PROJECT SUMMARY
GEOTHERMAL WATER RESOURCE INVESTIGATIONS
IN
GLENWOOD CANYON

FOR

COLORADO DIVISION OF HIGHWAYS

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BY

COLORADO GEOLOGICAL SURVEY

DECEMBER, 1985

PROJECT SUMMARY - GEOTHERMAL WATER SOURCE INVESTIGATIONS, GLENWOOD CANYON

INTRODUCTION

As part of an overall plan by the Colorado Department of Highways to use geothermal water to reduce bridge icing within Glenwood Canyon, the Colorado Geological Survey was contracted to review existing geologic and geothermal data, assist in additional data collection, and assess the potential for the use of local geothermal resources. Services for Phase I and II were performed by Jeffrey Hynes and Michael Galloway under the direction of Mr. Pat Rogers of the State Geological Survey.

Phase I results and conclusions were summarized in a report to the CDOH, in June, 1985 and are reiterated herein. Phase II was designed to test certain tentative interpretations of the Phase I report and, specifically, to collect additional data to help determine whether adequate supplies of warm water exist within the canyon. This was done by strategically locating additional exploration holes and measuring temperature gradients in them as well as in the previous holes. The results of this brief investigation are presented in this report in the discussion of Phase II.

In addition, an investigation into the water rights of known geothermal resources at the east end of the canyon was undertaken as part of Phase II. This material is found in Appendix A at the end of this report.

CONCLUSIONS AND RECOMMENDATIONS

1. The investigations of Phases I and II indicate that using warm water from a source within the canyon is not feasible for bridge heating. Should the CDOH want to continue to study the feasibility of using geothermal resources for bridge heating, the only practical source is the area at the eastern end of the canyon around Dotsero (Siloam) Hot Springs.

2. According to the preliminary water rights investigation, the way is clear for a water rights filing by the State of Colorado. This should be performed as soon as practical to insure first right to the water.

3. At this point, if the geothermal-use option is to be considered further, it is recommended that the engineering and economic feasibility of using Dotsero Hot Springs water be evaluated. The resource area has been extensively explored and reported by the U.S. Bureau of Reclamation. This technical information should suffice for such a preliminary evaluation, however, the economic feasibility of using this water must also be evaluated.

4. Conditions which need to be taken into consideration in the economic feasibility are:

   A. Because of the probable range of water temperatures and flow rates of nearby geothermal resource areas, it is highly unlikely that the bridges can be heated adequately to remain ice-free under all weather conditions. It is our conclusion that, as a practical matter, the bridge heating design should only consider maintaining ice-free conditions to the point of general roadway freezing.

B. The nearest demonstrated source of sufficient hot water is the Dotsero Hot Springs area at the east end of the canyon. This source appears to have adequate temperature and flow rates, and should be studied in detail if the concept of geothermal deicing is to be pursued.

C. Because of the relative elevations of the potential geothermal resource areas, the bridge sites, and the bridge decks, pumping will be required somewhere in the system. Several factors which will have to be considered are pipe material and diameter, friction losses, pumping costs, heat exchanger, and bridge heat distribution system.

D. Water rights and disposal issues will have to be addressed. Water rights are particularly critical and will require immediate action.

Mr. Galloway has obtained NPDES permits from the Colorado Department of Health for discharge of thermal water (21, 000 mg/l) from West Glenwood Springs into the Colorado River, using specific arguments which would apply to any use of Dotsero water. If handled properly, we see no particular problem in obtaining discharge permits for this project.

E. At this point in the study, it seems that there is no compelling evidence that the geothermal water cannot be used in any one of three ways: a) directly, using corrosion resistant material, b) "clean" water or other fluid heated in a heat exchanger, or c) ammonia tubes immersed either directly in the geothermal fluid or in heated "clean" water. There are possible advantages and disadvantages to each method, but published test data have not conclusively shown one system to be far superior to the others. The relative advantages of the possible systems were beyond the scope of this study. Parallel-plate heat exchangers should be considered as well as other types in any design for bridge heating.

5. If the economic feasibility study indicates further development work is appropriate, it is recommended that a review be conducted of the data collected by the U.S. Bureau of Reclamation during their study of the Dotsero Hot Springs area. Since this is the most likely thermal resource area for this project, utilization of the results from this previous study could well eliminate the expenditure of a great deal of time and money.

