture conditions in previously failed areas can be useful. Many times evaluation becomes a complex geometric problem of relating attitudes of weakness planes in the rock to the original and post-construction ground surface taking into account future changes in groundwater conditions. A liberal use of "geo-logic" (earth study-horse sense) provides considerable insight into predicting future problems and many times is more reliable than precise mathematical calculations. Although potentially unstable slopes may appear quite innocent, they may be more hazardous to future activities than slopes that have stabilized after previous failure.

3.2.1 Landslides

The largest landslide deposit in the area occurs between Gallo Bluff and Carbonate Creek, northwest of the town site (Appendix A, Figures 4 and 6). As mapped by Gaskill (1966), Rogers and Rold (1972), and Robinson and Cochran (1973), it extends more than a mile in length. The main mass of this old landslide now seems quite stable, although significant construction and drainage changes could easily reactivate parts of the slide. The complex origin of the slide mass is poorly understood. It may have originated as one or a series of major catastrophic landslides from Gallo Bluff. Such a future catastrophic slide from the Gallo Cliffs is possible, and would imperil future development near its base.

North of the landing strip, a large anomalous area of talus and igneous bedrock is delineated and crossed by landslide-like scarps. Some of the valleys along the scarps roughly parallel the slope and are 100 feet wide and 30 feet deep. Very probably, the disturbed area is underlain by large bedrock blocks which are slowly sliding down the hill along bedding planes in the Mesaverde or sloping planes of weakness within or below the Raspberry Creek Phacolith. The overlying coarse talus exhibits many characteristics of rock glaciers. Patterns of leaning trees indicate a slow but continuing movement that could be markedly accelerated by excavations in the toe of the slopes.

A series of both active and inactive bedrock slides in the Mancos occurs along the east bank of Carbonate Creek (Appendix A, Figure 4, Location 1a to 1e). Here, the Mancos Shale and its planes of weakness dip gently to the northwest into the deeply incised canyon of Carbonate Creek. Detailed mapping by Robinson and Cochran (1973) indicated discontinuous but prominent landslide release fractures along a zone nearly a mile long east of and paralleling the creek. Each of these slides and potential failures could have provided serious problems to the condominiums and high density facilities once planned at the base of the ski lifts.

One small, active, and growing landslide (Appendix A, Figure 4, Location 1c) triggered several interesting reactions. The previous developers recognized the slide from Gaskill's mapping. They avoided the slide itself but planned multistory condominiums immediately to the south, east, and north without determining the ultimate extent of the slide failure. During a wet period in May 1973,

the slide began to move rapidly and erratically (as much as several feet of movement were observed in one day). Townspeople immediately grasped the potential of a major block of Mancos Shale falling into the stream, temporarily creating a dam. The dam could quickly overtop and plunge a mud and debris flood into the Marble town site. Unpalatable choices faced the decision-makers in preparing for the possible event. The lower channel flow might be diverted to either the east or the west, thus condemning that part of the remaining town site, or the channel could be left alone in hopes the flow would remain in the present channel and harmlessly cover that portion of the town site previously destroyed in the 1941 and 1945 mudflows. Fortunately, the wet period ended before total collapse of the slide mass, and it returned to slow, periodic movement. Hopefully, Carbonate Creek's continued erosion of the toe may periodically remove small portions of much of the slide mass and avoid a possible catastrophic release. One must be aware that the risk still exists. Sometime in the future a large slide could dam the canyon of Carbonate Creek. Overtopping of that dam could cause a catastrophic debris flow into the town site. A large debris flow could easily plug the present channel and divert itself either to the east or west.

3.2.2 Potentially Unstable Slopes

A large typical area of unstable slopes (Appendix A, Figure 4, Location 1f) has been mapped on the slopes northeast of the town site. Although we saw little evidence of past failures during the site visits (Fall 1995), the steep slopes, weak, severely-jointed Mancos Shale bedrock and spring snow melt saturation indicate serious potential slope stability problems. The prediction of Rogers and Rold (1972),

> "Most slopes in this part of Mt. Daly range form 30% to 60%. Excavation of any cut
> slopes which will have the effect of steepening existing slopes and daylighting weak
> surficial layers will pose serious long-range stability problems."

came to pass May 14, 1975. A section of new road approximately 150 feet long and part of two condominium sites released as a wet landslide. Incorporation of additional runoff water quickly converted the material to a debris flow which poured rapidly down the mountainside into Beaver Lake. Observers in the valley reported hearing a grinding, rumbling sound and then being treated to a dramatic display of violent geologic processes that lasted only a few minutes. The lesson was not

lost on the county or the developer who then agreed to previous recommendations to greenbelt numerous condominium sites in similar geologic conditions.
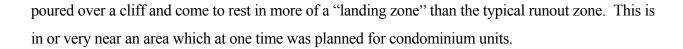
3.3   Avalanches

Although recognized by the earliest winter travelers, avalanches made their first entry into the history book March 7, 1912, when one hit the quarry operation and killed the timekeeper. Two weeks later, a large avalanche hit the processing mill "smashing it like an eggshell" (Vandenbusche 1970). The timing at 6:00 a.m. was fortunate because it was between shifts; the mill was unoccupied and there were no casualties. By 1915, a marble buttress wall 50 feet high had been constructed to protect the mill. Successive slides that winter filled the valley and then overtopped the wall going into the mill again. The next summer, the wall was raised to 65 feet and the mill was reportedly safe after that.

Because of the abundant geologic evidence of avalanches and the historic problems, they were evaluated and mapped during the CGS study. Later, a more detailed evaluation of avalanche hazards was conducted by Mears (1975) (see Drawing 6) as part of a CGS statewide evaluation of avalanche hazards. Persons interested in additional details of the avalanche problems in Marble or in general are referred to that publication, *Colorado Snow Avalanche Area Studies and Guidelines for Avalanche Hazard Planning,* Special Publication 7 of the CGS and its sequel, Bulletin 49 (Mears 1992).

In the Marble area, avalanche hazards are concentrated in two areas.

Avalanches present definite hazards on and near the base of the north-facing slope across the Crystal River from the mill site and westward where Mears mapped 11 separate tracks (Appendix A, Figure 4, Locations 4a and 4b). These tracks were shown on the original master plan for multi-family condominium units at a density of ten per acre, although it was indicated that the tracts would be reserved until snow accumulation studies were completed.

The second area of concentration consists of very large avalanches off of Elk Mountain, Gallo Bluff, and Mount Daly. At Gallo Bluff (Appendix A, Figure 4, Location 3c), an interesting avalanche has

poured over a cliff and come to rest in more of a "landing zone" than the typical runout zone. This is in or very near an area which at one time was planned for condominium units.

4.0   HYDROLOGIC SETTING

The geomorphology of the Crystal River drainage basin at Marble and upstream controls the hydrology and land forms in the study area. It is comprised of numerous ridgeline basin divides, hill slopes, and channel courses. The Crystal River drainage basin is the manifestation of geologic processes and is part of a subsystem controlled by the erosion, movement, and deposition of sediment moved by gravity and the surface water discharge. The Crystal River system can generally be described as having three zones. The first zone is the upper-most area of the watershed where much of the sediment and water are derived. The second zone is the zone of transfer where the river system transports both water and sediment. The third zone is referred to as the zone of sediment deposition or zone of aggradation (Chorley et al. 1984).

Within the Marble study area, zone 1 includes both the Carbonate and Slate Creek drainages. The valley bottom including Beaver Lake is a transition location between zones 1 and 2 for this portion of the Crystal River basin. This transition area, also referred to as a confluence plain, serves as the discharge point for the Lost Trail, Yule, Raspberry/Milton, Carbonate, Slate, and the North and South Forks of the Crystal River. Upstream of the study area, the North and South Forks of the Crystal River drain a 45-square-mile area, and the combined area of all drainages discharging into the Marble confluence plain is approximately 131 square miles.

Surface hydrology features of the zone 2 transition area include confluence points and alluvial deposition areas for each of the drainages mentioned herein, as well as Beaver Lake adjacent to the Town of Marble. Beaver Lake has a surface area of 28.5 acres and a water volume capacity of approximately 200 acre-feet (AF). Beaver Lake and the adjacent wetlands represent a localized "base level" which serves as a sediment deposition area for the upland drainage basins. The aerial extent of Beaver Lake and the wetlands are also significant because they represent a ground water recharge area for alluvial sediment deposits that serve as the primary domestic water source (aquifer) for the Town of Marble and adjacent low elevation sites.

The immediate setting of the Marble Ski Area Filings is generally characterized by steep, mountainous, southerly-facing slopes ranging in elevations from 8,000 to 10,000 feet with adjacent peaks and

high-mountain watershed rising to above 12,000 feet. The subject ski area filings are typically well-covered with fairly dense vegetation on land with slopes often over 30 percent.

4.1   Precipitation

Official detailed long-term weather records are not available for the Marble area. However, the Colorado Climate Center data indicates Marble precipitation to be similar to the Redstone Weather Station. The precipitation characteristics of that station are presented in Table 1 for 1992, 1993, and for an estimated average year. The average year is portrayed graphically in Figure 1 below. These data indicate that precipitation at Marble averages about 26 inches per year of which approximately one-half occurs as snowfall.

TABLE 1
REDSTONE WEATHER STATION PRECIPITATION

Month	Year 1992[1]		Year 1993[2]		Average Year[3]	
	Precipitation (inches)	**Monthly Distribution (percent)**	**Precipitation (inches)**	**Monthly Distribution (percent)**	**Precipitation (inches)**	**Monthly Distribution (percent)**
Jan.	0.61	0.03	3.32	0.11	1.97	0.070
Feb.	1.74	0.08	5.04	0.17	3.39	0.123
Mar.	3.04	0.13	1.82	0.06	2.43	0.097
Apr.	1.05	0.05	2.54	0.09	1.80	0.066
May	2.39	0.10	3.43	0.12	2.91	0.110
Jun.	0.54	0.02	1.10	0.04	0.82	0.030
Jul.	2.25	0.10	1.38	0.05	1.82	0.072
Aug.	3.21	0.14	2.31	0.08	2.76	0.109
Sept.	1.16	0.05	1.93	0.07	1.55	0.058
Oct.	1.57	0.07	2.82	0.10	2.20	0.082
Nov.	3.48	0.15	2.88	0.10	3.18	0.124
Dec.	2.03	0.09	0.86	0.03	1.45	0.059
Total	**23.07**	**100.00**	**29.43**	**100.00**	**26.25**	**100.00**

[1] 1992 precipitation was slightly below normal.
[2] 1993 precipitation was slightly above normal.
[3] The average of 1992 and 1993 of 26.25 inches is similar to the average annual precipitation shown for Redstone on the Colorado Climate Center isohyetal map of precipitation.

FIGURE 1
REDSTONE AVERAGE/YEAR PRECIPITATION (1992-1993)

Snow survey measurements were made near Marble in December 1972 and January 1973 at 25 points along 2¼ miles of trail between 9,400 and 10,800 feet elevation (Table 2).

TABLE 2
SNOW SURVEY MEASUREMENTS

Winter 1972-1973 Above Normal Year	December	January
Average snow depth, inches	33.0	41.0
Maximum depth	44.0	52.0
Minimum depth	13.0	23.0
Average water equivalent, inches	7.3	11.4
Maximum water equivalent	11.0	15.5
Minimum water equivalent	1.0	5.0

Runoff from the watersheds of Carbonate Creek and Slate Creek represents about one-half of the total precipitation volume, with the other one-half being consumed by sublimation, evapotranspiration, and local aquifer recharge. Much of the runoff from the lower slopes occurs as surface runoff

from the land surface via the stream system. Due to the nature of the soil stratum, recharge to the groundwater system is modest.

No official detailed precipitation measurements are available for the Crystal River Valley in the Marble vicinity, but high intensity summer storms frequently occur. While annual precipitation averages about 26 inches at Marble, the highest parts of its watershed receive as much as 50 inches. Growing season (May through September) precipitation should average about 12 inches at Marble to perhaps 16 at the highest elevations.

4.2 Surface Water Hydrology

Two principal streams drain the major portion of the subject ski area filing: Slate Creek and Carbonate Creek. Both are tributary to the Crystal River.

The Crystal River, as gauged at the Pitkin County-Gunnison County line several miles downstream of Marble, has an average annual flow of 215,000 AF. The unit runoff of the basin averages 1,278 AF per square mile, or 2.0 AF (650,000 gallons) per acre of land in the basin.

The Slate Creek and Carbonate Creek drainages represent the focal point of the Marble Ski Area Filing hydrologic setting. The drainages are flood prone, they transport sediment, they erode the channel banks and they deposit alluvial and debris flow fans at the lower elevations. Carbonate Creek is a potential source of water supply to the Marble Water Company, and for that reason the low flow hydrology of Carbonate Creek has been studied with results presented in Table 3.

TABLE 3
CARBONATE CREEK LOW-FLOW HYDROLOGY

Basin Area : 5.6 square miles
Mean Elevation : 10,520 feet
Mean Annual Precipitation : 32 inches
Mean Basin Slope : 0.4 ft./ft.[1]

	Mean Monthly Discharge (cfs)								
	Q[2]	a	A	b1	P	b2	EB	b3	SB
October	1.8	0.00164	5.6	0.969	22	0	5.52	3.16	0.4
November	1.2	0.00243	5.6	1.02	22	0	5.52	2.65	0.4
December	0.9	0.00205	5.6	1.04	22	0	5.52	2.55	0.4
January	0.7	0.00176	5.6	1.05	22	0	5.52	2.52	0.4
February	0.7	0.00265	5.6	1.06	22	0	5.52	2.24	0.4
March	0.8	0.01780	5.6	1.06	22	0	5.52	1.21	0.4
April	2.3	0.12700	5.6	1.07	22	0.373	5.52	0	0.4
May	15.7	0.56000	5.6	0.895	22	0.602	5.52	0	0.4
June	31.8	0.04740	5.6	0.800	22	0	5.52	3.04	0.4
July	11.4	0.000394	5.6	0.859	22	0	5.52	5.19	0.4
August	3.6	0.000201	5.6	0.963	22	0	5.52	4.81	0.4
September	2.2	0.000396	5.6	0.965	22	0	5.52	4.12	0.4
Average	**6.1**								

Lows (cfs)									
2-Year, 7-Day	0.5	0.000277	5.6	1.08	22	0	5.52	3.31	0.4
10-Year, 7-Day	0.2	2.54E-05	5.6	1.14	22	0	5.52	4.27	0.4
50-Year, 7-Day	0.2	3.39E-06	5.6	1.18	22	0	5.52	5.13	0.4

(1) Slope is *not* used for mean monthly and low flow calculations.
(2) The Q's calculated above by regression relations for "Mountain Region" in *Estimation of Natural Stream-flow Characteristics in Western Colorado,* USGS Water Resources Investigations Report 85-4086.

Carbonate Creek has a drainage basin of 5.6 square miles, while Slate Creek is approximately 0.9 square miles. Annual runoff in the two basins is estimated as follows:

	Area	Approximate Annual Runoff
Carbonate Creek	5.6 square miles	3,500 AF
Slate Creek	0.9 square miles	500 AF

While a detailed hydrologic study usually addresses site specific discharge rates, sediment yield data, stream channel dimensions and other related field observations; this types of hydrologic study is beyond the scope of this investigation. To provide a hydrologic evaluation for this study, the measurement of regional drainage basin land surface features has been determined from U.S. Geological Survey (USGS) topographic maps. The intent of this type of investigation is to deduce whether the Slate and Carbonate Creeks have obviously different stream geomorphologic characteristics or if similar process rates occur within all of the associated drainages. A total of 118 first order steams within the Crystal River drainage system were measured for six variables. Second-, third-, and forth-order stream segment data was also reviewed but not analyzed. Table 4 lists the basin geometry for each of the seven listed basins.

TABLE 4
BASIN CHARACTERISTICS FOR SELECTED STREAMS

Basin	Area (mi^2)	Channel Length (miles)	Drainage Density (mi/mi^2)	Frequency of channel	Basin Length (miles)	Relief (ft)
Slate	0.9	1.6	1.7	2.0	1.4	3806
Carbonate	5.6	14.8	2.6	3.1	4.5	4573
Lost Trail	7.9	17.4	2.2	2.3	5.9	4710
N. Crystal	19.5	33.6	1.7	1.5	8.3	5292
S. Crystal	18.8	34.2	1.8	1.8	7.5	4662
Yule	12.3	20.8	1.8	1.8	7.1	5502
Raspberry	7.4	11.7	1.6	2.4	3.9	4650

4.2.1 Column Description

Basin Area: The area of the basin in square miles

Channel Length: The total length of channels within the basin expressed in miles

Drainage Density: Channel length divided by the basin area

Frequency Density: Number of channels divided by the basin area

Basin Length: Length of the basin in miles

Relief: Highest point minus lowest point within the basin

4.2.2 Analysis and Information Pending

Two methods of statistical analysis were applied to the spatial data obtained for the listed drainage basins. The first statistical test is referred to as the Pearson Product-Moment Correlation Coefficient (*r*). This test is used to measure the strength or degree of relationship between the variables. The *r*-Coefficient analysis answers the question of whether individual drainages are similar in a geometric sense. Numeric relationships indicate that the channel length, overland flow area, basin length, elevation (relief), slope, and basin area for each of the drainages are similar. This infers that physical processes such as headwork erosion rates, sediment yield, channel geometry, and stream discharge rates are probably similar for each basin.

The second statistical analysis performed on the data sets, was a Multiple Regression Prediction (Y). Each data field was tested as a dependent variable in relation to the other data sets. This analysis indicates that two parameters, the basin area and the distance of overland flow, have a weak correlation to the other variables. This implies that other factors such as soils, geology, vegetation, and drainage aspect have a significant influence upon the distance of overland flow and basin area. Basin slope, elevation change, basin length, and channel length, however, show a strong degree of association. The basin length, channel length, relief, and slope control the bed channel gradient and, consequently, the potential energy which also influences a basin's geomorphology.

Because the correlation analysis implies that first-order basins are similar, observations in relation to other studies can be made. Trimble (1977) measured 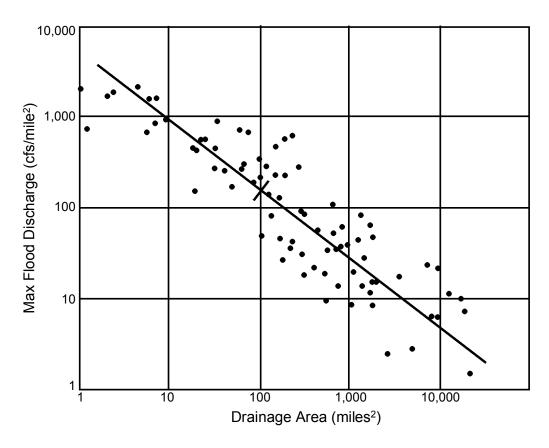the maximum flood discharge in relation to drainage basin areas in Colorado. Figure 2 shows that maximum flood discharge per unit area increases significantly in small basins such as those within the study area. These data suggest that a smaller basin such Slate Creek would have higher unit rates of runoff than larger streams, which is a well-established fact when other parameters are similar.
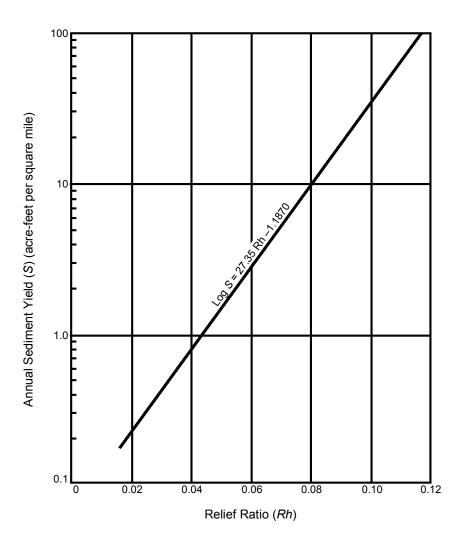
FIGURE 2
MAXIMUM UNIT FLOOD DISCHARGES VERSUS
AREA IN SQUARE MILES

Schumm (1963) analyzed the average sediment yield for small basins (under 1 mi^2) underlain by sedimentary strata in the western United States. This study showed that sediment yield increases exponentially with increased basin relief (see Figure 3). Both of these studies, along with the spatial data established for the study area, imply that small basins are subject to short periods of intense flooding and have the potential to erode and transport a significant amount of material in relation to their discharge potential. Slate Creek is well-known for its high and troublesome sediment yield. The analysis illustrates that the Slate Creek mudflows and debris fan are consistent with its hydrologic and geologic character. Carbonate Creek has many of the same problems as Slate Creek because of the shale deposits there coupled with a steep stream gradient which has caused deposits in the Town of Marble.

FIGURE 3
SEDIMENT YIELD RELATIONSHIP TO
TOPOGRAPHIC RELIEF (STEEPNESS)

Plot of Annual Sediment Yield (S) (acre-feet per square mile) versus Relief Ratio (Rh). Line labeled $\text{Log } S = 27.35\ Rh - 1.1870$.

4.3   Groundwater Hydrology

The surficial deposits outside of the Crystal River floodplain provide relatively poor groundwater resources under the ski area filings. The surficial deposits chiefly result from glaciation and fluvial action during and since glaciation about 10,000 years ago. Drawing 4 shows their distribution. As the glaciers moved down the major stream valleys, they scoured out the bedrock and pre-existing surficial deposits. The eroded material was deposited by the glaciers as moraines or by water flow-

ing from the glaciers as glacial fluvial deposits. The glacial erosion oversteepened the sides of the valleys and, as a result, talus deposits formed during and since the glaciation. Weathering of the bedrock and morainal deposits since glaciation and weathering of the talus deposits has formed fine-grained colluvial deposits. Recent streams flowing across the bedrock and surficial deposits erode the materials in their beds and at other localities deposit their loads to form alluvial fans, alluvial terraces, debris and mudflows, and channel alluvial deposits.

4.3.1 Morainal Deposits

Morainal deposits are composed of till left by the glaciers. The glaciers moving down the stream valleys oversteepened the bedrock slopes and blocks of bedrock, or talus, fell from the walls and formed mixed talus and morainal deposits. Moraines consist of slightly rounded boulders, gravel, sand and clay deposited by the glaciers. The deposits were dumped along the margins and below the glaciers and form unstratified, poorly-drained deposits with a hummocky topography. Locally, outwash streams from the glaciers flowed across the morainal deposits as they formed. Fluvial deposits formed from morainal material were incorporated within the moraines. The moraines were deposited at their natural angle of repose or above—some failed and slid downslope at or shortly following deposition. Most of the morainal slopes, like the colluvial slopes, are moving slowly downslope under the force of gravity. The mechanics of deposition and subsequent erosion cause highly varying thicknesses of these deposits. These factors also provide erratic and fairly low permeabilities for water flow.

4.3.2 Colluvial Deposits

Colluvial deposits are formed by the residual weathering of bedrock and older surficial deposits. The deposits of colluvium occur along the slopes between areas of outcrop on the sides of the valleys of the Crystal River and Carbonate and Slate Creeks. The colluvial deposits move downslope under the force of gravity. The rate of movement is determined by the thickness of the deposit, the slope, and the moisture content. Whereas the colluvium in this area derived largely from Mancos Shale and morainal deposits, permeability is generally fairly low and quite erratic.

4.3.3 Alluvial Deposits

Alluvial deposits are formed by running water. They include deposits that were formed, and are being formed, by the present streams. Included also are alluvial terraces that were deposited by the streams when they flowed at a higher level than present, alluvial fans formed where tributary streams flow out into a valley, and deposits of debris and mud left by floods. The principal deposits of alluvium are found along the Crystal River. The alluvium is derived chiefly from the upland areas and the streams reworking glacial or glacial fluvial deposits, colluvial deposits, and pre-existing alluvium. The deposits consist of sand, silt, gravel, and boulders. Therefore, permeabilities are usually quite high. This provides good well yields, but within deposits of gravels and boulders, the permeabilities are often too high for adequate septic systems.

4.3.4. Alluvial Terraces

Alluvial terraces were formed by the Crystal River when it flowed at a higher level. The alluvial terraces consist of silt, sand, and boulders that were derived from pre-existing deposits. In general, they are stable and can be developed.

4.3.5. Alluvial and/or Debris Flow Fans

Fans in the Marble area result from both alluvial and debris flow processes. Most of the material in the fans was emplaced by debris or mudflows during high-intensity thunderstorms. Flood waters carry colluvium and alluvium from the steep headwaters as well as material eroded from unstable channel banks. As the channel gradient moderates, the boulders, gravel, sand and mud settle out as a poorly-sorted mass. This material has poor permeability. During normal or spring runoff, perennial streams rework this material, winnowing out the mud and silt providing linear channels of sand and gravel, with fair to excellent permeabilities in upstream and downstream directions. Later, mud and debris flows bury these channels and the process repeats itself in a different location. If a well on a fan penetrates one or more of these permeable linear lenses, good recovery can result. If a leach field encounters these permeable lenses, water pollution can result. Earlier workers mapped these deposits as alluvial fans, but later workers (Rogers and Rold 1972), determining that most of the material originated from mud and debris flow processes, mapped them as debris flows. A more de-

tailed description of the fans along Carbonate Creek, Slate Creek, Raspberry Creek, and Milton Creek and their origin is discussed in Section 3.0, Geologic Constraints to Development.

4.3.6 Spring Deposits

Small deposits of calcareous tufa—sponge-like masses of calcium carbonate—occur at several places on the south-facing slopes between Gallo Hill and Carbonate Creek. These deposits result from groundwater precipitating calcium carbonate as the water flows to the surface. These spring deposits are typically in swampy areas. The exposed part of the deposits are about 100 to 200 square feet in aerial extent. The deposits are estimated to range from 5 to 10 feet thick. The material is a light brownish gray to very light gray sponge-like mass of fine-grained limestone that contains abundant remains of vegetative matter locally. Some of the deposits are still being formed by active springs. Other old deposits indicate where springs once existed.

4.3.7 Groundwater

Limited amounts of groundwater occur in surficial deposits throughout the Marble ski area filings. The bedrock has been baked, which destroyed, at least in part, the original porosity and permeability. The groundwater in the bedrock is confined to joints and fractures in the rock. The amount of groundwater in the bedrock is small and usually contains minerals dissolved from the surrounding rock. The bedrock fractures should not be considered as good sources of usable water.

The groundwater occurs chiefly in the surficial deposits. The alluvium in the stream valleys is saturated to the stream level. During the period of snowmelt and spring runoff the alluvial fans, alluvial terraces, moraines, and colluvium are saturated. During the summer, fall, and winter months, the groundwater levels gradually drop. Swamps occur where the groundwater surface intersects the topographic surface. Springs occur where the groundwater flow is forced to the surface. The swamps or swamp deposits and areas of springs or spring deposits are unstable, and unless the drainage is modified should be avoided in the development of the area. These swamps and springs constitute wetlands which also form an impediment to development.

4.3.8 Faults and Joints

Faults are fractures in the bedrock along which there has been movement of one side in relation to the other. They may range from simple breaks, where the sides are only an inch or less apart and the relative movement was less than a foot, to zones of brecciated rock that are tens of feet wide along which the movement may have been several thousand feet. Joints are simple fractures in the rock along which there has been little or no movement. An individual joint does not usually extend for more than a few feet along its strike. Major faults in some areas can be followed for miles. It can be presumed, because of the extensive cover of surficial deposits, that there are many more faults in the bedrock. In the area east of Carbonate Creek several northwest-trending faults were mapped in the bedrock. These are normal faults with the downslope side of the fault downdropped. The movement along the faults is estimated to be less than 100 feet of vertical displacement.

West of Slate Creek and east of Gallo Hill, and on the southwest slope of Gallo Hill along the sill of quartz monzonite porphyry, are two major northeast-trending faults. These faults are normal faults with the southeast side downdropped in relation to the northwest side. It is estimated that the movement along these faults is less than 100 feet of vertical displacement.

Fault zones are rarely exposed in the study area because they are zones of weakness and erode easily. The relation of the faults trends and the topography indicate most faults dip steeply. In general, the fault zones are vertical and 1 to 3 feet wide. The zone between the walls of the faults is filled with angular fragments of bedrock in a clay gouge. The fault zones in the sedimentary rocks are tight and usually do not serve as channels for the movement of groundwater. The faults in the igneous rock probably are more open, and may serve as channels for the groundwater movement.

