

RECLAMATION

Managing Water in the West

QUALITY OF WATER COLORADO RIVER BASIN Progress Report No. 23



U.S. Department of the Interior
Bureau of Reclamation
Upper Colorado Region

2011

Mission Statements

The U.S. Department of the Interior protects and manages the nation's natural resources and cultural heritage; provides scientific and other information about those resources; and honors its trust responsibilities or special commitments to American Indians, Alaska Natives, and affiliated island communities.

The mission of the Bureau of Reclamation is to manage, develop, and protect water and related resources in an environmentally and economically sound manner in the interest of the American public.

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SUMMARY

The Colorado River and its tributaries provide municipal and industrial water to about 33 million people and irrigation water to nearly 4 million acres of land in the United States. The river also serves about 3 million people and 500,000 acres in Mexico. The effect of salinity is a major concern in both the United States and Mexico. Salinity damages in the United States are presently about \$383 million per year at 2009 salinity concentrations. This biennial report on the quality of water in the Colorado River Basin is required by Public Laws 84-485, 87-483, and the Colorado River Basin Salinity Control Act (Salinity Control Act) (Public Law 93-320, as amended by Public Laws 98-569, 104-20, 104-127, and 106-459).



Salinity damages to municipal water pipe.

The Salinity Control Act authorizes the Secretaries of the U.S. Department of the Interior (Interior) and U.S. Department of Agriculture (USDA) to enhance and protect the quality of water available in the Colorado River for use in the United States and the Republic of Mexico.

Title I of the Salinity Control Act authorized the construction and operation of a desalting plant, brine discharge canal, and other features to enable the United States to deliver water to Mexico having an average salinity no greater than 115 parts per million (ppm) plus or minus 30 ppm over the annual average salinity of the Colorado River at Imperial Dam. The Title I program (administered by the Bureau of Reclamation [Reclamation]) continues to meet the requirements of Minute No. 242 of the International Boundary and Water Commission, United States and Mexico.



Salinity damages to crop production.

Title II of the Salinity Control Act authorizes the Secretary of the Interior (Secretary) and the Secretary of Agriculture to implement a broad range of specific and general salinity control measures in an ongoing effort to prevent further degradation of water quality to meet the objectives and standards set by the Clean Water Act.

In 1995, Public Law 104-20 authorized an entirely new way of implementing salinity control. Reclamation's Basinwide Salinity Control Program opened the program to competition through a "Request for Proposal" process, which greatly reduced the cost of salinity control by selecting the most cost effective projects. However, the price of salinity control will increase in the future as the less cost effective projects are left.

The Colorado River Basin Salinity Control Forum (Forum) in accordance with the requirements of the Clean Water Act, prepared the "2008 Review, Water Quality Standards for Salinity, Colorado River System" (Review). The Review reported that by 2030 a target of 1.85 million tons per year of salt will need to be diverted from entering the Colorado River in order to meet the water quality standards in the Lower Basin, below Lees Ferry, AZ. The combined Reclamation, USDA & BLM salinity reduction reported for 2010 shows that the Colorado River Basin Salinity Control Program (Program) has controlled over 1,192,000 tons of salt per year. In order to meet the 1.85 million tons of salt per year goal, it will be necessary to fund and implement potential new measures which ensure the removal of an additional 657,950 tons by 2030. The Forum stated that in order to achieve this level of salt reduction, the federal departments and agencies would require the following capital funding: Reclamation appropriation - \$17.5 million per year (bringing the total Reclamation program with \$7.5 million cost-sharing to \$25 million per year); and USDA EQIP appropriation - \$13.8 million per year (bringing the total on-farm program to \$19.7 million per year with Basin states parallel program). Beginning in 2005, BLM began a comprehensive program to minimize the salt loading from BLM lands in the Colorado River basin. BLM salinity funding from Congress began in FY 2006.

With the reported existing salt controlled, and assuming no reduction of the existing salinity control projects, then nearly 32,900 tons of new or additional controls will need to be implemented each year to maintain the standards with increased future water development. This Program goal is the combined target for the participating agencies within Interior and USDA. The participating agencies reported to the Colorado River Basin Salinity Control Advisory Council, showing that the agencies efforts have been able to exceed the program's target over the past several years.

The Upper Colorado River Basin continues to experience a protracted multi-year drought. Since 1999, inflow to Lake Powell has been below average in every year except water years 2005 and 2008. The overall reservoir storage in the Colorado River Basin, as of October 1, 2010, is 33.05 million acre-feet or 55.6 % of capacity. Salinity concentration has increased during this time period (while salinity loading has decreased), but has not exceeded the numeric salinity criteria on the Colorado River below Hoover Dam, Parker Dam and at Imperial Dam; 723, 747 & 879 mg/L respectively. Reclamation's short term future salinity modeling scenarios indicate that the numeric salinity criteria should be maintained even with an additional 1-2 years of drought. However, the uncertainty of the prediction is within reach of the salinity criteria. The salinity criteria could have been exceeded in 2003 or 2004 without the salinity control program and other salt reductions. Nevertheless, salinity damages are still very high at the 2009 salinity levels. This is the first observation of this level of reservoir draw down. This drought is providing new data, which will eventually reduce the uncertainty in salinity forecasting.

CHAPTER 1 - INTRODUCTION

The Bureau of Reclamation (Reclamation) of the U.S. Department of the Interior prepared this report in cooperation with State water resource agencies and other Federal agencies involved in the Colorado River Basin Salinity Control Program (Salinity Control Program). This Progress Report is the latest in a series of biennial reports that commenced in 1963. This report, Progress Report 23, should have been published in 2007, but due to long review times for the past Progress Reports 21 and 22, the time line has been delayed enough to include the 2007 and 2009 data in this report.

AUTHORIZATION FOR REPORT

The directive for preparing this report is contained in four separate public laws.

Public Law 84-485 states:

Section 15 – “The Secretary of the Interior is directed to continue studies and make a report to the Congress and to the States of the Colorado River Basin on the quality of water of the Colorado River,”

Section 5c – “All revenues collected in connection with the operation of the Colorado storage project and participating projects shall be credited to the Basin Fund, and shall be available, without further appropriation, for (1) defraying the costs of operation, maintenance, & replacement of, and emergency expenditures for, all facilities”. The ongoing water quality monitoring, studies, and report are considered part of the normal operation of the project and are funded by the Basin Fund.”

Public Law 87-483 states:

Section 15 - “The Secretary of the Interior is directed to continue his studies of the quality of water of the Colorado River System, to appraise its suitability for municipal, domestic, and industrial use and for irrigation in the various areas in the United States in which it is used or proposed to be used, to estimate the effect of additional developments involving its storage and use (whether heretofore authorized or contemplated for authorization) on the remaining water available for use in the United States, to study all possible means of improving the quality of such water and of alleviating the ill effects of water of poor quality, and to report the results of his studies and estimates to the 87th Congress and every 2 years thereafter.”

Public Law 87-590 states that January 3 would be the submission date for the report.

Public Law 93-320 states:

“Commencing on January 1, 1975, and every 2 years thereafter, the Secretary shall submit, simultaneously, to the President, the Congress, and the Advisory Council created in Section 204(a) of this title, a report on the Colorado River salinity control program authorized by this title covering the progress of investigations, planning, and construction of salinity control units for the previous

fiscal year; the effectiveness of such units; anticipated work needed to be accomplished in the future to meet the objectives of this title, with emphasis on the needs during the 5 years immediately following the date of each report; and any special problems that may be impeding progress in attaining an effective salinity control program. Said report may be included in the biennial report on the quality of water of the Colorado River Basin prepared by the Secretary pursuant to section 15 of the Colorado River Storage Project Act (70 Stat. 111; 43 U.S.C. 602n), section 15 of the Navajo Indian Irrigation Project and the initial stage of the San Juan-Chama Project Act (76 Stat. 102), and section 6 of the Frypan-Arkansas Project Act (76 Stat. 393).”

LEGAL ASPECTS

Water Quantity

Colorado River water was apportioned by the Colorado River Compact of 1922, the Boulder Canyon Project Act of 1928, the Water Treaty of 1944, the Upper Colorado River Basin Compact of 1948, and the United States Supreme Court (*Arizona v. California et al.*, 1963).

The Colorado River Compact divided the Colorado River Basin between the Upper and Lower Basins at Lee Ferry (just below the confluence of the Paria River), apportioning to each use of 7.5 million acre-feet (maf) annually. In addition to this apportionment, the Lower Basin was given the right to increase its beneficial consumptive use by 1 maf per year. The compact also contains provisions governing exportation of Colorado River water. The Water Treaty of 1944 obligates the United States to deliver to Mexico 1.5 maf of Colorado River water annually, absent treaty surplus or shortage conditions.

Upper Colorado Use - The Upper Colorado River Basin Compact of 1948 divided and apportioned the water apportioned to the Upper Colorado River Basin by the Colorado River Compact, allocating to **Arizona** 50,000 acre-feet annually, with the remaining water allocated to Upper Colorado River Basin States as follows:

- **Colorado** 51.75 percent
- **New Mexico** 11.25 percent
- **Utah** 23 percent
- **Wyoming** 14 percent

Lower Colorado Use - States of the Lower Colorado River Basin did not agree to a compact for the apportionment of waters in the Lower Colorado River Basin; in the absence of such a compact Congress, through Secretarial contracts authorized by the Boulder Canyon Project Act, allocated water from the mainstem of the Colorado River below Lee Ferry among California, Nevada, and Arizona, and the Gila River between Arizona and New Mexico. This apportionment was upheld by the Supreme Court, in 1963, in the case of *Arizona v. California*.

As confirmed by the U.S. Supreme Court in 1963, from the mainstem of the Colorado River (i.e., The Lower Basin):

- **Nevada** was apportioned 300,000 acre-feet annually and 4 percent of surplus water available,
- **Arizona** was apportioned 2,800,000 acre-feet annually and 46 percent of surplus water available,
- **California** was apportioned 4,400,000 acre-feet annually and 50 percent of surplus water available.

Water Quality

Although a number of water-quality-related legislative actions have been taken on the State and Federal levels, several Federal acts are of special significance to the Colorado River Basin: the Water Quality Act of 1965 and related amendments, the Federal Water Pollution Control Act Amendments of 1972 (Public Law 92-500), commonly referred to as the Clean Water Act and related amendments, and the Colorado River Basin Salinity Control Act (Salinity Control Act) of 1974 as amended. Also, central to water quality issues are agreements with Mexico on Colorado River System waters entering that country.

The Water Quality Act of 1965 (Public Law 89-234) amended the Federal Water Pollution Control Act and established a Federal Water Pollution Control Administration (now Environmental Protection Agency [EPA]). Among other provisions, it required States to adopt water quality criteria for interstate waters inside their boundaries. The seven Basin States initially developed water quality standards that did not include numeric salinity criteria for the Colorado River primarily because of technical constraints. In 1972, the Basin States agreed to a policy that called for the maintenance of salinity concentrations in the Lower Colorado River System at or below existing levels, while the Upper Colorado River Basin States continued to develop their compact-apportioned waters. The Basin States suggested that Reclamation should have primary responsibility for investigating, planning, and implementing the proposed Salinity Control Program.

The enactment of the Federal Water Pollution Control Act Amendments of 1972 affected salinity control, in that it was interpreted by EPA to require numerical standards for salinity in the Colorado River. In response, the Basin States founded the Colorado River Basin Salinity Control Forum (Forum) to develop water quality standards, including numeric salinity criteria and a basinwide plan of implementation for salinity control. The Basin States held public meetings on the proposed standards as required by the enacting legislation. The Forum recommended that the individual Basin States adopt the report, *Water Quality Standards for Salinity, Including Numeric Criteria and Plan of Implementation for Salinity Control, Colorado River System*. The proposed water quality standards called for maintenance of flow-weighted annual averaged total dissolved solids concentrations of 723 milligrams per liter (mg/L) below Hoover Dam, 747 mg/L below Parker Dam, and 879 mg/L at Imperial Dam. Included in the plan of implementation were four salinity control units and possibly additional units, the application of effluent limitations, industrial use of saline water, and future studies. The standards are to be reviewed at 3-year intervals. All of the Basin States adopted the 1975 Forum-recommended standards. EPA approved the standards.

The Salinity Control Act of 1974 (Public Law 93-320) provided the means to comply with the United States' obligations to Mexico under Minute No. 242 of the International Boundary and Water Commission, United States and Mexico, which included, as a major feature, a desalting plant and brine discharge canal for treatment of Wellton-Mohawk Irrigation and Drainage District (WMIDD) drainage water. These facilities enable the United States to deliver water to Mexico having an average salinity of 115 parts per million (ppm) plus or minus 30 ppm (United States' count) over the annual average salinity of the Colorado River at Imperial Dam. The act also authorized construction of 4 salinity control units and the expedited planning of 12 other salinity control projects above Imperial Dam as part of the basinwide salinity control plan.

In 1978, the Forum reviewed the salinity standards and recommended continuing construction of units identified in the 1974 act, placing of effluent limitations on industrial and municipal discharges, and reduction of the salt-loading effects of irrigation return flows. The review also called for the inclusion of water quality management plans to comply with section 208 of the Clean Water Act. It also contemplated the use of saline water for industrial purposes and future salinity control.

Public Law 98-569, signed October 30, 1984, amended Public Law 93-320. The amendments to the Salinity Control Act authorized the U.S. Department of Agriculture (USDA) Colorado River Salinity Control Program. The amendments also authorized two new units for construction under the Reclamation program.

In 1993, the Dept. of Interior Inspector General concluded that the lengthy congressional authorization process for Reclamation projects was impeding the implementation of cost-effective measures. Consequently, a public review of the program was conducted in 1994. In 1995, Public Law 104-20 authorized Reclamation to implement a basinwide approach to salinity control and to manage its implementation. Reclamation completed solicitations in 1996, 1997, 1998, 2001, and 2004 in which Reclamation requested proposals, ranking the proposals based on their cost and performance risk factors, and awarded funds to the highest ranked projects. The awards from the first three solicitations consumed the available appropriation ceiling of \$75 million authorized by Congress to test the new program. In 2000, Public Law 106-459 amended the Colorado River Basin Salinity Control Act to increase the appropriation ceiling for Reclamation's basinwide approach by \$100 million (\$175 million total). This appropriation authority allowed Reclamation to continue to request new proposals under its Basinwide Salinity Control Program.

In 1996, Public Law 104-127 significantly changed the authorities provided to USDA. Rather than carry out a separate salinity control program, the Secretary of Agriculture was directed to carry out salinity control measures in the Colorado River Basin as part of the Environmental Quality Incentives Program established under the Food Security Act of 1985. Public Law 104-127 also authorized the Secretary of Agriculture to cost share salinity control activities from the basin funds in lieu of repayment. Cost sharing has been implemented for both USDA and Reclamation programs. Under this new authority, each dollar appropriated by the Congress is matched by \$0.43 in cost sharing from the basin funds.

In 2002, Public Law 107-171, Title II, Subtitle D reauthorized the USDA's Environmental Quality Incentives Program (under which the Secretary of Agriculture carries out salinity control measures). In 2008, Public Law 110-246, again authorized the USDA's Environmental Quality Incentives Program. PL110-246 also amended the Salinity Control Act to clarify the authority and implementation of the "Basin States Program".

Nothing in this report is intended to interpret the provisions of applicable federal law including, but not limited to, The Colorado River Compact (42 Stat. 171), The Upper Colorado River Basin Compact (63 Stat. 31), The Utilization of Waters of the Colorado and Tijuana Rivers and of the Rio Grande, Treaty Between the United States of America and Mexico (Treaty Series 994, 59 Stat. 1219), the United States/Mexico agreement in Minute No. 242 of August 30, 1973, (Treaty Series 7708; 24 UST 1968), the 1964 Decree entered by the Supreme Court of the United States in *Arizona v. California et al.* (376 U.S. 340), as amended and supplemented, The Boulder Canyon Project Act (45 Stat. 1057), The Boulder Canyon Project Adjustment Act (54 Stat. 774; 43 U.S.C. 618a), The Colorado River Storage Project Act (70 Stat. 105; 43 U.S.C. 620), The Colorado River Basin Project Act (82 Stat. 885; 43 U.S.C. 1501), The Colorado River Basin Salinity Control Act (88 Stat. 266; 43 U.S.C. 1571), The Hoover Power Plant Act of 1984 (98 Stat. 1333), The Colorado River Floodway Protection Act (100 Stat. 1129; 43 U.S.C. 1600), or The Grand Canyon Protection Act of 1992 (Title XVIII of Public Law 102-575, 106 Stat. 4669).