PHASE I GEOTHERMAL INVESTIGATIONS

DATA REVIEW

Geologic logs of geotechnical holes drilled by the CDOH were reviewed during Phase I. Generally, these logs were used for determining the extent, thickness, and depth of a clay bed which occurs semi-continuously throughout the canyon. This clay bed separates the valley-fill gravels into two zones. The lower zone is, to some extent, isolated from the cold river water and contains warmer water of geothermal origin at some locations.

Before CGS involvment some information was recorded concerning downhole water temperature. However, for several reasons the recorded temperatures are probably not very valid. These reasons include: cold river water was used as a drilling fluid, circulation fluid was lost more than it was returned, no effort was made to seal drill holes to isolate the upper cold water, and temperatures were measured soon after drilling.

Despite these problems and potential inaccuracies in the data, a preliminary profile constructed by David Pitts of the CDOH suggests that warm water occurs beneath the confining clay layer east of the Bear Ranch graben, as defined by mapped north-south trending faults, but not west of the graben. Based on this preliminary information and temperature gradients measured in cased holes in the French Creek area, west of the graben, it appears likely that the graben block is acting as a barrier or interceptor to westerly-moving, warm, groundwater flow beneath the confining clay layer.

The likely source of this warm water is the Dotsero Hot Springs area (also known as Siloam Springs) at the east end of the canyon. An investigation by consultants to the U.S. Bureau of Reclamation reports that the source of hot water at Dotsero is the Leadville Limestone. The thermal water forming the springs is assumed to be moving upward from the Leadville through unconsolidated sediments, including the same layer that acts as an aquitard lower in the Canyon. It is reasonable to assume that some portion of the thermal water remains confined below the clay and moves downgradient beneath the upper gravel layers of the Colorado River in the canyon. Mixing with cold water can occur wherever the clay layer is discontinuous. At the point of the Bear Ranch graben, the warm water is either completely blocked from further westward movement or the clay layer is completely breached, allowing further mixing with cold water. In either case, data collected to date has not identified any significant evidence of warm water west of the graben.

Temperature Profiles

Since CGS involvement in this project, plastic pipe has been installed in all suitable geotechnical drill holes so that temperature gradients and water levels could be measured after allowing conditions to equilibrate. These measurements were taken on a opportunistic basis, depending upon weather, drilling schedules, and trips to the Glenwood area by CGS staff.

Temperature profiles were measured in two CDOH drill holes (#2131) and #2158) during January, 1985. The resulting profiles show no indication of elevated water temperatures in either hole. Slightly higher temperature readings in hole #2131 were checked with a second temperature probe and found to be in error, possibly due to a broken cable. The profile from #2158 indicated that once past the near surface effects, water temperature becomes isothermal at 10.7 degrees C. Because of instrument error, the lower portion of the profile measured in #2131 was not considered to be representative. The bottomhole temperature, as measured by the second probe, was between 10 and 11 degrees C, which was comparable to that measured in #2158.

Bridge Heat Requirements

In addition to basic data collection and observations, estimations of bridge heat requirements have been made. This was performed so that potential resource areas could be quickly compared to the likely heating needs of the bridge system to determine their adequacy prior to committing significant time and effort.

Two basic assumptions were made in assessing the hot water requirements of the bridges. The assumptions deal with the rate of bridge freezing and available water temperature. In all cases it was assumed that 100 degree F water can be delivered to the bridge site. The amount of deicing provided however, includes two possible scenarios: 1) the bridges would be allowed to freeze at the same time as the adjacent roadway or 2) the bridges would remain unfrozen 90% of the time that they would otherwise be frozen if not heated at all.

If the bridge temperature is to be maintained above freezing at least 90% of the time, approximately 700-800 GPM of 100 degree water would be required per bridge. If the bridges were allowed to freeze simultaneously with the surrounding roadway, 300-400 GPM of 100 degree water would be required per bridge. These numbers compare reasonably well with those suggested in a CDOH Internal report (January 1985).

Dotsero Hot Springs (Siloam Springs)

There is considerable confusion surrounding the name and location of the actual hot springs located at the east end of the canyon. CDOH personnel have referred to the springs as Siloam Springs, but known published information from both the Colorado Geological Survey and the U.S. Bureau of Reclamation refer to this area as Dotsero Hot Springs. It is uncertain where the name Siloam Springs originated, but is has not been seen in the published literature we reviewed for this project.

