3720

STATE OF COLORADO

COLORADO WATER CONSERVATION BOARD
Department of Natural Resources

823 State Centennial Building
1313 Sherman Street
Denver, Colorado 80203
Phone: (303) 866-3441

Richard D. Lamm
Governor

J. William McDonald
Director

David W. Walker
Deputy Director

QUARTERLY REPORT

on the

208 CLEAN WATER GRANT

for the

WATER QUALITY CONTROL DIVISION

of the

COLORADO DEPARTMENT OF HEALTH

prepared by the

COLORADO WATER CONSERVATION BOARD

August 16, 1982

3731

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August 16, 1982

Mr. Gary Broetzman, Director
Water Quality Control Division
Department of Health
4210 East 11th
Denver, CO 80220

Subject: 208 Clean Water Grant

Dear Gary:

In accordance with the contract between our agencies concerning the above subject, I have attached a copy of our quarterly report and a tabulation of our "in-kind" expenses for April, May, and June, 1982.

If you have any questions, please feel free to give me or Dan Law a call.

Sincerely,

/S/ 8/30/82

J. William McDonald
Director

JWM/gl

Attachments

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Summary of April through June Work Activities

Third quarter work activities under this contract were dedicated almost entirely to the completion of the Colorado Salt Loading Information Inventory described in Item I of the Clean Water Grant--Scope of Services. Item I directs the Water Conservation Board to review and analyze salt loading information on the Colorado River Basin in Colorado and identify conflicts or gaps as they exist in that information. To allow for a more orderly presentation of this information, the Colorado River Basin in Colorado was divided into the following seven subbasins: Yampa River, White River, Colorado River to Cameo, Grand Valley, Gunnison River, Dolores River, and San Juan River tributaries.

The review and analysis of salt loading information initiated during the second quarter was concluded midway through the third quarter after which work began on the narrative. Each subbasin discussion is introduced by a geographic description of the area as well as a brief description of subbasin land use practices. The introductions are followed by a brief summary of salt loading information from each of the various sources. Conflicts or gaps in information are considered in concluding each subbasin discussion. Total average salt yields for Colorado River Basin lands in Colorado during different time periods are presented in a table at the end of the report.

Site visits to two ongoing salinity control projects also accounted for part of the third quarter's work activities. The site of a brine collection and deep well injection proposal by the Bureau of Reclamation in the Paradox Valley in southwest Colorado was visited on June 1. The location of brine collection wells, transfer pipelines, the hydrogen sulfide stripping plant, and potential injection well sites were all laid out and discussed by Bureau of Reclamation personnel. On the following day, individual farm operations involved in the Soil Conservation Service's on-farm irrigation program in Colorado's Grand Valley were visited. Several of the measures currently being implemented to improve irrigation efficiency and reduce salt loading include land leveling, canal and lateral lining, gated pipeline, automated and semi-automated water release systems, and improved water management practices.

Item II of the Scope of Services directs the Colorado Water Conservation Board to evaluate the relative effectiveness of alternative technical salinity control measures in terms of their economic, social, and institutional impacts in the Colorado River Basin in Colorado. Fourth quarter efforts will concentrate on addressing this item and some time was spent in June identifying the various technical salinity control measures and potential impacts.

Salt Loading Source Inventory
Colorado River Basin in Colorado

Salinity has long been recognized as one of the major problems of the Colorado River. The Colorado River and several of its tributaries originate on lands in western Colorado. A significant amount of the Colorado River salt load at Imperial Dam is contributed by man caused and natural sources originating on the 38,542 square miles of Colorado River Basin in Colorado.

Natural sources of salt loading include saline springs and other ground waters in addition to surface erosion and solution of sediments. Most man caused contributions to salt loads are associated with irrigated agriculture or municipal and industrial use of water.

This report is an attempt to identify all available documentation of salt loading source studies produced by various government agencies and institutions. In order to allow for a more orderly presentation of salt loading information, the Colorado River Basin in Colorado has been divided into the following subbasins:

Yampa
White
Colorado River to Cameo
Grand Valley
Gunnison
Dolores
San Juan Tributaries

For each subbasin, salt loading information is summarized and gaps or conflicts are discussed.

Information developed during several of the more comprehensive investigations is utilized in each of the subbasin discussions. Water Resources of the Upper Colorado River Basin - Technical Report (Professional Paper 441), published by the U. S. Geological Survey (USGS), is authored by W. V. Iorns, C. H. Hembree, and G. L. Oakland. This report contains an analysis of the influence of natural environmental factors and the activities of man on the occurrance, quantity, and quality of the Upper Colorado River Basin water resource. The authors of the report utilized streamflow and water quality measurements taken at USGS gaging stations during water years 1914-1957. Salt budgets were developed using data from stations above and below areas affected by the activities of man. Increases in dissolved solids above that which could be accounted for by inflow and natural contributions in these areas were considered to be the amount added to the system by the activities of man. An attempt to further define man caused sources was made by attributing a conservative figure of 100 tons of salt per 1,000 people per year to municipal and industrial use of water. That portion of man caused salt load not attributed to municipal and industrial sources was attributed to irrigated agriculture.

Appendix A of the EPA's The Mineral Quality Problem in the Colorado River Basin also contains valuable salt loading information on Colorado subbasins. The report, released in 1971, is the result of short-term sampling programs and field investigations designed to further define and detail existing information on the location and magnitude of salt loading as well as fill in major gaps in existing water data. The studies were carried out from June of 1965 to May of 1966.

The EPA effort more clearly defines salt loading sources than does the USGS effort. It is important to note, however, that the EPA study period covered one year while the USGS utilized average salt yields covering a 43 year study period. Data collected by the EPA could easily represent an unusually wet year.

Evaluation of Ground Water Contribution to Salinity of Streams in the Upper Colorado River Basin in Colorado is a joint effort by the BLM and USGS. The reconnaissance level study involved a one-time sampling program of baseflow during December of 1977 and January of 1978. Groundwater inflow was considered to represent the bulk of the stream flow during the low flow winter months. It was also assumed that groundwater discharge remains nearly constant during the year and remains nearly constant from year to year.

The salt load estimates were derived from a mass balance using measurements from the various Colorado River system subbasins in Colorado. The percent of the total average annual salt load contributed by ground water inflow varied considerably from subbasin to subbasin. No real attempt was made to distinguish between natural and man caused sources of salt loading.