CHAPTER 2 – SALINITY CONDITIONS

CAUSES OF SALINITY

The Colorado River System is naturally very saline. At the USGS gauge below Hoover Dam, between 1940 and 1980 an average of approximately 9.4 million tons of salt were carried down the river every year. Since 1981, on average, approximately 8.8 million tons of salts have been measured in the river each year, including years of floods and drought, with the trend going down. The flow of the river dilutes this salt, and depending upon the quantity of flow, salinity can be relatively dilute or concentrated. Since climatic conditions directly affect the flow in the river, salinity in any one year may double (or halve) due to extremes in runoff. Because this natural variability is virtually uncontrollable, the seven Basin States adopted a non-degradation water quality standard.

Nearly half of the salinity in the Colorado River System is from natural sources. Saline springs, erosion of saline geologic formations, and runoff all contribute to this background salinity. Irrigation, reservoir evaporation, and municipal and industrial (M&I) sources make up the balance of the salinity problem in the Colorado

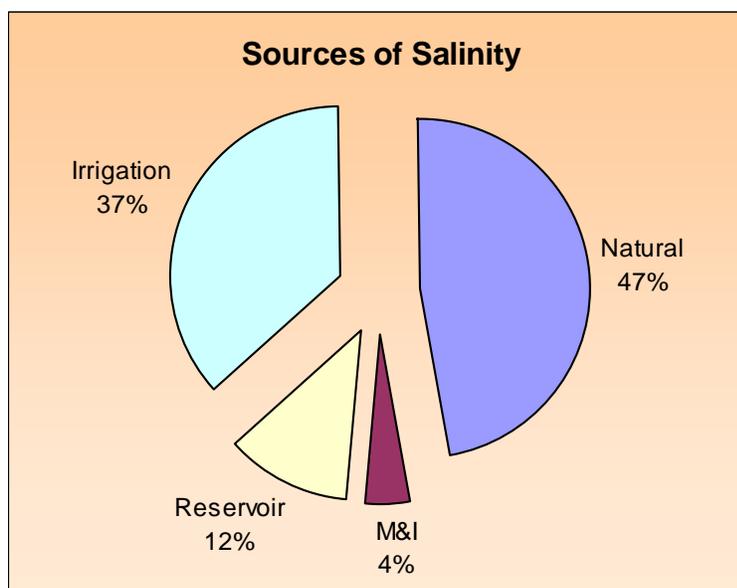


Figure 1 - Sources of Salinity

River Basin. Figure 1 shows the relative amount each source contributes to the salinity problem. The Environmental Protection Agency (EPA, 1971) estimated that the natural salinity in the Lower Colorado River at Imperial Dam was 334 milligrams per liter (mg/L). For 2009 the average annual flow weighted salinity at Imperial Dam was 717 mg/L, a 383 mg/L increase over the estimated natural salinity. Table 1, on the following page, quantifies the salinity from several of these known sources.

Salinity of the Colorado River has increased with the development of water resources in two major ways: (1) the addition of salts from water use and (2) the consumption (depletion) of water. The combined effects of water use and consumption have had a significant impact on salinity in the Colorado River Basin. The basin-wide drought, since 1999, has also had an influence on the present salinity of the Colorado River.

Current information indicates that the present salt levels in the Colorado River system have few if any negative health effects and the EPA's primary drinking water standards

Table 1 - Quantified Sources of Salt Loading

Source	Type of Source	Salt Loading (tons per year)
Paradox Springs	Springs / point	205,000 ¹
Dotsero Springs	Springs / point	182,600
Glenwood Springs	Springs / point	335,000
Steamboat Springs	Springs / point	8,500
Pagosa Springs	Springs / point	7,300
Sinbad Valley	Springs / point	6,500
Meeker Dome	Springs / point	57,000 ¹
Other minor springs in the Upper Basin	Springs / point	19,600
Blue Springs	Springs / point	550,000
La Verkin Springs	Springs / point	109,000
Grand Valley	Irrigation / non-point	580,000
Big Sandy	Irrigation / non-point	164,000
Uncompahgre Project	Irrigation / non-point	360,000 ¹
McElmo Creek	Irrigation / non-point	119,000
Price-San Rafael	Irrigation / non-point	258,000 ¹
Uinta Basin	mostly irrigation / non-point	240,000
Dirty Devil River Area	non-point	150,000
Price-San Rafael Area	non-point	172,000 ¹
Other, non regulated areas	Various	5,200,000
Total		8,724,000

1- Values listed are pre salinity control project loading

are not exceeded (see Progress Report 21, Health section). However, the EPA secondary drinking water standards of 500 mg/L for TDS (salinity) and 250 mg/L for sulfate may be exceeded. A regression of sulfate versus TDS shows that sulfate exceeds 250 mg/L when the TDS exceeds 612 mg/L. During dry cycles the secondary drinking water standards for TDS and sulfate are exceeded at many places in the Colorado River in both the Upper and Lower Basins, including the three salinity criteria sites.

The primary negative impact of the Colorado River salinity presently is seen as economics. Reclamation has developed a model which calculates damages from a given level of salt. Economic damages have been shown to begin at salinity levels above 500 mg/L and a change of 1 mg/L TDS equates to 10,000 tons of salt per year. Present annual economic damage using the 2008 & 2009 average annual salinity level at Imperial Dam (717 mg/l, latest data available) has been modeled at over \$350 million dollars. This impact comes out at a cost of \$173 per ton of salt or \$1,733,000 per mg/L TDS per year, over the 500 mg/L base point. Even though the salinity level has fluctuated slightly over the last few years, the salinity impact cost has increased primarily due to increased agricultural damage costs (increase in acreage and crop prices).

Salinity related damages are primarily due to reduced agricultural crop yields, corrosion, and plugging of pipes and water fixtures in housing and industry. Figure 2 breaks down the percentage of total damages. The seven Basin States have agreed to limit this impact and adopted numeric criteria, which require that salinity concentrations not increase (from the 1972 levels) due to future water development.

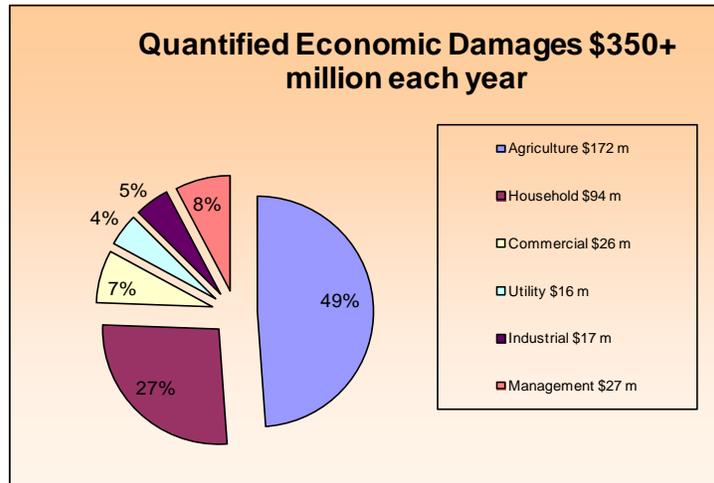


Figure 2 – Percentage of Salinity Damages

Salinity levels measured in the river may be low or high due to climatic conditions, but the goal of the Water Quality Criteria for the Colorado River Basin and the Colorado River Basin Salinity Control Program (Salinity Control Program) is to offset (eliminate) the salinity effects of additional water development.

HISTORIC SALINITY CONDITIONS

Salinity in the Colorado River is monitored at 20 key stations throughout the Colorado River Basin. Salt loads and concentrations are calculated from daily conductivity and flow records using methods developed jointly between Reclamation and USGS (Liebermann et al., 1986). Historical annual streamflow, and salinity concentrations from 1940 through 2009 are included in graphical form in Appendix A. Monthly and annual data may be obtained by request from Reclamation, Salt Lake City, Utah or by going to Reclamation’s Upper Colorado Regional Office Salinity Program web page; <http://www.usbr.gov/uc/progact/salinity/index.html>. The salinity of the 3 lower basin compact points since 1940 is shown in Figure 3. As Figure 3 shows, the last time the TDS exceeded or reached the salinity criteria at any of the compact points, was in 1972 – the year that the salinity standard was established for the Colorado River.

FACTORS INFLUENCING SALINITY

Stream flow, reservoir storage, water resource development, salinity control, climatic conditions, and natural runoff directly influence salinity in the Colorado River Basin. Before any water development, the salinity of spring runoff was often below 200 mg/L throughout the Colorado River Basin. However, salinity in the lower mainstem was often well above 1,000 mg/L during the low flow months (most of the year), since no reservoirs existed to catch and store the spring runoff.

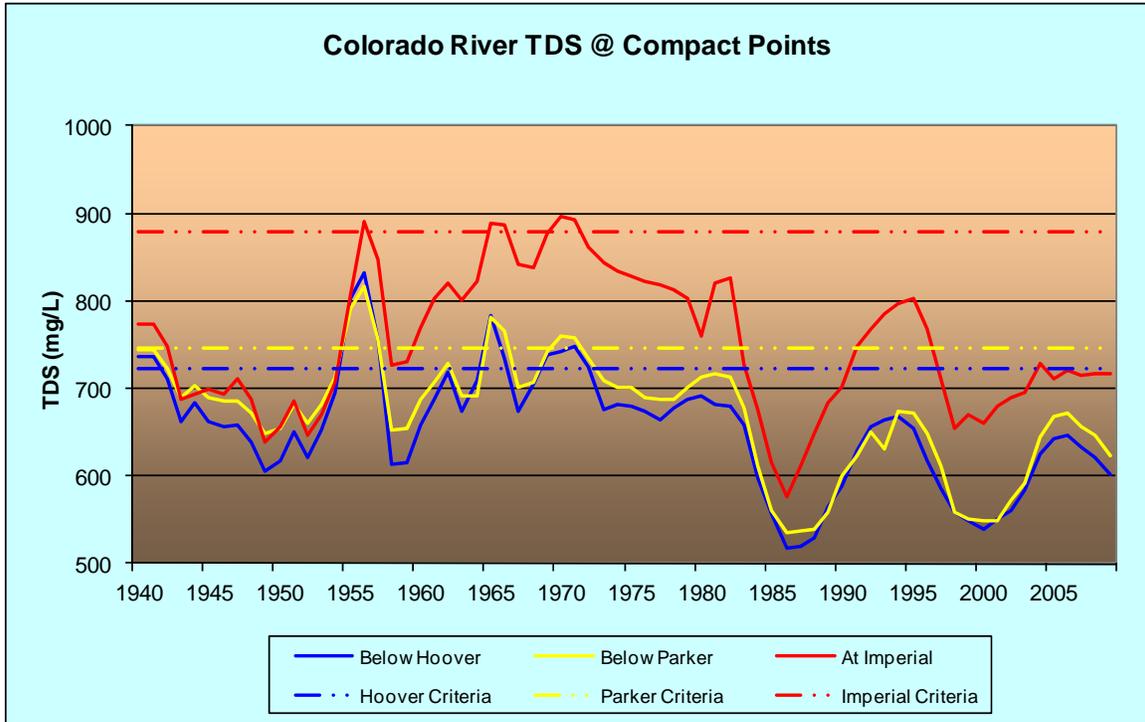


Figure 3 - Colorado River Salinity at Lower Basin Compact Points

Streamflow

Streamflow directly influences salinity. For the most part, higher flows (or reservoir releases) dilute salinity. The top graph in Figure 4 shows streamflow at two key points in the mainstem. In 1980, Lake Powell (Glen Canyon Dam) filled for the first time and spilled.

This spill went through Lake Mead (Hoover Dam) and on downstream through Imperial Dam. In 1983 and on through 1987, flows in the system were again extremely high and sustained, reducing salinity to historic lows. As shown in the bottom graph of Figure 4, more average flows in the system after 1987 returned the salinity in the reservoir system to more normal levels.

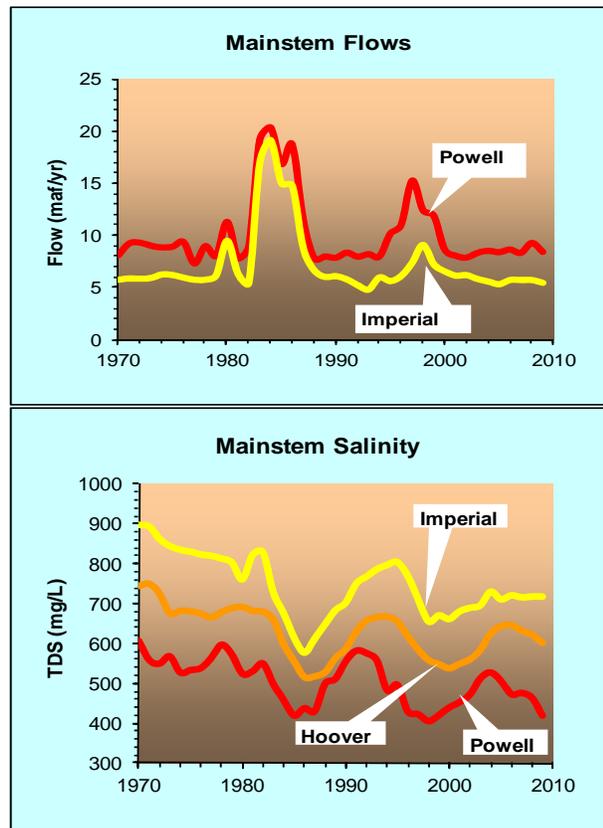


Figure 4 - Mainstem Flow and Salinity.

Reservoir Storage

The Colorado River Storage Project Reservoirs produce not only major hydrologic modifications downstream, but they also significantly alter the salinity variability of the downstream river. The overall long term salinity affects of the reservoirs are beneficial and have greatly reduced the salinity peaks and annual fluctuation (Figure 5). The high concentration low flow waters are mixed with low concentration spring runoff, reducing the month-to-month variation in salinity below dams (Mueller et al., 1988). At Glen Canyon Dam, the pre and post dam peak monthly salinity has been reduced by nearly 600 mg/L. Similar effects can be seen below Flaming Gorge, Navajo, and Hoover Dams, greatly improving the quality of water during the summer, fall and winter.

Large reservoirs like Lake Powell selectively route less saline water while holding more saline waters during low inflow periods. The poorer quality waters are then slowly released after the inflows have begun to increase, which helps to prevent exceeding the salinity criteria during drought years. The large reservoirs selectively retain higher salinity winter inflows in the bottom of the pool and route lower salinity overflow density currents from the spring runoff. The seasonal and long term affects of this selective retention and routing of salt has been shown below Glen Canyon Dam in Figure 5.

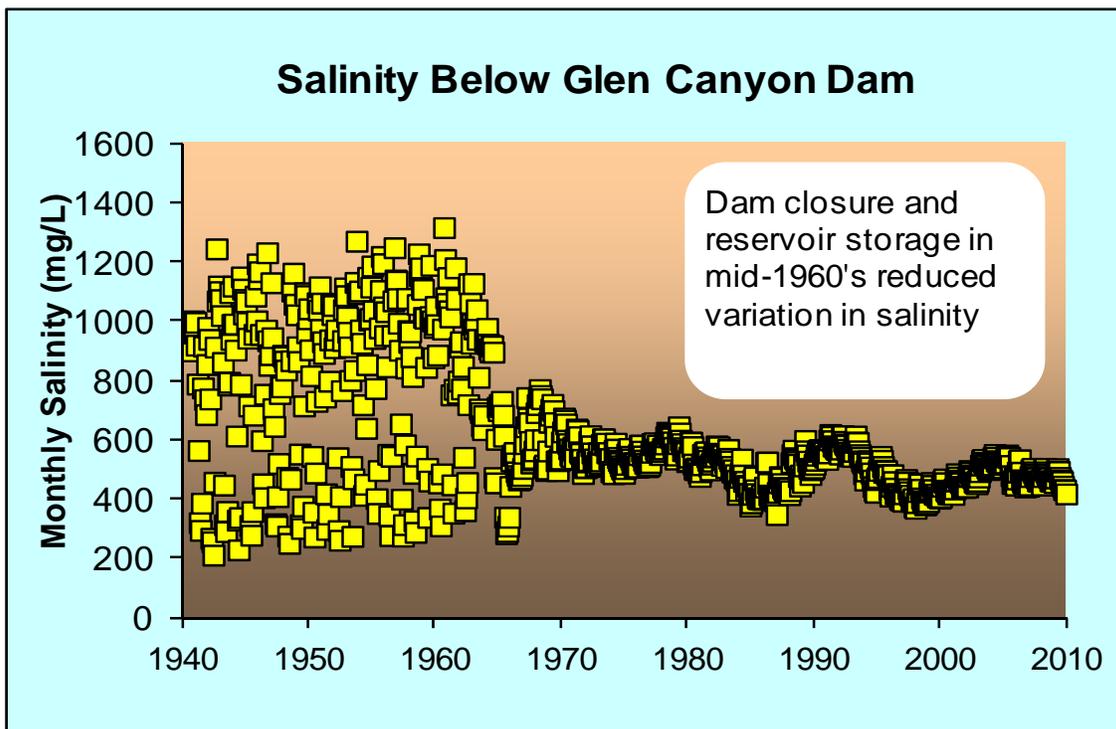


Figure 5 - Effects of Glen Canyon Dam on Colorado River Salinity at Lees Ferry.