Joints are conspicuous in the bedrock outcrops. The joints in the sedimentary rocks—mostly measured in the ski area east and west of Carbonate Creek—strike about N. 45° W. and dip steeply southwest or northeast. The strike of the joints is about parallel to the faults and the axis of the syncline to the southwest, and are probably related to these major structural features in origin. The joints, in general, are tight. A thin selvage of clay usually occurs along a typical joint.

The faults and joints can provide a source of groundwater. Most of the faults are stable and there will be no movement along the faults unless a fault block on the downslope side is undercut during the course of development. On the east side of Carbonate Creek fault blocks in bedrock have been undercut by the erosion of Carbonate Creek. These fault blocks probably will move with time and continued erosion of Carbonate Creek. Buildings should not be founded on bedrock across faults because there could be differential compaction of the bedrock on either side of the fault as the rock adjacent to the faults is typically more highly jointed or fractured. Joints would be capable of transporting limited quantities of leaching field effluent.

4.4 Soil Permeability

Permeability is one of several factors limiting the suitability of soil for septic tank use. Other factors include slope, water table, groundwater return flow paths, domestic well locations, etc. Soil permeability also provides a major control for infiltration and groundwater recharge.

Drawing 8 does not consider any factor other than permeability as a limitation to the use of septic tanks or groundwater recharge. Any subsequent map will use some different soil series names which may alter some of the USFS interpretations. The Natural Resources Conservation Services (NRCS), formerly the Soil Conservation Service, has not yet correlated the mapping units to soil series in Colorado. Since the NRCS has additional information on septic tank soil suitability and permeability, some of the limitations may change.

The reference map uses "stop light" colors with:

- <u>Red</u> indicating severe limitation of infiltration or leaching field use due to permeability ratings greater than 101 minutes per inch.

- <u>Yellow</u> indicating moderate limitation due to permeability rating between 100 and 61 minutes per inch.

- <u>Green</u> indicating slight limitation due to permeability rating equal to or less than 60 minutes per inch.

These interpretations are generalized by mapping unit for planning purposes. Any unit may contain inclusions of other soils, which may have different limitations. Septic tank placement always requires an on-site investigation. The following briefly describes the characteristics of the soil within each area:

AREA 104A
Permeability Limitations:
> Slight to severe because:
> Major soil type (65% Cryoborolls) has variable permeability from high to low.
> The 104A soils are situated in areas subject to flooding and high water table.

Conclusion: Slight to severe limitation.

> Wide range of permeability

AREA 203B
Permeability Limitations:
> Slight in major soil type (60% Handran), which has a permeability of 15 minutes per inch.
> Slight in second major soil type (30% Gateview) which has a permeability of 46 minutes per inch.

Conclusion: Slight limitation due to permeability.

> 6 to 60 minutes per inch—90%

AREA 210D
Permeability Limitations:
> Slight in major soil type (60% Cryoborolls), which has a permeability of 18 minutes per inch.
> Severe in second major soil type (25% Rock Outcrop), which has permeability rates greater than100 minutes per inch.

Conclusion: Slight to severe based on permeability.

> 6 to 60 minutes per inch—60%
> 101 to 500 minutes per inch—25%

AREA 212C
Permeability Limitations:
> Slight in major soil type (90% Scout), which has a permeability of 15 minutes per inch.

Conclusion: Slight limitations based on permeability.

> 6 to 60 minutes per inch—90%

AREA 281B
Permeability Limitations:
> Generally high permeability, but site-specific as to permeability.

Conclusion: High permeability.

> Partially in excess of 5 minutes per inch

AREA 333C

Permeability Limitations:

Severe in major soil type (60% Hern), which has a permeability of 461 minutes per inch. Slight in second major soil type (30% Kolob), which has a permeability of 54 minutes per inch.

Conclusion: Mostly severe limitations with some specific sites having slight limitations.

Greater than 101 minutes per inch—60%
Less than 60 minutes per inch—30%

AREA 347B

Permeability Limitations:

Severe in major soil type (50% Callings), which has a permeability of 461 minutes per inch. Slight in second major soil type (40% Skylick), which has a permeability of 46 minutes per inch.

Conclusion: Mostly severe limitations with some specific sites having slight limitations.

101 to 500 minutes per inch—50%
Less than 60 minutes per inch—40%

AREA 354B

Permeability Limitations:

Severe in major soil type (60% Argic Cryoborolls), based on D. Kimsey's opinion. Moderate in second major soil type (35% Typic Cyroboralf), which has a permeability of "Moderate" according to USFS.

Conclusion: Mostly severe limitations with some specific sites having moderate limitations.

101 to 500 minutes per inch—60%
61 to 100 minutes per inch—35%

AREA 376C

Permeability Limitations:

Severe in major soil type (90% Collings), which has a permeability of 461 minutes per inch.

Conclusion: Severe limitations.

101 to 500 minute per inch—90%

AREA 385D

Permeability Limitations:

Slight in major soil type (50% Scout), which has a permeability of 15 minutes per inch.

Severe in second soil type (25% Rock Outcrop), which has permeability rates greater than100 minutes per inch.

Severe in third major soil type (20% Hechtman), which has bedrock at about 15 inches.

Conclusion: This mapping unit requires an on-site survey to determine limitations.

Less than 60 minutes per inch—50%
Greater than 101 minutes per inch—45%

AREA 420C

Permeability Limitations:

Slight in major soil type (60% Subwell), which has a permeability of 46 minutes per inch.
Severe in the second major soil type (25% Duffymont), which has bedrock at about 15 inches.

Conclusion: Slight limitations.

Less than 60 minutes per inch—60%
Greater than 101 minutes per inch—25%

AREA 546B

Permeability Limitations:

Slight in major soil type (85% Cryoborolls), which has a permeability of 18 minutes per inch.

Conclusion: Slight limitations.

Less than 60 minutes per inch—85%

AREA 546C

Permeability Limitations:

Slight in major soil type (75% Cryoborolls), which has a permeability of 18 minutes per inch.
Severe in second major soil (25% Rock outcrop), which has permeability of greater than101 minutes per inch.

Conclusion: Slight to severe depending on depth to bedrock.

Less than 60 minutes per inch—75%
Greater than 101 minutes per inch—25%

AREA RO/RL

Permeability Limitations:

Severe in major soil type (100% Rock outcrop), which has a permeability of greater than100 minutes per inch.

Conclusion: Severe.

Greater than 101 minutes per inch—100%

AREA 254D

Permeability Limitations:

Severe in major soil type (40% Rock outcrop), which has permeability of greater than100 minutes per inch.
Severe in the second major type (30% Leighcan), which has a permeability of greater than100 minutes per inch.
Severe in third major soil type (20% Hechtman), which has bedrock at about 15 inches.

Conclusion: Severe.

Greater than 101 minutes per inch in bedrock—90%

AREA 348B
Permeability Limitations:
>Severe in major soil type (85% Tellura), which has a permeability of 46 minutes per inch.
>Severe in second soil type (7% Eyre), which has bedrock at about 17 inches.
Conclusion: Slight.

>6 to 60 minutes per inch—85%

AREA 317C
Permeability Limitations:
>Slight in major soil type (60% Stonyridge), which has a permeability of 46 minutes per inch.
>Severe in second soil type (25% Eyre), which has bedrock at about 17 inches.
Conclusions: Slight to severe limitations.

>6 to 60 minutes per inch—60%
>Greater than100 minutes per inch—25%

AREA 395D
Permeability Limitations:
>Slight in major soil type (40% Scout), which has a permeability of 15 minutes per inch.
>Severe in second major type (30% Rock outcrop), which has a permeability of greater than100 minutes per inch.
>Slight in third major type (25% Cryoborolls), which has a permeability of 18 minutes per inch.
Conclusion: Slight to severe depending on depth of bedrock and slope.

>6 to 60 minutes per inch—65%
>Greater than100 minutes per inch—25%

AREA 602C
Permeability Limitations:
>Slight in major soil type (85% Handran), which has a permeability of 15 minutes per inch.
Conclusion: Slight limitations.

>6 to 60 minutes per inch—85%

AREA 376B
Permeability Limitations:
>Severe in major soil type (90% Collings), which has a permeability of 461 minutes per inch.
Conclusion: Severe limitations.

>Greater than100 minutes per inch—90%

4.5   Groundwater Movement

Groundwater originates as rainfall and snowmelt. Its infiltration into the soil and its downward percolation to the water table are heavily influenced by the surface slope and permeability of the soil

and shallow impermeable layers, other surficial materials and shallow bedrock. Upon reaching the water table, the water moves in a downslope direction roughly following the topography. The direction and rate of movement depends heavily on the slope of the water table and the permeability characteristics of the material. Clay retards water movement. Shale bedrock is highly impermeable but water can move rapidly through its fractures. Water moves slowly through sand or permeable sandstone, but in coarse gravels as found along the Crystal River or lower Carbonate Creek, it will move several feet or more per day. If the water table is at or above the level of a stream, water flows into the creek increasing its flow. If the water table is lower than the level of a stream, water will percolate downward from the streambed toward the water table. This decreases the flow of the stream.

In the study area, rain and snowmelt on the slopes percolate downslope. Some of the groundwater flows into tributary streams. Other water remains underground until it reaches the alluvium along and under the Crystal River. Just below the confluence, with Rapid Creek downstream from the study area, the Crystal River flows through a bedrock channel. By that time, groundwater will have moved out of the alluvium into the surface flow.

4.6   Groundwater Availability

Both confined aquifers (bedrock faults and joint system water sources) and unconfined aquifers are found in the area. In general terms, confined aquifers have added forces regulating the piezometric head. Unconfined aquifers in the area are characterized by saturated unconsolidated sediments found in the Crystal River valley bottom and in the colluvium up on the side slopes. Unconfined aquifers have a head pressure approximately equal to the atmosphere and, as such, the actual water table level represents the aquifer head pressure.
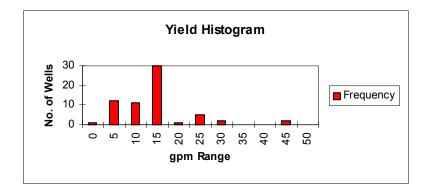
While excellent groundwater is available in the Crystal River valley bottom, the subject ski area filings generally do not have good groundwater availability. Nevertheless, over 65 registered domestic and commercial wells exist in the study area where files of the Colorado State Engineer's Office (SEO) indicate well yields range from 0.3 to 45 gallons per minute (gpm). Depth to water for the water table ranges from 0 to 140 feet, the 0-foot depths representing a seepage-type condition or spring for which several permits exist. The locations of the permitted wells have not been plotted on
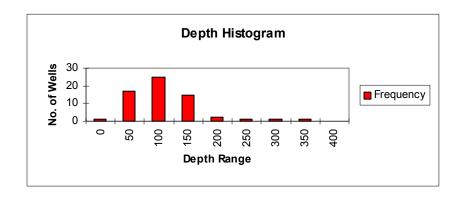
the maps because the permit locations are not adequate to identify location to the 0.3-acre lot level of accuracy. The depth of wells ranges from 10 to 305 feet. Data for the wells is presented in Figure 4. Appendix B provides official data from the SEO on the permitted wells in the study area.
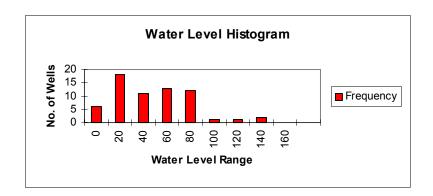
Statistically, the opportunity for developing successful domestic and commercial wells beyond the aquifers most closely associated with the Crystal River and lower Carbonate Creek is marginal. In the marginal zones, 60 percent of the wells attempted have, in fact, been dry. Of the dry hole first attempts, 90 percent of the second attempts have also been dry with 10 percent of the second attempts yielding slightly more water. Approximately 20 percent of the drilling customers request a third test hole.

Collins Drilling Company was interviewed in regard to well drilling history in the area. In general, the Marble area wells are good producers adjacent to the Crystal River and poor producers on the mountain. The influence of Mancos Shale formations severely limits the success of wells. Wells along Slate Creek have been marginal (<5 gpm based on drillers' testing).

FIGURE 4
YIELD, DEPTH, AND WATER LEVELS OF WELLS
MARBLE, COLORADO

According to Mike Collins, approximately one half of the wells in Marble are considered poor or marginal. Those located furthest away from the Crystal River and Carbonate Creek have the lowest yields. Wells are reported to be low (0 to 4 gpm) north of Beaver Lake (including Beaver Lodge). Good producing wells are located south of the road to Beaver Lake on the Carbonate Creek fan. The Marble Ski Area Subdivision has several good-producing wells (15 to 30 gpm) up to approximately the 8,080-foot contour. For example, at the 7,920-foot contour, a well 70 feet deep produces 30 gpm; at the 8,000-foot contour, a well 100 feet deep produces 25 gpm; and at the 8,080-foot contour, a well 120 feet deep produces 10 gpm. The above wells are located on the first, second, and third switchback, respectively, of the ski area road.

In summary, the available groundwater for residential wells above approximately the 8100-foot contour interval does not appear adequate for subdivision development relying on individual wells.

5.0   WATER QUALITY MANAGEMENT

The management of water quality for both groundwater and surface water resources in the upper Crystal River basin is an important consideration for long-term viability of water supplies. Of special interest is the cumulative effect of ISDS installations in the basins of Carbonate Creek and Slate Creek because of the Town of Marble urbanization where both the Marble Water Company and individuals have water supply wells. Whereas a community sewage waste collection and treatment system is not available now nor likely to be constructed in the foreseeable future, present and future homeowners must depend on ISDSs. In order to understand this problem and methods available for Gunnison County to address the situation, one must understand the workings of a septic system, factors affecting the proper operation of the system and regulations applying to the system.

The depositional zone of the Crystal River represents a rich and prolific underground alluvial aquifer water resource where good wells can be constructed that yield substantial rates of flow of high-quality water low in nitrate, phosphorous, pathogens, and other ISDS-related pollutants. It is important to manage and protect the Crystal River's underground resource.

The first step in protecting the alluvial aquifer of the Crystal River is to obtain baseline data on the aquifer extent, its characteristics, the water quality of the water in the aquifer, and its recharge areas.

While the fast-flowing surface stream of the Crystal River is measured in many thousands of acre-feet per year and over 40 cubic feet per second even at low flow, the flow in the alluvial aquifer is small and at low velocities. Once groundwater is polluted, it takes much longer for pollution to be cleared, and then only with major actions and significant cost.

5.1   *Mechanics of Operation of Septic Leaching Systems*

The concentration of chemical constituents and bacteria derived from sewage and household waste constitutes the main potential groundwater pollution problem in the study area. Leaching field systems are the most common ISDSs. Properly installed and maintained systems can be a viable method of sewage waste treatment and disposal.

In a leaching field system, household wastes are piped to a septic tank which retains the solids, part of which settle out as sludge, as the wastes are digested by various chemical and bacteriological processes in an anaerobic environment. Some nitrogen is removed as nitrogen gas in these processes. The fluids are then discharged by pipes into a leach field where aerobic reactions occur. Biological and chemical activity further break down any remaining solids and many of the dissolved chemical compounds. A biological mat in the leach field consisting mainly of organisms, such as bacteria and fungi, assist by filtering the effluent. As the waste material percolates from the leach field into the soil, the mineral particles and humic matter of the soil also adsorb many of the chemicals. Bacteria are continually dying, and in addition, are filtered out of the leachate. In this aerobic environment, nitrogen tends to be converted to nitrates which are soluble and remain in the leachate. The fluid then percolates down to the water saturated zone.

The following is a more-simplified version of the above explanation: Waste materials flow into the septic tank where heavier solids settle out and fatty substances rise to the surface. Bacteria slowly digest the waste and then convert it into simple chemical compounds. Sludge and scum are retained in the septic tank as effluent flows out and into the leach field. Digestion of organic pollutants by bacteria continues in the leach field, where in the presence of oxygen, protozoa prey on the bacteria and keep the soil pores open. With the soil pores open, the effluent filters down through the unsaturated soil with the removal of bacteria occurring in the first few feet.

5.2   *Factors Affecting Leaching Field Operation*

Several factors can interfere with the proper functioning of the septic tank leach field system and result in groundwater quality degradation. These factors are the density of sewage treatment systems (the distance between separate systems), inadequate distance between septic systems and wells, inadequate soil thickness, soil permeability, too steep a surface slope, shallow water table, and improper usage and maintenance.

Density of Treatment Systems. If treatment systems are too closely spaced, they accumulate the pollution load and interfere with each other and result in pollution of the water table.

Inadequate Distances Between Wells and Septic Systems. If a well is placed too close to a septic system the effluent from the leach field will not have been adequately treated before it flows into the well and is pumped to the surface. Both the CDPHE and Gunnison County require a 100-foot horizontal distance from the well head to the nearest point of the leach field.

Soil Thickness. To assure adequate treatment of septic tank effluent, the soil profile should be thick enough and have adequately-developed horizons to allow complete filtration and digestion of the waste by bacteria before the bedrock or the water table is encountered. Normally, this requires at least 4 feet of adequate material <u>below the bottom of the leach field and above bedrock or the water table</u>.

Permeability. The soil beneath and around the leach field must be permeable enough to allow the effluent to pass through it but not so permeable that waste passes through it too quickly and without complete treatment. Permeability is measured with percolation tests and is usually rated as the number of minutes it requires for the water level in the percolation hole to drop 1 inch. If the water level drops 1 inch in less than 5 minutes, the soil material is too permeable to allow for adequate treatment of the effluent. Normally, this occurs in gravels, coarse sands, or highly fractured bedrock. If the percolation rate is slower than 60 minutes for a 1-inch drop in the water level of the percolation hole, the soil is not permeable enough to allow the leachate to pass through it and the leaching system will plug. Normally, these are clay soils or impermeable bedrock.

Slope. If the slope of the surface of the ground at the septic tank location is too steep, the effluent from the leach field will percolate sideways as well as downward and come to the surface forming a leachate spring. Normally, this occurs on slopes greater than 20 percent.

Shallow Water Table. A shallow water table can interfere with proper functioning of the leach field. If the water table is too close beneath the leach field, then the effluent will not be adequately treated and the effluent will pollute the groundwater zone. Normally, this problem occurs when the water table is within 4 feet of the base of the leach zone or approximately 8 feet from the surface of the ground. Whereas, the water table in most areas fluctuates between the wet season and the dry season, one should be certain that these water levels relate to the water table during the wet season or

high water table season of the year. It does little good to measure a water table at 10 feet in the dry season of the year and then have the water table rise during the spring to where it is within 1 to 2 feet of the base of the leach field.

Improper Usage and Maintenance. Septic tank leach field systems will fail if they are improperly used or maintained. Depending upon the use of the leach field, the septic tank needs to be pumped out at regular intervals. If the septic tank becomes overloaded, solids will be forced out of the tank into the leach field. Suspended material in the waste will then clog the soil pores and cause effluent to rise to the surface of the leach field. Overloading can be caused by an inadequately sized septic tank or supplying more waste to the tank than it was designed for. Many types of household chemicals may also destroy the bacteria in the septic tank and prevent the proper functioning of the system. Also, as part of the normal operation, septic tanks, even when functioning properly, will accumulate sludge. This sludge needs to be pumped out on a periodic basis or it will fill the tank and flow into the leach field causing damage. Regrettably, most septic tank users do not realize that they have a problem until the septic effluent backs up into their home, comes to the surface of the ground or is detected in their water well (Hofstra and Hall 1975, and Hall et al. 1980).

5.3   Regulatory Aspects

Discharge of pollutants to groundwater is regulated by the Colorado Water Quality Control Commission (CWQCC) under Basic Standards for Groundwater, 3.11, 5 CCR 1002-8. In the case of septic systems, the primary mechanism for administering these regulations is through wastewater discharge permits for individual systems discharging greater than 2,000 gallons per day (gpd). For those septic systems that discharge less than 2,000 gpd, counties are responsible for issuing permits. The CWQCC assumes that, if the septic system meets either the county's regulations or state ISDS guidelines which are even more stringent, then adverse impacts to groundwater are not likely to occur. Thus, the primary regulations pertinent to the Marble study area are the "Gunnison County Individual Sewage Disposal System Regulations" which were adopted on June 20, 1995.

5.4 Summary of Gunnison County Individual Sewage Disposal System (ISDS) Regulations

The promulgation and enforcement by Gunnison County of regulations for ISDSs are authorized by state law, mainly CRS 25-10-101, 29-20-101, 30-21-101, 30-15-401, 30-20-101, 30-28-101 and 30-28-102. These Regulations are an integral part of a comprehensive land use sanitation, public works and public health, safety and welfare regulatory process in Gunnison County. The general policies of Gunnison County are to have consistent, plentiful and clean water, to protect the water resources for the purpose of maintaining the high quality of the water-dependent environment in the county, and to not adversely affect the availability or suitability of water for present or future uses in the county.

The following summarizes the pertinent regulations aimed at achieving their policies. The reader, before considering construction of a septic leaching system, is referred to the Gunnison County ISDS regulations as of June 20, 1995. Those factors which are underlined in the following discussion are those which are addressed in this report.

1. An ISDS permit is required and a building permit will not be issued until an ISDS permit has been issued or the house is connected into a central sewage disposal system. While each application regarding an ISDS will be evaluated in the context of the site and land use it is proposed to service, the issuance of an ISDS permit is not a guarantee that a County Land Use Change Permit, Building Permit, Driveway Permit or other required permit will be issued for a related project, nor is the issuance of any other required permit a guarantee of the issuance of an ISDS permit.

2. After application for a permit, a site inspection is required to evaluate the size of the property, a verification of the groundwater table, suitability of the soil, depth to bedrock, <u>ground slope</u>, the location of water supply systems, the location of the disposal system with reference to <u>water courses</u>, <u>lakes</u>, <u>ditches</u>, structures and other pertinent physical and environmental features. A determination of the general soils, <u>geology</u>, and <u>hydrology</u>, and an evaluation of the soil where the percolation tests are located are required.

3. No system shall be permitted on a parcel of land less than 1 acre in size.

4. There shall be no installation of ISDS systems in <u>a floodway</u>. No new system, new component, or extension of an existing system shall be installed, extended or repaired, or relocated wholly or partially in a 100-year floodplain unless that system and component meet or exceed all requirements of the National Flood Insurance Program as it may be amended and the Gunnison County Flood Damage Prevention Resolution as it may be amended.

5. No system shall be constructed in a wetland or within 100 feet horizontally from a wetland. Any system at a site which lies within 300 feet of a wetland that is 10 acres or greater in size, and is hydrologically connected to that wetland, must meet special design and requirements.

6. Percolation tests must utilize three holes approximately 5 to 8 feet apart, dug to a minimum depth of 3 feet below the surface or to the depth of the bottom of the proposed absorption field, whichever is greater. Percolation tests shall follow the specific regulations and requirements set forth by the County.

7. There shall be a soil profile hole dug to a depth of 8 feet or to impervious bedrock, whichever is shallower. This excavation hole must be large enough to permit observation of the soil profile and indicate if the soil zone 4 feet below the bottom of the proposed absorption system is a groundwater capillary zone.

8. Test holes must show that the depth of the maximum seasonal groundwater table would be at least 5 feet below the bottom of the proposed soil absorption system during the time of the year when groundwater is highest.

9. <u>Suitable soil must be proven to be at least 4 feet in thickness</u> below the bottom of the leaching zone and above bedrock and at least 4 feet above the maximum seasonal groundwater table. The soil shall have permeabilities at a rate between 5 minutes per inch and 60 minutes per inch.

10. The <u>slope of the leach field shall not exceed 20 percent</u>.

11. The design flow of the system shall be at least 150 percent of the predicted average flow calculated on the basis of 2 persons per bedroom or 3.5 persons per dwelling, whichever is greater.

12. Permits shall expire one year after date of issuance unless construction is completed and approved.

13. All sections of the ISDS must be set back <u>100 feet from a spring</u> or well and <u>100 feet from a lake, water course, stream or irrigation ditch</u>.

14. The absorption area must be contained wholly within the parcel and maintain a minimum setback of 10 feet from the parcel boundary.

15. No driveways, walkways, corrals, structures, or other soil compacting uses may exist over the absorption area.

16. Seepage pits, evapotranspiration systems and vault systems are prohibited.

17. Gray water systems must meet all minimum design and construction standards for an ISDS.

5.5   *Crystal River, Slate Creek And Carbonate Creek Classifications*

The Crystal River is Segment 8 of the Roaring Fork River Basin and is part of the Council of Governments (COG) Planning Region 12. Segment 8 is defined as the mainstem of the Crystal River, including all tributaries, lakes, and reservoirs from the source to the confluence with the Roaring Fork River, except for the mainstems, tributaries, lakes, and reservoirs of Coal Creek and North Thompson Creek. Crystal River classifications are Aquatic Life 1, Recreation 1, Water Supply, and Agriculture. It carries no temporary modifications or qualifiers. Mr. David Holm of the CWQCC confirmed that there are no changes pending in the classifications for the Crystal River. Contrary to the original CWQCC schedule, the Crystal River will not be included in the next triennial review by the CWQCC, which is due sometime around mid-1997. It is now planned to include it in the following triennial review.

The Crystal River is classified for Aquatic Life 1 and Recreation 1, which are not use protected. However, as with other streams with a similar class, the Crystal River is managed as if it carried the former High Quality designation. This means that the Crystal River is subject to antidegredation review.

5.6   In-Stream Flow

Table 5 shows the decreed minimum flows for the Crystal River.

TABLE 5
DECREED MINIMUM FLOWS FOR THE CRYSTAL RIVER
(Obtained from Colorado Water Conservation Board on September 6, 1995)

Decreed Name	Decreed Amount (cfs)	Location
Crystal River	100.0 (5/1 - 9/30) 60.0 (10/1 - 4/30)	Avalanche Creek to confluence with Roaring Fork River
Crystal River	80.0 (5/1 - 9/30) 40.0 (10/1 - 4/30)	Carbonate Creek to Avalanche Creek
Lower Crystal River	45.0	Yule Creek to Carbonate Creek
Upper Crystal River	35.0	North and South Forks of Crystal River to Yule Creek
South Fork Crystal River	17.0	Rock Creek to North Fork Crystal river
North Fork Crystal River	20.0	Headwaters to South Fork Crystal River

Table 6 shows some summary Crystal River water flow data measured at a gage station above Avalanche Creek near Redstone, Colorado. It can be seen that minimum flow requirements of 40 cfs between October 1 and April 30 are not always met, but that in general, the minimum flow requirements are substantially exceeded.

TABLE 6
SUMMARY FLOW DATA FOR THE CRYSTAL RIVER
(Above Avalanche Creek near Redstone, Colorado)

Summary Statistics	WY 1956-1994 (cfs)	Cal Y 1992 (cfs)	WY 1993 (cfs)	WY 1994 (cfs)
Annual Mean	298	227	441	257
Highest Annual Mean	468 (1957)	—	—	—
Lowest Annual Mean	107 (1977)	—	—	—
Highest Daily Mean	3,500 (6.25/83)	1,260 (5/21)	2,600 (6/17)	1,690 (6/4)
Lowest Daily Mean	22 (12/5/55, 2/15/64, 1/2/78, 2/17-18/78)	31 (12/20	31 (12/20	42 (1/31)
Annual 7-Day Minimum	27 (2/11/64)	42 (1/31)	38 (2/27	49 (1/28

5.7   Critical Water Quality Parameters

Because the Crystal River classification does not include a Use Protected qualifier, the antidegradation rule will apply. This rule states that no water quality degradation is allowed unless deemed appropriate to permit important economic or social development. Such a determination is made in a public antidegradation review by the CWQCC. At a minimum, the water quality necessary to protect all existing classified uses will be maintained and protected and no further water quality degradation will be allowed which would interfere with or be injurious to these uses. The classified uses will be deemed protected if the narrative and numerical standards established for the classified uses are not exceeded.

The existing water quality in the Crystal River for metal, inorganic, and organic parameters is better than that specified in the Basic Standards for protection of aquatic life, Class 1, and Recreation and Class 1 uses. A query to Dennis Anderson of CWQCC confirmed the present high water quality of the Crystal River. Mr. Anderson stated that the water quality parameter of greatest concern currently is sediment from Coal Creek. The high sediment load in Coal Creek arises both naturally from the geologic character of the Coal Creek Basin and because of past coal mining activities. Coal Creek lies several miles downstream on the Crystal River and, therefore, is not relevant to the Marble area. Appendix C contains a tabulation of water quality test results from 1979 to 1992 in the Crystal River.