This group of unused hot springs are located on both sides of the Colorado River approximately .5 miles east of the canyon (Barrett and Pearl, 1978). The total flow is reported to greatly exceed 1000 gpm. The water is a sodium chloride water with a total dissolved solids (TDS) concentration of about 10,000 mg/l. The relative constituent concentrations, as well as TDS, are about half of the concentrations of water from Glenwood Hot Springs, suggesting straight dilution by relatively fresh water. Significantly more detailed information about the spring area is available from the U.S. Bureau of Reclamation, but has not yet been reviewed.

SPECIAL NOTE

A CDOH Internal Report (1985) discusses the possible use of heat exchangers for use with the geothermal water, both in past tests and in future bridge heating systems. Parallel plate exchangers were not included in this analysis and discussion. Mr. Galloway has been involved with a geothermal project in West Glenwood Springs for the last four years and has determined through actual testing that certain compositions of stainless steel and titanium can be used in parallel-plate heat exchangers without significant plate corrosion and with no scaling. The inherent design of parallel-plate heat exchangers eliminates deposition and scaling through high velocity scouring. The composition of individual plates can be designed to withstand corrosion from most fluids. Additionally, the efficiency of this type of heat exchanger far exceeds other types of exchangers. As an example, a large parallel-plate heat exchanger has been used in the Pagosa Springs district heating system since October, 1981, at an efficiency of 99% at flow rates up to 2000 GPM.

PHASE II GEOTHERMAL INVESTIGATIONS

As stated in the Phase I report, geologic and geothermal data collected by the CDOH suggests that warm water occurs beneath the confining clay layer east of the Bear Ranch graben, as defined by north-south trending faults, but not west of the graben. During Phase II, to further test this potential geothermal resource, two additional holes were drilled and cased in the area of the graben. One hole was located just west of the graben near hole #2158. Depending upon the exact location of the graben's bounding faults, the second hole was either located east of the graben or along its eastern edge. Both holes were drilled through the confining clay layer and completed with PVC pipe, slotted below the clay.

During September, 1985, temperature profiles were measured in these two holes. As in previous temperature profiling for this project, no positive evidence of elevated temperatures was observed. Once below near surface effects, the water temperature becomes isothermal at about 10 degrees C, which is essentially river temperature (A river water temperature of 10 degrees C was measured on September 24, 1985). In addition to these two holes, other holes drilled during Phase I were also measured with the same result; no evidence of any significant geothermal water source was found.

WATER RIGHTS

Based upon the temperature profiling results of Phase I and II, the availability of geothermal water within the canyon is considered highly unlikely. Since the only remaining feasible source of hot water is Dotsero Hot Springs, a brief investigation of the water rights were performed to determine the status of this water. A memo with supporting information is attached as Appendix A.

The basic conclusion drawn from this investigation is that no one has yet filed on these springs. The CDOH is in a good position to file and have first rights to this water. If CDOH has any intention of ever utilizing this resource, the filing should be made immediately.

REFERENCES CITED

Barrett, J.K. and Pearl, R.H., 1978, An Appraisal of Colorado's Geothermal Resources, Colorado Geological Survey Bulletin 39, 224 p.

Colorado Department of Highways, January 1985, Geothermal Heating of Bridges in Glenwood Canyon, Internal Report.

APPENDIX

APPENDIX A

DATE: September 16, 1985

TO: Jeff Hynes, Pat Rogers

FROM: Craig Green, Mike Galloway

SUBJECT: Dotsero Hot Springs

Having talked to Mike Bessler of the USBR (Denver West office; 236-6787), we have found out that the USBR did indeed file on the Dotsero Hot Springs in Colorado water court. According to the URS report (and a subsection that I understand was prepared by Leonard Rice) on the Glenwood-Dotsero project, the USA filed on eight springs in December of 1981.

The Division 5 water court resume was reviewed for the eight spring filings, which included amounts, precise legal locations, appropriation dates and other information. The case numbers were 81CW372 through 81CW379.

According to the personnel at the water court in Glenwood Springs, the applicant (USA) requested and was granted a dismissal of these cases. The reason is unknown, but the bottom line is that the USA did file on the springs, but the cases were dismissed. Therefore the situation is just as if the filings never occurred. However, the USBR has done a considerable amount of groundwork, which can perhaps be used by the Colorado Dept. of Highways for a similar filing.