Six areas in Colorado have been authorized for planning or construction by the Colorado River Basin Salinity Control Act. Prior to developing a proposal to control salt loading in these areas, the Bureau of Reclamation and Soil Conservation Service conduct preliminary investigations to determine precisely the source, location and magnitude of salt loading. This information was utilized in all but the Yampa Subbasin.

References to salt loading in the Colorado River Basin appear in a variety of literature beyond those discussed above. Most of this literature, however, relies on previously discussed investigations conducted by the USGS, EPA, BLM, BuRec, and SCS.

YAMPA SUBBASIN

The Yampa River Basin is located in northwest Colorado and south-central Wyoming. The basin land area is approximately 9,530 square miles, 6,719 of which is in Colorado. The Red Desert Basin forms the northern boundary, the Continental Divide the eastern boundary, the White-Yampa divide forms the southern boundary, and the Colorado-Utah state line is the western boundary. Elevations range from 5,000 to more than 12,000 feet above sea level.

Approximately 6% of the land in the basin is used for crop production. The remaining 94% is used for grazing, timber production, watershed, recreation, wildlife, and other purposes. The average irrigated acreage during the 1943-60 period was 96,500. The 1980 population was approximately 26,500.

None of the salt loading by source investigations on the Yampa River Basin have attempted to separate Colorado and Wyoming contributions to the Little Snake River, the major tributary to the Yampa. For this reason, salt loading estimates include contributions from Wyoming sources. When considering only Colorado sources of salt loading to the Yampa River Basin, slight adjustments must be made to basinwide estimates presented hereinafter.

USGS - Professional Paper 441

The 1914-57 average annual dissolved solids discharge for the Yampa River Basin was 405,000 tons. Of this total, 343,000 tons per year were from natural sources. Although not quantified, a significant natural source of salt loading by groundwater was identified in the Yampa River headwaters above Oak Creek. Permeable tertiary volcanics in this area provide an opportunity for recharge to ground water reservoirs in contact with underlying Mancos Shale formations. Thermal springs, primarily in the vicinity of the town of Steamboat Springs, accounted for 34,000 tons of the total annual salt load attributed to natural sources.

Salt budgets were developed for three areas within the basin in order to compute the amount of dissolved solids contributed to stream systems by the activities of man. Twelve thousand acres of irrigated agriculture between Morrison Creek and Steamboat Springs yielded 1,800 tons per year; eight thousand acres in the Elk River tributary yielded 4,700 tons per year; and 4,000 acres on the Little Snake above Dixon yielded 5,400 tons per year. On a tons per square mile basis, the Little Snake River tributary lands yielded approximately twice as much dissolved solids as did the remaining Yampa Basin lands. The total salt load in the Yampa River Basin that was attributed to the irrigation of 73,700 acres of land was 61,000 tons per year. Approximately 1,400 tons per year were attributed to municipal and industrial use of water and constitutes the remainder of the man caused salt load in the basin.

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EPA-Mineral Quality Problem

For the period of record June 1965 to May 1966, the EPA measured a total dissolved solids load of 402,000 tons for the entire Yampa River Basin. Man caused sources were responsible for 46,200 tons per year and natural sources were responsible for 355,800 tons per year. The salt budget for the Yampa basin is shown below.

Source	TDS Load (tons/year)	Percent of Total Load
Springs	8,000	2.2
Irrigation	38,000	9.4
Industrial	7,000	1.5
Mine Drainage	2,000	.5
Runoff	347,000	86.4
TOTAL	402,000	

An abandoned coal mine located along Oak Creek downstream from the community of Oak Creek added 2,000 tons of salt per year to the system. The release of saline water from the Iles Dome Oil Field located south of Lloyd, Colorado was responsible for the addition of 7,000 tons of salt per year. The remaining portion of the total salt load caused by activities of man was attributed to irrigated agriculture. The irrigation of 78,100 acres along the Yampa mainstem and its tributaries and 32,000 acres along the Little Snake and its tributaries yielded a combined total of 38,000 tons of salt per year to the Yampa River Basin.

Almost 110,000 tons of the salt load attributed annually to naturally occuring sources was from natural diffuse runoff in the Elk River, Elkhead Creek, Trout Creek, and Fortification Creek tributaries. Natural runoff from Mancos Shale outcrop areas along Milk Creek accounted for another 32,800 tons per year.

The EPA made no other reference to salt loading from natural diffuse sources in specific areas within the basin. Mineral springs in the vicinity of Steamboat Springs contributed 8,800 tons of salt per year.

USGS & BLM - Ground Water Contribution

No data was collected in the Yampa Basin as part of this study. Data collected as part of a 3-year river basin assessment by the USGS (Analysis of Stream Quality in the Yampa River Basin, Colorado and Wyoming - Wentz and Steele, 1980) was used to estimate the baseflow salinity contribution of the Yampa River Basin.

It was estimated that approximately 160,000 tons of salt per year were contributed to the Yampa system by ground water inflow. This was 39% of the total average salt yield in the basin for water years 1966-75. Base flow was 50,000 and 110,000 tons per year for the Little Snake tributary and Yampa mainstem, respectively. A relatively large proportion of baseflow load from the Little Snake and Yampa mainstem is picked up along the lower and middle reaches where the river channels intersect the Mancos Shale and shales in the Mesa Verde Group.

Summary

Attempts to identify salt loads by source in the Yampa River Basin have been made by the USGS and EPA. The percentage of total salt load attributed to natural and man caused sources does not differ significantly in the two reports.

USGS	Man Caused	15.3%
	Natural	84.7%
EPA	Man Caused	11.4%
	Natural	88.6%

Although the total salt yields and natural-man caused breakdowns were close, the EPA study accounted for more of the naturally caused salt load by attributing it to diffuse runoff. The USGS attributed about 23,000 tons per year more to mineral springs in the basin than did the EPA.

The EPA study developed consistently lower salt yields (tons/acre) from irrigated agriculture which caused this basinwide estimate of irrigation related salt loading to be approximately 23,000 tons per year less than that of the USGS.

The USGS-BLM estimate of ground water contribution to total basin salt yield was 160,000 tons per year. At 39%, ground water contribution to total salt yield was lower in the Yampa River Basin than any other subbasin in this inventory.

The fact that no Salinity Control Units (Colorado River Water Quality Improvement Program) have been identified in this basin has limited BuRec and SCS involvement in salt loading investigations.