5.8 Allowable Pollutants

Given the applicability of the CWQCC standards and pollutants typically associated with septic tank/leach field effluent, the primary pollutant of regulatory concern expected to be associated with septic tank/leach field effluent is nitrate. Nitrate was selected as the limiting pollutant from the regulatory perspective for several reasons including: (1) pollutants associated with septic tank/leach field contamination are commonly known to be nitrate and viral/bacterial contaminants (Canter and Knox 1985); (2) nitrate is known to be highly mobile in subsurface environments, while viral/bacterial contaminants are more easily adsorbed onto soils (particularly clayey soils, such as those at the site) (Canter and Knox 1985); (3) the regulatory limit for nitrate is low relative to typical nitrate loadings in septic system effluent; and (4) nitrate concentrations are quite low in undeveloped and uncontaminated stream systems.

The CWQCC interim narrative standards for nitrate correspond to the maximum contaminant levels (MCLs) under the primary drinking water regulations established by the Safe Drinking Water Act (SWDA), the Colorado Public Drinking Water Act (CPDWA), and the CWQCC stream water quality standards. The CWQCC interim narrative basic groundwater standards for nitrate are shown in Table 7.

TABLE 7
CWQCC NUMERIC STANDARDS FOR NITRATE IN GROUNDWATER

Nitrogen Form	Domestic	Agricultural
Nitrate as N (dissolved)	10 mg/L	NA
Total Nitrate + Nitrite (dissolved)	10 mg/L	100 mg/L
Nitrite as N (dissolved)	1 mg/L	NA

Under the CWQCC regulations, the point of compliance for new facilities to meet groundwater standards is "the hydrologically downgradient limit of the area below the activity potentially impacting groundwater quality" (CCR 3.11.6, D.2). Under the 1990 revisions to the regulations, the point of compliance is the vertical surface downgradient from the regulated activity (as opposed to a point directly below the activity); however, the CWQCC reserves the right to identify an alternative point of compliance on a case by case basis.

Because nitrate is expected to be the limiting pollutant with respect to groundwater contamination, an understanding of nitrate concentrations typically associated with septic system effluent as well as nitrate's behavior in the unsaturated and saturated zones is important.

The total nitrogen in septic tank effluent, which is routed to the leaching field has a concentration of 40 mg/L (Canter and Knox 1985). Most of the nitrogen is converted to nitrate-nitrogen, which is referred to as nitrate.

Nitrate is very soluble and, therefore, mobile. It moves freely with groundwater without retardation. Therefore, the primary means of reducing nitrate concentrations is by dilution.

The 40 cfs winter (10/1-4/30) in-stream flow decree for the Crystal River downstream of Carbonate Creek and the 45 cfs year-around decree for the short reach upstream of Carbonate Creek to the confluence provides enormous dilution potential. As will be shown later, the impact of a large number of properly installed leaching fields in the Marble area would not substantially degrade the water quality of the surface flow of the mainstream due to nitrate loading. Other pollutants, such as pathogens, could have an adverse effect on its water quality. The groundwater in the Crystal River alluvial aquifer, however, is more susceptible to pollution than is the surface flow.

The tributaries of Slate Creek and Carbonate Creek are a different matter, however. These two creeks are subject to the same antidegradation rules as those which apply to the Crystal River.

As will be discussed later, the pollution potential of Slate Creek and Carbonate Creek is more severe from the standpoint of mountainside development.

5.9   *Typical Flows And Nitrate Loads*

A typical Equivalent Residential Unit (EQR) for the purposes of this water quality management study only is defined as:

1.   Single Family Residence (SFR);

2.   Two Bedrooms;

3.   Four Persons/SFR;

4.   Design capacity of 1.5 times average flow;

5.   Average flow for four persons times at 75 gallons per day (gpd) or 300 gpd; and

6.   Design capacity of 1.5 times 300 gpd or 450 gpd

Based on the above Equivalent Residential Unit (EQR), a typical leaching field area is assumed to be 1,000 square feet with a "design flow" of 450 gpd. However, this analysis is based on the 300 gpd estimated actual flow.

Using a nitrogen (N) concentration of 40 mg/L, the pounds of N per day per EQR is computed as follows:

$$N \quad = \quad 300 \text{ gpd x } 8.34 \text{ lbs/gal x } \frac{40}{1{,}000{,}000} = 0.10 \text{ lbs/day}$$

$$= \quad 37 \text{ lbs/year per EQR}$$

5.10   Pollution Constraints

To determine whether or not groundwater and surface water pollutional limitations would provide a constraint to the number of leaching fields in the subject study area, five types of impacts were investigated. They are:

1. Impact on the surface water flow of the Crystal River;

2. Impact on the groundwater of the Crystal River alluvial aquifer;

3. Impact on Carbonate Creek;

4. Impact on the shale bedrock; and

5. Impact on the colluvial aquifer.

5.10.1 Impact on the Surface Water Flow of the Crystal River

The decreed winter low flow in the Crystal River at the USGS gaging station below Marble is 40 cfs. The decreed year around in-stream flow of the CWQCC immediately upstream of Marble is for 45 cfs.

Assuming an allowable maximum N concentration of 10 mg/L during the low flow period of the Crystal River with ½ the N pollution being derived from the balance of the Upper Crystal River basin, the Marble Ski Area Filings development would hypothetically be allowed to utilize 50 percent of the dilution capacity of the river (example only).

The N loading of 100 EQR leaching fields is computed as follows:

1. 100 leaching fields would contribute 11 million gallons per year to the groundwater. With an average N concentration of 40 mg/L, the loading of N per year is 3,650 lbs/year, or 10 lbs per day.

2. One cfs of flow in the Crystal River with a pollution assimilation capacity of 5.0 mg/L would allow the addition of 26.9 lbs of N per day.

3. The potential assimilation capacity of the Crystal River at Marble would be 269 EQR per cfs of river flow.

4. The minimum flow of the Crystal River at 40 cfs would, therefore, allow up to 40 times that amount or 10,760 EQR of N pollution from the subject development.

5. Therefore, considering N pollution of the Crystal River as a limiting factor, a large number of EQRs could be constructed at the study area. Considering N only, the Crystal River is not a constraint to residential development of the Ski Area Filings.

5.10.2 Impact on the Groundwater of the Crystal River Alluvial Aquifer

Using the analysis described above for the surface flow at the Crystal River, assuming that the groundwater flow averages a total of 1 cfs for illustrative purposes and that 50 percent of the resi-

dences on the Ski Area Filings contribute leaching field leachate to the Crystal River alluvial aquifer, the following conclusions are reached.

1. 100 leaching fields in the Ski Area Filings would contribute 5.5 million gallons per year of leachate to the Crystal River alluvial aquifer with an average N concentration of 40 mg/L. The loading of N per year is 1,825 pounds per year, or 5 pounds per day.

2. One cfs of flow in the alluvial aquifer with a pollution assimilation capacity of 5.0 mg/L would allow the addition of 26.9 pounds of N per day.

3. The potential assimilation capacity of the Crystal River alluvial aquifer at Marble would be 538 EQR.

The above illustration tends to illustrate that the Crystal River alluvial aquifer is a constraint to the development of the Ski Area Filings. For that reason, baseline water quality data and alluvial aquifer characteristics should be determined for the Crystal River alluvial aquifer sediment deposits so as to be able to define the pollutional impact on the important water resource, which is a domestic water source for the Town of Marble.

5.10.3 Impact on Carbonate Creek

Carbonate Creek is a special case because the creek flows through the Marble town site and the creek recharges the alluvial aquifer into which water supply wells are drilled. The following provides an approximate method for estimating the pollutional impact on the surface flow of Carbonate Creek.

Assuming that the annual average flow in Carbonate Creek is 3,500 AF with a low flow condition of 1 cfs, a 7 mg/L measure in nitrate nitrogen would ultimately represent a daily contribution of nitrate-nitrogen to Carbonate Creek calculated as follows:

1. One cfs represents 646,000 gpd of water per day weighing 5.4 million pounds.

2. The allowable NO_3-N contribution of 7 mg/L is computed as follows:

$$5.4 \text{ million pounds x } \frac{7}{1,000,000} = 37.8 \text{ pounds of N/day}$$

3. With 1 EQR contributing 0.10 lbs of N per day, the allowable pollution load for leaching fields inflow would be 378 EQR. In the event the creek flow was at 2 cfs, the allowable number of EQR contributing pollutants to Carbonate Creek would be 756, twice that for a 1 cfs flow.

Taking into consideration the effluent from leaching fields, the cumulative pollutant impact of NO_3-N would impact Carbonate Creek surface flows at a relatively high level of leaching field density in the Carbonate Creek basin. Direct discharge of effluent to Carbonate Creek would have a numerically somewhat lower, but similar impact on the quality of Carbonate Creek. However, with a surface discharge, the impact would also relate to questions of harmful organisms, such as fecal coliform bacteria and viruses, during times that the sewage treatment plant malfunctioned.

This example provides a simplified approximate procedure for computing the carrying capacity of a basin under steady-state future conditions after pollutant inflow become equal to pollutant outflow.

5.10.4 Impact on the Shale Bedrock

Shale bedrock is characterized as having secondary permeability created by cracks and joints extending downward with varying distances, but generally no more than about 50 feet. The following approximate procedure provides a method of estimating the pollutional impact on a bedrock aquifer.

Assuming one such crack or fissure per 10 feet on the average and each crack or joint having a rate of flow capability of 0.5 gpm, a 209-foot-wide section of the aquifer would have a groundwater flow capability of approximately 10 gpm, or 14,400 gpd.

The question to be answered would be the number of leaching fields in series down the slope (steady state) and in long-term service before the groundwater would reach 10 mg/L of N with 3 mg/L being due to natural and other sources.

1. A flow of 14,400 gpd which would have a capability of assimilating 0.84 lbs of N per day is derived as follows:

2. 14,400 gpd x 8.3 lbs/gal x 7 mg/L ÷ 1,000,000 = 0.84 lbs/day of N

3. One EQR contributes 0.10 lbs of N per day. Therefore, a total eight residences extending in series up slope parallel to the groundwater table would be the limit before the ground water would reach its regulatory limit of 10 mg/L of N under the bottom-most lot in a series of eight residences.

4. The rate of water transmission of 10 gpm represents 14,400 gpd. Eight EQRs would represent a flow of 300 gpd x 8 = 2,400 gpd. Thus, the likely carrying capacity of the shale bedrock aquifer would be adequate to transmit the effluent, the pollutional loading of N being the constraint to development.

5.10.5 Impact on the Colluvial Aquifer

The colluvial deposits on the subject study area vary in thickness, permeability and depth to groundwater from area to area. For purposes of the evaluation, a condition as follows is selected:

Colluvium Depth	30 Feet
Depth to Water Table	10 Feet
Permeability of Aquifer	50 gpd/$\overline{FT}^2$
Slope of Water Table	15 Percent

For analysis purposes, a 160-acre rectangular tract is tested with 120 residential lots. The lower edge of the tract is one-quarter-mile-wide (1,320 feet). The following planning parameters result.

1. 120 EQR would produce 13,100,000 gallons per year of leachate (36,000 gpd).

2. The N loading of the 120 leaching fields would be 4,380 pounds/year (12 pounds/day).

3. Underflow in the Colluvium aquifer, using Darcy's Law of Q = PIA results in a discharge of 7.2 x 10^7 gal/year (198,000 gpd).

4. Assuming a maximum of 10 mg/L of N allowable in the groundwater of which 3 mg/L is contributed by natural and other sources, the 120 EQR would be allowed to increase the concentration of N in the groundwater by 7 mg/L.

5. With steady state conditions, the pollution dilution potential of the groundwater underflow of 198,000 gpd plus the added 36,000 gpd of leachates, would be approximately 234,000 gpd x 8.34 lbs/gal x 7 mg/L ÷ 1,000,000 = 13.7 lbs/day. This is higher than the 12 pounds per day allowable.

6. The groundwater water quality management plan, based upon keeping the groundwater within regulated limits for concentration of N, would then allow for about 105 homes on the 160-acre tract, or a minimum ***gross*** lot size of approximately 1.5 acres. The sample tract would have a length equivalent to about 18 lots in the direction of flow and a width of approximately 6 lots.

7. The example illustrates the cumulative effect of a series of residences on a long 1/4 section with leaching fields in sequence down the slope of the groundwater gradient.

8. The example lot layout and assumed aquifer characteristics, when coupled with the configuration of the subject colluvium deposit area, would indicate that a minimum ***net*** lot size of 1 acre would likely be satisfactory. This would assume that about 35 percent of the gross acreage was dedicated to roads, easements, and open space.

Regrettably, the colluvium in many areas has less than the required 8 feet of thickness which would be a severe limitation to ISDS.

5.11   ISDS Permit Application Rejection Scenarios

The following example scenarios represent conditions related to less than adequate permit applications. For each, an engineering recommendation is given.

1. Shallow, seasonal water table. Reject due to likely groundwater pollution.

2. Rapid ground testing permeability in excess of five minutes per inch. Reject due to likely groundwater pollution.

3. Percolation rates of 100 minutes per inch or less. Reject due to likely leaching field failure and pollution of the ground surface.

4. Request for use of evaporative system. Reject due to low evaporation in winter and during rainy periods which would leach to ground surface pollution.

5. Request for use of sewage vaults. Reject due to likely leaky joints and probable poor maintenance.

6. Request for use of "Wisconsin Leaching Fields" which represent use of fill to increase depth to a seasonable high water table. Reject due to likelihood of leaching field sideways leakage and pollution of the ground surface.

7. Request for a small mechanical system such as characterized by former Purecycle systems. Reject due to reliance on need for regular maintenance and potential for manufacture and maintenance firm to go out of business.

8. Request for individual small gravity-flow/storage-filtration system. Reject due to likelihood of lack of regular cleaning of detention storage and plugging of sand filter which would lead to direct discharge of untreated wastes onto ground surface or to stream.

9. Installation of leaching field in colluvial landslide-prone area. Reject due to the adverse result of adding more leachate groundwater to an unstable area. More water would contribute to the instability of the landslide-prone colluvial material.

10. Use of cut and fill to create suitable leaching field area. Review survey and engineering plans considering all stated regulatory requirements, including the need to create a 4:1 horizontal-to-vertical ratio between the leaching field bed edge and the natural ground surface. In the Ski Area Filings, most natural ground slopes are too steep to create a suitable leaching field area by using cut and fill.

11. Request for leaching field on land with shallow, fractured-shale bedrock. Reject due to pollution potential of water in fractures and joints of shale bedrock.

12. Request for leaching field on small lot. Reject due to need to avoid cumulative impacts of a high concentration of leaching and to avoid constraints related to spacing between wells and leaching fields.

6.0   EXPLANATION OF MAPS

There are nine maps provided with the report to assist the reader in understanding the complex geo-logical and engineering problems associated with the potential development of the Marble Ski Area Filings. They are all presented at a useful scale of 1 inch = 600 feet. The maps are:

1. Topographic Map;

2. Slope Map;

3. Plat Map;

4. Surficial and Engineering Geologic Map;

5. Slope Stability Evaluation;

6. Specific Hazards;

7. Soil Limitations to Leach Fields;

8. Soil Permeability; and

9. Development Limitations.

All maps were prepared by trained professionals and represent reasonable interpretations of complex data from various sources. In some instances conflict may exist between some data sources and the maps on a site-specific basis. For that reason, site specific questions should be resolved via a site specific analysis.

6.1   Topographic Map

This important map portrays the slope and shape of the land surface. It also serves as an index showing creeks and other features referred to in the report. The 25 foot contours of our map were digitized by Wright Water Engineers, Inc. (WWE), from a 1 inch = 500 feet, 5-foot contour interval source map. Detailed topographic data was not readily available, and therefore, WWE digitized the

map from a blue line print map in the Robinson and Cochran report. Topography for that map had been photogrametrically derived by Merrick and Co., for Ketchum, Konkel, Barrett, Nichol & Austin. Neither company had retained the original maps in their files. The topographic map forms part of the base for several of the maps in this report. It is the basic data for the slope map.

6.2   Slope Map

Utilizing digital data from the topographic map, a detailed slope map was computer generated by WWE. That detailed slope map portrayed slope brackets of 0 to 8 percent, 9 to 15, percent 16 to 20 percent, 21 to 30 percent, and steeper than 30 percent. Whereas the County regulations prevent septic tank construction on slopes greater than 20 percent and allow them on slopes gentler that 20 percent, a simplified derivative map showing only two areas—greater than 20 percent and less than 20 percent—is submitted with this report.

6.3   Plat Map

The plat map was furnished in digital format by Gunnison County. The development status shown reflects information supplied by Gunnison County. The map was prepared to provide a basis for data evaluation. Because well locations in the State Engineer's Office are not detailed enough to locate on individual lots, we were unable to portray that data. It in included as a table in the appendix.

6.4   Surficial and Engineering Geologic Map

The data for this map was prepared in 1972 by Robinson and Cochran as a work product of their detailed field study. This data was updated and modified slightly for this project. The resulting WWE map provides the basis for the five slope stability classifications used in portraying development limitation on later derivative maps. Specific features of the map are discussed in Sections 1.3, 2.0, and 3.0 of the report. Field work, both in the 1970s and during this project, has been used to check and generally verify this mapping.

Whereas surficial material blankets the underlying bedrock in most of the area, an engineering and surficial geology map provides more detail and usefulness for planning purposes than would a bedrock geology map.

6.5   Slope Stability Evaluation

Robinson and Cochran evaluated the slope stability of the study area and established five classifications of stability. The map legend defines the characteristics of each class. The field study and re-evaluation of their report verifies the validity of these classes for planning purposes.

Whereas water saturation is a major factor governing the stability of a landslide, the interrelationship between leaching field location and landslides should be an important consideration in the Marble area. Increased water saturation increases the weight and therefore the driving forces of a landslide. Increased water saturation weakens the internal structure of clayey materials and lubricates slide surfaces. Therefore serious problems can occur if a leaching field was to be constructed on or near a landslide. The slope stability evaluation map should be considered in acting upon ISDS permit requests.

6.6   Specific Hazards

This map portrays additional specific hazards to leach field construction and development, namely floodplains, avalanche paths and recent or active debris flows. Each would prevent or require serious mitigation investigation, design and construction for suitable site development. Planned construction within these areas should give special consideration to each of these hazards and conduct detailed site-investigation before proceeding.

Part of this map was derived from recent floodplain studies, part from Robinson and Cochran (1972) and part from the Rold-Wright field and government photo mapping. The avalanches were taken from Mears (1979).

6.7   Soil Limitations to Leach Fields

Soils data and maps from the NRCS and the USFS were digitized, mapped, and evaluated. The information is useful, but in a preliminary manner there are several reasons why the basic data and map would not be suitable for strict regulatory or policy making use at this time. For instance, the NRCS uses 15 percent slope as a severe limitation rather that Gunnison County's 20 percent. Furthermore, several of the soil classes are subject to change pending further actions by the Federal Agencies.

6.8   Soil Permeability

The soil permeability map represents permeability rates for soil mapping units and USFS interpretations which are subject to review by the NRCS.

6.9   Development Limitations

This map summarizes the limitations to ISDS and construction which are portrayed on each of the preceding maps prepared and assembled for this project.

Most of the red or severe limitations area results from the slope map which indicates much of the slopes in the Marble Ski Area filings exceed the 20 percent limitation. Other portions of the severe limitations area derive from highly unstable slopes, avalanche areas, active debris fans, and floodplains.

In using the above maps one must consider the scale and detail of the information available for preparing the maps. Detailed site specific investigation by competent engineering geologists and experienced professional engineers may find isolated adequate sites within areas shown as unfavorable.

7.0   CONCLUSIONS

The following is a list of conclusions drawn by the authors:

1. The methodology of transferring professional scientific and engineering findings related to natural resource characteristics to computer based digitized data based management (ARC/INFO) has been demonstrated to be practical.

2. The data based management system for the Marble Ski Area Filings is considered suitable for providing a basis for the development of appropriate land use and environmental policies and regulations.

3. The groundwater resources of the Marble Ski Area Filings are limited as to their viability to support significant and orderly residential and commercial development of the subject filings. However, the Crystal River bottom area, with the alluvial aquifer of the Crystal River, is a prolific water-supply area with good quality supplies available to wells of private parties and the Marble Water Company.

4. The potential for contamination of the limited groundwater resources under the Marble Ski Area Filings from independent sewage disposal systems is significant enough so as to justify adequate regulations and land use policies to protect the limited groundwater resources.

5. Based on nitrate loading evaluation, pollutional tendencies of independent sewage disposal systems at the Marble Ski Area Filings are *not* expected to cause any significant adverse impact on flow of the Crystal River surface stream. However, a large accumulation of such systems will likely adversely affect the groundwater quality of the Crystal River alluvium.

6. Currently available data indicates the waters of the Crystal River surface flow are now near pristine with little evidence of man-caused contamination.

7. The geologic constraints of mudflows, landslides and unstable slopes will prevent or seriously constrain construction on many of the platted lots and tracts in the Marble area. Little

can be done to overcome these constraints by either private individuals or government actions.

8. Applicants for building permits on tracts lying within stability classes III, IV and V on the Slope Stability Map; within areas having excessive flood and avalanches hazards; or the geologic hazard zones shown on the Engineering Geologic Map by Rogers and Rold (1972) should be required to conduct a site-specific floodplain and geologic investigation which would be reviewed by the CGS.

9. The soils and geologic data indicate that significant portions of the study area are infeasible for septic tank and leaching field construction. Even with detailed site investigations, many of these tracts will not be built upon.

10. Septic tank leaching systems should not be constructed on parcels of less than 1 acre in size.

11. Gunnison County present ISDS regulations, if strictly applied, will be adequate to safeguard the water quality and health of the community when utilized with the data in this report. Without strict application of the regulations and without relying on the report data and findings, the Ski Area Filings will cause a degeneration of the area and private and public costs.

12. Due to road width, traction limitations, grade, geologic, and geotechnical constraints, the existing narrow, unsurfaced access roads, particularly Serpentine Drive and the road between Slate Creek and Carbonate Creek, are not suitable for general public use. Widening, surfacing and bringing the main access roads up to county standards would be relatively difficult and expensive and would require higher and extended cut slopes, wider fills, and careful drainage control. Upgrading the roads would likely cause increased instability and landslide problems on steeper slopes.

13. Geotechnical constraints related to landslides would create hazards to utility pipelines due to potential settlement and fracturing at vertical displacements. Field inspections showed scarps in roadways which would cause shearing of water and sewer lines. Settlement of land

surfaces would cause low spots in drainage pipes and channels leading to water infiltration and further settlement and fracturing.

14. Specific baseline data should be collected for the Crystal River alluvial aquifer to define the following:

- Areal extent and depth;

- Permeability, transmissivity, and storativity;

- Quality of water and constituents;

- Well pumping rates;

- Recharge characteristics; and

- Water residence time in the aquifer.

8.0   REFERENCES

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APPENDIX A
THE MARBLE AREA
A DEVELOPMENT FRONTIER 1873-1977

THE MARBLE AREA
A DEVELOPMENT FRONTIER 1873-1977

by

John W. Rold[1]

ABSTRACT

Resource development, particularly in frontier areas, relates to two basic economic factors; the quality of the resource and therefore its price; and the cost of locating, developing, producing and marketing the resource. Geologic conditions usually play a major role in these factors.

The Marble area proves this thesis. Sedimentation, igneous intrusions, mountain building, glaciation and erosion produced high quality marble mineral resources as well as high quality scenic and recreational resources. From discovery of the marble resource in 1873 to the present, rugged inaccessible terrain, mudflows, avalanches, landslides and unstable slopes resulting from those same geologic forces have impeded development of first, the marble resource and, more recently, the recreational resources. As a result, the Marble area, from many standpoints, remains as much a development frontier as it was in 1873.

INTRODUCTION

Resource development in any area strongly depends on the interrelationship between two basic economic factors: the price to be received for the resource, and the cost of locating, developing and marketing that resource. These factors achieve even greater significance in frontier areas where their unpredictability and wide fluctuation promote and then impede or even halt development. Geologic characteristics normally play a major role in both these economic factors: the quality and, therefore, the value of the resource; and the location and, therefore, the cost factor of development and marketing it. Since 1873, attempts to develop both the marble mineral resource and the recreational resources of the Marble area have dramatically portrayed the results of this causal interaction between geology and economics. Repeatedly, the geologically rooted characteristics of high resource quality led to great expectations of a development boom only to be later doused by the geologically rooted technical problems and adverse costs of development, production and marketing. This interplay was first dramatically stated in the successive years of 1873 and 1874. Sylvester Richardson, who is credited with discovering the Yule marble deposits in August 1873 (Vandenbusche, 1970) was so impressed with the vast dome of marble on Treasure Mountain that he said,

"It's my opinion that this field will in time be a direct means of employment to thousands . . .and . . .in time, the average citizen of Gunnison may yet dwell in a marble hall . . .at a trifling cost."

In August of the following year, one of the adverse geologic conditions that would impede development was cited when W. H. Holmes, a geologist in charge of one of the early Hayden expedition parties, described a mudflow on the upper slopes of the Crystal valley as follows:

"On the 29th, a rainstorm had set in and everything was wet — thoroughly saturated. Muddy torrents poured down the upper slopes and dashed over the cliffs into the valley. Avalanches of wet earth carrying many rocks and trees formed near the summits and came roaring down, discharging great masses of debris into the river and tearing out such gorges in the alluvial bottoms as to make travel almost impossible."

Even in the 1870's, man had become aware of both the high quality of the resource and the adverse geologic conditions that would seriously affect the area's development.

GEOGRAPHIC SETTING

The Marble area lies in the northern portion of Gunnison County, Colorado in the Crystal River valley (Figure 1). Although the map distance to Gunnison is only 40 mi, one must travel 140 mi and over two mountain passes to reach the county seat by road. Marble, by highway, lies approximately 200 mi southwest of Denver. Normally, access to Marble today is by way of paved Colorado Highway 82 from Glenwood Springs and Interstate 70 to Carbondale; then, via Colorado Highway 133, to Placita. From Placita, an improved gravel road extends approximately six mi east up the Crystal River valley. Early day access to the valley was by trail and wagon road over Scho-
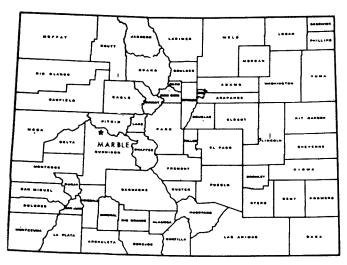
[1]State Geologist and Director, Colorado Geological Survey

Fig. 1 — Index map of Marble area.

field Pass, now an exciting and dangerous four-wheel-drive road.

GEOLOGIC SETTING

Regionally, the area lies between the southern edge of the Piceance Creek basin to the west and the Sawatch anticlinorium to the east. Locally, the Marble area centers on a broad, gentle, northwest-plunging syncline. This syncline has been modified by the Treasure Mountain stock, a prominent intrusive dome to the southeast, the Ragged Mountain laccolith and associated Raspberry Creek phacolith to the southwest and the Snowmass stock and Elk Range thrust to the northeast (Figures 2 and 3). Surficial deposits of varying thickness consisting of alluvium, landslides, mudflows, talus, colluvium and morainal material cover much of the area. Figures 2 and 4 portray the distribution of most of these pertinent deposits. Near the Marble town site, these surficial deposits lie on gently dipping Mesaverde Formation and Mancos Shale. To the southeast, the Treasure Mountain dome exposes a full section of Mesozoic and Paleozoic formations down to the Precambrian gneiss and its Tertiary granite-porphyry core. The Yule Marble, which is metamorphosed Leadville Limestone, crops out high on the southwest and northwest flanks of the dome. The Treasure Mountain intrusion has intensely metamorphosed the sedimentary rocks to distances of several thousand ft from the intrusive (Vanderwilt, 1947). To the northeast, the Snowmass stock and Elk Range thrust expose intrusive granodiorite and scattered outcrops of the Minturn and Maroon Formations. To the southwest, the Ragged Mountain laccolith of quartz monzonite porphyry intrudes into the Mancos Shale. The associated lens-shaped Raspberry Creek phacolith intrudes into the Mesaverde along the trough of the regional syncline. These intrusions mildly metamorphosed the adjacent Mesaverde and Mancos sedi-

ments. Scattered dikes and sills occur throughout most of the area.