Figure 6 further displays this retention. A long-term depth vs. time profile of salinity in the forebay of Glen Canyon Dam is a pictured history of salinity. The Y (vertical) axis is

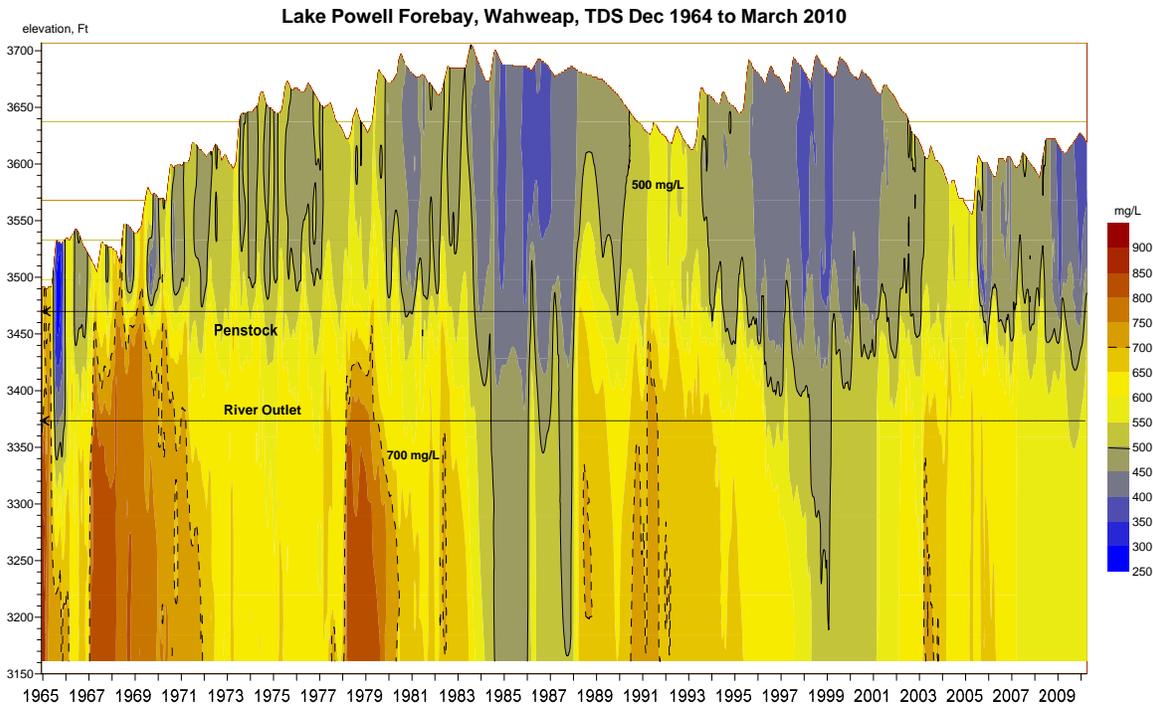


Figure 6 - Lake Powell Forebay, near Dam, Dec 1964 to March 2010 Salinity Concentration, mg/L

depth in the water column and the X axis is time in years. The color scale is the change in salinity.

Two things are demonstrated by this graphic: 1) Glen Canyon Dam selectively retains higher TDS water, especially during initial years of drought, and then routes those waters later, usually during wetter cycles. 2) Lake Powell has selectively retained higher salinity water during drier years, and then routed it with the increased mixing and shorter hydraulic retention times of wetter cycles as seen particularly in 1983 and 1999. During these wetter cycles there is a significant mixing and dilution of these previously stored salts.

There are 4 periods or trends which can be seen in the Colorado River salinity for the inflow to and outflow from Lake Powell which can be seen in Figure 7 (white and yellow trend lines). The overall inflow line (blue) in Figure 7 is the sum of TDS for the inflow stations to Lake Powell; Colorado River at Cisco, Green River at Green River, UT, San Rafael River near Green River and San Juan River near Bluff. The overall outflow line (red) is the TDS at the USGS gauge at Lee's Ferry below Glen Canyon Dam. There was the pre dam period, 1940 – 1964, where the average salinity trend was increasing with some divergence between the average annual inflow and outflow salinity levels and the inflow concentration generally being less than the outflow concentration. This difference between outflow and inflow may be impacted by the beginning hydraulic conditions, since the actual annual levels appear to track each other fairly closely. Next there was the dam filling period where Lake Powell and the upper basin reservoirs were completed and filling, 1965-1980. The average annual salinity during this time decreased with a convergence occurring between the inflow and outflow concentrations. The outflow

concentration decreased more than the inflow concentration, which could be due to the reservoir storing the higher TDS waters. Then there was the period, 1980 to present, when the basin hydrology went through both wet and dry periods and the salinity control projects in the upper basin were coming online. The declining trend of the average annual salinity concentration over this time is seen to be constant between the inflow and outflow stations. Since 1980 there appears to be an equilibrium between the salt entering the reservoir and what is being released. The last period, since 2000, covers the basinwide drought. The trend shows that the inflow TDS has declined, while the outflow TDS from Lake Powell has stayed constant with the 1980 to present TDS trend.

Lake Powell (and other reservoirs in the basin) went through an initial filling salt leach out which actually began with temporary water retention behind the coffer dam during construction in the mid 1950's. Long-term linear regression trend lines on the inflow and outflow salinity concentrations at Lake Powell indicate that internal salt leaching seems to have declined to a minimum by the mid-1990's suggesting a long-term salinity leach out which is approaching a dynamic equilibrium (Figure 7, red and blue trend line).

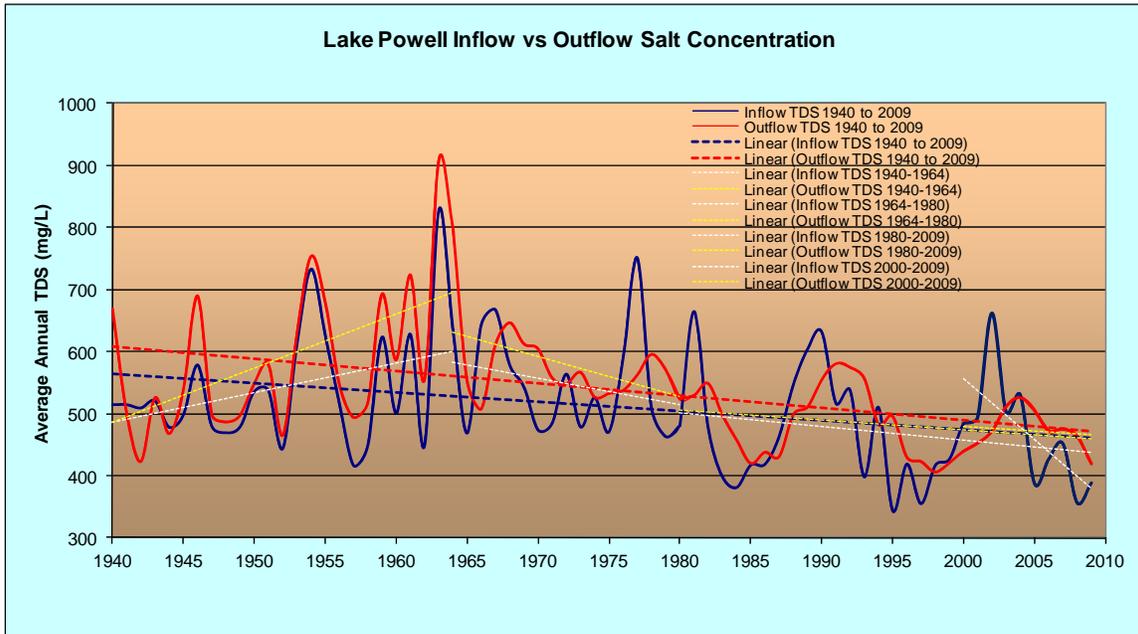


Figure 7 - Lake Powell Inflow and Outflow Salt Concentration, mg/L

NATURAL VARIATION IN SALINITY

Although seasonal swings in salinity have been greatly reduced, annual fluctuations in salinity are still observed. Natural climatic variations in rainfall and snowmelt runoff continue to cause large year-to-year differences in both flow and salinity and in some cases nearly doubling the salinity in the river.

The water quality standards require that the flow-weighted average annual salinity not to rise above the 1972 levels using a long-term mean water supply of 15 maf (2008 Review). This means that depending on the hydrology (drought conditions) salinities may

actually increase above the numeric criteria and it is not a violation of the standards, but is due to natural variations in the hydrologic conditions. Even with full compliance with the standards, the actual salinities at Imperial Dam (and elsewhere in the Colorado River Basin) will continue to fluctuate with hydrologic conditions in the future. The Salinity Control Program is designed to offset the effects of development, even as salinity varies from year to year in response to the climatic and hydrologic conditions. Assuming continued salinity control and full compliance with the standards, the potential range of annual salinities that might be observed in the future at Imperial Dam is quite wide. With Colorado River basin reservoir storage tempering the natural variability of the system, the range between the high and low salinity values at Imperial Dam has dropped to a monthly average of about 479 mg/L and an annual average around 266 mg/L since 1973.

AGRICULTURAL SOURCES OF SALINITY

Irrigated agriculture is the largest user of water in the Colorado River Basin and a major contributor to the salinity of the system. Iorns (Iorns et al., 1965) found that irrigated lands in the Upper Colorado River Basin contributed about 3.4 million tons of salt per year (37 percent of the salinity of the river). Irrigation increases the salt concentration of the source water by consuming water (evapotranspiration) and by dissolving salts found in the underlying saline soil and geologic formations, usually marine (Mancos) shale.

Irrigation mobilizes the salts found naturally on the soil surface as well as in the soil profile, especially if the lands are over irrigated. Many subbasins experienced significant changes in irrigation following development of available reservoir storage. For example, once late season irrigation supplies were assured, less water was applied to per unit of farmland during the snowmelt runoff, and overall irrigation efficiency increased.

Irrigation development in the Upper Colorado River Basin took place gradually from the beginning of settlement in about 1860, but was hastened by the purchase of tribal lands in the late 1800's and early 1900's. About 800,000 acres were being irrigated by 1905. Between 1905 and 1920, the development of irrigated land increased at a rapid rate, and by 1920, nearly 1.4 million acres were being irrigated. The "Upper Colorado Region Comprehensive Framework Study, June 1971", reported that more than 1.6 million acres were in irrigation in 1965. Since that time, development of new agricultural lands has leveled off because of physical, environmental, and economic limitations. Reclamation's latest "Colorado River System Consumptive Uses and Losses Report 2006-2010" estimated an average of 1.57 million acres was irrigated in the Upper Colorado River Basin in 2006 (latest data available).

Irrigation development in the Lower Colorado River Basin began at about the same time as in the Upper Colorado River Basin, but was slow due to the difficulty of diverting water from the Colorado River with its widely fluctuating flows. Development of the Gila area began in 1875 and the Palo Verde area in 1879. Construction of the Boulder Canyon Project in the 1930's, and other downstream projects, has provided for a continued expansion of the irrigated area. In 1970, an additional 21,800 acres were irrigated by private pumping either directly from the Colorado River or from wells in the flood plain. In 1980, nearly 400,000 acres were being irrigated along the Colorado River mainstem.

Total irrigated lands for the entire Lower Colorado River Basin is around 1.4 million acres.

Reclamation and the U.S. Geological Survey (USGS) continuously monitor the flow and salinity of the river system through a network of 20 gauging stations (See Appendix A, Figs. A1 & A2). Reclamation evaluates the data collected to determine if sufficient salinity control is in place to offset the impact of water development. In 2009, the actual salinity in the Colorado River was below the numeric criteria at the established monitoring stations. However, as the impacts of recent and future basin developments work their way through the hydrologic system, or as drought conditions persist, salinity would increase without salinity control to prevent further degradation of the river system. Through salinity control practices, excess salt loading to the river system can be reduced significantly, helping maximize the future beneficial uses of the river.

Most of the irrigation projects that deplete water and increase salt loading to the river were in place before 1965. Moreover, like the newly inundated soils in reservoirs, newly irrigated lands are subject to a leach-out period. In cases where lands with poor drainage stored salt, these areas were taken out of production. In addition, irrigation practices changed significantly with the introduction of canal and lateral lining, sprinkling systems, gated pipe, trickle systems and tile drains (initial operation of tile drains increase salt loading, which decreases after time). These changes have resulted in reduced return flows and salt loading.

WATER USE BY MUNICIPAL & INDUSTRIAL USERS

Salinity levels are directly influenced by depletion (consumption) of water flowing in the river system and salt loading. Agriculture increases salinity by consuming water through evapotranspiration and leaching of salts from soils by irrigation. Municipal and industrial (M&I) use increases salinity by the consumption of the water, thus reducing the dilution of salts in the river or by disposal on land.

Another source of salinity from municipal & industrial use is from an increase in the housing developments within the basin. This brings with it an associated increase in water softening needs, due to the hard water found throughout the basin. One result of the increase of water softening is an increase in the sodium chloride salt discharged into the Colorado River. Another impact of the increased population in the basin is that more roads are paved and developed. During the winter this increase in road mileage impacts the salt discharged into the basin due to the addition of salt on the roads in order to help keep the snow and ice off of the roads. The amount of salt added to the basin from new municipal development has not yet been quantified.

Reclamation continues to monitor water use and adjusts their future salinity control needs as water development plans may be postponed, delayed, or canceled. The depletion schedules used to project salinity conditions have been updated so that the implementation needs for the Salinity Control Program can be planned to offset the impacts of additional water development (see Tables 2 & 3).

ENERGY DEVELOPMENT

The large amounts of water use once forecasted for steam power generation, coal gasification, oil shale, and mineral development have not yet occurred. The few coal-fired power plants that have been constructed recently have obtained their water from existing agricultural rights rather than from developing additional water. This conversion of use reduces the salt loading to the Colorado River by eliminating the pickup of salt from canal seepage and on farm deep percolation.

Many of the geologic formations of the Colorado River Basin were deposited in marine (saline) or brackish water environments. Sulfates and sodium chloride are prevalent salts in most of these formations. Many of the formations were deposited in drier periods and are capable of transmitting water, but these aquifers are frequently sandwiched between hundreds or even thousands of feet of impermeable shale (aquicludes). These aquifers are, therefore, static and often saline. Many static and saline aquifers are present in the Colorado River Basin. When a path of flow is provided by drilling or mining, these aquifers are mobilized, and brackish or saline waters flow back to the surface.

The development of energy resources, specifically coal, oil, gas, oil shale, and coal bed methane, in the Colorado River Basin may contribute significant quantities of salt to the Colorado River. Salinity of surface waters can be increased by either mineral dissolution or uptake in surface runoff, mobilization of brackish groundwater, or consumption of good quality water. The location of fossil fuels is associated with marine-derived formations. Any disturbance of these saline materials will increase the contact surfaces, allowing for the dissolution of previously unavailable soluble minerals.

Salinity increases associated with mining coal can be attributed to leaching of coal spoil materials, discharge of saline groundwater, and increased erosion resulting from surface-disturbing activities. Spoil materials have a greater permeability than undisturbed overburden, allowing most of the rain falling on the spoils to infiltrate instead of running off. The water percolates through the spoils, dissolving soluble minerals.

Studies conducted on mining spoils in northwestern Colorado indicate that the resulting salinity of spoil-derived waters ranges from approximately 3,000 mg/L to 3,900 mg/L (Parker, et al., 1983; McWhorter, et al., 1979; and U.S. Department of the Interior, 1985). The variability in concentration depends on water residence time and the chemical and physical properties of the spoil.

Saline water is also a byproduct of oil and gas production in the Colorado River Basin. It is not uncommon to produce several times the amount of saline waters as oil. In one month the oil and gas operators in Colorado produced approximately 25 million barrels of saline water. The salinity of production waters varies greatly from location to location and depends upon the producing formation. Common disposal techniques include evaporation, injection, and discharge to local drainages.

The future development of the oil shale resources in Colorado, Utah, and Wyoming has the potential to increase salt loading to the Colorado River. Salt increases can be attributed to the consumptive use of good quality water, mine dewatering, and, if surface retorting is used, the leaching of spoil materials similar to those of surface coal mining.