Attached are two excerpts from the various URS volumes which comprised the Glenwood-Dotsero Salinity study. The first, pages A-3 through A-8, a section entitled "water rights", appears to be the most comprehensive account of water rights in the study. The second attachment, pages A-9 through A-11, is an excerpt from appendix C of the main phase I report, which locates the springs and describes their character. In addition to these, I have prepared the attached table of spring flows, locations and designations used in the original USBR filings.

RECOMMENDATIONS

We recommend that the State of Colorado file on one or more of these springs for the purposes of heating the highway structures, in accordance with a specific need. The parameters in the attached table may be used for such a filing, which can completed before the end of this year by the Attorney General's office. We also recommend that appropriation dates be established as early as possible, based on documented actual planning to use these springs by the State. Appropriation dates listed by the USBR are included, in case any of them were based on previous plans by the State.

SUMMARY OF DOTSERO HOT SPRINGS FILINGS BY USBR

Designated Name	Amount (cfs)	USBR Appropriation Date	Location (all in Eagle Co.)
DOT HOT SPRING 4	0.2	9/6/79	SW SE SE section 1, T5S,R87W (at a point whence the NE corner of section 1 bears N9°E 4650 feet.
DOT HOT SPRING 5	0.2	7/11/72	SW SE SE section 1, T5S,R87W (at a point whence the NE corner of section 1 bears N12°15´E 4800 feet.
DOT HOT SPRING 6	0.2	7/11/72	SW SE SE section 1, T5S,R87W (at a point whence the NE corner of section 1 bears N13°30´E 4850 feet.
DOT HOT SPRING 7	0.2	9/6/79	SW SE SE section 1, T5S,R87W (at a point whence the NE corner of section 1 bears N14°30´E 5000 feet.
DOT HOT SPRING 9	5.0	8/2/76	NW NE SW section 12,T5S,R87W (at a point whence the NW corner of section 11 bears N67°45´W 7300 feet.
DOT HOT SPRING 10	5.0	4/25/72	NE SW SW section 12,T5S,R87W (at a point whence the NW corner of section 11 bears N58°W 7700 feet.
DOT HOT SPRING 11	4.0	8/7/72	NE SW SW section 12,T5S,R87W (at a point whence the NW corner of section 11 bears N53°30´W 7600 feet.
DOT HOT SPRING 90	4.0	8/30/72	SE SW NW section 12,T5S,R87W (at a point whence the NW corner of section 11 bears N70°15´W 6750 feet.

5.0 Water Rights

Water rights are broken down into three categories for discussion. These categories are geothermal springs, spring source rights and surface rights.

The ownership of geothermal springs was obtained from Evaluation of Geothermal Energy for Heating Highway Structures (Colorado Department of Highways, May 1980). This information was gathered from records in the Garfield County Court House, offices of the Denver and Rio Grande Western Railroad Company (D&RGW), and interviews with the Division Engineer for Water Division 5, CDH Right-of-Way engineers, and officials of D&RGW railroad. A title search should be performed if it is necessary to verify these data; for example, if it is necessary to acquire a geothermal right, a thorough title search should be done. The ownership of geothermal springs is presented in Table 5.1.

Adjudicated rights for spring sources are shown in Table 5.2. These springs are located entirely within the study area.

The surface water rights on the mainstream of the Colorado River are summarized in Table 5.3. This table is divided into four subsections as shown; Dotsero to Glenwood Springs, Glenwood Springs to Canyon Creek, Canyon Creek to Newcastle, and Newcastle to the Colorado Utah boundary. This table was taken from a complete listing of surface rights on the Colorado River from the 1978 State Engineer's list for Water Division 5. The complete tabulation of adjudicated surface rights on the Colorado River from Dotsero to the Colorado-Utah state line is provided in Attachment 12.

The Colorado River is considered an "over-appropriated stream" during the late summer low flow period within the project area (including the Grand Valley area). With the possibilities that water demand will increase, it is essential that the water consumed in this salinity control project be replaced and that the acquisition of replacement water be done in accordance with Colorado water law. This will ensure that the project can move forward without delays due to water rights questions.