WHITE SUBBASIN

The White River Basin in Colorado encompasses 3,808 square miles in the west-central part of the state between the Colorado River Basin to the south and the Yampa River Basin to the north. Elevations range from 5,000 to 12,000 feet above sea level. The total basin population in 1980 was 6,300.

The primary use of lands in the basin is grazing. Timber production, wilderness, watershed, and recreation make up a smaller percentage of land use. Irrigation of approximately 35,000 acres constitutes the major use of water in the basin.

USGS - Professional Paper 441

Professional Paper 441 identified the average annual salt discharge for the White River Basin at Watson, Utah to be approximately 331,000 tons (water years 1914-57, adjusted to 1957 conditions). Of that total, 164,000 tons were determined to be man caused. Irrigation of 30,000 acres of farmland in the basin accounted for all but approximately 500 tons contributed by man's activities. The remaining 500 tons were attributed to municipal and industrial sources.

Natural sources of salinity in the White River account for 167,000 tons annually. It is estimated that total ground water contribution to the White River near Meeker is 102,000 tons annually due to the relative abundance of soluble minerals in rocks underlying this area.

EPA - Mineral Quality Problem

During the study period, the White River Basin yielded about 361,000 tons of salt. Natural runoff (defined as all surface runoff, interflow, and base flow entering the stream channel) accounted for the largest portion of the daily salt load at the Watson, Utah station. The salt budget for this area is given in the following tabulation.

Source	TDS Load (tons/yr)	Percent of Total Load
Irrigation	7,300	2.0%
Abandoned oil-test holes	64,600	17.9%
Springs	700	0.2%
Runoff	288,400	79.9%
TOTAL	361,000	

Irrigated agriculture along Piceance, Yellow, and Douglas Creeks as well as along the White mainstem added 7,300 tons of salt per year. An abandoned oil-test hole near Meeker and one along Piceance Creek contributed 58,400 and 6,200 tons per year, respectively. A sulfur spring at the mouth of Yellow Creek accounted for 700 tons of salt per year.

Although not quantified, the report refers to saline water in near surface formations east of Meeker that is under artesian pressure and could be entering the stream through naturally occurring fissures or other test holes.

BuRec - Progress Report #10

This report describes planning and construction developments associated with projects in the Colorado River Water Quality Improvement Program. The Meeker Dome Unit is located in the White River Basin of Colorado. The BuRec investigations in 1968 identified an abandoned oil test hole in the Dome as discharging 57,000 tons of salt annually. Since that time, this and other wells in the vicinity have been plugged by the BuRec. Data collection studies indicate that seepage is continuing and the salt loading estimate for 1979 approximated 27,000 tons.

BLM - Ground Water Contribution

The White River Basin at Watson, Utah yielded an average annual salt load of 275,000 tons from 1966-75. Of that total, approximately 196,000 tons, or 71% of the total basin salt yield, was attributed to ground water sources.

Summary

Both the EPA and USGS reports account for the entire White River salt yields contributed by lands within Colorado. Assuming there have been no significant changes in basin conditions since these investigations were conducted, no real gap in salt loading information exists. Conflicts in information, however, do exist.

USGS	Man Caused	50%
	Natural	50%
EPA	Man Caused	20%
	Natural	80%

The most obvious conflict involves the portion of total salt yield each report attributes to man caused sources of salinity. The USGS suggested that irrigated agriculture in the basin adds about 163,500 tons annually (50% of the total yield) while the EPA report attributes about 7,300 tons annually (2% of the total yield) to irrigated agriculture. There is no readily apparent explanation for these conflicting accounts.

Also, the USGS report makes no mention of discharge from abandoned oil test wells in the White River Basin. They do refer to an annual contribution of 11,000-tons by abandoned wells from the entire Green River Basin. The EPA determined contributions from this source to be 65,000 tons annually in the White River Basin alone. This number is closely on line with those presented in BuRec's Progress Report No. 10.

COLORADO RIVER TO CAMEO

The Colorado River mainstem from the upper most headwaters to the USGS gaging station near Cameo (station number 0905500) encompasses approximately 8,060 square miles. It is located in west-central Colorado. The Basin is bordered by the Continental Divide and Flat Tops Area on the north and the Continental Divide and Gunnison River Basin divide on the south with the east and northeast border abutting the Platte River Basin. Elevations range from 4,900 to 14,000 feet above sea level.

The major use of water within the Basin is for the irrigation of approximately 160,000 acres of agricultural land. Grazing and timber production constitute the most frequent use of land in the basin. The 1980 population was approximately 60,000.

USGS-Professional Paper 441

The average annual salt load in the Colorado River mainstem near Cameo, Colorado was 1,578,000 tons for water years 1914-57. The USGS identified a series of thermal springs in this basin which accounted for up to 476,000 tons of dissolved solids annually. Two springs below Dotsero and nine springs near Glenwood Springs accounted for approximately half of this total. Other springs occur near Hot Sulphur Springs, the Blue River near Dillon, and several tributaries to the Roaring Fork Basin. There was evidence that other thermal springs rise in the bed of the river.

An additional 738,000 tons per year was discharged to the river through natural runoff. The total salt load discharged to the basin by natural sources was determined to be 1,214,000 tons per year.

Man caused sources of salt loads make up a much smaller portion of the total basin yield. An increase in dissolved solids due to irrigation was determined to be approximately 361,000 tons per year. The remaining 2,400 tons were attributed to municipal and industrial use of water.

EPA - Mineral Quality Problems

The EPA study divided the Colorado mainstem to Cameo into three separate study areas. The salt budget for the three study areas has been consolidated and is presented below.

Source	TDS Load (tons/year)	Percent of Total Load
Irrigation	166,000	10.6
Runoff	912,000	57.2
Industrial Effluents	19,000	1.1
Springs	498,000	31.1
	1,595,000	

Mineral springs, located on both banks of the Colorado River approximately 2 1/2 miles below Dotsero, were responsible for a salt load increase of about 163,000 tons per year. Springs in the vicinity of Glenwood Springs added another 335,000 tons of dissolved solids annually.

During the 1965-66 study period, 912,000 tons of dissolved solids in the Colorado River at Cameo were attributed to natural runoff. The lower reaches of Gypsum Creek, Roaring Fork, and Eagle River were all identified as high source areas. These are areas where the stream bed flows through the highly saline Paradox formation outcrop. Approximately 1,410,000 tons of the total salt load at Cameo was from natural sources.