Reclamation, BLM and state agencies are attempting to identify abandoned exploration wells that are leaking and develop plans to control the leaks. The Meeker Dome Salinity Control Unit identified and plugged several abandoned wells along the White River to prevent a salt dome (a geologic formation) from discharging saline water into the river.

Coal Bed Methane - The increase of the price of natural gas has led to an increase in the interest of developing the methane gas, which is found with coal, in the plentiful coal formations of the Upper Colorado River Basin. This coal bed methane (CBM) development could result in an increase in the salt loading of the Colorado River if the water associated with this type of drilling is discharged on the ground surface and allowed to get into waterways.

In Utah, coal bed methane wells are located in Emery, Carbon, Duchesne, and Uinta counties. The State allows up to 4 wells per section. Most (99%) of existing product wastewater from the CBM wells is reinjected and 1 % is impounded for evaporation. No surface discharges have presently been permitted. It is projected that even with greater development of CBM wells, the handling of the produced wastewater will not change.



Figure 8 - Photo of Coal Bed Methane Well.

In Colorado, all the product water from CBM development in the San Juan Basin in southwest Colorado is presently, and in the foreseeable future will be, reinjected. New CBM wells are permitted in the northwest part of the State and in Moffat and Rio Blanco Counties, where new CBM developments are being considered. The State averages for product wastewater in the western part of the State are 90 % reinjected, 9.5 % impounded, and 0.5 % surface discharged. Any surface discharged water has to meet the water quality criteria of no more that 1 ton/day salt.

In Wyoming, new CBM well development is beginning in the Little Snake River drainage (Carbon County) with only a handful of wells permitted. This CBM development has the potential to spread into the whole southwest corner of the State (Sweetwater, Uinta, and Lincoln Counties) if the price of natural gas stays high. This part of the State could have over 10,000 new CBM wells if development takes off as it has in the Powder River Basin. Presently, the State will allow surface discharge of up to 1 ton/day per operator (not per well). CBM development in the southwest part of the State will most likely involve reinjection of most if not all of the waste water since the quality of the groundwater found in these coal beds is highly saline and of poor quality.

The recent push for increased development of coal bed methane and other energy sources in the Rocky Mountain area poses a potential for increased salinity due to the brine or saline ground water discharged from the wells into the Colorado River Basin.

FUTURE WATER DEVELOPMENT

Tables 2 and 3 summarize the projected depletions used by Reclamation to evaluate the effects of water use and depletions for this progress report. These water use estimates were compiled as the first step in the evaluation process.

Table 2 summarizes the projected future depletions by water uses in the Upper Colorado River Basin as adopted for planning purposes by the Upper Colorado River Commission in December 2007. Figure 9 illustrates the historic annual consumptive use by water uses in the Upper Basin as reported in Reclamation's *Colorado River System Consumptive Uses and Losses Reports* (CUL), and the projected future total depletions by water uses in the Upper Basin that are included as input into Reclamation's Colorado River System Simulation (CRSS) model. The consumptive uses or depletions shown in figure 9 exclude evaporation losses from Lake Powell, Flaming Gorge Reservoir and the Aspinall Unit reservoirs, which along with evaporation losses from Colorado River mainstem reservoirs in the Lower Basin are modeled within CRSS.

The annual depletions for the Lower Colorado River Basin shown in Table 3 include only depletions resulting from the use of water from the mainstem of the Lower Colorado River. Reclamation's CRSS model does not model or include as input consumptive uses made from tributaries to the Colorado River within the Lower Colorado River Basin. Fixed inflow values are used in the CRSS model for the Lower Basin tributaries. More detailed data on historic Colorado River Basin consumptive uses and losses (including tributary uses in the Lower Basin and reservoir evaporation losses) may be found in Reclamation's *Colorado River System Consumptive Uses and Losses Reports* or on the web at: www.usbr.gov/uc/library/envdocs/reports/crs/crsul.html

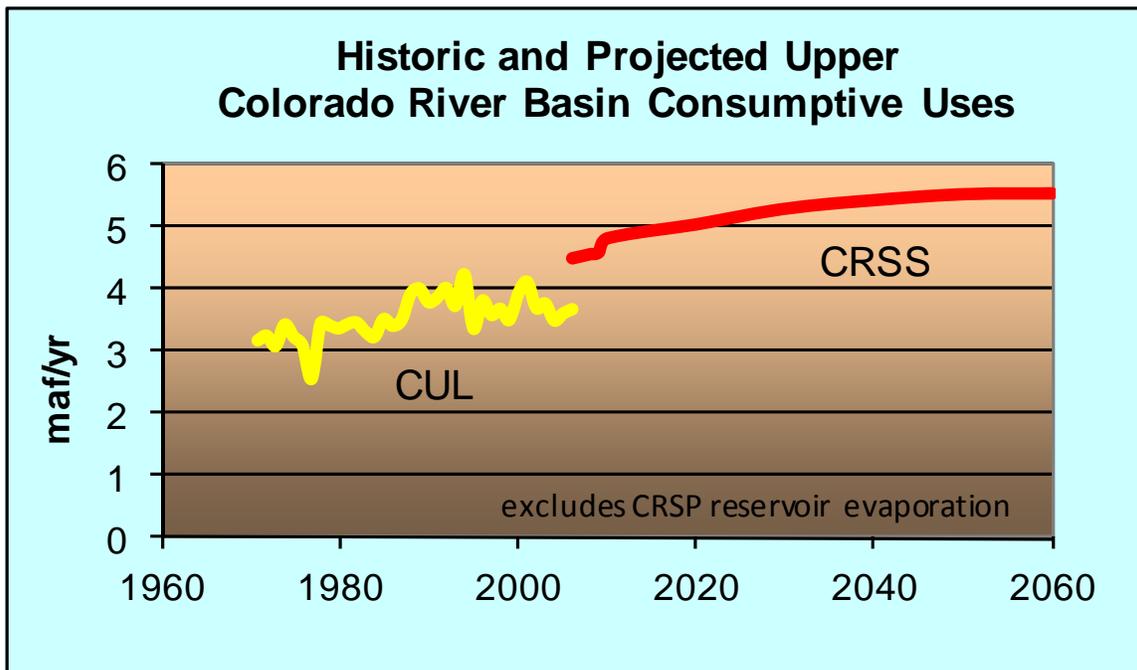


Figure 9 - Historic and Projected Water Uses.

Table 2 - Upper Basin Depletion Projections (1000 af/yr)

UPPER BASIN	2010	2020	2030	2040	2050	2060
Arizona						
Total scheduled depletion	50	50	50	50	50	50
Share of 2007 Hydro-Det Amount (5.76 maf)	50	50	50	50	50	50
Remaining available	0	0	0	0	0	0
Colorado						
Total scheduled depletions	2,796	2,842	2,891	2,919	2,955	2,955
Share of 2007 Hydro-Det Amount (5.76 maf)	2,955	2,955	2,955	2,955	2,955	2,955
Remaining available	159	113	64	36	0	0
Percent unused	5	4	2	1	0	0
New Mexico						
Total scheduled depletions	539	608	635	642	642	642
Share of 2007 Hydro-Det Amount (5.76 maf)	642	642	642	642	642	642
Remaining available	103	34	7	0	0	0
Percent unused	16	5	1	0	0	0
Utah						
Total scheduled depletions	907	955	1032	1118	1163	1163
Share of 2007 Hydro-Det Amount (5.76 maf)	1313	1313	1313	1313	1313	1313
Remaining available	406	358	281	195	150	150
Percent unused	31	27	21	15	11	11
Wyoming						
Total scheduled depletions	560	621	719	735	750	763
Share of 2007 Hydro-Det Amount (5.76 maf)	799	799	799	799	799	799
Remaining available	239	178	80	64	49	36
Percent unused	30	22	10	8	6	5

Note 1: This depletion schedule does not attempt to interpret the Colorado River Compact, the Upper Colorado River Basin Compact, or any other element of the "Law of the River." This schedule should not be construed as an acceptance of any assumption that limits the Upper Colorado River Basin's depletion.

Note 2: This depletion schedule is for planning purposes only. This estimate does not constitute an endorsement of the Bureau of Reclamation's 2007 Hydrologic Determination and should not be construed as in any way limiting the Upper Division States use of Colorado River water in accordance with the Commission's resolution of 6/5/06.

Note 3: The yield determined in the 2007 Hydrologic Determination excluding shared CRSP evaporation.

Table 3 - Lower Basin Depletion Projections (1000 af/yr)

LOWER MAINSTEM	2010	2020	2030	2040	2050	2060
Nevada						
Robert B. Griffith Water Project	264	264	280	280	280	280
Other users above Hoover Dam	7	7	7	7	7	7
Southern California Edison	16	16	0	0	0	0
Ft. Mohave Indian Reservation	9	9	9	9	9	9
Laughlin and users below Hoover Dam	4	4	4	4	4	4
Total	300	300	300	300	300	300
Arizona						
Imperial Wildlife Refuge	10	9	10	10	10	10
Lake Havasu Wildlife Refuge	5	5	5	5	5	5
Fort Mohave Indian Reservation	73	73	73	73	73	73
City of Kingman	0	0	0	0	0	0
Mohave Valley I&D District	23	17	17	17	17	17
Bullhead City and other M&I	4	5	6	6	6	6
Cibola Valley I&DD, Parker and others	24	27	30	32	34	34
Lake Havasu I&D District	13	12	12	12	12	12
Central Arizona Project	1425	1419	1406	1398	1395	1395
Colorado River Indian Reservation	414	463	463	463	463	463
Cibola Wildlife Refuge	8	8	16	16	16	16
Gila Project	505	477	476	476	476	476
City of Yuma	27	30	35	41	41	41
Yuma Project - Valley Division	248	234	229	229	230	230
Cocopah Indian Reservation	12	12	12	12	12	12
Other users below Imperial Dam	9	9	10	10	10	10
Total	2800	2800	2800	2800	2800	2800
California						
City of Needles	1	1	1	1	1	1
Metropolitan Water District	855	852	852	852	802	802
Fort Mohave Indian Reservation	12	12	12	12	12	12
Chemehuevi Indian Reservation	5	8	8	8	8	8
Colorado River Indian Reservation	19	39	39	39	39	39
Palo Verde Irrigation District	373	366	366	366	366	366
Yuma Project Reservation Division	47	54	54	54	54	54
Imperial Irrigation District	2711	2641	2611	2611	2661	2661
Coachella Valley Water District	376	426	456	456	456	456
Other uses Davis to Parker Dam	1	1	1	1	1	1
Other uses below Imperial Dam	0	0	0	0	0	0
Total	4400	4400	4400	4400	4400	4400
Unassigned						
Phreatophyte and native vegetation	515	515	515	515	515	515
Yuma Desalting Plant	120	120	52	52	52	52
Total	635	635	567	567	567	567

Note: In the LC Basin, depletions are from mainstem diversions of the Colorado River only. Does not include depletions from diversions of Colorado River tributaries or evaporation from mainstem reservoirs. The Figures represent measured diversions less measured and estimated, unmeasured return flow that can be assigned to a specific project. The evapotranspiration from the vegetation along the riparian zone is a constant unassigned depletion since the vegetation is permanent.

COMPLIANCE WITH THE SALINITY STANDARDS

Reclamation and the Basin States conducted salt-routing studies for the *2008 Triennial Review of the Water Quality Standards for Salinity, Colorado River Basin*. As part of the

triennial review process, Reclamation used the Colorado River Simulation System (CRSS) river system model to evaluate whether sufficient salinity control measures are in place to offset the effects of development. The information provided in the next two sections of the report was used to evaluate compliance with the water quality standards.

In response to the Clean Water Act, the States have adopted water quality (salinity) criteria for the Colorado River Basin and the Environmental Protection Agency (EPA) has approved them at all three locations in the Lower Colorado River Basin. The standards call for maintenance of flow-weighted average annual salinity concentrations (numeric criteria) in the lower mainstem of the Colorado River and a plan of implementation for future controls.

The water quality standards are based on the *Water Quality Standards for Salinity, Including Numeric Criteria and Plan of Implementation for Salinity Control, Colorado River System*, prepared by the Colorado River Basin Salinity Control Forum, June 1975. The document was adopted by each of the Basin States and approved by EPA. A summary of the report follows:

The numeric criteria for the Colorado River System are to be established at levels corresponding to the flow-weighted average annual concentrations in the lower mainstem during calendar year 1972. The flow-weighted average annual salinity for the year 1972 was used. Reclamation determined these values from daily flow and salinity data collected by the USGS and the Bureau of Reclamation. Based on this analysis, the numeric criteria are 723 mg/L below Hoover Dam, 747 mg/L below Parker Dam, and 879 mg/L at Imperial Dam.

It should be recognized that the river system is subject to highly variable annual flow. The frequency, duration, and availability of carryover storage greatly affect the salinity of the lower mainstem; and, therefore, it is probable that salinity levels will exceed the numeric criteria in some years and be well below the criteria in others. However, under the above assumptions, the average salinity will be maintained at or below 1972 levels.

Periodic increases above the criteria as a result of reservoir conditions or periods of below normal long-time average annual flow also will be in conformance with the standards. With satisfactory reservoir conditions and when river flows return to the long-time average annual flow or above, concentrations are expected to be at or below the criteria level.

The standards provide for temporary increases above the 1972 levels if control measures are included in the plan. Should water development projects be completed before control measures, temporary increases above the criteria could result and these will be in conformance with the standard. With completion of control projects, those now in the plan or those to be added subsequently, salinity would return to or below the criteria level.

The goal of the Salinity Control Program is to maintain the flow-weighted average annual salinity at or below the numeric criteria of the salinity standards. The program is not, however, intended to counteract the salinity fluctuations that

are a result of the highly variable flows caused by climatic conditions, precipitation, snowmelt, and other natural factors.

SALINITY CONTROL

Existing salinity control measures will prevent over a million tons of salt per year from reaching the river. By 2010 the salinity control program for Reclamation has controlled approximately 520,600 tons of salt, while the USDA NRCS (NRCS) program has reduced around 571,500 tons of salt, and the BLM has controlled an estimated 99,900 tons of

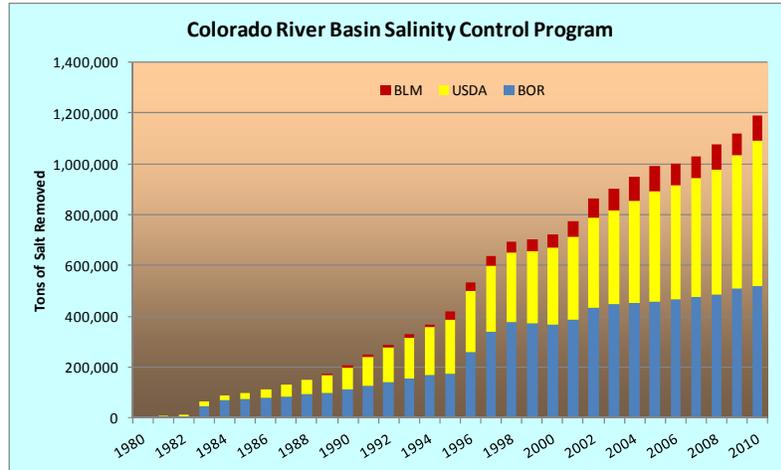


Figure 10 – 2010 Est. Salinity Control Progress: BOR, NRCS & BLM

salt per year from entering the Colorado River (Figure 10). Discussions within the Colorado River Salinity Control Forum have determined that salinity control units will need to prevent nearly 1.85 million tons of salt per year from entering the Colorado River by 2030, in order to meet the standard and keep the economic damages minimized. To reach this objective, as shown in Table 4, the program needs to implement 657,900 tons of new controls beyond the existing 1,192,000 tons of salinity control presently in place (2010) as reported by Reclamation, USDA & BLM. About 32,900 tons per year of new salinity control measures must be added each year if the program is to meet the cumulative target of 1,850,000 tons per year by 2030.

To achieve this goal, a variety of salinity control methods are being investigated and constructed. Saline springs and seeps may be collected for disposal by evaporation, industrial use, or deep-well injection. Other methods include both on-farm and off-farm delivery system and irrigation improvements, which reduce the loss of water and reduce salt pickup by improving irrigation practices and by lining canals, laterals, and ditches. See Progress Report #21 for a more detailed description of each salinity control project and the salinity controlled by Reclamation, NRCS and BLM.

Table 4 - Salinity Control Requirements and Needs Through 2030

Salinity control needs (2030)	1,850,000 tons
Measures in place (2010)	- 1,192,100 tons
Plan of Implementation Target	657,900 tons

CHAPTER 3 – TITLE I SALINITY CONTROL PROGRAM

The Colorado River Basin Salinity Control Act (Salinity Control Act), Public Law 93-320, as amended, authorized the Secretary of the Interior (Secretary) to proceed with a program of works of improvement for the enhancement and protection of the quality of water available in the Colorado River for use in the United States and the Republic of Mexico. Title I enables the United States to comply with its obligation under the agreement with Mexico of August 30, 1973 (Minute No. 242 of the International Boundary and Water Commission, United States and Mexico [Minute No. 242]), which was concluded pursuant to the Treaty of February 3, 1944 (TS 994).