In December 1981, the United States made applications for conditional water rights in District Court, Water Division No. 5, on all the identified surface springs in both the Dotsero and Glenwood Springs areas (Table 5.4). These filings are presently proceeding through the court.

Table 5.1

Identification	Colo. Geo. Survey Identification	Other Identification	Surface Owner[1]	Mineral Right Owner[1]	Water Right Owner	Decreed Amount (cfs)	Comments
DOT 4	-	-	-	-	-	-	-
DOT 5	Seeps		Dept. of Highways	Bair	BLM	Not Decreed	
DOT 6	Dugout Stock Pond Box		Dept. of Highways	Bair	BLM	-	
DOT 7	-	-	-	-	-		
DOT 9	Dotsero		Bair	Bair	BLM	Not decreed[2]	
DOT 10	Warm Springs		(on BLM land)	"	BLM	"	
DOT 11	South		"	"	BLM	"	
DOT 20	Dotsero		"	"	BLM	"	
DOT 30	Warm Springs		"	"	BLM	"	
DOT 40		"	"	"	BLM		
GLEN 10	Railroad Sp.	(rafter's)	D&RGW	D&RGW	-	Not decreed[2]	Was housed
GLEN 12			Dept. of Highways	Dept. of Highways	-	Not decreed[2]	Plans to claim
GLEN 15	Not on map		D&RGW	D&RGW	Glen Hot	-	
GLEN 20		(rafter's)	"	"	Spring & Pool	-	
GLEN 30	B		"	"	"	-	
GLEN 40			"	"	"	-	
GLEN 50	Vapor Caves Sp.		Vapor Caves	-	Vapor Caves	0.1,0.1C	Not in '78 tab
GLEN 60	Pool Overflow	Yampa Spring	Dept. of Highways	Dept. of Highways	-	Not decreed	
GLEN 70	Pool Outlet	Yampa Sp.	"	"	-	"	
GLEN 76	DOH Yard		"	"	-	"	
GLEN 78	DOH Yard		"	"	-	"	
GLEN 80	DOH Yard		"	"	-	"	
GLEN 90	Graves (E&W Gamba Springs)	Health Spa	Redstone Corp.		Redstone Corp.		Filed but <u>not</u> in '78 tab or decreed
GLEN 100	Hobo				Redstone or Gamba		Filed but <u>not</u> in '78 tab or decreed.
--	Drinking Spring				-	Not decreed[2]	Hot Spring Lodge

1 Source: "Evaluation of Geothermal Energy for Heating Highways Structures" Interim Report, May, 1980.

2 As of 1981 June.

Table 5.2
Water Rights with Spring Sources in Study Area

WATER DISTRICT #39

Spring Name	Location 10-40-160	Use of Water	Appro-priation Date	Adjud. Dates	Amount	Str. that spring is Trib. to	Controller	Diversion Records Available	Comments
Hubbard Spring Pipeline	5S-89W-27 NE SW	ID	10/03/1942	9/05/1952 11/23/1943	.1000 cfs	Mitchell Cr.	Earl Hubbard, Glenwood Springs Colorado	1970-77	
Besler Spring	5S-89W-27 NE SW	D	5/31/1935	12/31/1973 12/31/1972	.0132 cfs	Mitchell Cr.	Ralph E. Besler Renae D. Besler, Rt. 1, Box 248, Glenwood Springs, Colorado	No	
Glenwood Springs Pipeline #2	5S-89W-27 SE SW SW	P	10/16/1951 12/26/1905	11/10/1966 9/05/1952	1.8000 cfs	Mitchell Cr.	Dept. Fish & Game, Denver	1972-77	
Glenwood Springs Pipeline #4	5S-89W-27 SE SW SW	P	10/18/1951 12/26/1905	11/10/1966 9/05/1952	.1500 cfs	Mitchell Cr.	Dept. Fish & Game	1972-77	
Hermatage Ditch	5S-89W-28 SE	I	6/01/1886	11/13/1905	.2000 cfs	Mitchell Cr.	K Ranch, Glenwood Springs, Colorado	1950-77	
Burgin Spring Pipeline	5W-89W-33 SE SE	D	6/01/1944	9/05/1952 11/23/1943	.0300 cfs .033 cfs	Colorado R.	Howard Burgin, Ft. McPherson, GA	1972-77	
Glenwood Springs Pipeline #3	5S-89W-34 NW NW	P	10/17/1951 12/26/1905	11/10/1966 9/05/1952	1.8000 cfs	Mitchell Cr.	Dept. Fish & Game	1972-77	
Ernest Spring & Pipeline	5S-89W-34 NW SW	IDS	8/24/1948	9/05/1952 11/23/1943	.2980 cfs	Mitchell Cr.	Chester Earnest, Glenwood Springs, Colorado	1972-77	
Bowles Spring and Ponds	5S-90W-26 SE SW 5S-90W-35 NE NW SE NW SW NW	IPD	11/30/1946	9/05/1952 11/23/1943	1.0000 cfs	Gulch tributary to Colo. R.	Larry Bowles, Glenwood Springs Colorado	1970-77	Six Springs