Irrigation of 24,000 acres along the Colorado near Kremmling, 7,000 acres on Muddy Creek, 21,000 acres in the Roaring Fork Basin, and 16,000 acres along the Colorado River upstream from Silt was responsible for salt loading of an additional 166,000 tons per year.

Effluent discharged from the Union Carbide uranium mill near Rifle, Colorado added about 15,000 tons of dissolved solids annually to the river system. Seepage from tailings ponds at this site contributed an undetermined amount of salts. The New Jersey zinc mine and mill near Gilman discharged 4,000 tons per year in the form of process waste. The annual salt load attributable to man caused sources, at Cameo, approximated 185,000 tons.

BuRec-Progress Report #10

As a project authorized for planning under the Colorado River Water Quality Improvement Program, the Glenwood-Dotsero Springs Unit has been the subject of geologic and hydrologic studies by the Bureau of Reclamation. The Bureau has determined that in the 16-mile reach between Dotsero and Glenwood, about 25,000 acre-feet of water and more than 500,000 tons of salt enter the river annually.

About half of the salts come from eight identified springs located approximately 2.5 miles downstream from Dotsero and 10 springs located near Glenwood Springs. The remainder enters unseen through the stream channel as groundwater inflow.

USGS-BLM-Groundwater Contribution

Measured baseflow salt load in the Colorado River at Cameo was 1,254,100 tons. The total average annual salt load for the Colorado River at Cameo from 1966-75 was 1,510,000 tons. It is estimated that 83% of the total average annual salt load is contributed by groundwater sources. Relative to other Colorado subbasins considered in this investigation, groundwater contributions make up the largest part of the basin salt loads in the headwaters of the Colorado River.

Measurements taken during December 1977, and January 1978, identified salt loading in the Glenwood-Dotsero thermal spring area at 535,800 tons per year.

Summary

Both the USGS and EPA reports attempt to account for the salt load by source for the Colorado River mainstem at Cameo. The EPA report attributed more of the total salt yield to natural sources.

USGS	Man Caused	23.1%
	Natural	76.9%
EPA	Man Caused	11.7%
	Natural	88.3%

The various investigations of salt contributions by thermal springs in the Glenwood-Dotsero area have produced consistent conclusions. There is, however, a conflict between the EPA and USGS accounts of man caused sources in this basin. The USGS attributed over twice as much of the total basin salt yield to irrigated agriculture as did the EPA. The EPA apparently made this difference up by attributing a larger portion of the total salt load to industrial effluents and natural runoff.

An examination of streamflow and water quality data at the Cameo station for water years 1914 to the present identifies a fairly constant average annual salt load. The average annual salt load at Cameo for water years 1966-80 is 1,518,000 tons.

GRAND VALLEY SUBBASIN

The Colorado River mainstem between Cameo and the state line and excluding the Gunnison River Basin encompasses 1,870 square miles. A major portion of the area is within the valley carved by the Colorado River and is bounded on the north and west by the Roan and Book Cliffs and on the east by the Grand Mesa.

Elevations range from 4,500 to 10,000 feet above sea level in the headwaters of Plateau Creek.

The irrigation of 66,000-88,000 acres of land in the Grand Valley constitutes the largest use of water in this area. The 1980 population of this area was approximately 75,000.

USGS-Professional Paper 441

For water years 1914-57, the U. S. Geological Survey reported an average annual increase in dissolved solids of 496,700 tons for the stretch of the Colorado River between Plateau Creek and the Dolores River, excluding the Gunnison. Of this amount, about 52,600 tons came from natural sources and about 444,100 tons were contributed as a result of man's activities. Irrigation of 78,700 acres along this stretch of the Colorado accounted for an increase in salt loading of approximately 440,600 tons annually. The remainder of the man caused contribution is associated with municipal and industrial use of water in this area.

The U.S.G.S. produced a separate salt budget for Plateau Creek. Of the 66,000 tons of dissolved solids yielded by this basin annually, approximately 38,000 tons were caused by the irrigation of 29,000 acres of land. Slightly more than 300 tons per year were attributed to thermal springs in the headwaters of Plateau Creek and the remaining 27,700 tons per year were the result of natural diffuse sources.

The total salt yield for the Grand Valley Subbasin, as defined previously, could be estimated at 562,800 tons per year. Man caused sources accounted for 482,100 tons, while natural sources accounted for 80,700 tons.

EPA-The Mineral Quality Problem

The EPA study produced a salt budget for the Colorado River from Cameo to just inside the state line (excluding the Gunnison). For the period May 1965 to June 1966, this segment of the river yielded 784,700 tons of dissolved solids. The salt budget is shown below.

Source	TDS Load (tons/year)	Percent of Total Load
Industrial Effluents	16,100	2.1
Municipal Effluents	5,800	.7
Runoff	32,800	4.2
Irrigation	730,000	93.0
TOTAL	784,700	

During the study period, direct discharge of effluent from the Climax Uranium Mill at Grand Junction contributed a salt load of 13,000 tons per year to the system. Approximately 3,100 tons of dissolved solids per year in effluent from the American Gilsonite Corporation Plant near Fruita made up the remainder of total salt load attributed to industrial effluents.

Effluent from the Grand Junction-South Sewage Treatment Plant and Grand Junction-West Sewage Treatment Plant contributed 1,800 and 4,000 tons of dissolved solids per year respectively.

Irrigation of 88,000 acres of soils underlain by highly soluble Mancos Shale in the Grand Valley added about 703,000 tons of dissolved solids annually to the Colorado River. The 8 tons per acre per year average yield for this irrigated area was the highest observed in the Colorado River Basin during the study period.

Plateau Creek added 59,000 tons of salt per year to the Colorado River. Although an accurate salt budget for this drainage was not developed, salt load contribution by irrigation was estimated at 27,000 tons per year.

The EPA study attributed 751,900 tons per year of the total subbasin salt yield to man caused sources. Natural sources were identified as contributing 32,800 tons per year.

Bureau of Reclamation - Stage One Development Grand Valley Unit Special Report, September 1979

This report presents the results of definite plan studies on the proposed Stage One Development of the Grand Valley Unit of the Colorado River Basin Salinity Control Project. The unit is designed to reduce the salt contribution to the river from irrigated lands in the Grand Valley, from below Cameo to just below Mack, excluding the Gunnison River and Plateau Creek.