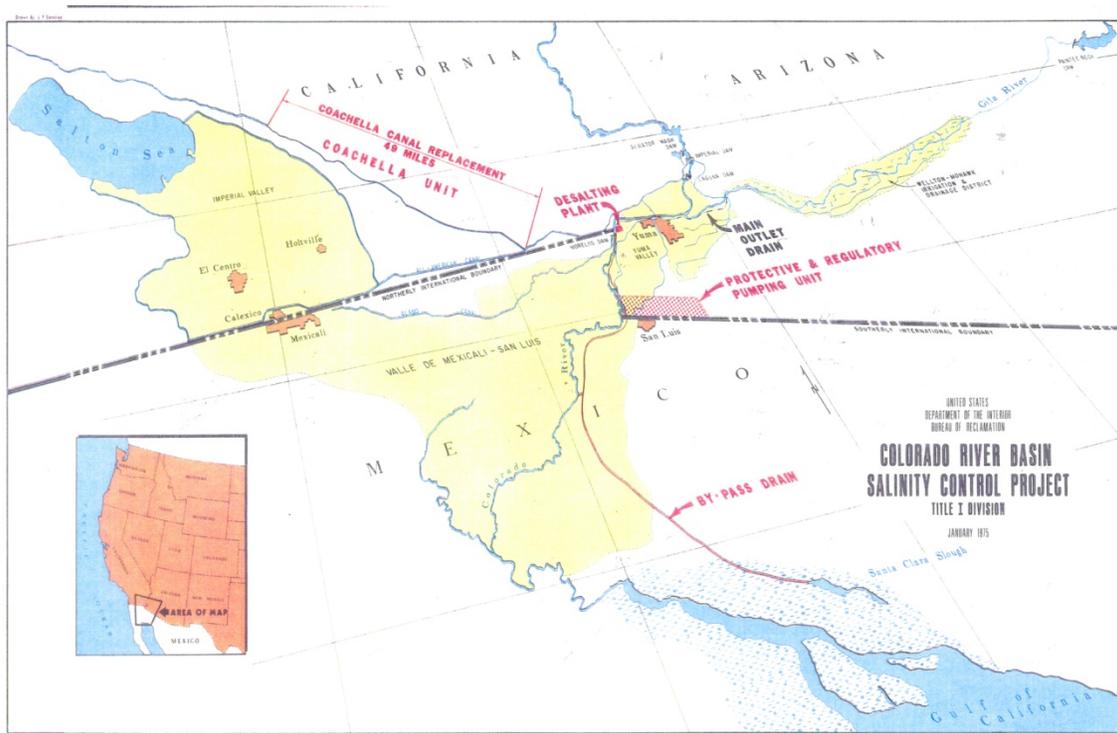


Figure 11 - Map of Title I Projects.

These facilities enable the United States to deliver water to Mexico with an average annual salinity concentration no greater than 115 parts per million (ppm) plus or minus 30 ppm (United States count) over the average annual salinity concentration of the Colorado River water at Imperial Dam.

The background and history of the Title I projects (Coachella Canal Lining, Protective and Regulatory pumping, Yuma Desalting Plant, Wellton-Mohawk Irrigation & Drainage District) can be found in Progress Report 22, chapter 4 at;

<http://www.usbr.gov/uc/progact/salinity/pdfs/PR22.pdf>

Updates for the Title I projects since Progress Report 22 are as follows:

Coachella Canal Lining

No new activity or change since last progress report.

Protective and Regulatory Pumping

No new activity or change since last progress report.

Yuma Desalting Plant

The Yuma Desalting Plant (YDP) was constructed under the authority of the Colorado River Basin Salinity Control Act of 1974 to recover through desalination, the majority of the Wellton-Mohawk Irrigation and Drainage District agricultural return flows which bypass the Colorado River, thereby allowing the treated water to be delivered to Mexico as part of the 1.5 million acre-feet of Colorado River water that the U.S. must deliver to Mexico under the 1944 Water Treaty. Due to the high cost of operating the plant and general agency budget constraints, as well as surplus and normal conditions in the lower Colorado River Basin prior to the current drought, the YDP has not been operated; however, the facility has been maintained.

The U.S. has met the Treaty's salinity requirements by bypassing an average of 107,000 acre-feet of saline agricultural flows and then releasing additional water from Lake Mead. Since the diverted agricultural flows bypass the Colorado River, they are not counted as part of the 1.5 million acre-feet of Treaty water delivered annually to Mexico.

Metropolitan Water District of Southern California, Southern Nevada Water Authority, and Central Arizona Water Conservation District, collectively referred to as the Municipal Utilities, have jointly requested that Reclamation conduct a Pilot Run of the YDP to consider long term, sustained operation as a means to extend water supplies on the lower Colorado River during an unprecedented drought. Such consideration requires: 1) collecting performance and cost data; 2) identifying any remaining equipment improvements that are needed; and 3) testing changes that have already been made to the plant. Reclamation has developed a plan for a Pilot Run, in which the plant will operate for 365 days within an 18 month period at 1/3 capacity.

The Pilot Run began in May, 2010 and ran about a year, adding approximately 30,000 acre-feet of water to Colorado River system storage for a cost of under \$23 million, of which a little more than ½ the cost was provided by the Municipal Utilities. Based on the Intentionally Created Surplus (ICS) provisions of the Colorado River Interim Shortage Guidelines of December 2007, the entities received ICS credits in proportion to their capital contributions to the Pilot Run. The Pilot Run was conducted in full compliance with all United States (U.S.) statutes. Reclamation finalized an Environmental Assessment with the Finding of No Significant Impact. Reclamation received a

discharge permit from the Arizona Department of Environmental Quality in accordance with the Clean Water Act.

Plant operation reduces the volume and increases the salinity of the flow to the Ciénega de Santa Clara (Ciénega) wetland in Mexico. Reclamation consulted with Mexico through the International Boundary and Water Commission which resulted in an agreement of joint cooperative actions including providing 30,000 acre-feet of water to the Ciénega. This water was provided in equal one-third increments by the U.S., Mexico, and a bi-national coalition of non-governmental organizations. In addition, the Municipal Utilities are collaborating with the bi-national coalition to develop a monitoring program for the Ciénega.

Through a Cooperative Research and Development Agreement (CRADA) with the Municipal Utilities alternative configurations of the YDP began to be tested in 2010 including alternative methods of pretreatment, low energy reverse osmosis membranes, and different feed water for the plant. The results of the Pilot Run and this CRADA should provide enough information to evaluate the YDP's potential as a means to augment water supplies on the lower Colorado River.

Wellton-Mohawk Irrigation and Drainage District (WMIDD)

All permanent measures implemented by WMIDD are still in use, although the Federal program has been discontinued. The original program was named the Irrigation Management System Program (IMS) which was Federally funded and manned. The Federal funding was discontinued in the late 90's and the Irrigation District had the option of dropping the program or continuing. The District (Board of Directors) chose to continue with the program. The original program required the use of a neutron probe to measure the soil moisture content. WMIDD no longer uses a soil moisture probe, but does monitor observation wells, which allows the district to maintain optimum soil moisture conditions.

Total crop acres have remained relatively stable since the early 1970's because more acreage is double-cropped than when the program was initiated. In particular, more vegetable crops are being grown in the district than in the past. Irrigation efficiency levels and return flow levels for 1990-2010 are shown on the following page, in Table 5.

Reclamation believes that the impacts of Gila River flows in 1992, 1993, and 1995 make irrigation efficiency and return flow data from the district questionable for 1992, 1993, 1994, 1995, and 1996. In 1993, the Gila River flood destroyed much of the WMIDD Main Conveyance Channel; so most of the drainage pumping went into the Gila River during 1993 and 1994 until these facilities could be repaired.

With the use of monthly groundwater table monitoring using observation well measurements as well as input from land users, WMIDD is able to maintain a drainage-pumping program that sufficiently maintains the agriculture root zone. Land users continue to maintain water efficient farming techniques with the use of dead level, high heads, and short runs.

Table 5 - WMIDD Irrigation Efficiency

Year	Pumped Drainage Return Flow (acre-feet)	Irrigation Efficiency, % (note: data provided by WMIDD)
1990	138,200	-
1991	144,900	68.8
1992	116,200	70.4
1993	8,970	68.8
1994	49,820	65.4
1995	121,500	64.3
1996	119,600	60.4
1997	91,695	62.2
1998	98,972	61.9
1999	94,869	63.0
2000	110,287	59.7
2001	107,908	60.9
2002	119,410	61.2
2003	116,477	57.8
2004	106,002	63.3
2005	110,770	64.6
2006	103,810	62.3
2007	112,910	62.6
2008	120,190	63.0
2009	105,482	62.7
2010	111,170	66.1

CHAPTER 4 - TITLE II SALINITY CONTROL PROGRAM

Title II of the Salinity Control Act authorizes the Secretary of the Interior (Secretary) and the Secretary of Agriculture to implement a broad range of specific and general salinity control measures in an ongoing effort to prevent further degradation of water quality in the United States. These efforts are shown on the map below. The USDA, BOR and BLM have a combined goal of controlling 1.9M tons of salt/per year, by the year 2025. These federal agencies are required to work together under, Public Law 93-320, “Colorado River Basin Salinity Control Act,” as amended; with the Bureau of Reclamation being the lead federal agency. The Act also calls for periodic reports on this effort. The report is to include the effectiveness of the units, anticipated work to be accomplished to meet the objectives of Title II with emphasis on the needs during the 5 years immediately following the date of each report, and any special problems that may be impeding an effective salinity control program. Title II also provides that this report may be included in the biennial Quality of Water Colorado River Basin, Progress Report. The history and background of the Title II projects can be found in Progress Report 21 at: <http://www.usbr.gov/uc/progact/salinity/pdfs/PR21.pdf> . Ongoing and active projects are listed in this report.

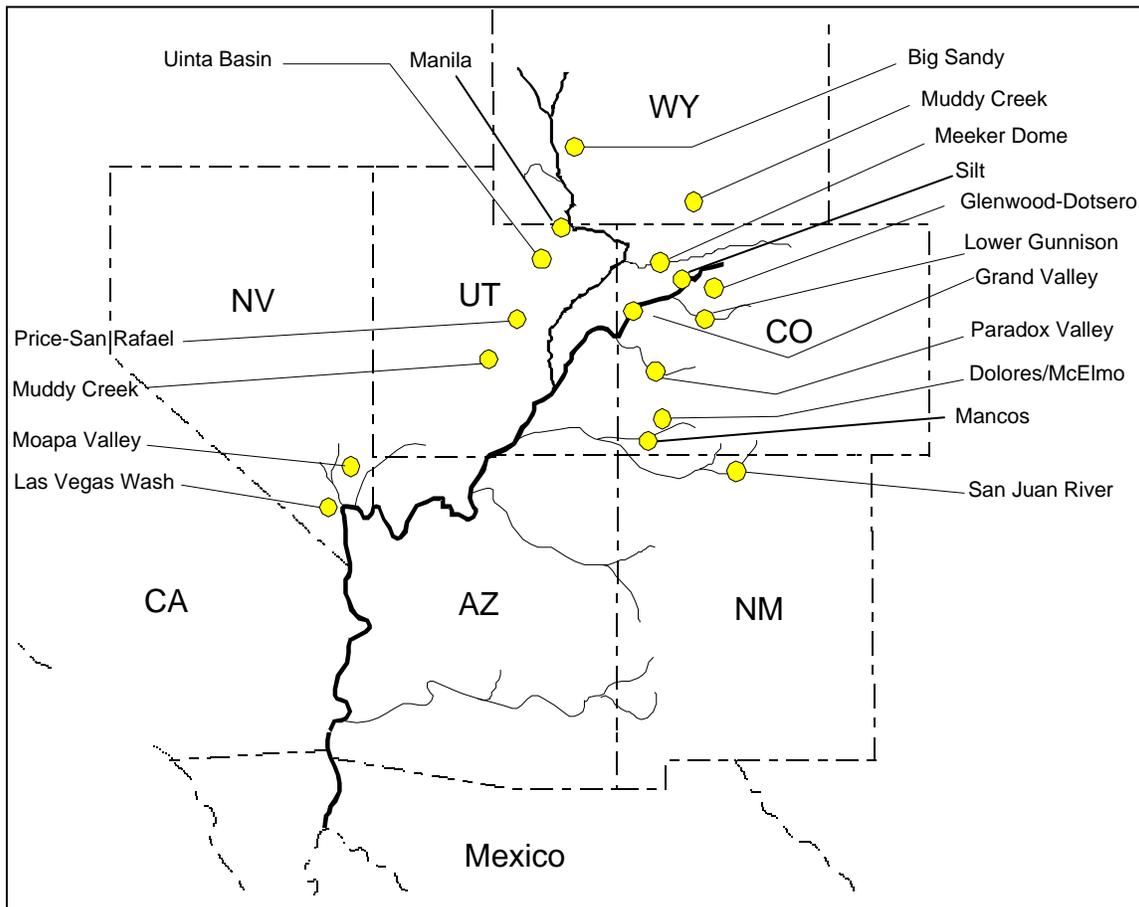


Figure 12 - Map of Title II Salinity Control Project Areas.

U.S. Bureau of Land Management

The Bureau of Land Management (BLM) administers 48 million acres in the Colorado River Basin above Imperial Dam, or 40 percent of the Colorado River Basin's area. Of the 48 million, approximately 7.2 million acres, or about 15 percent, contain saline soils (slightly, moderate, and strongly saline soils). Soil salinity is usually greatest where surface geology reflects saline marine shale and annual precipitation averages less than 12 inches. In depositional settings, soil salinity may also be high, even where the underlying geology is relatively non-saline.

The BLM is committed to its role in reducing the mobilization of salt on public lands. The BLM undertakes this responsibility through the multitude of individual management decisions that are made within each BLM jurisdiction. Progress in preventing salt from moving off BLM land is achieved through efforts to minimize the impacts of grazing, protect riparian areas, reduce off-road vehicle impacts, conduct prescribed burns, and generally manage vegetative cover and reduce erosion. As such, in the past, it has been difficult to single out salinity-control efforts for many of the projects that did have salt savings. In a step to strengthen our reporting effort, a restructuring of the allocation of salinity funding was done and new tracking and accounting systems were put in place in FY 2006. Thus, FY 2010 is the 5th year of reporting under the re-structured system.

For FY 2010 \$850,000 was allocated for BLM's salinity-control program. Funding goes to 4 major areas: Program administration (ADMIN); Planning (PLAN); Science (SCI); and On-the-ground implementation projects (OTG) (see Figure 13 for FY 2006 - 2010).

Tons of salt retained can not be calculated for program administration, planning, and science projects. However, one of the goals for the re-structured program in FY 2006 was to develop an accounting system to begin calculating more reliable 'tons of salt retained' for on-the-ground implementation projects.

Program Administration

During FY 2003, BLM created a new full-time, salinity coordinator position. The salinity coordinator began work in FY 2004. FY 2006 was the first full year of the newly re-structured program. The re-structured plan consists of 3 main parts: 1) Allocation of funds to the Upper Basin States (AZ, CO, NM, UT, and WY) based on submittal of project proposals; 2) A tracking system for projects that fit into BLM's Rangeland Improvement Project System (on-the-ground implementation projects); 3) Annual reporting consisting of narratives for on-going and current year, and a worksheet to determine 'tons of salt retained' for on-the-ground implementation projects. The objective for FY 2007 - 2010 program administration was a continuation of the framework put into place during FY 2006; however, there has been an increased emphasis on capturing the amount of salt loading for implementation projects (OTG spreadsheet). Projects that have been science or planning can become implementation projects in future years.