GEOLOGIC HISTORY

Geologically, the history of the area pertinent to resource development began with the deposition of the Mississippian Leadville Limestone some 320 million years ago when a shallow tropical sea that extended from Mexico to Canada covered the area. Calcium carbonate ($CaCO_3$), derived from the shells of various marine organisms, accumulated in the bottom of the sea to a thickness of approximately 250 ft. The remains of these organisms became lithified into limestone shortly after deposition. Later uplift of the Ancestral Rockies, both to the east and west of the area, had little effect on the limestone deposits for they were covered by coarse debris shed from the mountain ranges. This 280-million-year-old stream-laid debris became the bright red Pennsylvanian Maroon Formation so apparent in the walls of the Crystal River valley near Redstone. The next geologic event important to the mineral resources and development of the Marble area occurred approximately 70 to 100 million years ago in Cretaceous time. A widespread sea again covered the area, but this time the deposition consisted mostly of dark gray mud, approximately 4,500 ft in thickness. This mud later lithified and became the shales of the Mancos Formation, which is well exposed in the lower part of Gallo Bluff to the north of Marble. During one of the retreats in this Cretaceous sea, the shoreline advanced northeastward across the area. Widespread forest and swamp conditions existed on the landward side of the ancient shoreline. As these forest and swamp deposits were later buried and lithified, they became the coal beds of the Mesaverde Formation. Both the Mesaverde and, especially, the Mancos Shale, are weak, easily erodible rocks, which have little structural strength when saturated. These characteristics contribute significantly to the general slope instability, and provide much of the material for the numerous landslides and mudflows in the area. Later, several igneous rock masses; particularly, the Treasure Mountain stock, the Snowmass stock and the Ragged Mountain laccolith intruded into the area. These large molten masses of rock provided the heat and the pressures to metamorphose, or alter, the thick limestone beds of the Leadville Formation into the Yule Marble, and to a certain extent, change the Mesaverde coals from moderate grade bituminous to high grade coking coals and even, in some cases, anthracite. Mountain building forces that may or may not have been related to these igneous intrusions uplifted the area to its present elevations. During the last million years, in the Pleistocene, glaciers formed in the high mountain valleys and carved the basic shape of the Crystal valley through the Marble area. The glaciers in many places left a thin veneer of morainal material and formed the oversteepened, unstable valley walls in the soft bedrock of the Mancos and Mesaverde Formation, thus set-
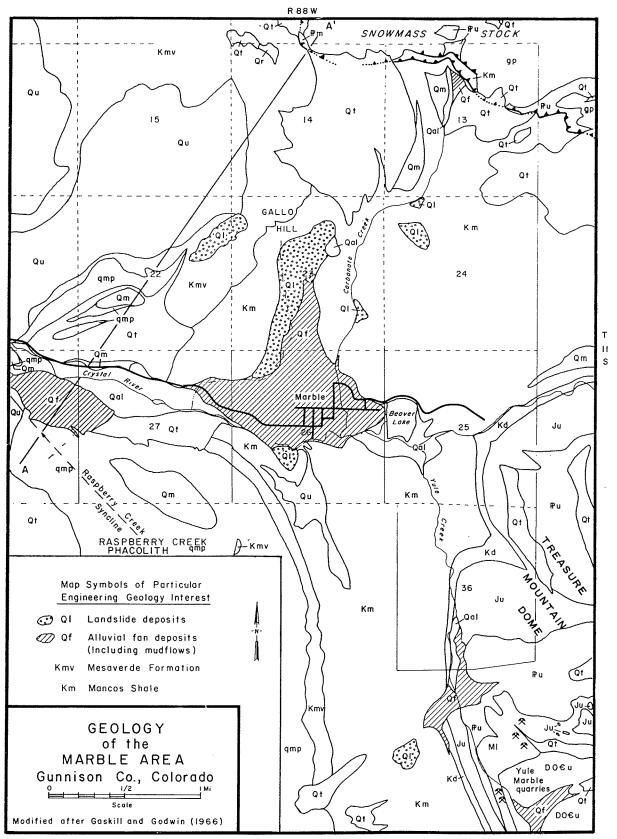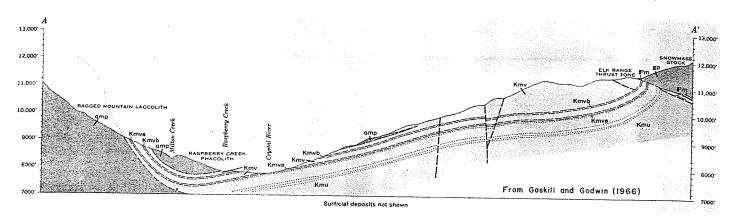
Figure 2

(Map labels, as they appear:)

R 88 W

A' SNOWMASS STOCK

Qt, Ƥm, Ƥu, Qt, Qr, Km, gp

Kmv

Qu

15

Qu

Qm, Qf, Qal, Qt

14   Qt

13

Qt

GALLO HILL

Ql

Carbonate Creek

Km

Qu

qmp

Qm

qmp

Qt

22

Kmv

Qt

23

Qf

Km

Ql

24

Km

qmp

Qm

Qm

Crystal River

Qal

Qm

Qf

Ql

Marble

Beaver Lake

Qm

Qu

Qf

27 Qt

Km

Ql

26

Qal

Kd

Ju

25

Km

A

qmp

Raspberry Creek

Qm

Km

Yule Creek

Ƥu

Qt

Qt

T 11 S

RASPBERRY CREEK PHACOLITH   qmp   Kmv

Syncline

Km

Kd

TREASURE MOUNTAIN DOME

Map Symbols of Particular
Engineering Geology Interest

Ql   Landslide deposits

Qf   Alluvial fan deposits
(Including mudflows)

Kmv   Mesaverde Formation

Km   Mancos Shale

-N-

36   Ju

Qal

Ƥu

Qt

Ju-Ꞓ

Ju

qmp

Qt

Ql

Ƥu

Ju

Ml

Yule Marble quarries

DOꞒu

GEOLOGY
of the
MARBLE AREA
Gunnison Co., Colorado

0   1/2   1 Mi
Scale

Kd

Km

Qt

Qf

DOꞒu

Modified after Gaskill and Godwin (1966)

Fig. 3 — Geologic cross section, Marble area.

ting the stage for the slope-instability and mass-wasting problems that plague the area yet today.

DEVELOPMENT HISTORY OF THE MARBLE RESOURCES[1]

The marble deposits that were first discovered by Sylvester Richardson in 1873 lay undisturbed until 1885 when G. D. Griffith, an ex-marble worker from Wales, began development of the quarries on Yule Creek. Even at that early stage, attempts were made to secure a contract to furnish stone for the future State Capitol Building in Denver. Early tests of the marble in London, England showed that it surpassed the Carrara Marble of Italy in quality and in strength with a crushing strength of 14,500 pounds per square inch. Attempts were begun to finance a railroad north from the D&RGW line at Crested Butte to the marble deposits. In 1895, a contract was won to use 140,000 sq ft of Yule Marble in the floors of the State Capitol Building. The selection, which was based mainly on quality, won out over bidders from thoughout the United States. The marble had to be hauled by horse and mule-drawn sleds to the railroad at Carbondale.

The third stage in marble development began in 1900 when J. G. Osgood of CF&I fame organized the Yule Creek White Marble Company, and brought in experienced quarry operators from Tennessee. He built the first wagon road from Marble to the quarry. With the backing of CF&I, plans were laid to extend the railroad from Carbondale to Marble and build an electric tram from Marble to the quarry. Quarrying of a single 11-ton block of marble which was perfect in color and texture proved to many doubters the quality of the resource. Use of marble throughout the United States was spurred in 1903 when a devastating fire in New Jersey proved the fireproof nature of marble

buildings. This stage closed when a desperate fight for control of the CF&I Company forced Osgood to relinquish his marble activities.

Colonel Channing F. Meek was the dominant factor in the next stage of development which began in 1905 with his incorporation of the Colorado Yule Marble Company for $2.5 million. Meek was a driving force in the development of the quarry, milling and transportation facilities and most importantly, markets for the product. The 735-horsepower hydroelectric generator he built in Marble was one of the earliest uses of electricity in mining. In 1906 Meek built the Crystal River and San Juan Railroad from Carbondale to Marble. Marble still had to be hauled from the quarries by 12-horse wagon teams in the summer, and skidded on sleds in the winter. Large blocks weighing 8 to 15 tons were handled in this primitive manner. By 1907 the town was a thriving community of 250 people with electric lights and telephone. Three million dollars in additional stock were issued, and predictions were made of up to 20,000 in future population. After Professor A. W. Smith of the Case School of Applied Science in Cleveland issued a glowing report showing the Yule Marble to be of superior quality and adequate quantity, Cuyahoga County in Cleveland, Ohio, let a $500,000 bid for their court house. This first major contract provided the financial stimulus for mill expansion and other large contracts. By 1910 the operation employed 500 to 600 people and had a $40,000 monthly payroll. Major contracts were secured for the Denver Post Office Building and the Montana State Capitol. An electric tram railroad was built over the 3.9 mi from the quarry to the mill at Marble. By 1911 the mill which was 1,465 ft long and 80 ft wide was the largest marble processing facility in the world. In 1912 Colorado ranked third in the nation in marble production, surpassed only by Vermont and Georgia. However, adverse geologic factors began to exert strong pressures on the operation. On March 7 of that year, a snow avalanche swept across the quarry killing the timekeeper. On March 20, an avalanche "crushed the mill like an eggshell." Fortunately, it occurred at 6:00 a.m. between shifts, and no one was injured.

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[1] This development history was essentially synthesized from Vandenbusche, 1970. Citing each specific reference would constitute a needless repetition. Persons interested in the details of the development history are referred to his excellent, well-researched history of the area — *Marble, Colorado, City of Stone.*

On August 12, this greatest surge of development activity essentially ended in tragedy when Meek and three other employees were riding the electric tram loaded with marble from the quarry to the mill. The brakes on the tram failed, and as speeds approached an estimated 60 miles per hour, the men jumped from the train. Meek died from internal injuries two days later. None of Meek's successors possessed his flair, vision or organizational ability and were never able to carry out his long-range plans. Marble hosted the National Retail Monument Dealers Association and boasted of 481 delegates from 25 states. This highly successful promotional effort resulted in $150,000 per month in orders and a contract for marble for the Lincoln Memorial. Even with these orders, the company floundered by 1921.

In 1921, the Yule Marble Company of Colorado and Carrara Yule Company, took over the assets of the previous company, and worked the quarries as competing companies. The Mormon Church also formed the Colorado White Marble Company to reopen the Strauss quarries. Although sales improved to $572,000, in 1923 and 1924, the competing companies struggled, merged and then, in 1928, were taken over by the Vermont Marble Company.

The expertise and marketing ability of the Vermont Marble Company secured contracts for the Customs House in Denver, and also for the famous Tomb of the Unknown Soldier. Over 100 men worked many months quarrying this single 124-ton block that was later fashioned into one of the more famous products of Colorado's mineral industry. Because the operations were in excellent financial condition, they were able to weather the damaging 1936 mudflows from Carbonate Creek. In 1938, CF&I petitioned the PUC to tear up the tracks from Carbondale to Marble, giving as a major reason, the great expense caused by periodic mud slides along the railroad. Although several contracts were obtained, including the Colorado State Office Building, a lack of operating capital and increasing operating expenses began to portend financial problems for the company. On August 8, 1941, a major mudflow down Carbonate Creek destroyed much of the town. Historians argue as to whether the mud flow caused the demise of the company, or whether it only created an added problem to a dying industry. Regardless, the next month, the Vermont Marble Company announced its closing. With closing of the mill on November 15, machinery and equipment were dismantled and sold. Much of it went to feed the growing war and related industrial demands. The railroad was dismantled in 1943.

Nature's dominance over the area was reiterated in July of 1945 when a mudflow even worse than that of 1941 destroyed the central portion of the town. By 1950 the Vermont Marble Company had given up and quit paying taxes on much of their property.

In 1953 the Basic Chemical Company began an operation to utilize the scrap marble (over 99 percent pure calcium carbonate) as a chemical. They trucked the marble to Glenwood for processing. By 1954, transportation costs were so great that they discontinued use of the high quality marble, substituting lower grade limestone from a quarry near Glenwood Springs.

A possible revival emerged in 1965 when the Vermont Marble Company proposed a 4 to 5 year plan to reopen the quarries and reestablish the industry if the state of Colorado or Gunnison County would improve the road from Carbondale to Marble. This plan did not take place because the Highway Department suggested the company first show its good faith by commencing their operations and then the state would make a decision on the road improvements.

The marble industry, as in other mineral resource industries, was strongly affected by outside impacts. Wars, changing architectural styles, rising labor costs, and a trend toward using artificial aggregate panels rather than stone all had a basic effect on the resource development. However, the constant impact of geologic factors such as rugged terrain, snow slides, and mudflows was a major factor in the various companies' inability to react to outside economic pressures.
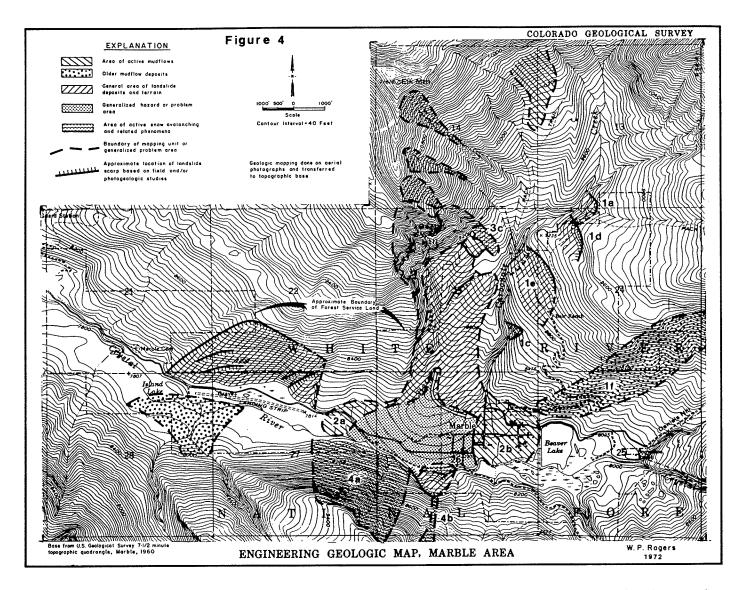
ENGINEERING GEOLOGIC FACTORS

The role of engineering geologic factors in constricting Marble area development has only become widespread knowledge in the past few years, but these factors have seriousy constrained development since man's first activities in the valley. Although these factors have become significant geologic hazards when they interacted with man's activities, they have also definitely affected the location, construction costs, and maintenance costs of transportation and development facilities, and have exerted strong constant economic pressures on all development activities. Such engineering geology terms as shear strength, angle of repose, excavatibility, and erodibility were unknown words to early workers, but they continually affected the cost and safety of all of man's construction activities.

Several specific engineering geologic factors have been evaluated and mapped by the Colorado Geological Survey and more recently by consultants for the ski area developers. These are discussed under three major categories: mudflows, slope instability and avalanches.

MUDFLOWS

Mudflows are defined and discussed by Rogers and others in Special Publication 6, *Guidelines and Criteria for Identification and Land Use Controls of Geologic Hazard in Mineral Resource Areas* (1974). The Colorado Survey's investigations at Marble contributed heavily to that discussion. Rogers and Rold (1972) described the origin and mechanics of Marble's alpine-type mudflows as follows:

Figure 4

ENGINEERING GEOLOGIC MAP, MARBLE AREA

"With a torrential or cloudburst type rainstorm, rapid water runoff occurs, generally accompanied by debris avalanching of the upper slopes. The water and debris obtained high velocities . . . incorporating the coarse lag deposits which accumulate at very steep angles of repose in the steep intermittent stream beds of the lower parts of the high slopes. The mixing of storm runoff, soil and rock debris forms a viscous slurry of the approximate consistency of a wet concrete mix . . . A rather high velocity is maintained by the channeling effect, the steep gradient and the pressure of the moving mass from above and behind. When this stream of mud reaches the lower slopes, it spreads out, loses velocity and deposits much of its coarse load."

The major Marble mudflow fan (frequently called an alluvial fan) is one of the more apparent features to the geologist or layman visiting the area, and has figured prominently in its his-

tory. The major composite flow (Figures 2 and 4) was first mapped by Gaskill (1970) and is readily apparent on aerial photographs (Figure 5). The fan-shaped mudflow deposit which is approximately a mile long, spreads out into the Crystal valley to a width of approximately a mile and a half. Rogers and Rold (1970) calculated the maximum thickness of the mudflow complex as approximately 175 ft. Detailed reconstruction of the total geomorphic history of this deposit would be a difficult and interesting challenge. Very probably the older part of the fan was deposited by ancestral Carbonate Creek at a location somewhere between the present location of Carbonate Creek and Slate Creek. Then, probable major landslide activity near the foot of Gallo Bluff (Fig. 7), or possibly a glacier, diverted Carbonate Creek eastward to its present channel, allowing the younger Slate Creek drainage to develop on the western edge of the upper reaches of the fan. In order to protect the town from mudflows, the townspeople in 1920 diverted the main channel to the western extremities of the fan.

The major mudflow fan postdates the glacial retreat and, therefore, is no older than apporoximately 10,000 years. The deposition of the fan has deflected the Crystal River southward and caused the upstream damming that was later modified by man to form Beaver Lake. Erosion of the south canyon wall by the deflected stream has triggered a landslide.

Carbonate Creek Mudflow (Fig. 4, Location 2b)

Carbonate Creek descends from a steep and sizeable drainage basin (approximately 3,500 acres) on the slopes of Mt. Daly and Elk Mountain to the north. The upper channel is entrenched and actively eroding a steep, incised canyon in the Mancos Shale. As it emerges from the steep canyon and its gradient flattens, coarse debris carried by the water is first deposited in a fan. Devastating mud floods have been recorded in 1936, 1941 and 1945. The "undeveloped" area in the center of the town represents the area devastated by the 1941 and 1945 floods (Fig. 8). Some of the more recent floods caused little or no damage because this central area had not been rebuilt. The lighter color of the Carbonate Creek mudflow reflects an additional provenance of igneous and Pennsylvanian sedimentary rocks not available to the Slate Creek drainage which drains only Mancos and Mesaverde terrain.

Slate Creek Mudflow (Fig. 4, Location 2a)

Slate Creek heads along the base of Gallo Bluff and follows an entrenched course along the western edge of the major mudflow. This highly erosive channel (Fig. 9) with oversteepened banks of old landslide and mudflow debris from the Mesaverde and Mancos is potentially very unstable. Both the rapidly wasting Gallo Bluff and the channel banks provide abundant source for mudflow debris during periods of thunderstorms. Where the channel emerges from its entrenched course, some 2,000 ft north of the Crystal River, the gradient flattens and the mudflow debris is deposited with the coarsest material being deposited closest to the mouth of the channel. Blocks in excess of six ft in diameter are common (Fig. 10). Fine muds are deposited all the way to Carbonate Creek. Our studies of aerial photographs of different ages, vegetation, topography, and the mudflow deposits, indicate a flow frequency of approximately every two years. Events since then have borne out those predictions. A mudflow on Slate Creek in September of 1972 which buried many platted lots and two subdivision roads was a major factor in convincing the developer that geologic factors were predictable and should be taken into account in development.

Many developers see the apparent channel of mudflows such as Slate Creek and Carbonate Creek as a permanent feature and feel that by avoiding that channel with a reasonable right-of-way, the remainder of the fan could be developed with impunity. At Marble, for example, residential lots were originally platted and sold at a density of 3 to 4 per acre across much of the

Slate Creek mudflow (Fig. 11). The history of this and other fans indicate, however, that over time these channels migrate back and forth across the entire fan surface much like a fire hose gone wild. Inspection of early photographs and detailed topography of the Marble fan show numerous old channels throughout the fan.

Debris flows of lesser magnitude but with the capability of considerable damage also occur at the mouths of Raspberry and Milton Creeks south of the landing strip. Serious flooding and debris deposition have been noted since development began. Most of the drainages downstream from Marble show strong mudflow and debris-fan deposition in the valley, and have exerted considerable adverse impact on the roads and railroad.

SLOPE INSTABILITY PROBLEMS

Slope instability problems include deep soil creep, old landslides in various stages of instability which could easily be reactivated by construction, active moving landslide masses and potentially unstable slopes where new slides could be activated by construction activity. Active landslides are relatively easily mapped. Old landslides have undergone erosion and varying degrees of modification with attendant variations in mapping difficulty. Precise delineation and prediction of the future behavior of potentially unstable slopes so common at Marble can be very difficult. Comparisons with similar geologic, topographic and moisture conditions in previously failed areas can be useful. Many times evaluation becomes a complex geometric problem of relating attitudes of weakness planes in the rock to the original and postconstruction ground surface taking into account future changes in ground water conditions. A liberal vides considerable insight into predicting future problems and many times is more reliable than precise mathematical calculations. Although potentially unstable slopes may appear quite innocent, they may be more hazardous to future activities than slopes that have stabilized after previous failure.

Landslides

The largest landslide deposit in the area occurs between Gallo Bluff and Carbonate Creek, northwest of the town site (Figures 4 and 6). As mapped by Gaskill, (1966) and Rogers and Rold (1972), it extends more than a mile in length. The main slide mass now seems quite stable, although significant construction and drainage changes could easily reactivate parts of the slide. The complex origin of the slide mass is poorly understood. It may have originated as one or a series of major catastrophic landslides from Gallo Bluff. The likelihood for such a future catastrophic slide from the Gallo Cliffs should be addressed prior to nearby future development.

North of the landing strip, a large anomalous area of talus and bedrock is delineated and crossed by landslide-like scarps. Some of the valleys along the scarps roughly parallel the slope

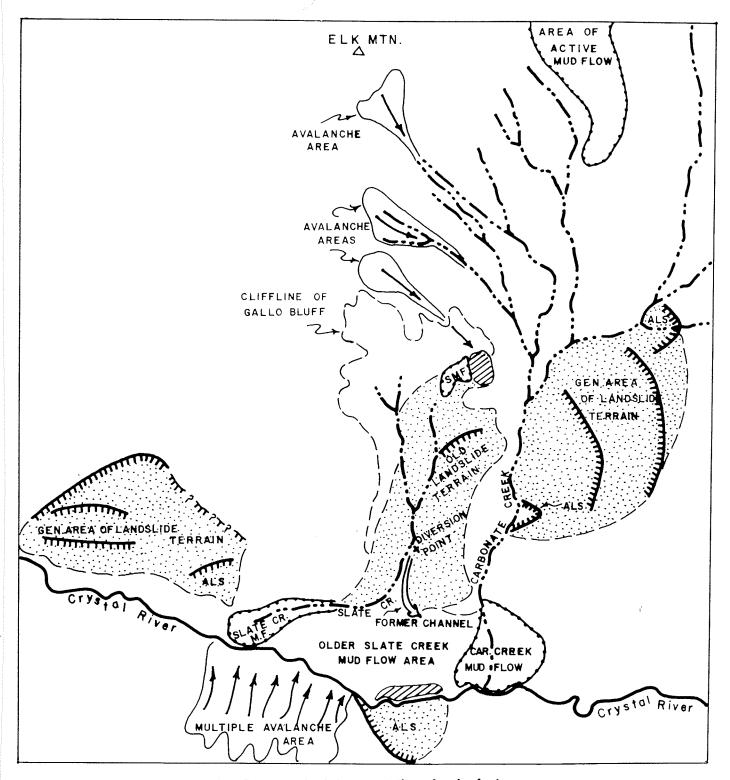Fig. 5 — Aerial photograph, Marble area.

Fig. 6 — Photogeologic interpretation of major features.

Easily identifiable features recognizable from photograph on facing page are shown in line drawing below. Symbols not self-explanatory are listed below.

ALS indicates areas believed to be active landslides.
Landslide Scarps are shown by heavy lines with teeth indicating direction of downslope movement.
Heavy Arrows indicate snow avalanche chutes, and *Diagonal Pattern* shows identifiable landing areas.
SMF indicates area of small mudflows at base of Gallo Bluff.

Fig. 7 — Cliffs on skyline are Gallo Bluffs. Upper portion is Mesaverde, lower is Mancos. Lower bare scarp in right center is Mancos shale outcrop on west bank of Carbonate Creek. Town of Marble in right foreground. Road in foreground was site of electric tram railroad to the quarry.

and are 100 ft wide and 30 ft deep. Very probably, the disturbed area is underlain by large bedrock blocks which are slowly sliding down the hill along bedding planes in the Mesaverde or sloping planes of weakness within or below the Raspberry phacolith. The overlying coarse talus exhibits many characteristics of rock glaciers. Patterns of leaning trees indicate a slow but continuing movement that could be markedly accelerated by excavations in the toe of the slopes.

A series of both active and inactive slides occurs along the east bank of Carbonate Creek (Fig. 4 Loc. Ia to Ie). Here, the

Fig. 8 — Top of two level park bandstand in town of Marble. Lower part was buried by mudflow debris of 1945 Carbonate Creek flood.

Mancos Shale and its planes of weakness dip gentl/ to the northwest into the deeply incised canyon of Carbonate Creek. Later detailed mapping by Robinson (1973) indicated discontinuous but prominent landslide release fractures along a zone nearly a mile long east of and paralleling the creek. Each of these slides and potential failures could have provided serious problems to the condominiums and high density facilities planned at the base of the ski lifts.

One small, active and growing landslide (Figure 4, Loc. Ic) triggered several interesting reactions. The developers recognized the slide from Gaskill's mapping. They avoided the slide itself but planned multistory condominiums immediately to the south, east and north without determining the ultimate extent of the slide failure. During a wet period in May, 1973, the slide began to move rapidly and erratically (as much as several ft of movement were observed in one day). Townspeople immediately grasped the potential of a major block of Mancos Shale falling into the stream, temporarily creating a dam. The dam could quickly overtop and plunge a

Fig. 9 — Entrenched portion of Slate Creek channel, showing steep banks and mudflow material in channel sides.

mud and debris flood on the Marble town site. Unpalatable choices faced the decision-makers in preparing for the possible event. The lower channel flow might be diverted to either the east or the west, thus condemning that part of the remaining town site, or the channel could be left alone in hopes the flow would remain in the present channel and harmlessly cover that portion of the town site previously destroyed in the 1941 and 1945 mudflows. Fortunately, the wet period ended before total collapse of the slide mass, and it returned to slow, periodic movement. Hopefully, Carbonate Creek's continued erosion of the toe may periodically remove small portions of much of the slide mass and avoid a possible catastrophic release.
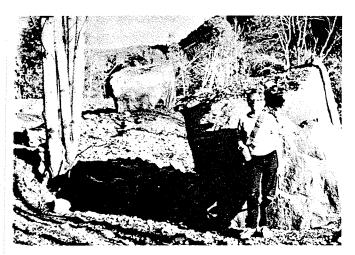
Fig. 10 — Large blocks of Mesaverde sandstone in recent mudflow debris at Slate Creek. Recency of deposit and depth of flow indicated by fine debris on top of blocks. Boy in foreground is approximately 5 feet tall.

Potentially unstable slopes

A large typical area of unstable slopes (Fig. 4, Loc. If) was mapped on the slopes northeast of the town site. Although we mapped no evidence of past failures, the steep slopes, weak, severely-jointed Mancos Shale bedrock and spring snow melt saturation, indicated serious potential slope stability problems. The prediction of Rogers and Rold (1972),

> "Most slopes in this part of Mt. Daly range from 30% to 60%. Excavation of any cut slopes which will have the effect of steepening existing slopes and daylighting weak surficial layers will pose serious long-range stability problems."

came to pass May 14, 1973. A section of new road approximately 150 ft long and part of two condominium sites released as a wet landslide. Incorporation of additional runoff water quickly converted the material to a mudflow which poured rapidly down the mountinside into Beaver Lake. Observers in the valley reported hearing a grinding, rumbling sound and then being treated to a dramatic display of violent geologic processes that lasted only a few minutes. The lesson was not lost on the county or the developer who then agreed to our previous recommendations to greenbelt numerous condominium sites in similar geologic conditions.

AVALANCHES

Although recognized by the earliest winter travelers, avalanches made their first entry into the history book March 7, 1912, when one hit the quarry operation and killed the timekeeper. Two weeks later, a large avalanche hit the processing mill "smashing it like an eggshell" (Vandenbusche,

1970). The timing at 6:00 a.m. was fortunate because it was between shifts; the mill was unoccupied and there were no casualties. By 1915, a marble buttress wall 50 ft high had been constructed to protect the mill. Successive slides that winter filled the valley and then overtopped the wall going into the mill again. The next summer, the wall was raised to 65 ft and the mill was reportedly safe after that.