In order to more clearly characterize salt loading from irrigated agriculture in the Grand Valley, the Bureau measured stream and groundwater flows and quality from 1974 through 1976. The annual salt contributions from irrigation are shown below.

Source	Tons per year
Canal Seepage	240,000
Lateral Seepage	230,000
On-Farm Ditch Seepage	160,000
Deep Percolation From Irrigation	140,000
Surface Runoff From Above Irrigated Lands	10,000
TOTAL	780,000

USDA - Soil Conservation Service, Final Report of the Grand Valley Salinity Study

One of the overall objectives of the SCS participation in the Grand Valley Salinity Control Study was to determine the contribution of salt loading from irrigated and related upland areas. The SCS Project Area encompasses the Colorado River Basin from Cameo to the state line, excluding Plateau Creek and the Gunnison River Basin. Salt contribution was reported to be 600,000-700,000 tons per year. Apparently, no attempt was made to account for the remaining portion of the Grand Valley salt yield.

USGS - BLM Groundwater Contribution

The USGS and BLM present an estimated salt load contributed by groundwater for the Colorado River mainstem below Glenwood Springs to the state line, excluding the Gunnison River. The average total salt load for this stretch of river between 1966 and 1975 was 1,113,100 tons per year. Measured base flow during the study period was1,040,000 tons per year which indicates that about 93% of the total annual salt load through this stretch was produced by groundwater sources.

BLM 1978-79 Status Report

In their 1978-79 Status Report, the BLM attempted to estimate the amount of the salt load in groundwater attributable to irrigation return flow. Drainage channels in the Grand Valley that were thought to be yielding only irrigation return flow were monitored for flow and quality. The total measured baseflow salt load for the Colorado River between Glenwood Springs and the state line was 1,040,000 tons per year.

It was determined that irrigation return flow was responsible for 690,800 tons per year (66%) of the total and natural groundwater inflow was responsible for the remaining 349,200 tons per year (34%).

Summary

The Grand Valley Subbasin is one of the more studied salt loading source areas in Colorado. The USGS, EPA, BuRec, SCS, and BLM have all developed salt load by source estimates for that portion of the Colorado River that includes the Grand Valley. The studies cover different periods of time and the areas included in the studies vary slightly. All these things limit the value of any direct comparison of results.

USGS	Man Caused	85.7%
	Natural	14.3%
EPA	Man Caused	95.8%
	Natural	4.2%
BuRec	Man Caused	98.7%
	Natural	1.3%
*BLM	Man Caused	66.0%
	Natural	34.0%

* Refers to percentage of salt load contributed by groundwater sources only.

All salt loading information on the Colorado River between Cameo and the state line identify man caused sources, irrigated agriculture in particular, as making up the largest portion of the increase through this stretch of river.

The Bureau of Reclamation study does not consider the effect of municipal and industrial use of water, and their estimate of 10,000 tons per year from natural surface runoff above irrigated lands is not consistent with other estimates.

Whereas the BuRec estimate for natural runoff contribution is inconsistently low, the BLM estimate of 349,000 tons per year appears high. The EPA (33,000 tons/year), USGS (80,000 tons/year) and SCS (80,000 tons/year) are much closer to agreeing on the significance of natural sources of salt loading in the subbasin.

Relative to other Colorado River subbasins in Colorado, the effect of man's activities in the Grand Valley Subbasin is much more prominent. All salt loading information refers to the irrigation of Mancos Shale derived soils in the Grand Valley as the most serious problem to the area.

GUNNISON SUBBASIN

The Gunnison River Basin encompasses an area of 8,020 square miles located in west-central Colorado. The Continental Divide forms the east and southeast boundary of the Basin and the San Juan Mountains and Uncompahgre Plateau form the south and southwest boundary. The Basin is bounded on the north by the Elk Mountains and the Grand Mesa and on the northwest by the Grand Valley. Elevations vary from 4,550 feet to 14,300 feet above sea level.

The major use of water in the Basin is for the irrigation of 269,000 acres of land (Bureau of Census 1957). Ninety-five percent of the basin land is used for grazing and timber production, watershed, and recreation purposes. The 1980 population was estimated at approximately 49,000.

USGS-Professional Paper 441

The USGS presents an average annual salt yield for the Gunnison River Basin. Measurements taken at gaging station No. 09152500 (Gunnison near Grand Junction) for water years 1914 through 1957 were used to determine an average annual salt yield of 1,519,000 tons.

The report attributed 977,000 tons of salt per year to the activities of man. Irrigated agriculture made up 973,200 tons of this total. The basinwide average salt yield was determined to be 3.6 tons per acre irrigated. It is estimated that a salt discharge of 3,800 tons per year was due to municipal and industrial use of water.

Natural sources contributed 542,000 tons of salt annually to the Gunnison River Basin. Natural diffuse surface and groundwater contributions accounted for all but 6,000 tons of this total. The 6,000 tons came from many small thermal springs throughout the subbasin. The combined discharge of all reported springs is slightly more than 7 cfs with TDS concentrations averaging 7,800 mg/l.

EPA-Mineral Quality Problem

During their 1965-66 study, the EPA calculated the annual salt yield for the Gunnison River Basin to be 1,705,000 tons with irrigated agriculture accounting for the largest portion of this amount. The salt budget for the Gunnison Basin is shown below.

Source	TDS Load (tons/yr)	Percent of Total Load
Municipal	13,140	0.8
Irrigation	1,131,500	66.4
Mine Drainage	5,110	0.3
Runoff and Springs	554,800	32.5
TOTAL	1,704,550	

The narrative discussion of the salt budget does not detail the 13,000 tons attributed to municipal use of water. The abandoned mines referred to in the budget, are located in the headwaters of the Uncompahgre and Lake Fork drainages. All but 36,000 tons per year of the total yield attributed to irrigated agriculture originate in the Lower Gunnison River Basin.

Mineral springs near Ouray and Ridgeway along the Uncompahgre River account for a small percentage of salt loads contributed by natural sources. Areas drained by the North Fork, the Uncompahgre, and the Lower Gunnison are underlain by soluble formations and therefore account for the largest portion of the 550,000 tons per year attributed to natural runoff. The headwaters of the Gunnison River, Tomichi Creek, and Lake Fork are underlain by more resistant rock and therefore yield high quality runoff.