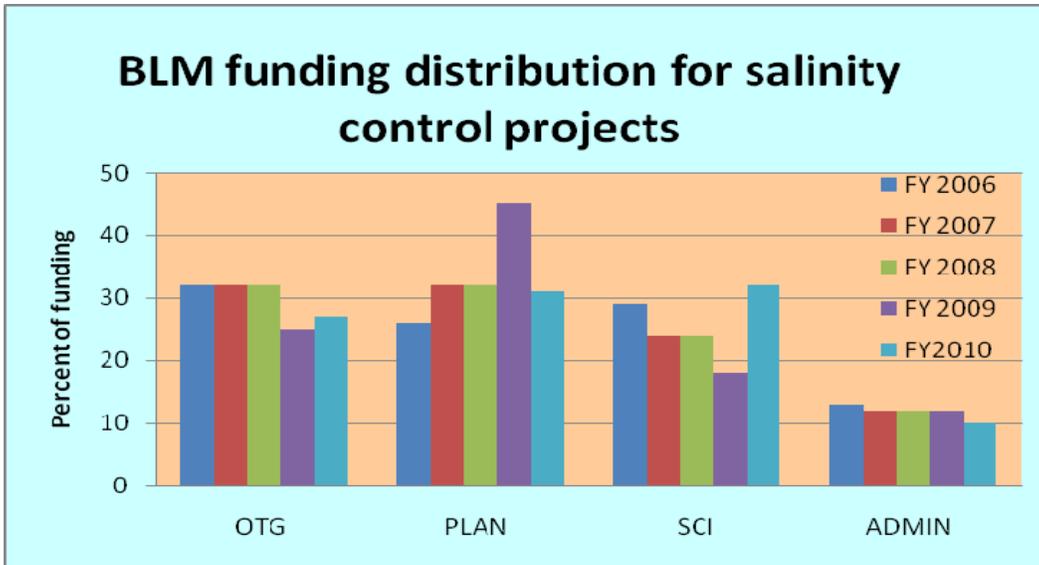


Figure 13 – BLM Salinity Control Program Funding Distribution

Planning

Planning is an important part of natural resource management. Resource management plans become the ‘blueprints’ for BLM’s near future. As such, this is an opportunity to plan for salinity control, especially for some of our most important activities on public land such as grazing, recreation, and energy development. Planning projects that successfully captured salinity funding for FY 2009 include:

Colorado

- San Luis Valley wetlands salinity study - \$20,000

Utah

- Factory Butte OHV impact and soil study (Planning/Science) – ongoing - \$35,000
- Pariette water-quality monitoring - ongoing - \$80,000

Wyoming

- Progressive soil surveys managed from the State Office - ongoing - \$100,000
- Erosion sediment transport modeling - ongoing - \$30,000

Science

Salt loading from public lands is often episodic and can be dependent on factors such as: precipitation amount and intensity; topography; content and texture of soils; and the types, amount, and architecture of vegetative ground cover. The transit mode of salt loading can be surface-water runoff, or it can be ground-water recharge to streams and rivers. In a watershed, understanding, through study, which factors are most important and what is the main transit mode of salt loading aids in determining the proper on-the-ground implementation project for good salinity control. The following science projects that investigated salt loading factors were funded during FY 2010:

Colorado

- Piceance salinity-loading dynamics including conductivity monitoring at Piceance Cr. With USGS Water Sciences - \$60,000
- Vegetation and soil stability project with USGS Biological Resources Discipline (BRD) in Badger Wash (central-western Colorado) to investigate grazing impacts on vegetation and sediments - ongoing - \$50,000
- Coal mine impact study with USGS on mine outside of Grand Junction in Big Salt Wash watershed - \$30,000

Utah

- Factory Butte OHV impact and soil study. LiDAR survey (Planning/Science) – ongoing \$10,000
- Salinity – Mancos shale wind erosion (with USGS BRD) - \$20,000

Wyoming

- Salinity baseline Muddy Creek - \$65,000

Upper Colorado River Basin Regional project

- Forecasting phenological plant stage in the Upper Colorado River Basin - ongoing - \$40,000

On-the-ground Implementation

When mechanisms of how salt loading occurs are understood and once planning is done, on-the-ground implementation projects follow. The success of an on-the-ground project is very much tied to understanding system mechanics and proper planning. The success is also tied to sufficient funding and trained natural resource personnel to go out in the field and construct or carry out the plan.

On-the-ground projects funded by salinity program allocations during FY 2010 include:

Arizona

- Rock Crossing dike system in Ft. Pierce Wash that is tributary to the Virgin River southeast of St. George, Utah – on-going - \$50,000

Colorado

- Gunnison Gorge National Conservation Area (NCA) Salinity Management - \$30,000

New Mexico

- Crow Mesa sage treatment - \$35,000
- La Manga Canyon watershed restoration - ongoing - \$35,000
- San Juan River salt/sediment retention structures - ongoing - \$30,000

Utah

- Reducing OHV impacts on saline soils near Moab, Utah - \$20,000
- Grazing exclosures in the Moab Field Office - \$20,000
- Nine Mile Canyon Fencing/Range Improvement Project - \$10,000

Table 6 – BLM Salt Retention Estimates for Fiscal Years 2006 – 2010

Project Category	SALT RETAINED IN TONS/YEAR ¹				
	FY 2006 ⁴	FY 2007 ⁴	FY 2008	FY 2009	FY 2010
POINT SOURCE ²	14,600	14,600	14,600	14,600	14,600
NONPOINT SOURCE ³	71,900	71,900	81,900	71,900	85,300
ALL PROJECTS	86,500	86,500	96,500	86,500	99,900

1. Rounded to the nearest 100 tons.
2. BLM's Salinity Report to Congress through the year 2002, plus the plugging of 2 wells in Utah during FY 2004 (approximately 5,000 tons/yr).
3. Amount that could be calculated, i.e., this is a minimum.
4. When the program was re-structured in FY 2006, we did not have a complete accounting the 1st year or even the 2nd year. As a result, the tons-of-salt-retained number on BLM administered land in the Upper Colorado River Basin (UCRB) was low. FY 2006 and FY 2007 numbers have been changed to reflect tonnage retained in FY 2009, because after 4 years on the new system, FY 2009 tonnage is probably a better estimate. Projects can become less effective in retaining salt over the years, but there is enough erosion control going on constantly in the UCRB on public land, that the tonnage is probably closer to FY 2009 than it was to the low incomplete numbers originally reported for FY 2006 and FY 2007.

U.S. Department of Agriculture (USDA)

The Natural Resource Conservation Service (NRCS) of the United States Department of Agriculture (USDA) conducts Colorado River Basin Salinity Control activities under the authorities of the Environmental Quality Incentives Program (EQIP). EQIP was enacted with passage of PL104-127, Federal Agricultural Improvement Act of 1996, a.k.a. "1996 Farm Bill" and reauthorized by PL 107-171, The Farm Security and Rural Investment Act of 2002, the "2002 Farm Bill" and by PL 110-246, The Food, Conservation, and Energy Act of 2008, the "2008 Farm Bill." The 2008 Farm Bill expires September 30, 2012.

Through EQIP, NRCS offers voluntary technical and financial assistance to agricultural producers, including Native American tribes, to reduce salt mobilization and transport to the Colorado River and its tributaries. Within the eleven approved salinity project areas, producers may be offered additional financial incentives to implement salinity control measures with the primary goal of reducing offsite and downstream damages and to replace wildlife habit impacted as a result of the salinity measures.

In fiscal year 2010, \$18.2 million of appropriated EQIP funding was allocated for financial and technical assistance to agricultural producers in eleven project areas in Colorado, Utah, and Wyoming to share the cost with landowners and operators to install conservation systems that provide salinity control and wildlife habitat replacement.

New Salinity Projects and Investigations

Expansion of Lower Gunnison, Colorado, Project Area

In October, 2009, NRCS Colorado undertook to include about 15,000 acres of irrigated lands in Ouray County into the Lower Gunnison Project Area. The original Lower Gunnison study considered these lands and their salt load contribution, but the selected alternative did not include Ouray County. The Ouray County Commissioners and the Shavano Conservation District petitioned NRCS to incorporate these lands into the Lower Gunnison project. NRCS's partners recommended that the expansion proceed.

Plateau Creek, Colorado

The Plateau Valley Pilot Project was initiated in 2009 by NRCS and the Colorado State Conservation Board. The Pilot Project was developed to determine if a combination of general EQIP and additional incentives from the Basin States program would accelerate the installation of high-efficiency irrigation systems that would provide salinity control. By the May, FY 2010, 807 acres had been enrolled. A verbal report on the Plateau Creek Project will be given during the Federal Advisory Council meeting in November.

McKinnon - Lone Pine - Burnt Fork, Wyoming

Throughout 2010, NRCS-Wyoming conducted inventories, public scoping meetings, and analysis of data leading to preparation of a salinity control project plan for the agricultural areas served by the Henrys Fork of the Green River. Local producer interest in a salinity control project is high. Alternatives will be presented to the local producers and upon selection of a preferred plan, the appropriate National Environmental Policy Act (NEPA) documents (either an Environmental Impact Statement (EIS) or Environmental Assessment (EA)) will be prepared for public comment. A maximum of about 20,000 irrigated acres could ultimately be treated in Wyoming and Utah if the project is adopted.

West Black's Fork, Wyoming

An area of some 28,000 acres of irrigated pasture and hayland near Lyman, Wyoming, contribute salt to the Blacks Fork River, tributary to the Green River. While a large portion of the geology contributes little salt, about 10,000 acres may contribute significant amounts of salt from canal and ditch seepage and deep percolation from water applied to fields.

The Wyoming Water Development Commission has provided a significant grant to the Austin-Wall Canal Company to conduct a Level II plan to modernize the irrigated areas within their service area. Local interest in upgrading the irrigation delivery infrastructure is high. NRCS-Wyoming anticipates that improvement of these large delivery systems will enable extensive implementation of on-farm salinity control.

Plateau Creek, Colorado

The Plateau Valley Pilot Project was initiated in 2009 by NRCS and the Colorado State Conservation Board. The Pilot Project was developed to determine if a combination of general EQIP and additional incentives from the Basin States program would accelerate the installation of high-efficiency irrigation systems that would provide salinity control.

By May 2010, 807 acres had been enrolled. A verbal report on the Plateau Creek Project was given during the Federal Advisory Council meeting in November.

White-Yampa Basin, Colorado

Narrow bands of irrigated pasture and hay land are found along the Yampa River near Craig, Colorado, and along the White River, near Meeker, Colorado. Extensive areas of dry cropland that is often summer fallowed also drain into these tributaries of the Green River. Recent salinity concentrations have trended upward. A hydrosalinity analysis is planned to determine if salt loading from agricultural lands is significant and cost effective to control.

San Juan Basin, New Mexico and Arizona

In the 1990's, a salinity study indicated that the Fruitland, Hogback and Cudei Irrigation Districts contribute an annual load of 157,000 tons of salt to the San Juan River. "Salinity Verification – Phase 1 Final Report, San Juan County, New Mexico, July 1993".

The San Juan River Dineh Water Users, Inc. (SJRDWU) has entered into a cooperative agreement with Reclamation to pilot the replacement of an earthen-lateral with pipeline. The necessary clearances for construction have been obtained from the Navajo Nation as well as support from the local chapters. Work has begun in designing the system, including the settling and regulating reservoir. The pipeline route is being cleared in anticipation of construction that will begin as soon as the irrigation season ends this October. A plan and location for wildlife habitat replacement has also been developed. With the assistance of Reclamation's Office of Native Affairs, the Arizona NRCS has hired a native-speaking civil engineer and placed him in Shiprock, New Mexico, to assist with the completion of the off-farm portion of the pilot and to assist the local farmers with the on-farm application system installation and operation.

Areas Beyond Current Project Boundaries

NRCS has undertaken to identify salt loading and salinity control from irrigated crop, pasture and haylands scattered widely throughout the Upper Colorado River Basin but outside of the existing project areas.

With the assistance of the U.S Geological Survey (USGS) and the Bureau of Reclamation, NRCS has been able to make use of the SPARROW model to assess salt loads outside of the existing salinity project areas. While the assessment is ongoing and will require considerable refinement, preliminary analysis indicates that as much as 50,000 tons of salt control has occurred in Utah and Colorado outside the project areas.

In 2010, Colorado, Utah and Wyoming all developed EQIP contracts providing salt control outside of the approved project areas but within the Colorado River Basin.

- Colorado, new contracts for 100 tons of control.
- Utah, new contracts for 877 tons of control.
- Wyoming, new contracts for 29 tons of control.

Monitoring and Evaluation

Project offices continue to monitor and evaluate the effectiveness and quantity of salinity control, wildlife habitat, and economic performance replacement in order to improve the overall performance and management of the program. Generally, the program continues to function effectively and economically, though the overall cost per ton of salt control continues to rise in some areas. It is also noted that additional efforts are needed to identify and implement valuable, low-maintenance, sustainable wildlife habitat replacement. The individual Monitoring and Evaluation reports for each project can be found on the world-wide-web at; <http://www.usbr.gov/uc/progact/salinity/index.html>

Active Salinity Control Projects

Table 7 – Active Salinity Control Projects

<u>Project Area</u> <u>State</u>	<u>Project</u>	<u>Potential Irrigated Acres</u>	<u>USDA Servicing Office</u>
Colorado	Grand Valley	50,000	Grand Junction
	Lower Gunnison River	171,000	Delta and Montrose
	McElmo Creek	29,000	Cortez
	Mancos Valley	11,700	Cortez
	Silt	7,400	Glenwood Springs
Utah	Uinta Basin	226,000	Roosevelt, Vernal, Ft. Duchesne
	Price/San Rafael Rivers	66,000	Price, Castle Dale
	Muddy Creek	6,000	Castle Dale
	Manila-Washam	8,000	Vernal
	Green River	2,600	Price
Wyoming	Big Sandy River	18,000	Farson
Total		595,700	

Grand Valley, Colorado

Implementation has been underway in this unit since 1979. In 2010, \$501,000 was obligated into new EQIP contracts to control 457 tons at a cost of \$121 per ton.

The NRCS, in cooperation with the Colorado State Conservation Board and the Mesa County Conservation District conducted a field survey in 2010 of current progress in implementing off-farm and on-farm irrigation system improvements with attendant salt control. Some key findings were:

- Approximately 12,500 acres of farmland has been converted to residential leaving 47,000 acres of irrigated farmland.
- NRCS has treated about 42,500 acres plus an additional 2,500 acres have been treated resulting in over 95% of all irrigated farmland acres receiving treatment.
- The original goal to reduce salt loading by 132,000 tons has been exceeded.
- Wildlife habitat replacement stands at about 71% of the original goal.

NRCS intends to publicize the results of the survey and conduct aggressive outreach over the next two years to provide every opportunity for the remaining producers to participate in the program. NRCS will also seek the remaining needed habitat. Beginning in 2013,

NRCS intends to offer general EQIP in lieu of salinity EQIP to producers within the project area. General EQIP may provide additional incentives and incentives for a wider array of conservation practices that does salinity EQIP.

Lower Gunnison Basin, Colorado

This project encompasses the irrigated farmland in the Gunnison and Uncompahgre River valleys and is located predominantly in Delta and Montrose counties. The Lower Gunnison project has more tons of potential remaining on-farm salt control than all the other projects combined. In early FY 2010, irrigated areas in Ouray were also included in the Lower Gunnison project.

Implementation was initiated in 1988 in this unit. Nearly 50 percent of the salt control goal has been achieved but the rate of application and implementation has slowed. In 2010, \$1.5M was obligated in salinity EQIP contracts that will control 1,322 tons at a cost of \$126 per ton. New sprinklers were installed on 215 acres while new surface systems were installed on 1,579 acres. Drip or micro-spray systems were installed on 9 acres.

NRCS is cooperating with the Colorado Conservation Commission, the county conservation districts, the Colorado Water Conservancy District, Reclamation and the U.S. Geological Survey to acquire a highly detailed survey of the irrigation delivery infrastructure, the status on on-farm application systems, and local salt loading. Such data should assist the partners to develop tactics to accelerate salt control measures.

Mancos River, Colorado

This project, near the town of Mancos, Colorado, was initiated and approved for funding and implementation by the NRCS in April 2004. The first EQIP contracts were signed in 2005 and implementation of improved irrigation systems is proceeding on schedule. Currently, about 596 contracts on 2,732 acres have been developed with EQIP and Basin States Parallel funds or about 51% of the project acres. One large wildlife habitat replacement project has been installed. It is anticipated that approximately 5,400 acres of improved irrigation systems with salt control benefits will be installed over the project life. To date, 1,649 acres of sprinkler systems and 605 acres of improved surface irrigations systems have been installed resulting in salt control of 2,339 tons. An additional 1,706 tons have been controlled by replacing off farm laterals with pipeline.

McElmo Creek, Colorado

Implementation was initiated in this unit in 1990. Application of salinity reduction and wildlife habitat replacement practices continue to be implemented in this area with sprinkler systems, underground pipelines, and gated pipe being installed.

Development and use of automatic shutoff valves for sprinkler systems continue to be widely implemented in the project to achieve water management. This project planned to install predominantly sprinkler systems with a small number of improved irrigation systems. Currently about two thirds of improved systems are sprinklers and one third are improved surface systems. In 2010, 378 acres of sprinklers were installed and 237 acres of improved surface systems were installed. Of a goal of 46,000 tons of salt control,

about 26,000 tons or 56% has been implemented. Applications have declined compared to previous years likely due to recessionary pressures. This area is also experiencing the conversion of agricultural lands to residential properties.