Because of the abundant geologic evidence of avalanches and the historic problems, they were evaluated and mapped during the Colorado Geological Survey study. Later, a more detailed evaluation of avalanche hazards was conducted by Mears (1975) as part of a CGS statewide evaluation of avalanche hazards. Persons interested in additional details of the avalanche problems in Marble or in general are referred to that publication, *Snow Avalanche Hazards in Colorado* (in press), or Special Publication 6 of the Colorado Geological Survey.

Avalanches presented definite hazards on the north-facing slope across the Crystal River from the mill site and westward where seven separate tracks were noted, (Fig. 4, Loc. 4b and 4a). These tracks were shown on the original master plan for multifamily condominium units at a density of 10 per acre, although it was indicated that the tracts would be reserved until snow accumulation studies were completed.
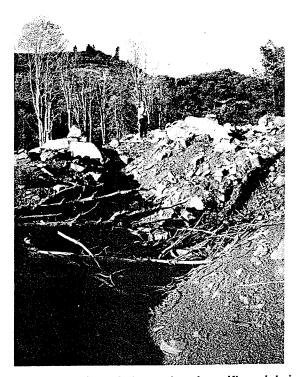

Fig. 11 — Abandoned channel and mudflow debris in subdivided portion of recent Slate Creek mudflow. Boy is standing at a lot corner stake.

At Gallo Bluff (Fig. 4, Loc. 3c), an interesting ava-
lanche has poured over a cliff and come to rest in more of a
"landing zone" than the typical runout zone. This was in or
very near an area platted for condominium units.

RECREATIONAL RESOURCE DEVELOPMENT
HISTORY

Although the climate and the scenery have attracted many
people to the Marble area since its earliest settlement, the
first attempt to commercialize this resource occurred in 1956
when Wade Loudermilk assembled several hundred acres of
land and formed the Crystal River Enterprises. He built the
air strip and landed a plane there in 1957. The first recorded
attempt to evaluate the area for commercial ski development
occurred in 1967 when Crystal Basin Outlife, Ltd. was formed
and contracted with Sno-Engineering and Willie Schaeffler to
evaluate the ski area potential.

In 1969, the Marble Ski Area, Inc. was formed and assem-
bled 1,950 acres. They developed a master plan envisioning
8,800 dwelling units on private land and a major ski develop-
ment utilizing 4,600 acres of federal lands covering the slopes
of Mt. Daly, Arkansas Mountain, Sheep Mountain and Buck-
skin and Coyote Basins. This grandiose plan would have
resulted in a major ski complex larger than Vail, Aspen or
any now developed in the state. With a density of three people
per unit, the 8,800 units would have provided rooms for
26,400 people on their property alone.

In late 1970, the Colorado Geological Survey became
aware of this major development activity. Our then current
knowledge of the geology of the area and a cursory investigation
indicated numerous serious geological constraints to the
development and caused us understandable serious concern.
Believing that the potential for serious geological hazards
existed, the Colorado Geological Survey contacted the devel-
oper to determine his exact development plans and began a
crash program of geological investigation. When the prelim-
inary results outlining the serious geologic problems affecting
the development were relayed to the developer, a violent con-
frontation arose. This confrontation soon provided front-page
news, and it became apparent that a readily available public
document was needed to objectively portray the geologic prob-
lems of the area to the developer, state and local decision-
makers, investors, and the potential lot buying public. That
Colorado Geological Survey report, *Engineering Geologic
Factors of the Marble Area,* was published in June, 1972. It
quickly became a key document in a pitched battle between
the opponents and proponents of the Marble Ski Area. At that
time, Senate Bill 35 had not been passed and Gunnison County
did not have adequate subdivision regulations or staff to
address such a major problem. Several of the early filings had

already been approved. At that time, the Colorado Survey's
only statutory reason for involvement was the enabling act
which charged it to "delineate areas of natural geologic
hazard which could affect the safety of or cause economic loss
to the citizens of the state," and the charge, "to provide
advice and counsel to all agencies of state and local govern-
ment on geologic problems." In the early heated stages of the
confrontation, Gunnison County was not aware they had a
geologic problem, had not asked for the advice and counsel and
resented our interference in their activities.

Our basic concern arose from a comparison of the master
plan document and geological conditions that would affect
those activities. Particularly, the Slate Creek mudflow had
been platted for residential development and an area of com-
mercial development. Numerous lots had already been sold.
East of Carbonate Creek near the base facilities of the lift
area, numerous condominium sites were platted on or adjacent
to active landslides and on unstable slopes. As indicated
earlier, one of these dramatically failed in May 1973, when
a catastrophic landslide took out the subdivision road, and
several condominium sites ended up in Beaver Lake several
hundred ft below. In the upper Slate Creek drainage, high den-
sity development was planned close to Gallo Bluff with little
credence being given by the master plan to avalanches, mud
flows, and potential landslides. South of the Crystal River, a
school site was platted in the flood plain directly across the
river from where the Carbonate Creek mudflow hit the river.
Condominium units were master-planned in the avalanche ter-
rain south of the Marble town site.

On September 19, 1972, a small mudflow on Slate Creek
buried a subdivision road and covered numerous platted lots
up to a depth of 3 to 4 ft. This event more than anything else
demonstrated to the developer that geology was not an academic
exercise, and would be a fact of life (or death) in his develop-
ment plans. This event marked a change in our dealings with the
developer, who began to buy back lots that had been sold in the
Slate Creek mudflow area and other hazardous areas. In an
attempt to revise the development to conform to the serious
geological problem areas, the total area was placed in a Planned
Unit Development with platting concentrated in the better areas,
and with many of the hazard areas placed in an undisturbed or
greenbelt status. Gunnison County became quite cognizant of
geologic problems and refused to approve any plats or construc-
tion plans until they had been investigated and approved by the
Colorado Geological Survey. The ultimate plan to utilize some
4,600 acres of Forest Service land for ski terrain and lift de-
velopment was turned down by the Forest Service, and a more
modest plan utilizing approximately 600 acres on the slopes of
Mt. Daly was formally proposed. Earlier, a 4,200 foot chair lift
and three ski trails had been constructed on private land. A

rather thorough study of environmental, ecological, and geological factors affecting the total development and the Forest Service's special use permit area was contracted to Thorne Ecological Institute of Boulder in 1973. Environmentalists, other opponents to the ski area and governmental agencies raised questions of the impact on wildlife, particularly elk and deer winter range, proximity to the neighboring proposed Snowmass Wilderness area, air and water pollution and numerous other factors. The State Land Use Commission conducted an investigation of the area. Numerous charges of improper and illegal sales technique were leveled at the developer, (Schneider, 1974). Several lots were allegedly illegally sold from unplatted and unapproved filings. The state Real Estate Commission and the Securities Exchange Commission began investigations. Although by this time the developer had begun to realize the seriousness of the geological problems and begun to take them into account, the reverse cash flow and the adverse publicity from many different angles exerted a serious drop in land sales and frightened away potential investors.

In 1973 the area was reorganized into the Marble Holding Company, Inc. with a change in management and an infusion of new personnel, new consultants, new enthusiasm and new capital. The new corporation was not successful in overcoming the myriad problems and in September, 1974 petitioned for bankruptcy. Now, in 1977, the Federal Bankruptcy Court is attempting to liquidate the land assets in order to satisfy the many creditors. Regrettably, the potential adverse impacts of subdivision and land sales in the area by the Bankruptcy Court may have problems equal to or greater than similar sales by a private developer.

SUMMARY

The processes of sedimentation formed the original thick limestone and coal deposits. The forces and pressures of igneous intrusion and mountain building transformed ordinary limestone to some of the finest marble in the world and ordinary bituminous coal to high-quality coking coal and anthracite. Geology has created high-quality mineral resources.

At Marble the outcropping formations, the highly varied combination of geomorphic landforms and the intensity of active geologic processes have combined to form one of the most beautiful settings in North America. The geologic uplift and erosive processes have combined to produce high winter snowfall, interesting terrain for skiing and hiking and a delightful summer climate. The geology likewise has created high-quality recreational resources.

These same geologic processes produced soft, easily erodable rock formations adjacent to very strong erosion-resistant rocks. Over-steepened glacial terrain, adverse jointing, abundant ground water, rapid erosion, intense mass wasting and at times violent weather have combined to form rugged inaccessible terrain, landslides, mudflows, and avalanches. These geologic conditions have played a major role in inhibiting development of both the mineral resources and the recreational resources. The high quality of the resources has initiated several booms of intense development. In each case, geology-related conditions have seriously inhibited development. Marble was an obvious frontier area when the fabulous marble deposits were discovered in 1873.

Because of these factors, Marble, in 1977, still remains a development frontier.

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MARBLE

Marble was never a ghost town, but it came close a few times.

According to an old newspaper account, "there is enough marble there to build forty Babylons," but the brief moment of Marble's prosperity was between 1908 and 1916. The rest of the time Marble has had to scratch for a living, and the living has not been easy.

Sylvester Richardson, the geologist who founded the town of Gunnison, discovered marble in the area in August 1873. The following year George Yule staked claims on the creek that now bears his name. Yule became sheriff of Gunnison County, a task that required all his attention, and his claims were taken over by others. The first marble quarry in the region was opened in 1884. It was located three-quarters of a mile upstream above Crystal. Work on the Yule Creek deposits began late in 1885.

Carbonate Creek falls down the south side of Elk Mountain to the Crystal River thousands of feet below. Incredible as it seems in retrospect, two adjoining communities sprang up on the north side of Crystal River, separated only by the shallow and frequently debris-laden water of Carbonate Creek. The hamlet on the east bank was called Clarence; the one on the west bank was Marble City. In 1890, both applied for a post office. It was granted to Marble in 1892. On the Fourth of July, Clarence and Marble buried the hatchet in a day of celebration. Marble was incorporated in 1899.

An elaborate display of Yule Creek marble was shown at the World's Columbian Exposition in Chicago in 1893. It was the consensus of several experts that the marble was "as good as any in the world." The cornerstone for the Colorado State Capitol had been laid on July 4, 1890, and 140,000 square feet of marble was needed in its construction. The contract was awarded to a Yule Creek quarry. After several delays, and a trip to Marble by an anxious construction superintendent, the first commercial shipment of marble was made in late November, 1895. The marble was freighted from the quarry by wagons and sleds to the railroad at Carbondale. Transportation was under the most trying of conditions. A block of marble weighing eleven tons, however, was hauled to the railroad in 1902, which by this time had crept as far south as Redstone.

The railroad finally arrived at Marble in 1906. Expansion was under way in earnest. The Colorado-Yule Marble Co. spent over three million dollars for a mill and other facilities. Marble had its own hydroelectric plant by 1907, and was connected with the outside world by telephone. Its population now was about 250, and was probably about 2,000 at its zenith, although several estimates are much higher.

A strange thing happened in 1908. Marble was voted dry. The area became a sort of experimental testing site for bootleggers. Skilled labor had been recruited from marble quarries in Italy. Some local Italian homemade wines showed great originality in the use of native berries and even the lowly Oregon grape.

Commercial expansion began with a half-million dollar contract for marble for the new courthouse in Cleveland, Ohio, followed shortly by an order for the courthouse at Youngstown, Ohio. Orders came in from coast to coast. From 1909 until 1916, Colorado Yule marble ranked fourth in production nationally. A slab of marble bearing the Colorado state seal was placed in the Washington Monument. Colorado Yule marble became a prestige building stone when it was chosen in 1914 for the Lincoln Memorial. In 1915, the three largest industries in Colorado were the Colorado Fuel & Iron mills at Pueblo, the Portland Cement plant near Florence, and the Colorado-Yule Marble Company at Marble.

The bubble burst in 1916. The Colorado-Yule Marble Company went into receivership due to poor market conditions caused by World War I, thin profit margins, and inadequate working capital. The railroad quit running. The road between Redstone and Marble fell into disrepair.

Marble began to stir in 1922. Railroad service was resumed. In 1924, the Consolidated Yule Marble Company was formed from the merger of the Carrara Company and the Yule Marble Company. At a time when the new company was just getting on its feet in 1925, a fire in the mill did more than a half-million dollars worth of damage. In 1928, the property was sold to the Vermont Marble Company.

Marble revived in 1930, and once again missed being a ghost town. The Yule-Colorado Company, the Vermont Marble Company subsidiary, was awarded the contract for the Tomb of the Unknown Soldier. The unfinished block of marble was the largest ever quarried, and took more than a year to cut. Its rough weight was approximately 124 tons, trimmed at the quarry to 56 tons. It took four days to get the block from the quarry to the mill. There it was under constant guard to prevent souvenir hunters from chipping fragments from it. It was put in place at the Arlington Memorial on November 11, 1932.

In the words of a song from a local musical show, Marble was a place "where the sun goes down at noon, and water pipes are frozen until June." Heavy snow hampered the work in winter. Roofs collapsed under its weight. Snowslides came down the mountains south of town in winter, and flash floods and mudslides came down Carbonate Creek north of town in summer. One glance at the hummocky topography on which Marble is built is enough to make an experienced geologist shudder.

The quarry and mill were closed in 1941 because of World War II. Mill and quarry equipment was dismantled and sold in 1942. The Crystal River & San Juan Railroad ("Can't Run & Seldom Jumps") between Marble and Carbonate was dismantled in 1943. The Marble post office closed.

The marble is recrystallized Mississippian Leadville limestone. And there is probably enough of it left in the ground today to build forty Babylons.

W. Lyle Dockery

APPENDIX B
THE MARBLE AREA
WELL PERMIT LOCATIONS

PERMITTED WELLS FOR THE MARBLE AREA
GUNNISON COUNTY, COLORADO

PERMIT NO.	NAME	RNG	TWN	SECT	QTR 160	QTR 40	COORD NS	COORD EW	PERF TOP	PERF BOT	YIELD	DEPTH	R LEVEL	ACRES IRRIG
36174	MARBLE METROPOLITAN DIST	88W	11S	23	NE	SE	1800N	0800E	0086	0200	45.00	200	45	0.00
108206	STROUD BLEV	88W	11S	25	NE	SW	2530N	2540E	0120	0180	6.00	90	130	0.00
80862	ORLOSKY MARJORIE	88W	11S	25	NW	SE	2610N	1720W	0000	0000	15.00	10	0	1.00
143524	LEBEAU LINDA	88W	11S	25	SW	NE	2500S	2050W	0204	0305	7.00	305	30	0.00
97281	BONTRAGER PERRY & MARTHA	88W	11S	26	NE	NE	1150N	4200W	0000	0000	8.00	62	41	0.00
25081	WAGGONER BEN E	88W	11S	26	NE	SE	0000	0000	0000	0000	1.00	120	50	0.00
130246	ILLIAM J	88W	11S	26	NE	SE	0000	0000	0000	0000	5.00	100	2	0.00
159884	THOMPSON TOMMY R	88W	11S	26	NE	SE	3000S	0350E	0000	0000	15.00	14	0	0.11
46722	BAUMLI JAKE H	88W	11S	26	NE	SE	0000	0000	0000	0000	15.00	29	12	0.00
87261	PETROCCO DORIS	88W	11S	26	NE	SE	2220N	1180E	0000	0000	15.00	35	12	0.00
156278	VILLALOBOS CHRISTY	88W	11S	26	NE	SE	2290N	0670E	0031	0046	15.00	46	13	0.00
160077	ROBERTS J D & MARTHA	88W	11S	26	NE	SE	1720N	1260E	0074	0089	15.00	89	61	0.00
155654	BAUER ZDENEK	88W	11S	26	NE	SE	1360N	1319E	0100	0115	15.00	115	78	0.00
24800	BLUE JUNE K	88W	11S	26	NE	SE	0000	0000	0000	0000	20.00	55	9	0.00
24627	DOOLITTLE N E & ELIZABETH D	88W	11S	26	NE	SE	0000	0000	0000	0000	25.00	27	8	0.00
24626	REECE HAL & CARMELLA R	88W	11S	26	NE	SE	0000	0000	0000	0000	25.00	30	8	0.00
24799	JOHNSON THANO A	88W	11S	26	NE	SE	0000	0000	0000	0000	25.00	45	9	0.00
53731	VILLAGE LAND CO. & FLETCHER LOREN	88W	11S	26	NE	SE	0000	0000	0000	0000	30.00	31	8	3.00
56392	MAC ADAMS ELMORE K.	88W	11S	26	NE	SW	1355N	2074E	0074	0097	0.30	97	78	0.00
63352	SEIDEL K A	88W	11S	26	NE	SW	2450N	1900E	0000	0000	15.00	45	30	0.00
99586	JONES DAVID I	88W	11S	26	NE	SW	2450N	2075E	0045	0058	15.00	58	28	0.00
66694	GIFFORD PHILLIP H. II	88W	11S	26	NE	SW	2294N	1892E	0000	0000	15.00	75	45	1.00

Permits with direction coordinates

Permits without direction coordinates

PERMITTED WELLS FOR THE MARBLE AREA
GUNNISON COUNTY, COLORADO

PERMIT NO.	NAME	RNG	TWN	SECT	QTR 160	QTR 40	COORD NS	COORD EW	PERF TOP	PERF BOT	YIELD	DEPTH	R LEVEL	ACRES IRRIG
100289	PATTEN TERRY LEE	88W	11S	26	NE	SW	2540N	2380E	0062	0072	30.00	72	50	0.00
172444	NAVE GREGORY	88W	11S	26	NW	NW	0810N	1275W	0024	0120	2.00	120	85	0.00
85115	MCCOLLUM OSCAR D & LOIS ANN	88W	11S	26	NW	SE	1670N	2850E	0000	0000	4.50	120	68	0.00
154713	STAPELFELDT J.D.	88W	11S	26	NW	SW	2560N	1260W	0118	0132	1.00	132	62	0.00
76121	TAYLOR JACK W. & NADINE I.	88W	11S	26	NW	SW	2410N	0550W	0000	0000	3.00	130	70	0.00
164027	PAIGE LISA M	88W	11S	26	NW	SW	1700N	0080W	0080	0100	5.00	100	78	0.00
62106	HERMAN JOHN T	88W	11S	26	SE	NW	0000	0000	0000	0000	15.00	0	0	2.00
167412	TICCONI BRUNO & JOAN	88W	11S	26	SE	NW	2400S	2075E	0000	0000	15.00	40	0	0.00
25893	MARBLE TOWN OF & MARBLE WATER C	88W	11S	26	SE	NW	2600S	1800E	0033	0053	23.00	53	12	0.00
46723	MARBLE SKI AREA INC	88W	11S	26	SW	NW	0000	0000	0000	0000	15.00	90	39	0.00
143526	LYON KELLY & JEANETTE	88W	11S	27	NE	NE	1150N	1050E	0000	0000	14.00	25	5	0.00
161255	WALTRIP DENNIS MARK	88W	11S	27	NE	NW	1300N	2500E	0060	0100	15.00	100	55	0.00
158783	FARRIS, BRYAN	88W	11S	27	NE	SE	3460S	0270E	0000	0000	0.00	90	0	0.00
44487	MANAGEMENT & CONST CO	88W	11S	27	NE	SE	0000	0000	0000	0000	10.00	50	28	0.00
109747	CONNOR PAUL R & DENISE J	88W	11S	27	NW	SW	1695N	0600W	0050	0063	10.00	63	43	0.00
158722	THOMPSON RONALD M	88W	11S	27	NW	SW	2400N	0300W	0092	0149	13.00	140	120	0.00
58561	MARBLE SKI AREA INC	88W	11S	27	NW	SW	0000	0000	0000	0000	15.00	60	32	0.00
44488	MARBLE SKI CORP	88W	11S	28	NE	NE	0000	0000	0000	0000	10.00	97	48	0.00
113027	SKEFFINGTON JAMES	88W	11S	28	NE	NW	0000	0000	0050	0075	15.00	75	0	0.00
156762	RIGG SONYA	88W	11S	28	NE	SE	0000	0000	0076	0125	5.00	125	75	0.00
46516	MARBLE SKI AREA	88W	11S	28	NE	SE	0000	0000	0000	0000	15.00	115	73	0.00
25089	MURPHY J C	88W	11S	28	NE	SE	0000	0000	0000	0000	25.00	40	18	0.00

Permits with direction coordinates   Permits without direction coordinates

<div style="border: 1px solid black; padding: 1em;">

APPENDIX C
TABULATION OF WATER QUALITY TEST RESULTS
1979 TO 1992
CRYSTAL RIVER AT REDSTONE, COLORADO

</div>

The data in this appendix were kindly furnished by Mr. Dennis Anderson, Water Quality Control Division, Colorado Department of Public Health and Environment (CDPHE). Wright Water Engineers is indebted to the CDPHE for their cooperation in mailing this tabulation available for use by Gunnison County.

Monitoring Station 000145 is 1.3 miles downstream of the confluence of the Crystal River with Coal Creek. Coal Creek influences the suspended solids and iron concentration.

The table designations used are as follows:

  $ = Calculated value
  K = Less than
  U = Not detected; below value

```
                                                   000145
                                                   39 12 06.0 107 13 53.0 2
                                                   CRYSTAL RIVER AT REDSTONE
                                                   08097    COLORADO          PITKIN
/TYPA/AMBNT/STREAM                                 COLORADO RIVER            110300
                                                   UPPER COLORADO RIVER
                                                   21COL001   800419              14010004008 0003.390 CN
                                                   0000 FEET DEPTH
```

INITIAL DATE INITIAL TIME MEDIUM				79/05/15 1500 WATER	79/07/23 1640 WATER	79/09/10 1600 WATER	79/11/14 1540 WATER	80/02/27 1520 WATER	80/04/21 1330 WATER	80/06/09 1305 WATER	80/08/25 1530 WATER	80/10/20 1455 WATER
00010	WATER	TEMP	CENT	11.1$	15.0$	16.7$	1.1$		7.8$	8.9$	17.2$	7.2$
00011	WATER	TEMP	FAHN	52.0	59.0	62.0	34.0		46.0	48.0	63.0	45.0
00021	AIR	TEMP	FAHN						60.0	35.0	80.0	60.0
00076	TURB	TRBIDMTR	HACH FTU	112.0	4.0	3.6	3.0	20.0	600.0	23.0		
00095	CNDUCTVY	AT 25C	MICROMHO	310	190	330	47	530	270	150		
00300	DO		MG/L	9.6	7.3	8.2	12.3		7.1	9.6	8.2	10.3
00301	DO	SATUR	PERCENT	80.5$	76.5$	84.5$	86.6$		76.5$	82.8$	84.5$	84.4$
00310	BOD	5 DAY	MG/L	1.0	2.0	2.0	2.0	2.0		1.0K		
00400	PH		SU	7.80	6.90	8.20	7.90		7.40	7.30	8.10	7.00
00410	T ALK	CACO3	MG/L	91			110			63		
00530	RESIDUE	TOT NFLT	MG/L	210	10	10K	10K	30	1550	50	10K	10K
00610	NH3+NH4-	N TOTAL	MG/L	.120	.100K	.050K	.050K	.050	.100K	.050K	.050K	.050K
00612	UN-IONZD	NH3-N	MG/L	.002$	.0002$	.002$	.0004$		.0004$	.0005$	.002$	.00007$
00615	NO2-N	TOTAL	MG/L	.003								
00619	UN-IONZD	NH3-NH3	MG/L	.002$	.0003$	.003$	.0004$		.0005$	.0006$	.002$	.00009$
00625	TOT KJEL	N	MG/L		1.000K	1.000K	1.000K	1.000K	1.000K		1.000K	1.000K
00630	NO2&NO3	N-TOTAL	MG/L	1.30	.11	.08	.13	.21	.14	.12	.50K	.50K
00665	PHOS-TOT		MG/L P	.050	1.000K	.050K	.060	.050K	.570	.050	.050K	.050K
00723	CYANIDE	DISSOLVE	UG/L	.005K	.005K	.005K	.005K	.005K	.005K	.005K	.005K	.01K
00900	TOT HARD	CACO3	MG/L	130	90	170	250	270	130	76		
00910	CALCIUM	CACO3	MG/L	100.0	72.0	150.0	210.0	230.0	120.0	50.0		
00927	MGNSIUM	MG/TOT	MG/L	7.0	4.0	7.0	9.0	10.0	3.0	4.0		
00929	SODIUM	NA/TOT	MG/L	10.00	5.00K	5.00	5.00	7.00	6.00	5.00K		
00931	SODIUM	ADSBTION	RATIO	.4	.2	.2	.2	.02	.2			
00937	PTSSIUM	K/TOT	MG/L	1.30K			1.00K			1.00K		
00940	CHLORIDE	TOTAL	MG/L	3	2	3	3K	4	2	4		
00945	SULFATE	S04-TOT	MG/L	50	30	80	150	170	60	5K	77	130
00980	IRON	TOT REC	UG/L	1500	300	100K	100K	230	6000	640	100K	130
00998	BERYLIUM	TOT.REC.	UG/L	50K				50K		50K		
01002	ARSENIC	AS/TCT	UG/L	5K				5K		5K		
01022	BORON	B/TOT	UG/L	40K				40K		40K		
01074	NICKEL	TOT.REC.	UG/L	100K				50K		50K		
01079	SILVER	TOT.REC.	UG/L	50K				.2K		.2K		
01094	ZINC(ZN)	TOT.REC.	UG/L	20	20K	20K	20	40	60	20	20K	20K
01104	ALUMINUM	TOT.REC.	UG/L	1000K			2000K			1600K	20K	20K

(SAMPLE CONTINUED ON NEXT PAGE)

WRIGHT WATER ENGINEERS, INC.

```
000145
39 12 06.0 107 13 53.0 2
CRYSTAL RIVER AT REDSTONE
08097    COLORADO        PITKIN
COLORADO RIVER           110300
UPPER COLORADO RIVER
21COL001  800419          14010004008 0003.390 0M
0000 FEET DEPTH
```

/TYPA/AMBNT/STREAM

(SAMPLE CONTINUED FROM PREVIOUS PAGE)

				79/05/15	79/07/23	79/09/10	79/11/14	80/02/27	80/04/21	80/06/09	80/08/25	80/10/20
INITIAL DATE / INITIAL TIME / MEDIUM				1500 WATER	1640 WATER	1600 WATER	1540 WATER	1520 WATER	1830 WATER	1305 WATER	1530 WATER	1455 WATER
01113	CADIUM T	TOT.REC.	UG/L	.6	.6K	.4	.3K	.5	.4	1	.3K	.3K
01114	LEAD(PB)	TOT.REC.	UG/L	9K	9K	9K	9K	10K	17	5K	5K	5K
01118	CHRMIUM	TOT.REC.	UG/L	20K	20K	10K	5K	5K	21	5K	5K	5K
01119	COPPER	TOT.REC.	UG/L	6K	12K	6	6K	11	21	5K	5K	5K
01123	MNGANESE	TOT.REC.	UG/L	50K	50K	50K	50K	50K	440	50K	50K	50K
01147	SELENIUM	SE.TOT	UG/L	5K			2K			2K		
22703	U-NAT	DISOLVED	UG/L	.930			5.000K					
31615	FEC COLI	MPN.CMID	/100ML	30K	3K	4	3K	3K		4	3K	4
70300	RESIDUE	DISS-180 C	MG/L	130	110	200	320	360	130	100	200	290
71900	MERCURY	HG.TOTAL	UG/L	.5K						.5K		
74041	WQF	SAMPLE	UPDATED	870217	870217	870217	870217	860828	860828	860828	860828	860828