SCS-Final Report on the Lower Gunnison Salinity Control Study

The SCS presents an estimate of salt loading by source for the Gunnison River Basin. Using measurements from the USGS gaging station No. 09152500 - Gunnison River near Grand Junction, the SCS estimated the average annual salt yield since

1975 to be 1,400,000 tons. Of the total, about 600,000 tons came from natural sources and about 840,000 tons (440,000 tons from on-farm irrigation sources and 400,000 tons from off-farm distribution systems) are attributed to irrigated agriculture.

It is probably important to note that these figures are based on a study of only a portion of the Gunnison River Basin. The study unit encompasses the Lower Gunnison River drainage from the Black Canyon of the Gunnison National Monument to just downstream from the confluence of the Uncompahgre and the Gunnison. Estimates of salt loading for irrigated acreage within this area were developed. That portion of the total basin annual salt yield not accounted for by irrigated agriculture in the Lower Gunnison Unit was then attributed to natural sources from the remaining unstudied portion of the basin.

BuRec-Feasibility Report

The Bureau of Reclamation describes salt loading from the area within their study. The Bureau studied that portion of the Lower Gunnison River Basin which is within the Uncompahgre River Valley and specifically is the area encompassed by the boundaries of the Uncompahgre Project. Seepage from canals and laterals in combination with inefficient irrigation practices result in a salt loading to the Colorado River of about 360,000 tons annually.

BLM-1978-79 Status Report

It is estimated that approximately 53% of the total salt load in the Gunnison River at Grand Junction is contributed by groundwater sources. As was done in the Grand Valley, water quality data were collected from drainage channels in the Lower Gunnison that were thought to be yielding only return flows. From this data, the BLM estimated that of the total salt load contributed by groundwater, 344,400 tons per year were from irrigation return flows and the remaining 381,800 tons per year were from natural baseflow.

Summary

The USGS, EPA, SCS, and BLM have all developed estimates of salt yields by source for the Gunnison River Basin. With the exception of the BLM estimate of salt loading from irrigation return flows, the portions of total basin salt load attributed to the various man caused and natural sources do not differ significantly from one study to the next.

USGS	Man Caused	64%
	Natural	36%
EPA	Man Caused	67%
	Natural	33%
SCS	Man Caused	58%
	Natural	42%

The BLM estimated that 344,400 tons of salt per year were contributed by irrigation return flows in the Gunnison River Basin. All other agency estimates of salt loading from irrigation in the Basin were more than twice as high.

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DOLORES SUBBASIN

The Dolores River Basin is located in southwestern Colorado and east central Utah. Its boundary encompasses an area of approximatley 4,645 square miles, 4,092 square miles of which are in Colorado. The basin is bounded on the south and west by the San Juan Mountains and the Uncompahgre Plateau. Elevations range from 4,100 to more than 14,000 feet above sea level.

Approximately 2 percent of the land in the basin is used for crop production. The remaining 98 percent is used for grazing, lumber production, mining, wildlife, and other purposes. The major use of water in the basin is for the irrigation of 47,000 acres. In 1980, the population of this area was 15,500.

USGS - Professional Paper 441

For water years 1914-57, the USGS reported the average annual salt yield for the Dolores River at Cisco, Utah to be approximately 460,000 tons. All but an insignificant portion of the total salt load at this station (No. 0918000) originates on lands within Colorado.

Approximately 112,000 tons of salt per year were attributed to the irrigation of 47,000 acres of agricultural land within the basin. An additional 1,000 tons per year were attributed to municipal and industrial use of water making the total salt yield attributable to the activities of man about 113,000 tons per year.

The Dolores River crosses two collapsed salt anticlines which together account for a salt pickup of approximately 251,000 tons per year. Paradox and Gypsum Valleys contribute 230,000 and 21,000 tons respectively. Several small thermal springs in the headwaters of the Dolores and San Miguel Rivers contribute a total of 400 tons of salt annually. Although not quantified, the report identifies drainages entering the Dolores River from the east, between Dolores and Bedrock, as significant natural diffuse sources of salt loading. The drainages, including Disappointment Creek, are underlain by rocks containing readily soluble minerals. The total salt yield by natural sources was estimated at 347,000 tons per year.

EPA - Mineral Quality Problems

The EPA measured the salt yield for the Dolores River near Cisco at 606,000 tons for the period beginning in June, 1965 and ending in May, 1966. Close to 90 percent of that total was traced back to natural sources. The Dolores River Basin salt budget for the period of study is shown below.

Source	TDS Load (tons/year)	Percent of Total Load
Irrigation	16,800	2.8
Industrial effluent & seepage from ponds	43,400	7.2
Springs and salt seeps	253,700	41.8
Mine drainage	7,300	1.2
Runoff	284,800	47.0
TOTAL	606,000	

A mean salt load addition of 251,000 tons per year was due to the solution of minerals from the Paradox Valley salt anticline. A similar phenomenon was responsible for a contribution of another 2,000 tons per year at Sinbad Valley.

Hot Paradise Springs, located on the West Fork of the Dolores River, added another 700 tons of salt annually.

The remaining portion of the mineral quality problem attributable to natural sources took the form of surface runoff, interflow, and baseflow entering stream channels. Discharge from Disappointment Creek added over 140 tons per day at certain times during the study period.

Mine drainage referred to in the salt budget originates in the headwaters of the Dolores near Rico (2,200 tons per year), the headwaters of the San Miguel (1,500 tons per year), and the headwaters of the South Fork of the San Miguel (3,600 tons per year). Effluent from the Union Carbide Uranium Mill at Uravan contributes close to 9,000 tons annually to the San Miguel. An unknown amount of increase within the Uravan reach was contributed by seepage from the industrial waste holding ponds near the mill. The Idarado Mining Corporation mill above Telluride added small amounts of salt through seepage from a tailings pond.

The report refers to two areas in which irrigated agriculture has resulted in salt load increases. Irrigation of approximately 6,000 acres along Naturita Creek near Norwood resulted in an increased salt load of 16,800 tons annually. A small amount of irrigation in the headwaters of the West Fork of the Dolores was identified as a source of additional salt loading.

BuRec - Progress Report #10

The Paradox Valley Unit is an authorized project under Title II of Public Law 93-320. The Bureau of Reclamation established a water quality sampling program for this unit in 1972. Analysis of 5 years of streamflow and water quality records indicates that the annual salt yield for the Unit area is about 205,000 tons.