I = Irrigation, D = Domestic, P = Fishery, S = Stock, R = Recreation, F = Fire, C = Commercial, N = Industrial, O = Other

Table 5.3

Summary Table of Water Rights from Dotsero to State Line

From:	To:	Rights*
Dotsero	Glenwood Springs	1,419.149 cfs 10,000 cfs C 137,600 AF
Glenwood Springs	Canyon Creek	.033 cfs 6.09 cfs C
Canyon Creek	Newcastle	7.04 cfs
Newcastle	State Line	7,251.404 cfs 13,964.84 cfs C 195,999.52 AF 331,877.05 AF C
	Total:	8,677.262 cfs 12,970.93 cfs C 195,999.52 AF 469,477.05 AF C

* - C indicates conditional right to be used later.
  - AF indicates storage right.

Table 5.4

Conditional Water Rights Applied for by
United States Government

Spring Name	Discharge (cfs)
Dot Hot Spring 4	0.2
Dot Hot Spring 5	0.2
Dot Hot Spring 6	0.2
Dot Hot Spring 7	0.2
Dot Hot Spring 9	5.0
Dot Hot Spring 10	5.0
Dot Hot Spring 11	4.0
Dot Hot Spring 90	4.0
Glen Hot Spring 10	1.2
Glen Hot Spring 12	0.8
Glen Hot Spring 20	3.4
Glen Hot Spring 30-40	2.0
Glen Hot Spring 50	0.9
Glen Hot Spring 60	10.0
Glen Hot Spring 70	14.0
Glen Hot Spring 76	0.5
Glen Hot Spring 78	0.3
Glen Hot Spring 80	1.0
Glen Hot Spring 90	0.8
Glen Hot Spring 100	2.0

The Bureau proposes to collect 11.8 cfs of saline water at Dotsero and pipe this water to Glenwood Springs where 9.7 cfs of saline water will be collected. The total flow (21.5) will then be piped to evaporation ponds near the Colorado-Utah border.

The 21.5 cfs consumed could be replaced by water obtained from one of the following sources:

1. Replacement water from Green Mountain Reservoir or Ruedi Reservoir. This option will require acquisition of an additional 4.25 cfs to compensate for conveyance losses from the release point to Glenwood Springs. The additional 4.25 cfs is based on a stream loss of 0.05 cfs per mile from Green Mountain Reservoir to Glenwood Springs (85 miles).

2. Replacement with water acquired from senior water rights. These can be a combination of surface rights and/or groundwater rights. This option will require acquisition of senior rights for direct flow and storage for periods when salinity appropriations are out of priority.

At this time it is not known if the Colorado State Engineer would accept either of the proposals for replacement of the 21.5 cfs required for the Glenwood-Dotsero Unit. It is assumed that the Bureau will initiate the necessary legal work required to obtain sufficient replacement water by either of the methods discussed above. Since the Bureau owns the water in Green Mountain and Ruedi Reservoirs, it would appear that this is the most likely source of water. However, if this is not feasible then the work necessary to prepare an augmentation plan should be initiated. This will involve preparation of well permit applications, identification of senior direct flow rights and storage that could be purchased, and analysis of depletions and replacement.

sandstone lenses found within the Wasatch are aquifers. Hydraulic conductivity values for the Wasatch Sandstones are not available; however, wells with yields of as much as 900 gpm have been reported (Boettcher, 1972). Natural gas and associated oil is produced from the Wasatch Sandstone in the Piceance Basin. Connate waters associated with oil and gas production from Wasatch Sandstone have TDS concentrations of about 3,500 mg/1 (Colorado Oil and Gas Conservation Commission, 1980).