				80/12/18	81/01/20	81/03/16	81/05/25	81/06/29	81/07/20	81/09/21	81/11/13	81/12/13
INITIAL DATE / INITIAL TIME / MEDIUM				1500 WATER	1110 WATER	1300 WATER	1250 WATER	1338 WATER	1400 WATER	1420 WATER	1555 WATER	1505 WATER
00010	WATER	TEMP	CENT	2.2$	1.1$	6.1$	7.8$		15.6$	15.0$	3.3$	.6$
00011	WATER	TEMP	FAHN	36.0	34.0	43.0	46.0		60.0	59.0	38.0	33.0
00021	AIR	TEMP	FAHN	45.0	35.0	50.0	70.0		90.0	75.0	30.0	35.0
00095	CNDUCTVY	AT 25C	MICROMHO							330	380	440
00300	DO		MG/L	11.8	12.0	12.2	10.3		8.4	8.2	10.8	11.8
00301	DO	SATUR	PERCENT	85.5$	84.5$	97.5$	86.6$		84.0$	80.4$	80.0$	83.1$
00400	PH		SU	7.90	8.20		8.30		8.50	8.40	8.20	7.90
00410	T ALK	CACO3	MG/L	120			80		72	92	104	116
00530	RESIDUE	TOT NFLT	MG/L	10K	10K	10K	10K		10K	10K	10K	15
00610	NH3+NH4-	N TOTAL	MG/L	.050K	.100K	.170	.100K		.100K	.100K	.100K	.100K
00612	UN-IONZD	NH3-N	MG/L	.0004$	.001$		.003$		.008$	.006$	.002$	.0007$
00619	UN-IONZD	NH3-NH3	MG/L	.0005$	.002$		.004$		.010$	.008$	.002$	.0008$
00625	TOT KJEL	N	MG/L	1.000K	1.000K	1.000K	1.000K		1.000K	1.000K	1.000K	1.000K
00630	NO2&NO3	N-TOTAL	MG/L	.50K	.50K	.50K	.50K		.50K	.50K	.50K	.50K
00665	PHOS-TOT		MG/L P	.050K	.050K	.050K	.050K		.050K	.050K	.050K	.050K
00723	CYANIDE	DISSOLVE	UG/L	.01	.01K	.01K	.01K		.01K	.01K	.01	.01K
00900	TOT HARD	CACO3	MG/L	240								
00910	CALCIUM	CACO3	MG/L	200.0								
00927	MGNSIUM	MG.TOT	MG/L	9.0								
00937	PTSSIUM	K.TOT	MG/L				.70				1.00K	
00945	SULFATE	SO4-TOT	MG/L	150	140	150	50		53	98	110	130
00980	IRON	TOT REC	UG/L	100	100K	100K	160		100K	210	100K	150
00993	BERYLIUM	TOT.REC.	UG/L	50K			50K				50K	

(SAMPLE CONTINUED ON NEXT PAGE)

WRIGHT WATER ENGINEERS, INC.

```
                                               030145
                                               39 1E 06.0 107 13 53.0 2
                                               CRYSTAL RIVER AT REDSTONE
                                               08097   COLORADO         PITKIN
/TYPA/AMBNT/STREAM                             COLORADO RIVER       110300
                                               UPPER COLORADO RIVER
                                               21CCL001  800419          14010004008 0003.390 OM
                                               0000 FEET DEPTH
```

(SAMPLE CONTINUED FROM PREVIOUS PAGE)

			80/12/13 1500 WATER	81/01/20 1110 WATER	81/03/16 1300 WATER	81/05/25 1250 WATER	81/06/22 1338 WATER	81/07/20 1400 WATER	81/09/21 1420 WATER	81/11/18 1555 WATER	81/12/13 1505 WATER
INITIAL DATE											
INITIAL TIME											
MEDIUM											
01002 ARSENIC	AS,TOT	UG/L	10K			10K				10K	
01022 BORON	B,TCT	UG/L	60			60K				60K	
01074 NICKEL	TOT.REC.	UG/L	100K			100K				100K	
01079 SILVER	TOT.REC.	UG/L	.2K			.2K				.2K	
01094 ZINC(ZN)	TOT.REC.	UG/L	20K	10K	10K	10K		10K	10K	10K	10
01104 ALUMINUM	TOT.REC.	UG/L	1000K			1000K				1500K	
01113 CADIUM T	CT.REC.	UG/L	2	.3K	.3K	.3K		.3K	.3K	.3K	4
01114 LEAD(P3)	TOT.REC.	UG/L	5K	5K	5K	5K		5K	5K	5K	5K
01118 CHRMIUM	TOT.REC.	UG/L	5K	5K	5K	5K		5K	5K	5K	5K
01119 COPPER	TOT.REC.	UG/L	5K	5K	5K	5		5K	10	5K	9
01125 MNGANESE	TOT.REC.	UG/L	50K	50K	50K	50K		50K	50K	50K	50K
01147 SELENIUM	SE,TCT	UG/L	2K			2K				2K	
22703 U-NAT	DISOLVED	UG/L					1.000			1.000	
31615 FEC COLI	MPNECMED	/100ML	3K	3K	3K	3K		4	4	3K	4
70300 RESIDUE	DISS-180 C	MG/L	330	340	340	160		150	230	270	320
71900 MERCURY	HG,TOTAL	UG/L	.5K			.5K				.5K	
74041 WQF	SAMPLE	UPDATED	860828								

			82/02/09 1520 WATER	82/04/19 1405 WATER	82/06/15 1505 WATER	82/08/23 1440 WATER	82/10/23 1455 WATER	82/12/14 1445 WATER	83/01/17 1325 WATER	83/03/17 1305 WATER	83/05/23 1515 WATER
INITIAL DATE											
INITIAL TIME											
MEDIUM											
00010 WATER	TEMP	CENT	1.1$	7.2$	8.3$	15.0$	4.4$	.0$	1.1$	5.6$	11.1$
00011 WATER	TEMP	FAHN	34.0	45.0	47.0	59.0	40.0	32.0	34.0	42.0	52.0
00021 AIR	TEMP	FAHN	25.0	50.0	65.0	75.0	45.0	20.0	35.0	30.0	
00095 CNDUCTVY	AT 25C	MICROMHO	460	310	160	250	350	420	450	440	270
00300 DO		MG/L	10.8	10.0	10.4	8.2	10.8	11.9	11.8	10.5	9.2
00301 DO	SATUR	PERCENT	76.1$	32.0$	37.4$	80.4$	82.4$	81.5$	81.7$	84.0$	82.9$
00400 PH		SU	8.10	8.30	8.10	8.30	8.00	8.10	8.30	8.40	8.20
00410 T ALK	CACO3	MG/L	120	120	54	76	110	114	112	123	100
00530 RESIDUE	TOT NFLT	MG/L	10K	59	40	10K	16	13	10K	19	510
00610 NH3+NH4-	N TOTAL	MG/L	.100K	.100K	.100K	.200	.100K	.100K	.100K	.100K	.100K
00612 UN-IONZD	NH3-N	MG/L	.001$	.003$	.002$	.010$	.001$	.001$	.002$	.003$	.003$
00619 UN-IONZD	NH3-NH3	MG/L	.001$	.004$	.002$	.013$	.001$	.001$	.002$	.004$	.004$
00625 TOT KJEL	N	MG/L	1.000K	1.000K	1.000K	1.000K	1.000K	1.000K	1.000K	1.000K	1.500
00630 NO2&NO3	N-TOTAL	MG/L	.50K	.50K	.40K	.50K	.50K	.50K	.50K	.50K	.50K
00665 PHOS-TOT		MG/L P	.050K	.060	.050K	.050K	.050K	.050K	.050K	.050K	.350
00723 CYANIDE	DISSOLVE	UG/L	.01K	.01K	.01K	.01K	.01K	.01K	.01K	.01K	.01K
00937 PTSSIUM	K,TCT	MG/L			1.00K			1.00K			1.30

(SAMPLE CONTINUED ON NEXT PAGE)

WRIGHT WATER ENGINEERS, INC.

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                                              000145
                                              39 12 06.0 107 13 53.0 2
                                              CRYSTAL RIVER AT REDSTONE
                                              03097   COLORADO        PITKIN
/TYPA/AMBNT/STREAM                            COLORADO RIVER          110300
                                              UPPER COLORADO RIVER
                                              21COL001  800419            15010004008 0003.390 ON
                                              0000 FEET DEPTH
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(SAMPLE CONTINUED FROM PREVIOUS PAGE)

INITIAL DATE INITIAL TIME MEDIUM				82/02/09 1520 WATER	82/04/19 1405 WATER	82/06/15 1505 WATER	82/08/23 1440 WATER	82/10/28 1455 WATER	82/12/14 1445 WATER	83/01/17 1325 WATER	83/03/17 1305 WATER	83/05/23 1515 WATER
00945	SULFATE	SO4-TOT	MG/L	130	63	14	55	86	110	98	120	35
00980	IRON	TOT REC	UG/L	100K	530	170	100K	240	100K	100K	190	
01002	ARSENIC	AS,TOT	UG/L			10K			10K			10K
01034	CHROMIUM	CR,TOT	UG/L							5K		
01045	IRON	FE,TOT	UG/L									3250
01079	SILVER	TOT.REC.	UG/L			.2K			.2K			.2K
01094	ZINC(ZN)	TOT.REC.	UG/L	10K	10K	105	10K	10K	10K	10K	10K	20
01113	CADIUM T	OT.REC.	UG/L	2	1	.3K	.3K	.6	.5	2	.3K	.3K
01114	LEAD(PB)	TOT.REC.	UG/L	5K	5K	5K	5K	7	5K	5K	5K	17
01118	CHRMIUM	TOT.REC.	UG/L	5K	5K	5K		5K	5K		5K	
01119	COPPER	TOT.REC.	UG/L	5K	5	5K	5K	5K	5K	5K	5K	6
01123	MNGANESE	TOT.REC.	UG/L	50K	50K	170	50K	50K	50K	50K	50K	190
22703	U-NAT	DISOLVED	UG/L			1.000			2.000			3.000K
31615	FEC COLI	MPNECMED	/100ML			4		4	4		3K	
70300	RESIDUE	DISS-180 C	MG/L	330	200	120	130	240	280	290	300	160
71900	MERCURY	HG,TOTAL	UG/L			.5K			.5K			.5K

INITIAL DATE INITIAL TIME MEDIUM				83/07/18 1400 WATER	83/09/21 1430 WATER	83/11/30 1445 WATER	84/02/21 1530 WATER	84/05/01 1110 WATER	84/06/27 1455 WATER	84/08/28 1810 WATER	84/10/11 1515 WATER	84/12/04 1355 WATER
00010	WATER	TEMP	CENT	12.8$	9.4$	1.1$	1.7$	7.2$	11.1$	15.1$	9.4$	.6$
00011	WATER	TEMP	FAHN	55.0	49.0	34.0	35.0	45.0	52.0	61.0	49.0	33.0
00021	AIR	TEMP	FAHN	80.0	65.0	30.0	35.0	40.0	75.0	70.0	60.0	35.0
00095	CNDUCTVY	AT 25C	MICROMHO	170	380	350	490	400	150	270	300	430
00300	DO		MG/L	9.4	9.2	10.5	11.8	10.5	9.7	8.2	9.6	10.9
00301	DO	SATUR	PERCENT	88.7$	79.3$	73.9$	85.5$	86.1$	87.4$	82.0$	82.8$	76.8$
00310	BOD	5 DAY	MG/L	1.0K	1.0K	1.0	2.0	1.0K	1.0K	1.00		1.0
00400	PH		SU	7.90	7.90	7.90	8.00	8.20	8.30	8.30	8.20	8.30
00410	T ALK	CACO3	MG/L	62	100	78	140	134	58	80	100	120
00530	RESIDUE	TOT NFLT	MG/L	15	10K	10K	61	40	47	43	100	13
00610	NH3+NH4-	N TOTAL	MG/L	.100K	.100K	.100K	.100K		.100K	.100U	.100U	.100U
00612	UN-IONZD	NH3-N	MG/L	.002$	.001$	.0007$	.0009$		.004$	.006$	.003$	.002$
00619	UN-IONZD	NH3-NH3	MG/L	.002$	.002$	.0009$	.001$		.005$	.007$	.003$	.002$
00625	TOT KJEL	N	MG/L	1.000K	1.000K	1.000K	1.000K		1.000K	1.000U	1.000U	1.000U
00630	NO2&NO3	N-TOTAL	MG/L	.50K	.50K	.50K	.50K		.50K	.500	.500	.500
00665	PHOS-TOT		MG/L P	.050K	.050K	.050K	.050K	.050K	.059	.050U	.050U	.050U
00900	TOT HARD	CACO3	MG/L	110	170	220	250	200	74	150	170	210
00945	SULFATE	SO4-TOT	MG/L	19	91	120	140	34	20	40	80	100

(SAMPLE CONTINUED ON NEXT PAGE)

WRIGHT WATER ENGINEERS, INC.

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                                           000145
                                           39 12 06.0 107 13 53.0 2
                                           CRYSTAL RIVER AT REDSTONE
                                           08097   COLORADO          PITKIN
/TYPA/AMBNT/STREAM                         COLORADO RIVER            110300
                                           UPPER COLORADO RIVER
                                           21COLO01  800419            14010004003 0003.390 ON
                                           0000 FEET DEPTH
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(SAMPLE CONTINUED FROM PREVIOUS PAGE)

			83/07/13	83/09/21	83/11/30	84/02/21	84/05/01	84/06/27	84/08/23	84/10/11	84/12/04
INITIAL DATE											
INITIAL TIME			1400	1430	1445	1530	1110	1455	1610	1515	1355
MEDIUM			WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER
00980 IRON	TOT REC	UG/L	340	130	100K	450	350	560	390	190	300
01094 ZINC(ZN)	TOT.REC.	UG/L	260	10K	10K	10K	10K	10K	10U	25	10U
01113 CADIUM T	OT.REC.	UG/L	.3K	.3K	.3K	5	.3K	.3K	.3U	.3U	.3U
01114 LEAD(PB)	TOT.REC.	UG/L	5K	5K	5K	5K	5K	5K	5U	5U	5U
01118 CHRMIUM	TOT.REC.	UG/L	5K	5K	5K	5K	5K	5K	5U	5U	5U
01119 COPPER	TOT.REC.	UG/L	5K	5K	5K	5K	5K	5K	5U	5U	5U
01123 MNGANESE	TOT.REC.	UG/L	50K	50K	50K	50K	80	50K	50U	50U	50U
31615 FEC COLI	MPNECMED	/100ML						3K	4		4
70300 RESIDUE	DISS-180 C	MG/L	110	240	290	330	260	82	170	210	270

			85/01/24	85/03/20	85/05/14	85/07/17	85/09/18	85/11/26	86/02/18	86/04/14	86/06/11
INITIAL DATE											
INITIAL TIME			1650	1010	1245	1420	1600	1605	1440	1355	1415
MEDIUM			WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER
00010 WATER	TEMP	CENT	.0$	3.3$	6.7$	12.2$	11.1$			6.7$	9.4$
00011 WATER	TEMP	FAHN	32.0	38.0	44.0	54.0	52.0			44.0	49.0
00021 AIR	TEMP	FAHN	20.0	35.0	55.0	70.0	70.0	35.0	40.0	45.0	70.0
00095 CNDUCTVY	AT 25C	MICROMHO	470	440	370	200	350	400	450	320	190
00300 DO		MG/L	10.6	11.2	9.8	8.6	9.0	10.6	11.0	11.8	10.8
00301 DO	SATUR	PERCENT	72.6$	83.0$	80.3$	79.6$	81.1$			98.7$	93.1$
00310 BOD	5 DAY	MG/L	1.0	2.0	1.0U	1.0U	1.0U	1.0	1.0U	1.0U	1.0U
00400 PH		SU	8.10	8.10	8.00	7.20	8.30	8.10	7.90	8.30	8.00
00410 T ALK	CACO3	MG/L	116	132	98	62	90	128	108	122	72
00530 RESIDUE	TOT NFLT	MG/L	16	51	30	10U	13	10U	11	50	24
00610 NH3+NH4-	N TOTAL	MG/L	.100U	.100U	.100U	.100U	.100U	.100U	.100U	.100U	.100U
00612 UN-IONZD	NH3-N	MG/L	.001$	.001$	.001$	.0003$	.004$			.003$	.002$
00619 UN-IONZD	NH3-NH3	MG/L	.001$	.002$	.002$	.0004$	.005$			.003$	.002$
00625 TOT KJEL	N	MG/L	1.000U	1.000U	1.000U	1.000U	1.000U	1.000U	1.000U	1.000U	1.000U
00630 NO2&NO3	N-TOTAL	MG/L	.50U	.50U	.50U	.50U	.50U	.50U	.50U	.50U	.50U
00665 PHOS-TOT		MG/L P	.050U	.050	.050U	.050U	.050U	.050U	.050U	.070	.054
00700 TOT HARD	CACO3	MG/L	220	220	120	90	150	190	210	160	80
00945 SULFATE	SO4-TOT	MG/L	120	100	36	28	75	92	120	55	23
00980 IRON	TOT REC	UG/L	130	830	680	100U	310	100U	150	430	1500
01094 ZINC(ZN)	TOT.REC.	UG/L	10U	10U	10U	10U	10U	10U	10U	10U	10U
01113 CADIUM T	OT.REC.	UG/L	.3U	.3U	.3U	.3U	.3U	.3U	.3U	.3U	.3U
01114 LEAD(PB)	TOT.REC.	UG/L	5U	5U	5U	5U	5U	5U	5U	5U	5U
01118 CHRMIUM	TOT.REC.	UG/L	5U	5U	5U	5U	5U	5U	5U	5U	5U
01119 COPPER	TOT.REC.	UG/L	5U	5U	5U	5U	5U	5U	5U		
01123 MNGANESE	TOT.REC.	UG/L	50U	50U	50U	50U	50U	50U	50U	50U	120

(SAMPLE CONTINUED ON NEXT PAGE)

WRIGHT WATER ENGINEERS, INC.

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                                                    000145
                                                    39 12 06.0 107 13 53.0 2
                                                    CRYSTAL RIVER AT REDSTONE
                                                    08097    COLORADO         PITKIN
/TYPA/AMBNT/STREAM                                  COLORADO RIVER           110300
                                                    UPPER COLORADO RIVER
                                                    21CCL001  800419            14010004008 0003.590 ON
                                                    0000 FEET DEPTH
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(SAMPLE CONTINUED FROM PREVIOUS PAGE)

				85/01/24	85/03/20	85/05/14	85/07/17	85/09/18	85/11/26	86/02/18	86/04/14	86/06/11
	INITIAL DATE											
	INITIAL TIME			1550	1010	1245	1420	1600	1605	1440	1355	1415
	MEDIUM			WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER
31615	FEC COLI	MPNECMED	/100ML	4		3U	4	4	4	3U	23	4	9
70300	RESIDUE	DISS-180	C MG/L	300	290	150	110	210	240	270	200	110
74041	WQF	SAMPLE	UPDATED							860717	860717	860828

				86/08/26	86/10/28	86/12/16	87/01/26	87/03/04	87/05/28	87/07/30	87/09/29	87/11/09
	INITIAL DATE											
	INITIAL TIME			1640	1425	1545	1330	1435	1705	1330	1355	1620
	MEDIUM			WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER
00010	WATER	TEMP	CENT	16.1$	7.2$	1.7$	2.2$	5.0$	11.1$	15.6$	10.6$	5.1$
00011	WATER	TEMP	FAHN	61.0	45.0	35.0	36.0	41.0	52.0	50.0	51.0	43.0
00021	AIR	TEMP	FAHN	75.0	60.0	30.0	35.0	40.0	60.0	75.0	75.0	50.0
00095	CNDUCTVY	AT 25C	MICROMHO	270	320	380	470	490	240	240	470	410
00300	DO		MG/L	9.4	11.0	11.3	10.6	10.6	9.3	8.3	10.5	11.0
00301	DO	SATUR	PERCENT	94.0$	90.2$	81.9$	76.8$	80.8$	83.8$	83.0$	94.6$	88.0$
00310	BOD	5 DAY	MG/L	1.0U	1.0U	1.0U	1.0U	1.0	1.0U	1.2	1.0	1.0U
00400	PH		SU	8.10	8.10	3.00	8.20	8.10		8.40	8.00	8.30
00410	T ALK	CACO3	MG/L	72	92	112	120	130	85	74	112	104
00530	RESIDUE	TOT NFLT	MG/L	10U	10U	10U	27	14	10U	10U	10U	10U
00610	NH3+NH4-	N TOTAL	MG/L	.100U	.100U	.100U	.120	.220	.100U	.270	.100U	.100U
00612	UN-IONZD	NH3-N	MG/L	.004$	.002$	.0009$	.002$	.003$		.018$	.002$	.003$
00619	UN-IONZD	NH3-NH3	MG/L	.004$	.002$	.001$	.002$	.004$		.022$	.002$	.003$
00625	TOT KJEL	N	MG/L	1.400	1.000U	1.000U	1.000U	1.000U	1.500	1.000U	1.000U	1.000U
00630	NO2&NO3	N-TOTAL	MG/L	.50U	.50U	.50U	.50U	.50U	.50U	.50U	.50U	.50U
00665	PHOS-TOT		MG/L P	.050U	.050U	.050U	.050U	.050U	.050U	.050U	.050U	.050U
00900	TOT HARD	CACO3	MG/L	120	160	200	230	240	110	120	190	210
00945	SULFATE	SO4-TOT	MG/L	51	73	110	130	140	35	53	110	120
00980	IRON	TOT REC	UG/L	100U	100U	110	140	360	100	200	100U	100U
01094	ZINC(ZN)	TOT.REC.	UG/L	10U	10U	10U	10U	10U	10U	10U	10U	10U
01113	CADIUM T	OT.REC.	UG/L	.3U	.3U	.3U	.3U	.3U	.3U	.3U	.3U	.3U
01114	LEAD(PB)	TOT.REC.	UG/L	5U	5U	5U	5U	5U	5U	5U	5U	5U
01118	CHRMIUM	TOT.REC.	UG/L	5U	5U	5U	5U	5U	5U	5U	5U	5U
01119	COPPER	TOT.REC.	UG/L				5U	5U	5U	5U	5U	5U
01123	MNGANESE	TOT.REC.	UG/L	50U	50U	50U	50U	50U	50U	50U	50U	50U
31615	FEC COLI	MPNECMED	/100ML	3U	4	3U		.9	3U	50U	50U	500
70300	RESIDUE	DISS-180	C MG/L	140	220	260	300	350	140	130	270	30
74041	WQF	SAMPLE	UPDATED	870121	870121	870309	870416	870527	870825	871105	871214	880121

WRIGHT WATER ENGINEERS, INC.

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                                              000145
                                              39 12 06.0 107 13 53.0 2
                                              CRYSTAL RIVER AT REDSTONE
                                              03097   COLORADO          PITKIN
/TYPA/AMBNT/STREAM                            COLORADO RIVER            110300
                                              UPPER COLORADO RIVER
                                              21COL001   800419              14010004008 0003.390 CN
                                              0000 FEET DEPTH
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			88/02/15	88/04/14	88/06/13	88/08/16	88/10/12	88/12/01	89/01/30	89/03/28	89/05/15
INITIAL TIME			1445	1225	1540	1640	1440	1500	1405	1300	1340
MEDIUM			WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER
00010 WATER	TEMP	CENT	.6$	8.3$	9.4$	16.7$	11.1$	1.7$	1.1$	7.8$	7.2$
00011 WATER	TEMP	FAHN	33.0	47.0	49.0	62.0	52.0	35.0	34.0	46.0	45.0
00021 AIR	TEMP	FAHN	25.0	60.0	75.0	70.0	65.0	30.0	35.0	60.0	
00095 CNDUCTVY	AT 25C	MICROMHO	510	310	180	610	510	530	590	520	230
00300 DO		MG/L	12.5	10.2	10.0	7.5	10.6	11.4	10.9	10.0	10.5
00301 DO	SATUR	PERCENT	89.0$	85.7$	86.2$	78.4$	95.5$	82.6$	76.8$	84.0$	86.1$
00310 BOD	5 DAY	MG/L	2.0	1.0	1.0U	2.0	1.0	1.0	1.0U		
00400 PH		SU	8.70	8.40	8.30	8.50	8.60	8.70	8.50	9.10	8.50
00410 T ALK	CACO3	MG/L	132	94	58	154	110	115	132	128	88
00530 RESIDUE	TOT NFLT	MG/L	10	94	10U	970	10U	10U	77	42	16
00610 NH3+NH4-	N TOTAL	MG/L	.100U	.100U	.100	.130	.100U	.100U	.100U	.100U	.100U
00612 UN-IONZD	NH3-N	MG/L	.004$	.004$	.003$	.012$	.007$	.005$	.003$	.016$	.005$
00619 UN-IONZD	NH3-NH3	MG/L	.005$	.005$	.004$	.014$	.009$	.006$	.004$	.020$	.005$
00625 TOT KJEL	N	MG/L	1.000U	1.000U	2.200	2.200	1.000U	1.000U	2.200	1.000U	1.000U
00630 NO2&NO3	N-TOTAL	MG/L	.50U	.50U	.50U	.50U	.50U	.50U	.50U	.50U	.50U
00665 PHOS-TOT		MG/L P	.050U	.070	.050U	.540	.050U	.050U	.050U	.050U	.050U
00900 TOT HARD	CACO3	MG/L	280	170	78	160	200	240	250	210	110
00945 SULFATE	SO4-TOT	MG/L	150	73	21	150	140	160	130	110	40
00980 IRON	TOT REC	UG/L	160	310	330						
01025 CADMIUM	CD,DISS	UG/L				.3U	.3U	.3U	.3U	.3U	.3U
01030 CHROMIUM	CR,DISS	UG/L				5U	5U	5U	5U	5U	5U
01040 COPPER	CU,DISS	UG/L				5U	5U	5U	5U	5U	5U
01046 IRON	FE,DISS	UG/L				100U	100U	100U	100U	100U	100U
01049 LEAD	PB,DISS	UG/L				5U	5U	5U	5U	5U	5U
01056 MANGNESE	MN,DISS	UG/L				50.0U	50.0U	50.0U	50.0U	50.0U	50.0U
01090 ZINC	ZN,DISS	UG/L				10U	10U	10U	10U	10U	10U
01094 ZINC(ZN)	TOT.REC.	UG/L	20	10U	10U						
01113 CADIUM T	OT.REC.	UG/L	.3U	.3U	.3U						
01114 LEAD(PB)	TOT.REC.	UG/L	5U	5U	5U						
01119 CHRMIUM	TOT.REC.	UG/L	5U	5U	5U						
01119 COPPER	TOT.REC.	UG/L	5U	5U	5U						
01123 MNGANESE	TOT.REC.	UG/L	50U	50U	50U						
31615 FEC COLI	MPN/CMED	/100ML	3U	3U	3U	230	4	30	30	30	4
70300 RESIDUE	DISS-180 C	MG/L	340	200	96	400	310	370	390	320	150
74041 WQF	SAMPLE	UPDATED	880412	880609	880801	881103	881128	890207	890425	890607	890627

WRIGHT WATER ENGINEERS, INC.