BLM 1978-79 Status Report

With this report, the BLM has expanded its study of salinity from public lands to include salinity from groundwater discharge. A preliminary investigation to determine the technical and economic feasibility of a plan to control saline springs in the Salt Creek Canyon area (Sinbad Valley) of Colorado is discussed in the report.

The BLM determined discharge from the saline springs at the mouth of Sinbad Valley to be perennial, yielding approximately 100 gpm or 160 acre-feet per year. Dissolved solids concentration of the water was 61,200 mg/l, resulting in a total salt yield of 13,317 tons annually.

BLM - Groundwater Contribution

The Dolores River Basin yielded an average annual salt load of 489,800 tons from 1966-75. Of that total, the BLM estimated that 58 percent or 282,500 tons were contributed by groundwater sources.

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Summary

As in the other Colorado subbasins, the USGS and EPA have attempted to account for total basin salt loads by source during their respective study periods. As shown below, the reports differ somewhat in the portion of total basin salt yield attributed to man caused and natural sources.

USGS	Man caused	24.5 percent
	Natural	75.5 percent
EPA	Man caused	11.2 percent
	Natural	88.8 percent

The EPA report gave much more consideration to industrial sources and natural runoff sources. The USGS report attributed a much larger portion of the total salt yield to irrigated agriculture.

The EPA estimate of salt yield from the Sinbad Valley-Salt Creek area was developed during the 1965 and 1966 study period and appears to be significantly lower than the BLM estimate of over 13,000 tons per year. This is partially explained by the fact that the EPA measurements of TDS concentration were much lower than the BLM measurements. The EPA also references unquantified additional amounts of salts that enter the Dolores River as underflow from alluvium in Salt Wash Canyon.

The three sources which considered salt loading in the Paradox Valley were relatively close. The Bureau of Reclamation's determination of 205,000 tons of salt per year appears to be the most accurate since it reflects the most current information.

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SAN JUAN TRIBUTARIES SUBBASIN

The San Juan River Basin drains a 24,945 square mile area of which approximately 5,740 square miles are in Colorado. The Colorado portion of the Basin is located in the southwest corner of the state. It is bordered by the Dolores and Gunnison River Basins to the north, the Continental Divide to the east and the state lines to the west and south. Elevations range from more than 14,000 feet above sea level in the San Juan Range to around 6,000 feet at points where the various tributaries exit the state.

San Juan tributaries which originate in Colorado are the San Juan mainstem, Piedra River, Los Pinos River, Animas River, La Plata River, Mancos River, and McElmo Creek. Water from these tributaries and a diversion from the Dolores River Basin are used to irrigate 186,700 acres of agricultural land in Colorado. Timber, grazing, mining and recreation are also important uses of land in the San Juan tributaries. Based on the 1980 Census Report, approximately 47,000 people live in the San Juan Tributaries area of Colorado.

The tributaries to the San Juan River in Colorado will be analyzed individually. Although most salt loading studies on the San Juan Tributaries discuss areas not in Colorado, only dissolved solid yields and source identification from lands in Colorado will be presented in this report.

The USGS identifies average annual dissolved solids discharges for the following San Juan River tributaries at points near where they exit the state. The average annual dissolved solids discharge for all San Juan tributary lands in Colorado for 1914-57 approximated 476,000 tons.

Tributary	Salt Discharge (tons/yr)
San Juan Main	77,000
Piedra River	47,100
Los Pinos River	29,600
Animas River	155,200
La Plata River	13,500
Mancos River	39,000
McElmo Creek	115,000
	476,400

The La Plata River Basin is the only area for which sufficient data were available to allow the USGS to accurately determine the effect of the activities of man on salt loads. The irrigation of 16,500 acres along the La Plata north of the New Mexico line contributed 6,500 tons of salt per year to the La Plata River total salt load at the state line. In other areas of the San Juan basin for which sufficient data were not available to make similar determinations, calculations indicate that the amounts of dissolved solids added to the streams as a result of irrigation ranges from about 0.4 to 2.6 tons per acre per year. Land underlain by valley alluvium similar to that of irrigated areas in the Los Pinos River Basin had the lower rate, and lands underlain by Mancos Shale similar to the irrigated lands along the Mancos River had the higher rate.

EPA - The Mineral Quality Problem

The EPA considered the effect of irrigated agriculture on salt loads at two areas along the San Juan mainstem in Colorado. The irrigation of 12,000 acres above Pagosa Springs yielded 1,500 tons of salt during the study period while irrigated agriculture between Pagosa Springs, Colorado and Carracus, New Mexico added 36,500 tons of salt to the system. The difference in yields above and below Pagosa Springs was attributed to the insoluble nature of formations underlying soils above Pagosa Springs and the soluble nature of the Mancos Shale and Tertiary sediments underlying soils below Pagosa. Mineral springs contributed an additional 7,300 tons of salt during the study period.

Because of complex interrelations between diversions and return flows within the Animas River, the Florida River, and the Los Pinos River drainages, a salt budget was prepared for the entire area. An unspecified amount of irrigated acreage between Durango and the state line for these three drainages contributed 12,000 tons of salt to the system during the study period.

The irrigation of 15,000 acres in Colorado along the La Plata River added 20,000 tons of salt to the system. The presence of Mancos Shale in the area accounted for the 1.4 tons per acre per year rate of yield.

Relatively high total dissolved solids concentrations were observed in the Mancos River drainage. The Mancos River above Navajo Wash contributed a salt load of approximately 36,500 tons during the study period. Irrigation return flow from the Cortez-Towaoc area accounted for virtually all of the 29,000 tons of salt added by Navajo Wash. Return flows from irrigation in the Cortez area, supplied by water diverted from the Dolores River, accounted for most of the flow in McElmo Creek. McElmo Creek yielded 195,000 tons of salt during the study period.

Since the EPA has not determined total salt yields for all of the San Juan tributaries in Colorado, it is not possible to determine percentages of the total yield attributed to natural and man caused sources as has been done for other Colorado River Basin drainages in Colorado.

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Colorado Soil Conservation Board - Agriculture Water Quality Management for Colorado

The Colorado State Soil Conservation Board has identified Mancos Valley as one of seven critical agricultural water quality areas in the state. This assessment is the result of incorporating existing information with data obtained by the Board from a water quality monitoring program conducted over a three year period.