Silt, Colorado

The first applications were funded in 2006. The cumulative cost effectiveness for these new contracts is \$72 per ton which falls midway among the other active project areas. Several wildlife projects have been identified. Applications are a mix of improved surface and sprinkler irrigation systems.

Uinta Basin, Utah

Implementation began in this unit in 1980. More than 91 new irrigation contracts and nine new wildlife habitat contracts were developed in 2010. A significant number of systems have reached or are nearing the end of their useful life. While these systems are a lower priority than first-time improvements, NRCS has begun providing incentives for replacement or up-grading. Sprinkler irrigation systems remain, by far, the preferred type of system. Producer participation is exceeding the original projections. Recently awarded off-farm delivery system grants by the Bureau of Reclamation should enable additional on-farm gravity sprinkler systems. While more than 120,000 tons of on-farm salt control have occurred in the Uinta Basin (second only to the Grand Valley) and the original goal has been exceeded, the potential exists for an additional 46,000 tons to be controlled.

Price-San Rafael, Utah

Implementation of salinity control continues at a rapid pace in the Price-San Rafael Project area. More than 94 contracts of new irrigation systems and two wildlife habitat contracts were authorized in 2010. The Huntington-Cleveland Project is proceeding as planned and may ultimately lead to the improvement of 16,000 acres. The first phase of the Cottonwood Project is expected to initiate construction in late 2010 and will enable additional EQIP in future years. The Price-San Rafael project area has achieved about 51% of its salt control goal in the 16 years since the project began.

Muddy Creek, Utah

NRCS received and funded the first project in the Muddy Creek area for about \$106,000. The local irrigation district has replaced their old and deteriorated diversion structure and has constructed a large sediment-settling structure as the necessary first phase towards ultimately providing pressurized water delivery to its water users.

Green River, Utah

This project is the most recently authorized by NRCS. Funds for salinity control were allocated to the Green River project in FY 2010. The timing of the start of project activity is important as newly irrigated lands are being brought into production for the first time in this area.

Two contracts for salinity control were enacted in FY 2010. These two contracts will install high-efficiency sprinkler systems on 114 acres to result in 350 tons of annual salt control. The annualized cost per ton is \$47.

Manila-Washam, Utah/Wyoming

Astride the Utah-Wyoming border, and adjacent to the shores of Flaming Gorge Reservoir, the Manila-Washam Project is the newest, authorized project area. This area of 11,000 acres of irrigated pasture and hayland contributes about 53,000 tons of salt annually to the Green River. Nearly 2000 acres have been treated or contracted since the first plans were developed in 2007. All new irrigation systems have been some form of sprinkler system, such as side roll, pods, or center pivots.

Big Sandy River, Wyoming

Implementation has been underway in this unit since 1988. The application of salinity reduction and wildlife habitat replacement practices continues to be implemented. In this area, farmers are converting from surface flood irrigation to low-pressure center pivot irrigation systems for salinity control. Approximately 13,500 acres of the planned 15,700 acres have been treated (86 percent). Producers also report that the water savings from improvements in irrigation systems now allows a full irrigation season of water for the entire irrigation district. In 2010, NRCS developed six new contracts on 926 acres for about \$139,000 of financial assistance. NRCS also continued to provide technical and financial assistance to all interested producers to up-grade sprinkler nozzle packages. Sprinklers were re-nozzled on 880 acres for a financial expenditure of \$28,832. These latest nozzles, along with more intensive soil-moisture monitoring, provide additional irrigation efficiencies and salt savings.

Table 8 - USDA Salinity Control Unit Summary Through 2010

Unit	Controls¹ (tons)	Goal (tons)	Percent of Goal	Costs	Annualized Costs	Projected Total Cost	Cost/ton²
Uinta Basin, UT	149,030	140,500	106%	\$ 99,575,982	\$ 8,254,849	\$ 93,876,572	\$55
McElmo Creek, CO	25,862	46,000	56%	\$ 18,901,097	\$ 1,566,901	\$ 33,618,841	\$61
Silt, CO	4,038	3,990	101%	\$ 3,489,154	\$ 289,251	\$ 3,447,678	\$72
Muddy Creek, UT	0	11,677	0%	\$ 0	\$ 0	\$ 11,655,523	\$75 ³
Lower Gunnison, CO	105,502	186,000	57%	\$ 66,417,187	\$ 5,505,985	\$117,093,484	\$52
Manila-Washam, UT	7,087	17,430	41%	\$ 6,202,656	\$ 514,200	\$ 15,255,015	\$73
Grand Valley, CO	170,028	132,000	129%	\$ 51,817,220	\$ 4,295,648	\$ 40,227,922	\$25
Price/San Rafael, UT	75,507	146,900	51%	\$ 31,174,675	\$ 2,584,381	\$ 60,650,797	\$34
Mancos, CO	4,045	11,940	34%	\$ 6,140,175	\$ 509,021	\$ 18,214,522	\$126
Big Sandy, WY	56,637	83,700	68%	\$ 13,431,318	\$ 1,113,456	\$ 19,849,238	\$20
Green River, UT	0	6,540	0%	\$ 0	\$ 0	\$ 8,700,000	\$47 ³
TOTALS	597,736	786,677	71%	\$297,149,464	\$24,633,691	\$410,844,069	\$41

¹Includes off-farm control funded with EQIP or Basin States Parallel funds.

² Cost per ton based on amortization over 25 years at 6.625% interest

³Estimate based on project plan.

Grand Valley includes 47,500 tons for on-farm ditches, not part of in-field control.

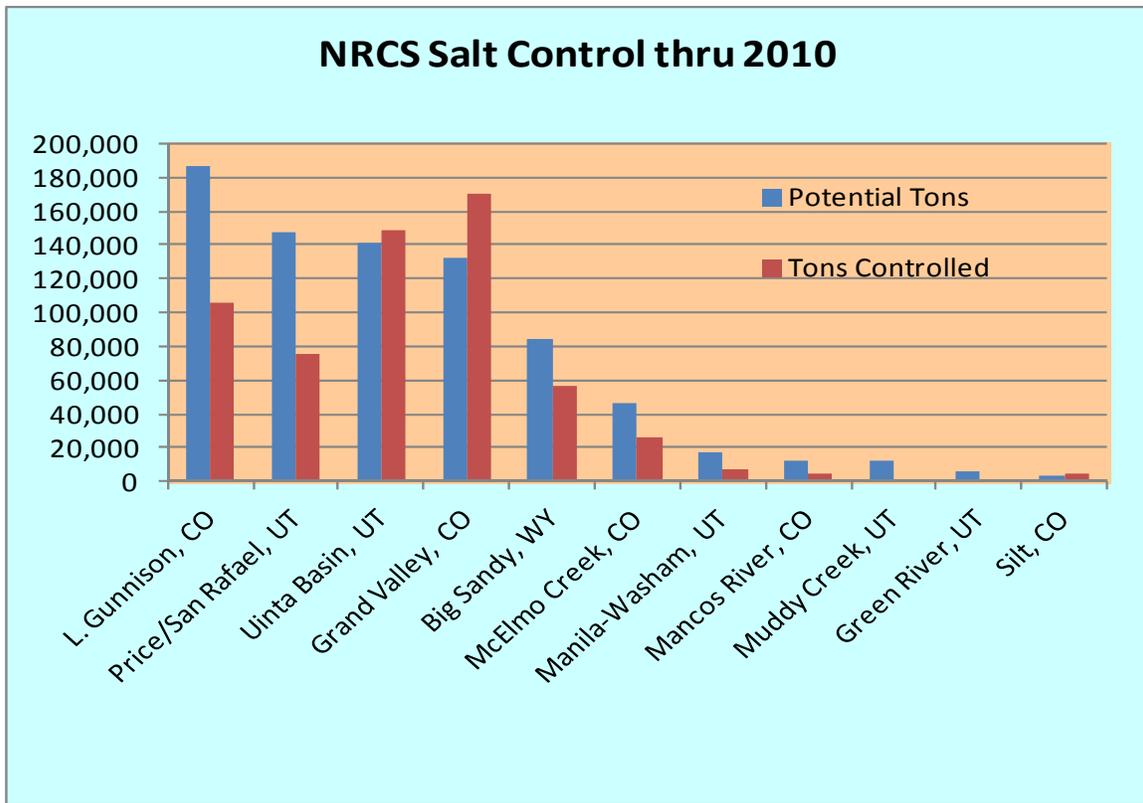


Figure 14 – NRCS On-Farm Salt Control Through 2010

U.S. Bureau of Reclamation

Program Summary

Background -- The Bureau of Reclamation involvement in the Colorado River Basin Salinity Control Program dates back to the early 1960's when salinity levels in the river started to rise. In 1968, Reclamation initiated a cooperative reconnaissance study in the Upper Colorado Basin. Study objectives were to identify feasible control measures and estimate their costs. This investigation evolved into several salinity control units. In 1974, Public Law 93-320 authorized the construction of the Grand Valley, Paradox, Crystal Geyser, and Las Vegas Wash Units. In 1984, Public Law 98-569 authorized the construction of the Lower Gunnison and McElmo Creek Units.

By 1993, Reclamation had gained 20 years of experience with the program and identified new and innovative opportunities to control salinity, including cooperative efforts with USDA, BLM, and private interests, which would be very cost effective. However, these opportunities could not be implemented because the Congress did not specifically authorize them. The Inspector General's audit report (1993) noted the Salinity Control Act directed that "the Secretary shall give preference to implementing practices which reduce salinity at the least cost per unit of salinity reduction." The Inspector General concluded that the congressional authorization process for Reclamation projects impedes

the implementation of cost-effective measures by restricting the program to specific, authorized units (specific areas).

The Inspector General recommended that Reclamation seek changes in the Salinity Control Act to simplify the process for obtaining congressional approval of new, cost-effective salinity control projects. Specifically, the Inspector General recommended Reclamation seek authorities similar to those provided to USDA in the 1984 amendments to the act, wherein USDA was empowered with programmatic planning and construction authority. At the time, USDA had only to submit a report to Congress and wait 60 days before it could proceed if Congress did not object. In contrast, Reclamation was required to seek approval of its projects through legislation. This had proved to be a cumbersome way to manage the program. With broader authorities, Reclamation would be able to take advantage of opportunities as they presented themselves, thus reducing costs.

Reclamation agreed with the Inspector General and wanted to explore any other innovative ideas, which would help improve the effectiveness of its program and take advantage of opportunities that were not envisioned 20 years earlier. With most of the cost-effective portions of the authorized program nearing completion, this was a pivotal moment for the program. It would either be reauthorized or end in 1998 due to appropriation ceiling limits. From Reclamation's point of view, it seemed a very appropriate time to reassess the direction of the program.

In 1994, Reclamation and the Basin States developed legislation to broaden Reclamation's authorities so that it could manage the implementation of the program without further congressional approval. This legislation was introduced in Congress late in 1994 and was approved and signed into law (Public Law 104-20) in 1995. Congress retained its fiscal oversight, but leaves the program's management to Reclamation. The 1995 amendments to the Salinity Control Act authorized Reclamation to pursue salinity control throughout the Colorado River Basin and required Reclamation to develop guidelines on how it would implement this new, basinwide approach to the program.

Guidelines -- Reclamation has prepared guidelines for its new Basinwide Salinity Control Program, which implements the recommendations made in the review of the program. As an alternative to adopting new, specific regulations, Reclamation administers the program through existing procurement techniques and established Federal regulations. Since February 1996, the program has been made available to the general public through this competitive process.

In 1984, Public Law 98-569 directed the Secretary to give preference to those projects which reduce salinity at the least cost per ton of salinity control. Since that time, cost effectiveness (cost per ton of salt removed) has been used to prioritize the implementation of salinity controls. However, cost effectiveness is only an estimate (prediction) of the project's cost and effectiveness at controlling salinity. Depending upon the project, there can be a degree of uncertainty in either of these values. Given the diversity of proposals that Reclamation may receive, an evaluation of the proposal's risks has been included in the current selection process.

All proposals (including those studied by Reclamation) are first ranked on their cost per ton of salt removed. This ranking is then adjusted for risk factors that might affect the project's performance. The performance risk evaluation considers both financial and

effectiveness risks. For example, the Government is interested in limiting its risk of cost overruns. One way that performance risk could be reduced would be for the proponent to accept some risk through contractual limits on the Government's payments. Another method of limiting the costs would be to have the work bonded through a private bonding agency. The other major area of performance risk is in the amount of salinity control realized versus projected. Some types of salinity control are inherently more predictable or consistent than others. For example, industrial processes might have very little salinity control performance risk if the payments were based on a measurable product. On the other hand, the effectiveness of water management is often highly variable from farmer to farmer. Automation would be one way a farmer might propose to reduce this type of risk.

Ultimately, there is a tradeoff between risk and cost. In the end, eliminating risk may cost more than accepting some risk. A ranking committee is assembled to evaluate the tradeoffs between cost effectiveness and performance risks. The ranking committee is made up of representatives from the two cost-sharing partners, the Basin States and Reclamation. After the committee ranks the proposals, Reclamation attempts to negotiate the final terms of an agreement with the most highly ranked proponents. The first awards under this new process began in FY 1997.

Performance Review -- Past projects (Grand Valley, Paradox, Lower Gunnison, Dolores) have averaged slightly over \$70 per ton. For a number of reasons, the new projects are much more cost effective, ranging between \$20 and \$35 per ton (see Tables 7 and 8).

One of the greatest advantages of the new program comes from the integration of Reclamation's program with USDA's program. Water conservation within irrigation projects on saline soils is the single most effective salinity control measure found in the past 30 years of investigations. By integrating USDA's onfarm irrigation improvements with Reclamation's off-farm improvements, significantly higher efficiencies can be obtained. If landscape permits, pressure from piped delivery systems (laterals) may be used to drive sprinkler irrigation systems at efficiency rates far better than those normally obtained by flood systems. The new authorities allow Reclamation much greater flexibility (in both timing and funding) to work with USDA to develop these types of projects.

The new authorities also allow Reclamation to respond to opportunities that are time-sensitive. Cost-sharing partners (State and Federal agencies) often have funds available at very specific times.

Another significant advantage of the program is that projects are "owned" by the proponent, not Reclamation. The proponent is responsible to perform on its proposal. Costs paid by Reclamation are controlled and limited by an agreement. Yet, unforeseen cost overruns can occur. The proponent has several options: the project may be terminated or the proponent may choose to cover the overruns with their own funds or borrow funds from State programs. The proponent may also choose to reformulate the project costs and recompute the project through the entire award process. For example, pipeline bedding and materials costs for the Ferron Project were underestimated in the proposal and subsequent construction cooperative agreement. The proponent was denied

permission to award materials contracts for the pipeline, since the costs were beyond those contained in the agreement. After months of negotiations and analysis, the proponents elected to terminate the project, reformulate it, and re-compete against other proposals the following year. Their project was found to be competitive at the reformulated cost and was allowed to proceed. Since this project ran into difficulties, none of the other projects have shown any problems.

Due to several issues that had arisen in the recent years from managing the Salinity Program, the Upper Colorado Regional Director, Reclamation, requested that an evaluation and review (Review) be completed of the Colorado River Basin Salinity Control Program (Salinity Program) administered by the Upper Colorado Region. A Project Management Plan for the Review was prepared and approved in May 2007, by the Regional Director and the Chairman of the Colorado River Basin Salinity Control Forum Work Group. Initial and Draft Review Documents were prepared during calendar year 2007 by a Project Team, comprised mostly of Reclamation's Salinity Coordinators and provided to the Review Team, comprised of Reclamation staff outside of the Salinity Control Program and members of the Work Group, to review and provide comments. The Final Review Document was prepared during the spring of 2008 and sent to the Review Team and all members of the Work Group, June 27, 2008.

The Review served the following purposes:

1. Documented all existing procedures and policies
2. Sought recommendations to improve the Program, particularly in the areas where issues have arisen recently:
 - a. Reimbursement requirement for operation and maintenance (O&M) for salinity control improvements
 - b. Procedures for determining the tons of salt claimed
 - c. The Request for Proposals (RFP) and agreement processes
 - d. Differing standards and requirements for habitat replacement
 - e. Salinity control improvements on Federal facilities versus non-Federal facilities
 - f. The use of funds from Basin Funds
3. Identified areas where new procedures and policies need to be developed
4. Created a Standard Operation Procedure manual that can serve as guide for the future management and execution of the Program

The Review Document is a living document and will be subject to updating and revisions as the program progresses.