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                                                000145
                                                39 12 06.0 107 13 53.0 2
                                                CRYSTAL RIVER AT REDSTONE
                                                08097   COLORADO        PITKIN
                                                COLORADO RIVER          110300
/TYPA/AMBNT/STREAM                              UPPER COLORADO RIVER
                                                21COL001  800419             14010004003 0003.390 ON
                                                0000 FEET DEPTH
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				89/07/06	89/09/25	89/11/20	90/02/12	90/04/05	90/06/07	90/08/02	90/10/29	91/01/16
INITIAL DATE												
INITIAL TIME				1415	1355	1310	1320	1440	1320	1500	1225	1410
MEDIUM				WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER
00010	WATER	TEMP	CENT	15.6$	13.3$	5.0$	2.2$	6.7$	9.4$	13.3$	7.2$	1.7$
00011	WATER	TEMP	FAHN	60.0	56.0	41.0	36.0	44.0	49.0	56.0	45.0	35.0
00021	AIR	TEMP	FAHN		60.0	50.0	40.0		75.0	65.0	65.0	35.0
00095	CNDUCTVY	AT 25C	MICROMHO	200	430	520	580	410	150	270	410	430
00300	DO		MG/L	8.6	9.0	12.6	11.4	10.8	9.4	8.8	10.4	12.2
00301	DO	SATUR	PERCENT	86.0$	84.9$	98.4$	92.6$	88.5$	81.0$	83.0$	85.2$	88.4$
00400	PH		SU	3.30	3.70	3.60	8.60	8.70	8.40	3.40	8.50	8.50
00410	T ALK	CACO3	MG/L	50	104	132	120	116	60	98	93	120
00530	RESIDUE	TOT NFLT	MG/L	10U	10U	10U	10U	47	69	10U	10U	11
00610	NH3+NH4-	N TOTAL	MG/L	.110	.100U	.100U	.100	.100U	.320	.100U	.100U	.100U
00612	UN-IONZD	NH3-N	MG/L	.006$	.011$	.005$	.004$	.007$	.014$	.006$	.005$	.004$
00619	UN-IONZD	NH3-NH3	MG/L	.007$	.013$	.006$	.005$	.008$	.017$	.007$	.005$	.004$
00625	TOT KJEL	N	MG/L	1.000U	6.600	1.000U	1.000U	1.000U	1.000U	1.000U	1.000U	1.000U
00630	NO2&NO3	N-TOTAL	MG/L	.50U	.50U	.50U	.50U	.50U	.50U	.50U	.50U	.50U
00665	PHOS-TOT		MG/L P	.050U	.050U	.050U	.050U	.050U	.140	.050U	.050U	.050U
00900	TOT HARD	CACO3	MG/L	94	210	240	270	190	82	150	200	220
00945	SULFATE	SO4-TOT	MG/L	38	110	140	170	100	20	74	110	150
01025	CADMIUM	CD,DISS	UG/L	.3U	.3U	.3U	.3U	.3U	.3U	.3U	.3U	.3U
01030	CHROMIUM	CR,DISS	UG/L	5U	5U	5U	5U	5U	5U	5U	5U	5U
01040	COPPER	CU,DISS	UG/L	5U	5U	5U	5U	5U	5U	5U	40	40
01046	IRON	FE,DISS	UG/L	100U	100U	100U	100U	100U	100U	100U	100	100
01049	LEAD	PB,DISS	UG/L	5U	5U	5U	5U	5U	5U	5U	5U	5U
01056	MANGNESE	MN,DISS	UG/L	50.0U	50.0U	50.0U	50.00	50.00	50.00	50.00	5.0	4.00
01090	ZINC	ZN,DISS	UG/L	10U	10U	10U	25U	10U	10U	10U	80	80
31615	FEC COLI	MPNECMED	/100ML	3U	3U	3U	3U	3U	4	4	30	30
70300	RESIDUE	DISS-180	C MG/L	110	270	370	400	260	97	210	290	360
74041	WQF	SAMPLE	UPDATED	391003	391204	900323	900515	900620	901002	901109	910412	910826

				91/03/18	91/07/15	91/09/06	91/11/12	92/04/09
INITIAL DATE								
INITIAL TIME				1355	1430	1350	1440	1345
MEDIUM				WATER	WATER	WATER	WATER	WATER
00010	WATER	TEMP	CENT	4.4$	15.5$	16.1$	6.1$	9.4$
00011	WATER	TEMP	FAHN	40.0	60.0	61.0	43.0	49.0
00021	AIR	TEMP	FAHN	55.0	85.0	70.0	50.0	70.0
00095	CNDUCTVY	AT 25C	MICROMHO	520	200	370	470	400

(SAMPLE CONTINUED ON NEXT PAGE)

WRIGHT WATER ENGINEERS, INC.

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                                        000145
                                        39 12 06.0 107 13 53.0 2
                                        CRYSTAL RIVER AT REDSTONE
                                        08097   COLORADO              PITKIN
/TYPA/AMBNT/STREAM                      COLORADO RIVER                110300
                                        UPPER COLORADO RIVER
                                        2100L001  800419                    14010004008 0003.390 ON
                                        0000 FEET DEPTH
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(SAMPLE CONTINUED FROM PREVIOUS PAGE)

				91/03/13	91/07/15	91/09/06	91/11/12	92/04/09
INITIAL DATE				91/03/13	91/07/15	91/09/06	91/11/12	92/04/09
INITIAL TIME				1355	1430	1350	1440	1345
MEDIUM				WATER	WATER	WATER	WATER	WATER
00300	DO		MG/L	11.0	9.0	8.6	11.3	10.6
00301	DO	SATUR	PERCENT	84.0$	90.0$	86.0$	90.4$	91.4$
00400	PH		SU	8.30	8.40	8.60	8.60	8.60
00410	T ALK	CACO3	MG/L	124	64	90	120	114
00530	RESIDUE	TOT NFLT	MG/L	10U	10U	10U	10U	42
00610	NH3+NH4-	N TOTAL	MG/L	.100U	.100U	.100U	.100U	.100U
00612	UN-IONZD	NH3-N	MG/L	.002$	.007$	.011$	.005$	.007$
00617	UN-IONZD	NH3-NH3	MG/L	.003$	.008$	.013$	.006$	.008$
00625	TOT KJEL	N	MG/L	1.000U	1.000U	1.000U	1.000U	1.000U
00630	NO2&NO3	N-TOTAL	MG/L	.50U	.50U	.50U	.50U	.50U
00665	PHOS-TOT		MG/L P	.050U	.050U	.050U	.050U	.050U
00900	TOT HARD	CACO3	MG/L	240	96	170	190	190
00945	SULFATE	SO4-TOT	MG/L	160	33	91	100	96
01025	CADMIUM	CD/DISS	UG/L	.3U	.3U	.3U	.3U	.3U
01030	CHROMIUM	CR/DISS	UG/L	5U	5U	5U	5U	5U
01040	COPPER	CU/DISS	UG/L	4U	4U	4U	4U	4U
01046	IRON	FE/DISS	UG/L	10U	10U	10U	10U	18
01049	LEAD	PB/DISS	UG/L	5U	5U	5U	5U	5U
01056	MANGNESE	MN/DISS	UG/L	4.0U	4.0U	4.0U	4.0U	4.0U
01090	ZINC	ZN/DISS	UG/L	8U	3U	3U	3U	8U
31515	FEC COLI	MPNECMED	/100ML	3U	4		3U	3U
70300	RESIDUE	DISS-180 C	MG/L	360	110	220	300	260
74041	WQF	SAMPLE	UPDATED	920407	911213	920311	920701	920701

WRIGHT WATER ENGINEERS, INC.

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                                              000146
                                              39 24 30.0 107 13 44.0 2
                                              CRYSTAL RIVER NEAR MOUTH
/TYPA/AMBNT/STREAM                            08045    COLORADO        GARFIELD
                                              COLORADO RIVER           110300
                                              UPPER COLORADO RIVER
                                              21CCL001   300419            14010004005 0000.600 CN
                                              0000 FEET DEPTH
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INITIAL DATE INITIAL TIME MEDIUM			79/05/29 1450 WATER	79/06/27 1600 WATER	79/07/23 1600 WATER	79/08/27 1420 WATER	79/09/10 1530 WATER	79/10/22 1340 WATER	79/11/14 1400 WATER	79/12/04 1515 WATER	80/01/07 1230 WATER
00010 WATER	TEMP	CENT	10.6$	14.4$	15.0$	15.0$	17.2$	7.8$	5.6$	2.3$	1.7$
00011 WATER	TEMP	FAHN	51.0	58.0	59.0	59.0	63.0	46.0	42.0	36.2	35.0
00076 TURB	TRBIDMTR	HACH FTU	140.0	22.0	4.0	3.0	3.2	4.6	2.0	1.4	.9
00095 CNDUCTVY	AT 25C	MICROMHO	190	190	260	600	430	540	620	700	610
00300 DO		MG/L	9.4	9.6	7.5	8.6	8.6	10.9	11.7	11.7	11.6
00301 DO	SATUR	PERCENT	84.7$	92.3$	73.5$	84.3$	88.7$	91.5$	93.6$	84.8$	84.1$
00310 BOD	5 DAY	MG/L	1.0	1.0	1.0	1.0	1.0K	1.0K	2.0	2.0	2.0
00400 PH		SU	7.90	7.00	7.00	7.90	8.00	7.80	7.90		8.30
00410 T ALK	CACO3	MG/L	57						170		
00530 RESIDUE	TOT NFLT	MG/L	280	50	10	10K	10K	10	10K	10K	10K
00610 NH3+NH4-	N TOTAL	MG/L	.190	.100K	.100K	.050K	.050K	.050K	.060	.050	.050K
00512 UN-IONZD	NH3-N	MG/L	.003$	.0003$	.0003$	.001$	.002$	.0005$	.0006$		.0009$
00615 NO2-N	TOTAL	MG/L	.006								
00619 UN-IONZD	NH3-NH3	MG/L	.004$	.0003$	.0003$	.001$	.002$	.0005$	.0007$		.001$
00625 TOT KJEL	N	MG/L			1.000K		1.000K		1.000K		
00630 NO2&NO3	N-TOTAL	MG/L	.20	.19	.23	.17	.18	.43	.25	.20	.26
00665 PHOS-TOT		MG/L P	.060	.030K	1.000K	.050K	.050K	.050K	.050K	.050K	.100
00723 CYANIDE	DISSOLVE	UG/L	.005K		.005K		.050K		.005K		
00900 TOT HARD	CACO3	MG/L	87	107	120	240	270	300	300	280	300
00910 CALCIUM	CACO3	MG/L	64.0	69.0	93.0	200.0	220.0	240.0	240.0	240.0	280.0
00927 MGNSIUM	MG/TOT	MG/L	6.0	9.0	6.0	10.0	12.0	15.0	14.0	10.0	6.0
00929 SODIUM	NA/TOT	MG/L	5.00K	5.00K	5.00K	10.00	10.00	12.00	15.00	20.00	21.00
00931 SODIUM	ADSBTION	RATIO	.2	.0	.2	.3	.3	.3	.4	1.0	.5
00937 PTSSIUM	K/TOT	MG/L	1.00						2.40		
00940 CHLORIDE	TOTAL	MG/L	5	5	4	6	6	9	8	9	12
00945 SULFATE	SO4-TOT	MG/L	10		45		120		170		
00980 IRON	TOT REC	UG/L	4200	1000	300	100K	100K	100K		100K	100K
00998 BERYLIUM	TOT.REC.	UG/L	50K						50K		
01002 ARSENIC	AS/TOT	UG/L	5K								
01022 BORON	B/TOT	UG/L	85						40K		
01074 NICKEL	TOT.REC.	UG/L	100K						50K		
01079 SILVER	TOT.REC.	UG/L	50K								
01094 ZINC(ZN)	TOT.REC.	UG/L	30	20	20K	20K	20K	20K		20K	20K
01104 ALUMINUM	TOT.REC.	UG/L	2700						2000K		
01113 CADIUM T	OT.REC.	UG/L	.3K		.5		.3K				

(SAMPLE CONTINUED ON NEXT PAGE)

WRIGHT WATER ENGINEERS, INC.

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                                                      000146
                                                      39 24 30.0 107 13 44.0 2
                                                      CRYSTAL RIVER NEAR MOUTH
                                                      08045    COLORADO          GARFIELD
                                                      COLORADO RIVER             110300
/TYPA/AMBNT/STREAM                                    UPPER COLORADO RIVER
                                                      21CCL001  880419              14010004005 0000.600 ON
                                                      0000 FEET DEPTH
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(SAMPLE CONTINUED FROM PREVIOUS PAGE)

			79/05/29	79/06/27	79/07/23	79/08/27	79/09/10	79/10/22	79/11/14	79/12/04	80/01/07
INITIAL DATE											
INITIAL TIME			1450	1600	1500	1420	1530	1340	1400	1515	1230
MEDIUM			WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER
01114 LEAD(PB)	TOT.REC.	UG/L	9K	9K	9K	9K	9K	9K		9K	9K
01113 CHRMIUM	TOT.REC.	UG/L	20K		20K		20K				
01119 COPPER	TOT.REC.	UG/L	9	6K	9	6K	6K	5K		6	6K
01123 MNGANESE	TOT.REC.	UG/L	140	70	50K	50K	50K	50K		50K	50K
01147 SELENIUM	SE/TOT	UG/L	5K						2K		
22703 U-NAT	DISCLVED								5.000K		
31615 FEC COLI	MPNECMED	/100ML	43	23	4	15	43	93	9	3K	3K
70300 RESIDUE	DISS-180	C MG/L	120	110	140	610	350	400	370	390	420
71900 MERCURY	HG/TOTAL	UG/L	.5K								
74041 WQF	SAMPLE	UPDATED	370217	370217	370217	370217	370217	370217	370217	370217	860828

			80/02/27	80/04/21	80/05/21	80/06/09	80/07/14	80/08/25	80/09/02	80/10/20	80/11/19
INITIAL DATE											
INITIAL TIME			1555	1700	1645	1210	1220	1320	1100	1540	1710
MEDIUM			WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER
00010 WATER	TEMP	CENT		11.1$	12.2$	8.3$	11.1$	16.7$	12.2$	10.0$	3.9$
00011 WATER	TEMP	FAHN		52.0	54.0	47.0	52.0	62.0	54.0	50.0	39.0
00021 AIR	TEMP	FAHN	80.0	60.0		80.0	70.0	75.0	70.0	65.0	30.0
00076 TURB	TRBIDMTR	HACH FTU	2.8	100.0	44.0	30.0	3.8				
00095 CNDUCTVY	AT 25C	MICROMHO	590	335	230	170	220				
00300 DO		MG/L		9.4	8.9	10.0	8.7	9.1	9.8	9.3	10.6
00301 DO	SATUR	PERCENT		84.7$	82.4$	84.0$	78.4$	93.8$	90.7$	86.7$	80.9$
00310 BOD	5 DAY	MG/L	2.0		7.0	1.0K	1.0K				
00400 PH		SU		7.50	8.00	8.00	7.70	8.40	8.20	7.90	8.20
00410 T ALK	CACO3	MG/L				66					
00530 RESIDUE	TOT NFLT	MG/L	10K	230	110	80	19	10K	10K	15	10K
00610 NH3+NH4-	N TOTAL	MG/L	.030	.100K	.120	.050K	.050K		.050K	.130	.050K
00612 UN-IONZD	NH3-N	MG/L		.0005$	.003$	.0003$	.0005$		.002$	.002$	.0009$
00619 UN-IONZD	NH3-NH3	MG/L		.0003$	.003$	.0010$	.0006$		.002$	.002$	.001$
00625 TOT KJEL	N	MG/L	1.000K	1.000K		1.000K	1.000K		1.000K	1.000K	
00630 NO2&NO3	N-TOTAL	MG/L	.51	.13	.08	.12	.50K		.50K	.50K	
00665 PHOS-TOT		MG/L P	.050K	.130	.100	.030	.050		.050K	.050K	
00723 CYANIDE	DISSOLVE	UG/L	.005K	.005K		.005K		.005K		.005K	
00900 TOT HARD	CACO3	MG/L	310	180	120	140	120				
00910 CALCIUM	CACO3	MG/L	250.0	150.0	95.0	120.0	92.0				
00927 MGNSIUM	MG/TOT	MG/L	15.0	3.0	7.0	5.0	6.0				
00929 SODIUM	NA/TOT	MG/L	17.00	12.00	5.00	5.00K	5.00K				
00931 SODIUM	ADSETION	RATIO	.4	.4	.2	.2	.2				
00937 PTSSIUM	K/TOT	MG/L				1.00K					

(SAMPLE CONTINUED ON NEXT PAGE)

WRIGHT WATER ENGINEERS, INC.

```
                                        000146
                                        39 24 30.0 107 13 44.0 2
                                        CRYSTAL RIVER NEAR MOUTH
                                        08045   COLORADO          GARFIELD
/TYPA/AMBNT/STREAM                      COLORADO RIVER            110300
                                        UPPER COLORADO RIVER
                                        21COL001  800419                      14010004005 0000.500 ON
                                        0000 FEET DEPTH
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(SAMPLE CONTINUED FROM PREVIOUS PAGE)

			80/02/27	80/04/21	80/05/21	80/06/09	80/07/14	80/08/25	80/09/02	80/10/20	80/11/19
INITIAL DATE			80/02/27	80/04/21	80/05/21	80/06/09	80/07/14	80/08/25	80/09/02	80/10/20	80/11/19
INITIAL TIME			1555	1900	1645	1210	1220	1320	1100	1340	1710
MEDIUM			WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER
00940 CHLORIDE	TOTAL	MG/L	11	6	7	3	6				
00945 SULFATE	SO4-TOT	MG/L	190	95		24		110		170	
00930 IRON	TOT REC	UG/L	100K	1500	1200	1100	390	100K	100K	160	100K
00995 BERYLIUM	TOT.REC.	UG/L				50K					
01002 ARSENIC	AS,TOT	UG/L				5K					
01022 BORON	B,TOT	UG/L				40K					
01074 NICKEL	TOT.REC.	UG/L				50K					
01079 SILVER	TOT.REC.	UG/L				.2K					
01094 ZINC(ZN)	TOT.REC.	UG/L	30	20	0	20K	20K	20K	20K	20K	20K
01104 ALUMINUM	TOT.REC.	UG/L				1600K					
01113 CADIUM T	OT.REC.	UG/L	5K	.3K		2		.3K		9	
01114 LEAD(PB)	TOT.REC.	UG/L	10K	6	9	5	10K	5K	10K	5K	5K
01113 CHRMIUM	TOT.REC.	UG/L	5K	5K		5K		5K		5K	
01119 COPPER	TOT.REC.	UG/L	5K	5K	0	5	9	5K	5K	5K	5K
01123 MNGANESE	TOT.REC.	UG/L	50K	50	0	50	50K	50K	50K	50K	50K
01147 SELENIUM	SE,TOT	UG/L				2K					
31615 FEC COLI	MPNECMED	/100ML	3K		150	23	430	430	150	7	3K
70300 RESIDUE	DISS-180 C	MG/L	440	260	160	110	140	350	350	380	430
71900 MERCURY	HG,TOTAL	UG/L				.5K					
74041 WQF	SAMPLE	UPDATED	860828	860828		860828	860828	860828	860828	860828	860828

			80/12/18	81/01/20	81/02/17	81/03/16	81/04/08	81/05/25	81/06/15	81/07/09	81/07/20
INITIAL DATE			80/12/18	81/01/20	81/02/17	81/03/16	81/04/08	81/05/25	81/06/15	81/07/09	81/07/20
INITIAL TIME			1505	1030	1355	1230	1155	1210	1155	1355	1315
MEDIUM			WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER
00010 WATER	TEMP	CENT	5.0$	2.8$	6.7$	8.9$	6.1$	10.6$	7.8$		16.7$
00011 WATER	TEMP	FAHN	41.0	37.0	44.0	48.0	43.0	51.0	46.0		62.0
00021 AIR	TEMP	FAHN	40.0	35.0	50.0	50.0	50.0	60.0	70.0		90.0
00300 DO		MG/L	11.6	12.8	12.4	11.6	11.2	10.0	10.2		8.5
00301 DO	SATUR	PERCENT	90.6$	94.8$	101.5$	100.0$	89.8$	90.1$	85.7$		97.6$
00403 PH		SU	8.00	8.20	8.60			8.40	8.20	8.30	8.30
00410 T ALK	CACO3	MG/L	150					112	80		120
00530 RESIDUE	TOT NFLT	MG/L	10K	10K	10K	10K	10K	14	14		14
00610 NH3+NH4-	N TOTAL	MG/L	.050K	.100K	.100K	.100K	.140	.100K	.150		.100K
00612 UN-IONZD	NH3-N	MG/L	.0006$	.002$	.005$		.005$	.003$	.005$		.006$
00619 UN-IONZD	NH3-NH3	MG/L	.0007$	.002$	.007$		.006$	.004$	.006$		.007$
00625 TOT KJEL	N	MG/L	1.000K	1.000K			1.000K	1.000K			1.000K
00630 NO2&NO3	N-TOTAL	MG/L	.50K	.50K		.50K		.50K			.50K
00665 PHOS-TOT		MG/L P	.050K	.050K		.050K		.050K			.050K

(SAMPLE CONTINUED ON NEXT PAGE)

WRIGHT WATER ENGINEERS, INC.

```
                                              000146
                                              39 24 30.0 107 13 44.0 2
                                              CRYSTAL RIVER NEAR MOUTH
                                              08045   COLORADO        GARFIELD
                                              COLORADO RIVER          110300
/TYPA/AMBNT/STREAM                            UPPER COLORADO RIVER
                                              21CCL001  800419              14010004005 0000.600 ON
                                              0000 FEET DEPTH
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(SAMPLE CONTINUED FROM PREVIOUS PAGE)

INITIAL DATE			80/12/18	81/01/20	81/02/17	81/03/16	81/04/03	81/05/25	81/06/15	81/07/09	81/07/20
INITIAL TIME			1605	1030	1355	1230	1155	1210	1155	1355	1315
MEDIUM			WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER
00723 CYANIDE	DISSOLVE	UG/L	.01	.01K		.01K		.01K			.01K
00900 TOT HARD	CACO3	MG/L	500								
00910 CALCIUM	CACO3	MG/L	230.0								
00927 MGNSIUM	MG/TOT	MG/L	16.0								
00937 PTSSIUM	K/TOT	MG/L						1.40			
00945 SULFATE	SO4-TOT	MG/L	500	180		200		79			85
00980 IRON	TOT REC	UG/L	100K	100K	100K	100K	100K	250	150		100K
00993 BERYLIUM	TOT.REC.	UG/L	50K					50K			
01002 ARSENIC	AS/TOT	UG/L	10K					17			
01022 BORON	B/TOT	UG/L	80					60K			
01074 NICKEL	TOT.REC.	UG/L	50K					100K			
01079 SILVER	TOT.REC.	UG/L	.2K					.2K			
01094 ZINC(ZN)	TOT.REC.	UG/L	20K	10K	10K	10K	10K	10K	10K		10K
01104 ALUMINUM	TOT.REC.	UG/L	1000K					1000K			
01113 CADIUM T	OT.REC.	UG/L	.6	.3K		.3K		.3K			.3K
01114 LEAD(PB)	TOT.REC.	UG/L	5K	5K	10K	5K	5K	5K	7		5K
01115 CHRMIUM	TOT.REC.	UG/L	5K	5K		5K		5K			5K
01119 COPPER	TOT.REC.	UG/L	5K	5K	5K	5K	5K	5K	6		5K
01123 MNGANESE	TOT.REC.	UG/L		50K	50K	50K	50K	50K	50K		50K
01147 SELENIUM	SE/TOT	UG/L	2K					2K			
22703 U-NAT	DISCLVED	UG/L								3.000	
31615 FEC COLI	MPNECMED	/100ML	3K	9	3K	3K	4	43	9		23
70300 RESIDUE	DISS-180 C	MG/L	430	470	450	430	530	230	140		230
71900 MERCURY	HG/TOTAL	UG/L						.5K			
74041 WQF	SAMPLE	UPDATED	860329								

INITIAL DATE			81/08/13	81/09/21	81/10/21	81/11/13	81/12/13	82/01/13	82/02/09	82/03/10	82/04/19
INITIAL TIME			1455	1515	1100	1640	1425	1110	1430	1255	1320
MEDIUM			WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER
00010 WATER	TEMP	CENT	16.7$	17.2$	7.2$	5.0$	3.9$	2.3$	1.1$	6.1$	6.1$
00011 WATER	TEMP	FAHN	62.0	63.0	45.0	41.0	39.0	37.0	34.0	43.0	43.0
00021 AIR	TEMP	FAHN	75.0	80.0	70.0	35.0	35.0	35.0	25.0	50.0	50.0
00095 CNDUCTVY	AT 25C	MICROMHC		460	720	510	490	570	610	620	340
00300 DO		MG/L	7.8	8.3	10.8	10.4	11.8	12.2	11.0	11.6	10.8
00301 DO	SATUR	PERCENT	80.4$	85.6$	88.5$	81.3$	90.1$	90.4$	77.5$	92.8$	86.3$
00400 PH		SU	8.00	8.30	8.10	8.10	8.20	8.10	8.20	8.30	8.30
00410 T ALK	CACO3	MG/L	130	160	140	136	152	112	148	160	128
00530 RESIDUE	TOT NFLT	MG/L	680	33	13	10K	10K	15	10K	39	170

(SAMPLE CONTINUED ON NEXT PAGE)

WRIGHT WATER ENGINEERS, INC.

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000146
39 24 30.0 107 13 44.0 2
CRYSTAL RIVER NEAR MOUTH
08045    COLORADO           GARFIELD
COLORADO RIVER             110300
UPPER COLORADO RIVER
21CCL001   300419                     14010004005 0000.500 CN
0000 FEET DEPTH
```

/TYPA/AMBNT/STREAM

(SAMPLE CONTINUED FROM PREVIOUS PAGE)

Code	Name	Stat	Units	81/08/13 1455 WATER	81/09/21 1515 WATER	81/10/21 1100 WATER	81/11/18 1640 WATER	81/12/13 1425 WATER	82/01/18 1110 WATER	82/02/09 1430 WATER	82/03/10 1255 WATER	82/04/19 1320 WATER
00610	NH3+NH4-	N TOTAL	MG/L	.100	.100K	.100K	.100K	.100K	.100K	.100K	.100K	.100K
00612	UN-IONZD	NH3-N	MG/L	.004$	.006$	.002$	.002$	.002$	.001$	.001$	.003$	.003$
00519	UN-IONZD	NH3-NH3	MG/L	.005$	.007$	.002$	.002$	.002$	.002$	.002$	.003$	.003$
00625	TOT KJEL	N	MG/L		1.000K		1.000K	1.000K		1.000K		1.000K
00630	NO2&NO3	N-TOTAL	MG/L		.50		.50K	.50K		.50K		.50K
00665	PHOS-TOT		MG/L P		.050K		.050K	.050K		.050K		.170
00723	CYANIDE	DISSOLVE	UG/L		.01K		.01K	.01K		.01K		.01K
00937	PTSSIUM	K,TOT	MG/L				2.10					
00945	SULFATE	SO4-TOT	MG/L		130		140	150		180		79
00980	IRON	TOT REC	UG/L	3300	100K	100K	100K	100K	100	100K	610	1100
00998	BERYLIUM	TOT.REC.	UG/L				50K					
01002	ARSENIC	AS,TOT	UG/L				10K					
01022	BORON	B,TOT	UG/L				140					
01074	NICKEL	TOT.REC.	UG/L				100K					
01079	SILVER	TOT.REC.	UG/L				.2K					
01094	ZINC(ZN)	TOT.REC.	UG/L	30	10K	10K	10K	10K	10K	10K	10	10K
01104	ALUMINUM	TOT.REC.	UG/L				1500K					
01113	CADIUM T	OT.REC.	UG/L		.3K		.3K	.3K		.4		.3K
01114	LEAD(PB)	TOT.REC.	UG/L	25	5K	5K	5K	5K	8	5K	5K	7
01118	CHRMIUM	TOT.REC.	UG/L		5K		5K	5K		5K		5K
01119	COPPER	TOT.REC.	UG/L	14	5K	5K	5K	5K	5K	6	5K	8
01123	MNGANESE	TOT.REC.	UG/L	320	50K	50K	50K	50K	50K	50K	50K	70
01147	SELENIUM	SE,TOT	UG/L				2K					
22703	U-NAT	DISOLVED	UG/L				2.000					
31615	FEC COLI	MPNECMED	/100ML	430	23	23	3K	3K	3		5	
70300	RESIDUE	DISS-180 C	MG/L	180	340	360	370	410	420	430	390	290
71900	MERCURY	HG,TOTAL	UG/L				.5K					

Code	Name	Stat	Units	82/05/17 1145 WATER	82/06/15 1425 WATER	82/08/23 1400 WATER	82/10/28 1400 WATER	82/12/14 1355 WATER	83/01/17 1245 WATER	83/03/17 1400 WATER	83/05/16 1540 WATER	83/07/18 1445 WATER
00010	WATER	TEMP	CENT	7.8$	10.0$	17.8$	6.7$	3.3$	3.9$	5.0$	5.0$	14.4$
00011	WATER	TEMP	FAHN	46.0	50.0	64.0	44.0	38.0	39.0	41.0	41.0	58.0
00021	AIR	TEMP	FAHN	60.0	75.0	85.0	50.0	30.0	35.0	35.0		85.0
00095	CNDUCTVY	AT 25C	MICROMHO	330	180	420	460	520	570	550	350	200
00300	DO		MG/L	10.8	10.2	8.2	10.7	11.2	11.2	9.8	11.3	9.2
00301	DO	SATUR	PERCENT	90.8$	90.3$	86.3$	87.7$	83.0$	85.5$	76.6$	88.3$	88.5$
00310	BOD	5 DAY	MG/L									1.0K

(SAMPLE CONTINUED ON NEXT PAGE)

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                                        000146
                                        39 24 30.0 107 13 44.0 2
                                        CRYSTAL RIVER NEAR MOUTH
                                        08045   COLORADO          GARFIELD
                                        COLORADO RIVER            110300
/TYPA/AMBNT/STREAM                      UPPER COLORADO RIVER
                                        21COL001   800419                 14010004005 0000.600 ON
                                        0000 FEET DEPTH
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(SAMPLE CONTINUED FROM PREVIOUS PAGE)

			82/05/17	82/06/15	82/08/23	82/10/28	82/12/14	83/01/17	83/03/17	83/05/16	83/07/18
INITIAL DATE INITIAL TIME MEDIUM			1145 WATER	1425 WATER	1400 WATER	1400 WATER	1355 WATER	1245 WATER	1400 WATER	1540 WATER	1445 WATER
00400	PH	SU	8.10	7.90	8.10	8.00	8.20	8.40	8.40	8.30	7.60
00410	T ALK	CACO3 MG/L	116	72	136	132	134	140	150	112	74
00530	RESIDUE	TOT NFLT MG/L	14	49	31	28	20	10K	44	51	10
00610	NH3+NH4-	N TOTAL MG/L	.130	.100K	.100K	.100K	.100K	.100K	.100K	.100K	.100K
00612	UN-IONZD	NH3-N MG/L	.003$	.001$	.004$	.001$	.002$	.003$	.003$	.002$	.001$
00619	UN-IONZD	NH3-NH3 MG/L	.003$	.002$	.005$	.002$	.002$	.003$	.004$	.003$	.001$
00625	TOT KJEL	N MG/L		1.000K	1.000K	1.000K	1.000K	1.000K	1.000K	1.000K	1.000K
00630	NO2&NO3	N-TOTAL MG/L		.50K	.50K	.50K	.50K	.50K	.50K	.50K	.50K
00665	PHOS-TOT	MG/L P		.050K	.050K	.050K	.050K	.050K	.050K	.055	.050K
00723	CYANIDE	DISSOLVE UG/L		.01K	.01K	.01K	.01K	.01K	.01K	.01K	
00900	TOT HARD	CACO3 MG/L									100
00937	PTSSIUM	K/TOT MG/L		1.00K			1.90			1.40	
00945	SULFATE	SO4-TOT MG/L		15	88	120	150	110	150	66	30
00980	IRON	TOT REC UG/L	290	250	190	240	100K	100K	340		350
01002	ARSENIC	AS/TOT UG/L		94			10K			10K	10K
01034	CHROMIUM	CR/TOT UG/L						5K			
01045	IRON	FE/TOT UG/L								310	
01079	SILVER	TOT.REC. UG/L		.2K			.2K			.2K	
01094	ZINC(ZN)	TOT.REC. UG/L	10K	10K	10K	10K	10K	10K	10K	10	10K
01113	CADIUM T	OT.REC. UG/L		.7	.3K	.3K	.3K	.3K	.3K	.3K	.3K
01114	LEAD(PB)	TOT.REC. UG/L	5K	5K	5K	5K	5K	5K	5K	5K	5K
01118	CHRMIUM	TOT.REC. UG/L			5K	5K	5K		5K		
01119	COPPER	TOT.REC. UG/L	5K	5K	5K	12	5K	5K	5K	5K	5K
01123	MNGANESE	TOT.REC. UG/L	50K	170	50K	50K	50K	50K	50K	50K	50K
22703	U-NAT	DISOLVED UG/L		1.000			2.000			3.000K	
31615	FEC COLI	MPNECMED /100ML	93	15		4	4		23		
70300	RESIDUE	DISS-180 C MG/L	210	130	240	320	370	370	380	200	140
71900	MERCURY	HG/TOTAL UG/L		.5K			.5K			.5K	

			83/09/21	83/11/30	84/02/21	84/04/05	84/06/27	84/09/04	84/10/11	84/12/04	85/03/20
INITIAL DATE INITIAL TIME MEDIUM			1350 WATER	1540 WATER	1625 WATER	1200 WATER	1530 WATER	1235 WATER	1200 WATER	1440 WATER	1100 WATER
00010	WATER	TEMP CENT	13.3$	3.9$	3.9$	11.1$	12.2$	13.9$	3.9$	3.9$	7.2$
00011	WATER	TEMP FAHR	56.0	39.0	39.0	52.0	54.0	57.0	48.0	39.0	45.0
00021	AIR	TEMP FAHN	60.0	30.0	35.0	55.0	80.0	80.0	60.0	40.0	40.0
00095	CNDUCTVY	AT 25C MICROMHO	490	430	600	600	200	460	430	580	560
00300	DO	MG/L	9.0	10.2	10.9	9.6	10.0	8.7	10.5	11.0	10.1
00301	DO	SATUR PERCENT	84.9$	77.9$	83.2$	86.5$	92.6$	83.7$	90.5$	84.0$	82.8$

(SAMPLE CONTINUED ON NEXT PAGE)

WRIGHT WATER ENGINEERS, INC.