Based on data collected during the 1981 water year, approximately 20,000 tons of salt were added to the river system as it passed through 8,600 acres of irrigated land in the Mancos Valley. The Valley encompasses 123,500 acres in the Mancos River drainage above the Ute Mountain Ute Indian Reservation. Salt loading within the area accounted for close to 50% of the total salt load in the Mancos River at the Colorado-New Mexico state line.

A segmental analysis revealed that 75% of the salt load increase occurred in the Mud Creek and Weber Canyon drainages.

BuRec - McElmo Creek Unit, Status Report, July 1981

The McElmo Creek Unit investigation, described in this report, attempts to determine the most cost-effective way to reduce the 115,000 tons of salt entering the San Juan River annually from the McElmo Creek drainage. Although they don't attempt to attribute a specified amount of the McElmo Creek total salt yield to irrigated agriculture, they expect to decrease the salt yield by 57,000 tons annually by combining two ditches and lining 34 miles of canal with concrete.

SCS - Draft Report of the McElmo Creek Salinity Control Study

The SCS inventoried and analyzed current irrigation systems and practices on a sample of irrigated land and off-farm laterals in the Montezuma Valley, which is drained by McElmo Creek. Results of the analyses were expanded to be representative of the approximately 29,100 acres of irrigated land and about 235 miles of off-farm laterals in the Montezuma Valley.

Of the 115,000 tons of salt that McElmo Creek delivers annually to the Colorado River, the SCS estimates that 46,000 tons come from on-farm irrigation systems and practices, and about 8,000 tons come from small off-farm laterals.

San Juan Regional Commission - Water Quality Management Plan for the San Juan Region

The 208 Plan for this region contains a discussion of water quality problems for San Juan tributary streams in Colorado. As has all previously discussed literature, the Plan cites irrigation of Mancos Shale derived soils as a major contributor to salt loading in the San Juan Basin.

Sources of salt loading to the Animas River not previously discussed include mine drainage in the headwaters, urban runoff and municipal discharges below Durango. Although salt loading from these sources has not been quantified, increases in dissolved solids concentrations (over 500 mg/l) have been observed.

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Summary

Relative to other subbasins in the state, salt loading information on the San Juan Tributaries in Colorado is less complete. McElmo Creek, under the authority of the Colorado River Salinity Control Program, and the Mancos Valley, under the authority of the Watershed Protection and Flood Prevention Act are scheduled for more detailed investigations. The remaining tributaries do not appear to present unusual salt loading problems. This is explained in part by the fact that much of the tributary area in Colorado is underlain by insoluble geologic formations associated with most headwater areas.

The EPA measurement of a 533 tons per day salt load in McElmo Creek due to irrigation in the Cortez area works out to about twice as much annually as the USGS and BuRec estimated for this same area. The EPA also came up with a higher salt yield per irrigated acre per year in the La Plata drainage area in Colorado. It is important to note that the USGS estimates are annual averages while the EPA study covers a one year period from June 1965 to May 1966.

Average Annual Salt Loads for Colorado River Subbasins in Colorado

Professional Paper 441 presents average annual dissolved solids discharges for water years 1914-57 adjusted to 1957 conditions. The BLM's 1977 Status Report presents average annual salt yields for 1966-75. Periodic measurements of total dissolved solids concentrations and continuous stream flow measurements presented in Water Resources Data for Colorado (water years 1969-80) were used to determine salt loading for

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the various subbasins. The USGS-Water Resources Division has developed a computer program that will determine salt loads at gaging stations with daily specific conductance and streamflow data. Historical salt loads for the Colorado River subbasins in Colorado are presented for comparison in Table 1 below.

TABLE 1

Average Annual Salt Loads
for Colorado River Subbasins
in Colorado (tons)

	Professional Paper 441 1914 - 1957	BLM 1977 Status Report 1966 - 1975	Water Resources Data 1969- 1980	Daily Specific Conductance 1970 - 1980
Yampa River	339,300	411,700	407,000	381,000
White River	330,600	275,100	278,000	244,000
Colorado River to Cameo	1,578,000	1,510,000	1,525,000	No daily specific conductance
Grand Valley	562,800	720,400	709,000	No daily specific conductance
Gunnison River	1,519,000	1,364,000	1,302,500	1,265,000
Dolores River	460,200	489,800	514,200	No daily specific conductance
San Juan Tributaries	476,400		559,000	No daily specific conductance
SanJuan	77,000		82,000	
Piedra	47,100		61,000	
Los Pinos	29,600		36,000	
Animas	155,200		179,000	
La Plata	13,500		27,000	
Mancos	39,000		47,000	
McElmo	115,000		127,000	
	5,266,300		5,294,700	

DS:dm

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208 Clean Water Grant
Matching "In-Kind" Expenses

April 1982 -

J. William McDonald: 7 Hours @ $24.28 = $170
Total $170

The major topics of work included amendments to P.L. 93-320, salinity impacts of weather modification, Glenwood, Dotsero Springs Unit and the Lower Gunnison Unit.

Daniel L. Law: 43 Hours @ $18.12 = $779
Total $779

The major topics of work included attendance at a conference dealing in salinity and related issues, the salt load report, state salinity standards and supervision of grant person.

Total April Expenses $949

May 1982 -

J. William McDonald: 19 Hours @ $24.28 = $461
Total $461

The major topics of work included state salinity standards, amendments to P.L. 93-320 and 208 salinity issues

Daniel L. Law: 34 Hours @ $18.12 = $616
Total $616

The major topics of work included state salinity standards, Grand Valley Unit, Aquatrain, salt load report and supervision of grant person.

Total May Expenses = $1077

June 1982 -

J. William McDonald: 33 Hours @ $24.28 = $ 801
Travel Expenses = $ 460
Total $1261

The major topics of work included amendments to P.L. 93-320 (trip to Washington to testify) and the Lower Gunnison Unit.

Daniel L. Law: 52 Hours @ $18.12 = $ 942
Travel Expenses = $ 230
$1172

The major topics of work included the quarterly report, amendments to P.L. 93-320, salt load report, and supervision of grant person.

Total June Expenses = $2433

"In-Kind" Expense Summary

April	$ 949
May	$1077
June	$2433
Total	$4459

Previous "In-Kind" Expenses	$ 9,526
Total to Date	$13,985

Since the contraact requires an "In-Kind" expense match of only $11,750 and since this amount has been exceeded as shown above, no further "In-Kind" expenses will be submitted.