2.3.1.7 Late Cenozoic Volcanic Rocks

Remnants of formerly more extensive Miocene and and Pliocene basalt flows and minor interbedded sedimentary rocks are present on the uplands adjacent to the valleys of the Colorado River and its tributaries. In addition to these older flows, localized younger volcanism also occurs in lower elevations along some of the present-day valleys. Young basalts are present in the study area near Dotsero, to the northeast of the study area along Rock Creek north to McCoy, and to the southeast of the study area in the Roaring Fork River valley north of Aspen.

Hydraulic conductivity determined for basalt flows near Carbondale range from 370 to 14,600 feet per year (Brogden and Giles, 1976). TDS concentration in water obtained from these basalts ranges from 110 to 480 mg/1 (Brogden and Giles, 1976). It is anticipated that the feeder plugs for the basalt flows will also provide permeable zones with relatively high vertical secondary permeabilities which extend to considerable depth.

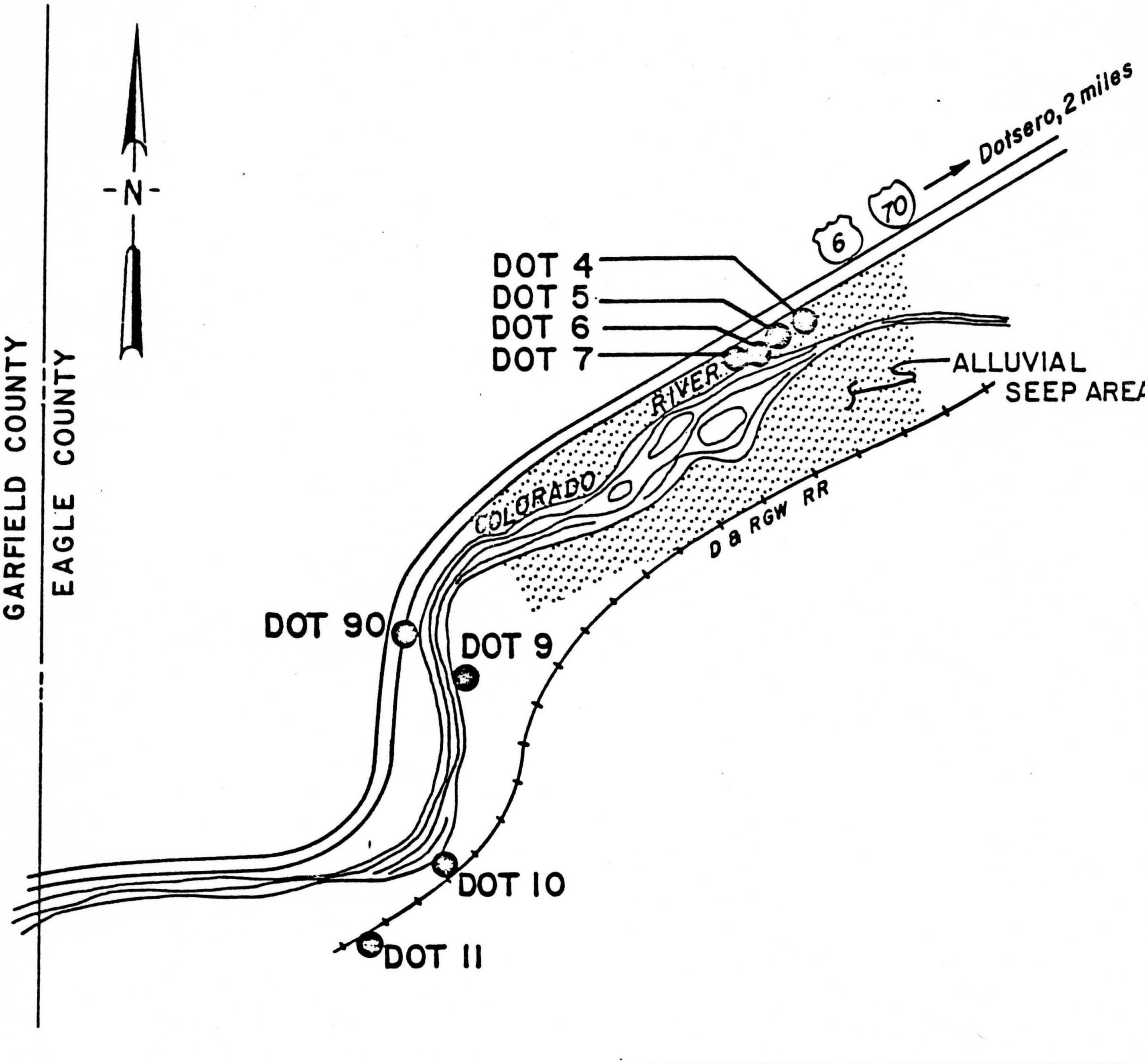
2.3.2 Location of Saline Springs

2.3.2.1 Dotsero Area

Specific locations for the Dotsero saline springs as they are presently configured are shown in Figure 2.6. The springs were originally numbered by the BOR in downstream ascending order. With the addition of new springs and the combining of old springs by highway construction, this numbering system has been somewhat altered.

The upstream group of springs occurring at river level has been affected periodically by highway construction. When monitoring of the springs by the BOR began in 1972, this group consisted of two springs, Dot 5 and Dot 6. In 1978, these two springs were covered by construction of I-70 and later re-emerged as Dot 4, Dot 5, Dot 6 and Dot 7.

Downstream about one mile and also on the north bank of the Colorado River is Dot 90. This spring also occurs at river level. Prior to highway construction in 1978, this spring existed as three separate springs: Dot 20, Dot 30, and Dot 40. When the BOR began monitoring these springs in 1972, their outflow was combined into a single flume to enable more accurate flow measurements to be taken. Since 1978, their outflow has been combined into two culverts and labeled Dot 90.



No Scale

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

COLORADO RIVER WATER QUALITY IMPROVEMENT PROGRAM
SALINITY INVESTIGATION OF GLENWOOD – DOTSERO SPRINGS UNIT

DOTSERO AREA
SALINE SPRING LOCATIONS

DESIGNED _____ TECHNICAL APPROVAL _____
DRAWN Malmone SUBMITTED _____
CHECKED _____ ADMIN. APPROVAL _____

URS Company, DENVER, COLORADO