```
                                    000146
                                    39 24 30.0 107 13 44.0 2
                                    CRYSTAL RIVER NEAR MOUTH
                                    08045    COLORADO          GARFIELD
                                    COLORADO RIVER            110300
/TYPA/AMBNT/STREAM                  UPPER COLORADO RIVER
                                    21COL001  800419              14010004005 0000.500 CN
                                    0000 FEET DEPTH
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(SAMPLE CONTINUED FROM PREVIOUS PAGE)

INITIAL DATE				83/09/21	83/11/30	84/02/21	84/04/05	84/06/27	84/09/04	84/10/11	84/12/04	85/03/20
INITIAL TIME				1350	1540	1525	1200	1530	1235	1200	1440	1100
MEDIUM				WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER
00310	BOD	5 DAY	MG/L	1.0K	1.0	2.0	2.0	1.0K	1.0U		1.0	2.0
00400	PH		SU	7.90	7.90	7.90	8.20	8.10	7.80	7.90	8.20	8.00
00410	T ALK	CACO3	MG/L	200	120	156	158	68	134	136	144	148
00530	RESIDUE	TOT NFLT	MG/L	10K	10K	10K	72	44	10U	10U	10U	67
00610	NH3+NH4-	N TOTAL	MG/L	.100K	.180	.100K	.100K	.100K	.100U	.100U	.100U	.100U
00612	UN-IONZD	NH3-N	MG/L	.002$	.002$	.0009$	.003$	.003$	.002$	.001$	.002$	.001$
00619	UN-IONZD	NH3-NH3	MG/L	.002$	.002$	.001$	.004$	.003$	.002$	.002$	.002$	.002$
00625	TOT KJEL	N	MG/L	1.000K	1.000K	1.000K	1.000K	1.000K	1.000U	1.000U	1.000U	1.000U
00630	NO2&NO3	N-TOTAL	MG/L	.50K	.50K	.50K	.50K	.50K	.50U	.50U	.50U	.50U
00665	PHOS-TOT		MG/L P	.050K	.050K	.050K	.050K	.069	.050U	.050U	.050U	.030
00900	TOT HARD	CACO3	MG/L	210	280	300	290	100	220	230	270	260
00945	SULFATE	SO4-TOT	MG/L	120	160	180	170	27	100	110	150	140
00980	IRON	TOT REC	UG/L	100K	100K	100K	300	530	160	140	100	970
01002	ARSENIC	AS,TOT	UG/L	10K	10K	10K	10K	10K	10U	10U	10U	10U
01094	ZINC(ZN)	TOT.REC.	UG/L	14	10K	10K	10K	10K	10U	23	10U	10
01113	CADIUM T	OT.REC.	UG/L	.4	.3K	.3K	.3K	.3K	.3U	.3U	.3U	.30
01114	LEAD(PB)	TOT.REC.	UG/L	5K	5K	5K	5K	5K	5U	5U	5U	5U
01119	COPPER	TOT.REC.	UG/L	5K	5K	5K	8	5K	5U	5U	5U	5U
01123	MNGANESE	TOT.REC.	UG/L	50K	50K	50K	50K	50K	50U	50U	50U	50U
31615	FEC COLI	MPNECMED	/100ML				4	23	30		30	9
70300	RESIDUE	DISS-180 C	MG/L	380	390	420	420	110	270	370	360	350

INITIAL DATE				85/05/14	85/07/17	85/09/18	85/11/26	86/02/18	86/04/14	86/06/11	86/08/26	86/10/28
INITIAL TIME				1200	1330	1505	1435	1330	1210	1305	1740	1345
MEDIUM				WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER
00010	WATER	TEMP	CENT	5.6$	13.3$	12.8$			5.6$	8.9$	16.7$	8.9$
00011	WATER	TEMP	FAHN	42.0	56.0	55.0			42.0	48.0	62.0	48.0
00021	AIR	TEMP	FAHN	55.0	75.0	65.0	50.0	45.0	45.0	75.0	70.0	65.0
00095	CNDUCTVY	AT 25C	MICROMHO	390	260	510	500	550	360	220	380	430
00300	DO		MG/L	10.5	8.8	9.4	11.2	11.2	11.9	11.1	9.5	12.2
00301	DO	SATUR	PERCENT	84.0$	83.0$	88.7$			95.2$	95.7$	97.9$	105.2$
00310	BOD	5 DAY	MG/L	1.0U	1.0U	1.0U	1.0	1.0	1.0	1.0U	1.0U	1.4
00400	PH		SU	8.00	7.30	8.10	8.30	8.10	8.30	8.10	8.10	8.40
00410	T ALK	CACO3	MG/L	98	80	166	140	132	120	76	124	112
00530	RESIDUE	TOT NFLT	MG/L	33	10U	12	10U	10U	40	35	10U	10U
00610	NH3+NH4-	N TOTAL	MG/L	.100U	.100U	.100U	.100U	.100U	.100U	.100U	.100U	.100U
00612	UN-IONZD	NH3-N	MG/L	.001$	.0005$	.003$			.003$	.002$	.004$	.004$
00619	UN-IONZD	NH3-NH3	MG/L	.002$	.0006$	.003$			.003$	.003$	.005$	.005$

(SAMPLE CONTINUED ON NEXT PAGE)

WRIGHT WATER ENGINEERS, INC.

```
                                              000145
                                              39 24 30.0 107 13 44.0 2
                                              CRYSTAL RIVER NEAR MOUTH
                                              08045    COLORADO              GARFIELD
                                              COLORADO RIVER                 110300
/TYPA/AMBNT/STREAM                            UPPER COLORADO RIVER
                                              21CCL001  300419                   14010304005 0000.600 CN
                                              0000 FEET DEPTH
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(SAMPLE CONTINUED FROM PREVIOUS PAGE)

			85/05/14 1200 WATER	85/07/17 1330 WATER	85/09/13 1505 WATER	85/11/26 1435 WATER	86/02/13 1330 WATER	86/04/14 1210 WATER	86/06/11 1305 WATER	85/08/26 1740 WATER	86/10/28 1345 WATER
INITIAL DATE											
INITIAL TIME											
MEDIUM											
00625 TOT KJEL	N	MG/L	1.000U	1.000U	1.200	1.000U	1.000U	1.000U	1.000U	1.000U	1.000U
00630 NO2&NO3	N-TOTAL	MG/L	.50U	.50U	.500	.50U	.50U	.500	.500	.50U	.50U
00665 PHOS-TOT		MG/L P	.070	.050U	.050U		.050U	.050U	.063	.050U	.050U
00900 TOT HARD	CACO3	MG/L	130	120	220	240	260	180	96	200	220
00945 SULFATE	SO4-TOT	MG/L	45	47	120	130	150	75	30	88	110
00980 IRON	TOT REC	UG/L	990	100U	100	100U	200	370	840	100U	100U
01002 ARSENIC	AS,TOT	UG/L	10U	10U	10U	10U	10U	10U	10U	10U	10U
01094 ZINC(ZN)	TOT.REC.	UG/L	10U	10U	10U	10U	10U	10U	10U	10U	10U
01113 CADIUM T	OT.REC.	UG/L	.3U	.3U	.3U	.3U	.3U	.3U	.3U	.3U	.3U
01114 LEAD(PB)	TOT.REC.	UG/L	5U	5U	5U	5U	5U	5U	2	5U	5U
01119 COPPER	TOT.REC.	UG/L	5U	5U	5U	5U	5U				50
01123 MNGANESE	TOT.REC.	UG/L	50U	50U	50U	50U	50U	50U	50U	50U	50U
31615 FEC COLI	MPNECMED	/100ML	23	23	93	4	9	43	9	23	4
70300 RESIDUE	DISS-180	C MG/L	160	170	310	300	360	220	120	240	310
74041 WQF	SAMPLE	UPDATED					860717	860717	860328	870121	870121

			86/12/16 1500 WATER	87/01/26 1220 WATER	87/03/04 1355 WATER	87/05/20 1445 WATER	87/07/30 1245 WATER	87/09/29 1320 WATER	87/11/09 1535 WATER	88/02/18 1520 WATER	88/04/14 1150 WATER
INITIAL DATE											
INITIAL TIME											
MEDIUM											
00010 WATER	TEMP	CENT	4.4$	5.0$	8.3$	10.0$	18.3$	15.6$	10.0$	4.4$	8.9$
00011 WATER	TEMP	FAHN	40.0	41.0	47.0	50.0	65.0	60.0	50.0	40.0	48.0
00021 AIR	TEMP	FAHN	35.0	40.0	45.0	50.0	85.0	80.0	60.0	25.0	55.0
00095 CNDUCTVY	AT 25C	MICROMHO	470	480	560	210	360	610	580	640	400
00300 DO		MG/L	11.4	12.1	.6	10.0	7.9	10.0	10.0	12.8	10.0
00301 DO	SATUR	PERCENT	37.0$	94.5$	5.0$	88.5$	83.2$	100.0$	88.5$	97.7$	85.2$
00310 BOD	5 DAY	MG/L	1.0U	1.0	1.0	1.0U	1.1	1.0	1.0U	1.0	2.0
00400 PH		SU	3.00	3.40	3.20		8.30	8.40	3.30	3.80	3.40
00410 T ALK	CACO3	MG/L	134	134	100	72	128	200	154	152	108
00530 RESIDUE	TOT NFLT	MG/L	10U	10U	23	41	150	10U	10U	10U	140
00610 NH3+NH4-	N TOTAL	MG/L	.100U	.100U	.220	.200	.270	.100U	.100U	.100U	.100U
00612 UN-IONZD	NH3-N	MG/L	.001$	.003$	.006$		.018$	.007$	.004$	.007$	.004$
00619 UN-IONZD	NH3-NH3	MG/L	.001$	.004$	.007$		.021$	.008$	.004$	.009$	.005$
00625 TOT KJEL	N	MG/L	1.000U	1.000U	1.000U	1.000U	1.000U	1.000U	1.000U	1.000U	1.000U
00630 NO2&NO3	N-TOTAL	MG/L	.50U	.50U	.500	.500	.50U	.50U	.500	.500	.50U
00665 PHOS-TOT		MG/L P	.050U	.050U	.050U	.050	.050U	.050U	.050U	.050U	.110
00900 TOT HARD	CACO3	MG/L	250	280	270	100	200	290	230	310	190
00945 SULFATE	SO4-TOT	MG/L	150	170	170	31	32	140	160	200	100
00980 IRON	TOT REC	UG/L	100U	100U	360	640	2900	100U	100U	1000	1200

(SAMPLE CONTINUED ON NEXT PAGE)

WRIGHT WATER ENGINEERS, INC.

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                                                  000146
                                                  39 24 30.0 107 13 44.0 2
                                                  CRYSTAL RIVER NEAR MOUTH
                                                  08045    COLORADO          GARFIELD
/TYPA/AMBNT/STREAM                                COLORADO RIVER            110300
                                                  UPPER COLORADO RIVER
                                                  21CCL001   800419              140100004005 0000.600 CN
                                                  0000 FEET DEPTH
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(SAMPLE CONTINUED FROM PREVIOUS PAGE)

			86/12/15	87/01/26	87/03/04	87/05/20	87/07/30	87/09/29	87/11/09	88/02/18	88/04/14
INITIAL TIME			1500	1220	1355	1445	1245	1320	1535	1520	1150
MEDIUM			WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER
01002 ARSENIC	AS,TOT	UG/L	10U	10U	10U	10U	10U	10U	10U	10U	10U
01094 ZINC(ZN)	TOT.REC.	UG/L	10U	10U	10U	40	10U	10U	10U	10	10
01113 CADIUM T	OT.REC.	UG/L	.3U	.3U	.3U	.3U	.3U	.3U	.3U	.3U	.3U
01114 LEAD(PB)	TOT.REC.	UG/L	5U	5U	5U	5U	5U	5U	5U	5U	5U
01119 COPPER	TOT.REC.	UG/L		5U	5U	5U	5U	5U	5U	5U	5U
01123 MNGANESE	TOT.REC.	UG/L	50U	50U	50U	50U	60	50U	50U	50U	5U
31615 FEC COLI	MPNECMED	/100 ML	3U		3U	43	230	9	43	3U	70
70300 RESIDUE	DISS-180 C	MG/L	350	370	400	140	230	390	380	450	430 260
74041 WQF	SAMPLE	UPDATED	870309	870527	870527	870825	871105	871214	880128	880420	880609

			88/06/13	88/08/16	88/10/12	88/12/01	89/01/30	89/03/28	89/05/15	89/07/06	89/09/25
INITIAL TIME			1505	1555	1535	1420	1250	1215	1255	1255	1310
MEDIUM			WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER
00010 WATER	TEMP	CENT	10.0$	18.3$	15.0$	5.6$	4.4$	8.9$	3.9$	15.6$	16.1$
00011 WATER	TEMP	FAHN	50.0	65.0	59.0	42.0	40.0	43.0	43.0	60.0	61.0
00021 AIR	TEMP	FAHN	70.0	75.0	65.0	35.0	35.0	60.0			80.0
00095 CNDUCTVY	AT 25C	MICROMHO	220	470	670	630	610	600	290	290	570
00300 DO		MG/L	10.2	8.8	8.0	11.4	11.3	10.8	10.4	9.4	9.2
00301 DO	SATUR	PERCENT	90.3$	92.6$	78.4$	91.2$	86.3$	93.1$	89.7$	94.0$	92.0$
00310 BOD	5 DAY	MG/L	1.0U	1.0	1.0	1.0	1.0U				
00400 PH		SU	8.30	8.60	3.60	3.80	8.60	9.00	3.60	8.40	8.70
00410 T ALK	CACO3	MG/L	70	202	200	160	142	136	74	80	176
00530 RESIDUE	TOT NFLT	MG/L	20	10U	10U	10U	10U	23	24	10U	10U
00610 NH3+NH4-	N TOTAL	MG/L	.100U	.100U	.100U	.100U	.100U	.100U	.100U	.110	.100U
00612 UN-IONZD	NH3-N	MG/L	.004$	.012$	.010$	.003$	.005$	.015$	.006$	.007$	.013$
00619 UN-IONZD	NH3-NH3	MG/L	.004$	.015$	.012$	.009$	.006$	.018$	.008$	.009$	.016$
00625 TOT KJEL	N	MG/L	1.000U	1.000U	1.000U	1.000U	1.000U	1.000U	1.000U	1.000U	1.000U
00630 NO2&NO3	N-TOTAL	MG/L	.50U	.50U	.50U	.50U	.50U	.50U	.50U	.50U	.50U
00665 PHOS-TOT		MG/L P	.050U	.060	.050U	.050U	.050U	.050U	.050U	.050U	.050U
00900 TOT HARD	CACO3	MG/L	100	300	320	310	310	250	140	150	320
00945 SULFATE	SO4-TOT	MG/L	34	120	150	200	310	140	140	150	130
00980 IRON	TOT REC	UG/L	410				210	140	60	60	
01000 ARSENIC	AS,DISS	UG/L			10U	10U	10U	10U	10U	10U	10U
01002 ARSENIC	AS,TOT	UG/L	10U								
01025 CADMIUM	CD,DISS	UG/L		.3U	.3U	.3U	.3U	.3U	.3U	.3U	.3U
01040 COPPER	CU,DISS	UG/L		5U	5U	5U	5U	5U	5U	5U	5U
01046 IRON	FE,DISS	UG/L		100U	100U	100U	100U	100U	100U	100U	100U
01049 LEAD	PB,DISS	UG/L		5U	5U	5U	5U	5U	5U	5U	5U

(SAMPLE CONTINUED ON NEXT PAGE)

WRIGHT WATER ENGINEERS, INC.

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000146
39 24 30.0 107 13 44.0 2
CRYSTAL RIVER NEAR MOUTH
08045    COLORADO          GARFIELD
COLORADO RIVER             110300
UPPER COLORADO RIVER
21CCL001  800419           14910004005 0000.600 ON
0000 FEET DEPTH
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/TYPA/AMBNT/STREAM

(SAMPLE CONTINUED FROM PREVIOUS PAGE)

			88/06/13	88/08/15	88/10/12	88/12/01	89/01/30	89/03/28	89/05/15	89/07/06	89/09/25
INITIAL TIME			1505	1555	1535	1420	1250	1215	1255	1255	1310
MEDIUM			WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER
01056 MANGNESE	MN,DISS	UG/L		50.0U	50.0U	50.0U	50.0U	50.0U	50.0U	50.0U	50.0U
01090 ZINC	ZN,DISS	UG/L		10U	10U	10U	10U	10U	10U	10	20
01094 ZINC(ZN)	TOT.REC.	UG/L	10U								
01113 CADIUM T	OT.REC.	UG/L	.3U								
01114 LEAD(PB)	TOT.REC.	UG/L	5U								
01119 COPPER	TOT.REC.	UG/L	5U								
01123 MNGANESE	TOT.REC.	U3/L	500								
31615 FEC COLI	MPNECMED	/100ML	93	43	9	30	30	30	43	30	7
70300 RESIDUE	DISS-180 C	MG/L	130	410	440	470	490	380	190	180	400
74041 WQF	SAMPLE	UPDATED	880801	881108	881128	890207	890531	890607	890814	891003	891204

			89/11/20	90/02/12	90/04/05	90/06/07	90/08/02	90/10/16	90/12/26	91/01/09	91/03/13
INITIAL TIME			1220	1230	1125	1235	1540	1115	1530	1230	1215
MEDIUM			WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER
00010 WATER	TEMP	CENT	7.2$	5.0$	10.0$	9.4$	15.6$	11.7$	.6$	1.7$	5.0$
00011 WATER	TEMP	FAHN	45.0	41.0	50.0	49.0	60.0	53.0	33.0	35.0	41.0
00021 AIR	TEMP	FAHN	60.0	40.0	55.0	85.0	65.0	65.0	20.0	20.0	60.0
00095 CNDUCTVY	AT 25C	MICROMHO	590	680	530	180	420	600	550	500	640
00300 DO		MG/L	12.4	11.6	10.0	10.4	3.6	10.3	12.6		11.2
00301 DO	SATUR	PERCENT	101.6$	90.6$	83.5$	89.7$	85.0$	95.4$	88.7$		87.5$
00400 PH		SU	8.70	8.60	8.60	8.20	8.40	8.60	8.60	8.50	8.70
00410 T ALK	CACO3	MG/L	162	152	140	74	170	130	148	148	140
00530 RESIDUE	TOT NFLT	MG/L	10U	10U	10U	10U	10U	10U	33	10U	10U
00610 NH3+NH4-	N TOTAL	MG/L	.100U	.100U	.100U	.100U	.100U	.100U	.100U	.100U	.100U
00612 UN-IONZD	NH3-N	MG/L	.007$	.005$	.007$	.003$	.007$	.003$	.003$	.003$	.006$
00619 UN-IONZD	NH3-NH3	MG/L	.008$	.006$	.008$	.003$	.008$	.009$	.004$	.004$	.007$
00625 TOT KJEL	N	MG/L	1.000U	1.000U	1.000U	1.000U	1.000U	1.000U	1.000U	1.000U	1.000U
00630 NO2&NO3	N-TOTAL	MG/L	.50U	.50U	.50U	.50U	.50U	.50U	.50U	.50U	.50U
00665 PHOS-TOT		MG/L P	.050U	.050U	.080	.200	.050U	.050U	.050U	.050U	.050U
00900 TOT HARD	CACO3	MG/L	300	320	240	69	260	320	310	300	300
00945 SULFATE	S04-TOT	MG/L	130	200	140	29	110	150	130	180	210
01000 ARSENIC	AS,DISS	UG/L	10U	10U	10U		10U	10U	10U	10U	10U
01025 CADMIUM	CD,DISS	UG/L	.3U	.3U	.3U	.3U	.3U	.3U	.3U	.3U	.3U
01040 COPPER	CU,DISS	UG/L	5U	5U	5U	5U	5U	40	40	40	.3U
01046 IRON	FE,DISS	UG/L	100U	100U	100U	100U	100U	100	100	100	100
01049 LEAD	PB,DISS	UG/L	5U	5U	5U	5U	5U	5U	5U	5U	5U
01056 MANGNESE	MN,DISS	UG/L	50.0U	50.0U	50.0U	50.0U	50.0U	5U	5U	5U	50
01090 ZINC	ZN,DISS	UG/L	10U	25U	10U	10U	10U	6.0	5.0	4.0U	4.0U
								30	30	30	80

(SAMPLE CONTINUED ON NEXT PAGE)

WRIGHT WATER ENGINEERS, INC.

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                                                 000146
                                                 39 24 30.0 107 13 44.0 2
                                                 CRYSTAL RIVER NEAR MOUTH
                                                 08045      COLORADO          GARFIELD
                                                 COLORADO RIVER               110300
/TYPA/AMBNT/STREAM                               UPPER COLORADO RIVER
                                                 21COL001   800419                        14010004005 0000.500 ON
                                                 0000 FEET DEPTH
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(SAMPLE CONTINUED FROM PREVIOUS PAGE)

			89/11/20	90/02/12	90/04/05	90/06/07	90/08/02	90/10/15	90/12/25	91/01/09	91/03/18
INITIAL DATE											
INITIAL TIME			1220	1230	1125	1235	1540	1115	1530	1230	1215
MEDIUM			WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER
31615 FEC COLI	MPNECMED	/100ML	3U	3U	430	150	43		4	30	30
70300 RESIDUE	DISS-180	C MG/L	460	490	360	100	360	420	450	450	450
74041 WQF	SAMPLE	UPDATED	900323	900515	900620	901002	901109	910412	910527	910826	910826

			91/07/10	91/09/06	91/11/12	92/02/24	92/04/09
INITIAL DATE							
INITIAL TIME			1310	1305	1320	1535	1300
MEDIUM			WATER	WATER	WATER	WATER	WATER
00010 WATER	TEMP	CENT	12.2$	17.8$	7.3$	6.7$	10.6$
00011 WATER	TEMP	FAHN	54.0	64.0	46.0	44.0	51.0
00021 AIR	TEMP	FAHN	70.0	75.0	60.0	40.0	70.0
00095 CNDUCTVY	AT 25C	MICROMHO	510	540	580	640	490
00300 DO		MG/L	6.6	8.3	11.8	10.3	10.4
00301 DO	SATUR	PERCENT	79.6$	92.6$	99.2$	88.5$	93.7$
00400 PH		SU	8.20	8.50	8.70	8.70	8.50
00410 T ALK	CACO3	MG/L	68	164	150	148	132
00530 RESIDUE	TOT NFLT	MG/L	25	10U	10U	10U	98
00610 NH3+NH4-	N TOTAL	MG/L	.100	.100U	.100U	.100U	.100U
00612 UN-IONZD	NH3-N	MG/L	.003$	.010$	.007$	.007$	.006$
00619 UN-IONZD	NH3-NH3	MG/L	.004$	.012$	.009$	.008$	.007$
00625 TOT KJEL	N	MG/L	1.000U	1.000U	1.000U	1.000U	1.000U
00630 NO2&NO3	N-TOTAL	MG/L	.50U	.50U	.50U	.50U	.50U
00665 PHOS-TOT		MG/L P	.050U	.050U	.050U	.050U	.100
00900 TOT HARD	CACO3	MG/L	100	260	240	260	230
00945 SULFATE	SO4-TOT	MG/L	38	97	140	180	120
01000 ARSENIC	AS/DISS	UG/L	10U	10U	10U	10U	10U
01025 CADMIUM	CD/DISS	UG/L	.3U	.3U	.3U	.3U	.3U
01040 COPPER	CU/DISS	UG/L	4U	4U	4U	4U	4U
01046 IRON	FE/DISS	UG/L	10U	10U	10U	11	16
01049 LEAD	PB/DISS	UG/L	5U	5U	5U	5U	5U
01056 MANGNESE	MN/DISS	UG/L	4.0U	4.0	5.0	4.0U	4.0
01090 ZINC	ZN/DISS	UG/L	3U	8U	8U	8U	8U
31615 FEC COLI	MPNECMED	/100ML			4	3U	43
70300 RESIDUE	DISS-180	C MG/L	170	340	390	550	330
74041 WQF	SAMPLE	UPDATED	911213	920311	920311	920421	920609

THAT'S ALL FOLKS

WRIGHT WATER ENGINEERS, INC.