PROJECT NO. 0080

0-07-40-S1359

FIGURE 2.6

Three spring occurrences at river level on the south bank of the Colorado at Dotsero are being monitored by the BOR. These are designated as Dot 9, Dot 10, and Dot 11. These springs have remained in their present configuration throughout the period of monitoring.

Since all of the Dotsero saline springs are thermal in nature, anomalies identified on thermal infrared imagery indicated some potential occurrences of thermal-saline water not obviously associated with known springs. Investigations of these anomalies did not identify any major sources of saline water. The anomalies occur in the vicinity of saline water seepage faces or within the river itself. These anomalies undoubtedly represent saline inflows through river alluvium which are not being monitored because their flows are unseen, inaccessible, or too small to measure.

Field investigations also identified a number of saline seepage faces characterized by salt deposits along the banks of the Colorado. Growths of salt cedar were found to be closely associated with these seepage faces and with the measured springs. Areas of salt cedar not in close proximity to seepage faces or saline springs probably indicate further inflows of unseen saline groundwater.

2.3.2.2 Glenwood Springs Area

All of the saline springs in the Glenwood Springs area occur at river level. Their specific locations are shown in Figure 2.7. The Glenwood saline springs are also numbered in downstream ascending order. Springs on the south bank of the Colorado River were numbered independently of those on the north bank.

Glen 10, Glen 20, and Glen 30-40 occur on the south bank of the Colorado River above the Roaring Fork confluence. Glen 30-40 is located downstream of both Glen 20 and a water supply siphon crossing the river. Glen 30 and Glen 40 were separate springs prior to the construction involving the siphon. At that time, the flows from these two springs were combined into a single culvert now labeled Glen 30-40. A number of seeps occur from between Glen 10 and Glen 20 to a point about 20 feet downstream of Glen 20. A number of seeps are also found downstream of Glen 30-40. These seeps issue from the southern bank of the Colorado River as well as from travertine mounds located in the river about 20 to 30 feet from the river's edge.

Glen 12, Glen 50, and Glen 60 are located on the north bank of the river across from the south bank group. Glen 12 is located directly across the river from Glen 10. Flow issues from highway fill and rip-rap a few feet above the low flow level of the river.