Basinwide Salinity Control Program (Basinwide Program)

In July 1995, Public Law 104-20 was signed into law. It authorizes the Secretary of the Interior to implement a basinwide salinity control program, directs the Secretary of the Interior to prepare a planning report on the new program, and authorized \$75,000,000 to be appropriated. Additional authority was provided in November 2000 which increased the appropriation ceiling to \$175,000,000. With cost sharing from the Upper and Lower Colorado River Basin Funds, the program has authority to expend up to \$250 million

within the Basin. In FY 2007 Reclamation obligated and/or expended approximately \$8.9 million in appropriations and approximately \$3.8 million in up-front cost-sharing from the Basin Funds for a total Basinwide Program of \$12.7 million and \$11.4 million in 2008. Since the authorization of the Basinwide Program in 1996, approximately \$105.6 million in appropriations and approximately \$45.3 million in up-front cost sharing from the Basin Funds have been expended for a total program of \$150.9 million. Through the last Request for Proposals (RFP) process in FY 2006, five new project proposals were selected for funding totaling about \$22 million and the cost effectiveness ranged from \$27 to \$33 per ton of salt. Construction on four of the projects and a project from the previous RFP were completed in FY 2008. The fifth proposal selected in 2006 has encountered problems with increases in pipe prices and was advised to reformulate their proposal and submit it again in the future.

In 2007, it was determined that instead of soliciting proposals through the RFP process, they would be solicited through a process for financial assistance agreements called Funding Opportunity Announcements (FOA). Instead of evaluating the proposals in the Technical Proposal Evaluation Committee (TPEC) process, they would be evaluated in a process common to negotiated procurement procedures where an evaluation committee would be organized that would be chaired by the Program Manager and have representatives from the Work Group and Reclamation area offices. This process would not follow the construction contract procedures and should allow more flexibility in the evaluation and agreement process.

In order to have projects ready to utilize the Basinwide Program funding in 2008 and beyond, an FOA was released in February 2008 soliciting applications to be submitted by May 2008. Twenty-five applications totaling over \$167 million in salinity control projects were received. An Application Evaluation Committee (ARC) was organized that was chaired by the Program Manager and had representatives from the Work Group and Reclamation area offices. The applications were reviewed, evaluated, and ranked by the ARC under the criteria set forth in the FOA. Applications receiving highest rankings within the competitive range of less than \$57 per ton of salt were selected and proposers were notified of the selection and negotiations were begun to execute an agreement. The proposers of the unsuccessful applications were also notified. If agreements are executed for all of the successful applications, \$27 million worth of salinity control projects could be installed over the next 3-4 years.

American Recovery and Reinvestment Act of 2009, P.L. 111-5, (ARRA)

The purposes of the ARRA are, among others, to quickly and prudently commence activities that preserve and create jobs promoting economic recovery and to invest in infrastructure providing long-term economic benefits.

Reclamation's Upper Colorado Region solicited applications for reducing salinity contributions to the Colorado River through a Funding Opportunity Announcement (FOA) announced in the spring of 2009. Applications were evaluated and ranked by an Application Review Committee with representatives from the Colorado River Basin States and Reclamation. Reclamation awarded grants in August 2009 totaling more than \$11.1 million in ARRA funds and \$4.8 million in cost share funds from the Basin Funds

to irrigation companies in Colorado, Utah, and Wyoming. These projects when constructed will help control nearly 12,000 tons of salt loading.

The projects were projected to be completed by September 30, 2010. By the spring of 2010 four of the projects had the majority of the construction completed by the time irrigation water was turned in and the remaining construction was completed by September 30, 2010. However, these four projects requested and were granted additional time to complete habitat replacement measures and other minor tasks and were completed by December 30, 2010. The Cortez, CO area encountered an unusually high snowfall and winter conditions during the winter of 2009 and 2010 and construction of the Lone Pine Project was hindered. The sponsors of the project requested and were granted additional time to complete the construction during the upcoming winter. The project was completed by March 31, 2011.

Parallel Program

Section 205 of the Act authorizes Reclamation to expend amounts from the Basin Funds to repay the Treasury the reimbursable cost allocation of salinity projects or provide a cost share amount. This includes appropriations expended by the NRCS in their salinity program. The NRCS has questioned its ability to accept Basin Funds for cost sharing directly into its salinity program. Rather than repay the Treasury, the Colorado River Basin States (Basin States), NRCS, and Reclamation developed a “Parallel Program” (PP). Cost share funds from the Basin Funds have been used to accelerate and supplement implementation of the NRCS salinity measures by funding – through state agencies in Colorado, Utah, and Wyoming – salinity control measures that are separate, but parallel to, the salinity control measures implemented by the NRCS. Reclamation, with recommendations from the Basin States, had interpreted the Act to allow funds from the Basin Funds to be expended in the PP to further the general purposes of the Act.

To clarify authority for the administration of the PP, the Basin States prepared and put forth legislation through then-Senator Salazar’s office into the 2008 Farm Bill to amend the Act that has now created the Basin States Program (BSP). Public Law 110-246 amended the Act and established the BSP. The BSP is explained in more detail later in the report.

With the creation of the BSP, the PP is in the process of being phased out and all funds not used in the PP will become part of the BSP. As of October 15, 2010, the state agencies are no longer authorized to enter into contracts under the PP. Contracts that the state agencies have executed must have all practices installed, constructed, or implemented by September 30, 2012, in order to receive reimbursement. The state agencies may request reimbursement from Reclamation until December 30, 2012.

New Reclamation Salinity Projects

Gunnison Basin, Colorado

Uncompahgre Valley Water Users Association (UVWUA) Phase 3 Project: In FY 2010, the UVWUA continued construction of Phase 3 of their East Side Laterals (ESL) project which involves the piping of 10.5 miles of laterals under the South and Selig Canal systems and the reduction of about 2,300 tons of salt loading annually. This phase is utilizing \$1.3 million of salinity-control funding as well as funding from the Reclamation's Departmental Irrigation Drainage (selenium) Program. Construction of Phase 3 will be completed in 2011.

UVWUA Phase 4 Project: As a result of the 2008 Basinwide Program FOA, the UVWUA was awarded a cooperative agreement for Phase 4 of the ESL in December 2008. This phase involves an additional 11 miles of laterals under the Selig and East Canal systems and the reduction of about 3,700 tons of salt loading annually. Approximately \$2 million of salinity-control funding will be supplemented with approximately \$800,000 from a Section 319 grant obtained through the Colorado Division of Public Health and Environment. Construction of one short lateral was completed in FY 2009. Additional laterals were completed in FY 2010 and the remaining portions of Phase 4 will be completed in 2012.

Grandview Canal and Irrigation Company Project: Awarded from the 2008 FOA, this project involves piping a portion of the Grandview Canal and several laterals in an area tributary to the North Fork of the Gunnison River near Crawford in Delta County. In July 2009, Reclamation entered into an agreement to provide \$5.3 million to pipe 4.8 miles of main canal and 5 miles of laterals and convert about 900 acres of currently flood-irrigated farmland to sprinkler irrigation. Construction began in September 2010 with completion expected by late 2011. The project is expected to reduce salt loading by 6,400 tons/year.

Grand Valley Unit, Colorado

Grand Valley Irrigation Company (GVIC) Project: As a result of selection under the 2008 Basinwide Program FOA, the GVIC was awarded a \$3 million cooperative agreement to line about 2.9 miles of their main canal within the city of Grand Junction. A salt loading reduction of approximately 4,500 tons annually is expected. The canal lining will consist of a PVC membrane with a shotcrete cover. Construction began in November 2008 and approximately 2.0 miles of canal lining have been completed. The remaining 0.9 miles of canal lining will be completed in 2011. The habitat replacement work was completed this past summer.

San Juan River Basin, New Mexico

San Juan River Demonstration Project: The San Juan River Dineh Water Users, Inc. operates the Hogback and Fruitland irrigation projects located on both sides of the San Juan River near Shiprock, NM. The projects consist of about 50 miles of lined main canals and over 250 miles of unlined laterals that provide water to about 13,000 acres of irrigated land. The average irrigated parcel size is about 13 acres. This \$194,000 demonstration project would replace about a lateral about 7,900 feet long with an

approximately 2 acre settling pond and about 5,000 feet of PVC pipe. The estimated salt savings for this activity is about 199 tons/year and the project will be completed in 2011. The purpose of the demonstration is to determine if the NRCS EQIP can be successfully implemented on the Navajo Reservation. This lateral provides water to about 167 acres of irrigated land consisting of 12 separate parcels. Successful implementation of land leveling and installation of gated pipe would result in an estimated salt savings of 384 tons/year. Combined cost effectiveness of this project is about \$43/ton. The majority of the habitat replacement work was completed in 2010 and construction of the salinity features will begin this fall with completion scheduled later this winter.

Ongoing Reclamation Salinity Control Projects

Big Sandy River Unit

The Big Sandy River Unit is located near Farson and Eden in Sweetwater County in southwestern Wyoming. The purpose of the Big Sandy River Unit investigation was to determine the feasibility of lowering the salt inflow to the Big Sandy River. The study was specifically directed toward reducing salt pickup from seeps and springs along a 26-mile reach of the Big Sandy River west of Eden, Wyoming. Feasibility planning was authorized by the Colorado River Basin Salinity Control Act (Public Law 93-320) of 1974 and the Water Resource Development Feasibility Investigations Act (Public Law 96-375) of October 1980.

Investigations indicate that seeps, which surface in the Bone Draw and Big Bend areas, produce saline water at a rate of about 27 cubic feet per second (ft³/s). The salinity here varies from 1,000 to 6,000 mg/L along the Big Sandy River, with a total annual contribution of more than 164,000 tons of salt. Indications are that salt is picked up by water contacting the shale of the Green River Formation beneath the surface and eventually seeping into the river. Irrigation was identified as a significant contributor to the water source recharging the springs.

Reclamation has studied alternatives to intercept the springs and seeps and then transport, treat and use, or dispose of the saline water. In the irrigated area, off-farm solutions such as selective lining of canals and laterals were studied.

Studies conducted in cooperation with USDA indicated that control of onfarm irrigation is the most cost-effective alternative for controlling salinity from the Big Sandy River Unit. Because of past selective lining programs, the canals and laterals showed relatively low seepage rates, offering little room for improvement.

In 2006 the local water district applied for funding for a new salinity control project. This funding was to be supplemented by the state of WY. In 2006 & 2007 new seepage tests were conducted by Reclamation to determine if the linings on various canals and laterals were still functioning. It appears that at some locations as the canals were cleaned the clay lining was removed and deposited along the bank.

Eden Valley, Farson/Eden Pipeline Project: The Farson/Eden Pipeline Project is located in Sweetwater County, in the vicinity of Farson, Wyoming. It was selected from

the applications received in the 2008 FOA. A Cooperative Agreement was executed in February of 2009 for the amount of \$6,453,072. This project will replace approximately 24 miles of earthen laterals with irrigation pipe resulting in the annual reduction of 6,594 tons of salt in the Colorado River at an anticipated cost of approximately \$52.57 per ton of salt. This project is about half complete and will be completed by 2012.

Lower Gunnison Basin Unit

The Lower Gunnison Basin Unit is located in west-central Colorado in Delta and Montrose Counties. The unit was authorized for investigation by the Colorado River Basin Salinity Control Act (Public Law 93-320) of 1974. An amendment to the act, Public Law 98-569, authorized construction of the unit to begin in 1984.

An estimated 360,000 tons of salt is added to the Colorado River annually from the Uncompaghe Project, a Reclamation irrigation project built in the early 1900's. Studies indicate that salt loading occurs when irrigation conveyance system seepage and irrigation return flows pass through highly saline soils and the underlying Mancos Shale Formation. By reducing the amount of groundwater percolating through these saline soils, salt loading to the Colorado River is being reduced.

With Reclamation funding, the water districts have completed the winter water facilities. Reclamation has completed plans for local improvements to the irrigation delivery systems. USDA is implementing onfarm improvements, including upgrading irrigation systems and improving irrigation management.

The Uncompaghe Project is a Federal development constructed in the early 1900's for irrigation of approximately 86,000 acres. Approximately 34 percent of the total 86,000 irrigated acres are on Mancos-Shale-derived soils. These soils are naturally high in both salt and selenium. Reclamation and USDA have implemented various salinity control measures in the area.

The Salinity Control Act authorizes the construction of winter water replacement facilities in the Uncompaghe River Valley and irrigation delivery system improvements on the more saline, east side of the valley. The plan of development includes the winter water replacement and lateral lining programs. Although authorized for construction, the canal lining has not been competitive with other, lower cost alternatives within the Salinity Control Program. The canal lining construction program remains in a deferred status.

The objective of the winter water replacement program is to eliminate winter livestock watering from the unlined canal and lateral system. Water is made available for livestock through an expansion of the existing culinary water system using relatively small, 2- to 6-inch polyvinyl chloride pipe. This modification reduces canal seepage during the non-irrigation season, reducing salinity from the system by about 50 percent. Work on this portion of the unit was completed in 1995.

The remaining portion of the project, the East Side Lateral portion, will compete for funding in Reclamation's Basinwide Salinity Control Program under the authorities of Public Law 104-20. In FY 1998, Reclamation solicited proposals for salinity control efforts under its basinwide authorities. The Uncompaghe Valley Water Users Association (UVWUA) submitted a proposal for a project which would cost share

salinity control activities with the Department of the Interior's National Irrigation Water Quality Program (NIWQP). Cost sharing from the NIWQP enabled this project to be competitive with other projects. The project was recommended for implementation by Reclamation's salinity control evaluation committee. The project reduces salinity in the Colorado River by about 2,300 tons of salt per year. The Salinity Control Program has contributed \$890,000. The NIWQP has contributed \$730,000. Environmental compliance for this project was completed in 1995 as part of Reclamation's Lower Gunnison Basin Unit, Environmental Assessment/Finding of No Significant Impact. The UVWUA has replaced approximately 7.5 miles of unlined earthen irrigation laterals with buried pipe in the Uncompaghre Project's South Canal system. Construction of this portion of the project was completed in 2000. A report titled *Effects of Piping Irrigation Laterals on Selenium and Salt Loads, Montrose Arroyo, Western Colorado*, WRI Report 01-4204 by the USGS shows the project reducing both salinity and selenium. It is anticipated that in the future more joint projects will be pursued between the two programs.

Lower Gunnison Basin Unit, Colorado

In FY 2007, the Uncompaghre Valley Water Users Association continued with Phase 2 of the East Side Laterals piping project in the Cedar Creek area, southeast of Montrose. The current effort, which began in FY 2005, is piping a total of 20.5 miles of laterals under the South Canal system using \$2.1 million of Basinwide Salinity Program funding supplemented by \$2.2 million of Departmental Irrigation Drainage Program (DIDP) funding for selenium remediation. Phase 2 was completed in 2009.

Phase 3 involves the piping of another 11 miles of laterals. This phase has salinity-control funding as well as funding from DIDP and also from an EPA Section 319 grant. Construction of Phase 3 began in November 2007 and is scheduled for completion by the end of 2011.

Mancos Valley Unit

The Mancos Valley Unit is a 9,200-acre-irrigated area along the Mancos River, a tributary to the San Juan River. The area is very saline (Mancos shale) and should respond well to joint Reclamation/USDA irrigation efficiency improvements similar to those being implemented in Utah. Planning studies of this unit, which began in 2002, continue.

Paradox Valley Unit

The Paradox Valley Unit was authorized for investigation and construction by the Salinity Control Act (Public Law 93-320) of 1974. The unit is located in southwestern Colorado along the Dolores River in the Paradox Valley, formed by a collapsed salt dome (Figure 15). Groundwater in the valley comes into contact with the top of the salt formation where it becomes nearly saturated with sodium chloride. Salinities have been measured in excess of 250,000 mg/L, by far the most concentrated source of salt in the Colorado River Basin. Groundwater then surfaces in the Dolores River. Studies conducted by Reclamation show that without salinity controls the river would pick up more than 205,000 tons of salt annually as it passes through the Paradox Valley. This project intercepts the high saline water (brine), before it reaches the Dolores River, and disposes of it by deep well injection (injection interval about 14,000 feet below ground surface) (Figure 16).

In its definite plan report (September 1978), Reclamation recommended that a series of wells be drilled on both sides of the Dolores River to intercept the brine before it reached the river. The brine would then be pumped to an evaporation pond in Dry Creek Basin. A draft environmental statement was prepared for this plan and made public on May 11, 1978; a final statement was filed with EPA on March 20, 1979. Due to the potential for environmental impacts, EPA recommended that Reclamation investigate deep-well injection as an alternative method of disposal.

A private consulting firm completed a feasibility study of deep-well injection and concluded it to be technically, economically, and environmentally feasible. Reclamation then contracted with a second consulting firm to do a more detailed study of injection and to design the disposal system including injection well and surface facilities. A final design for the test injection well was completed in August 1985.

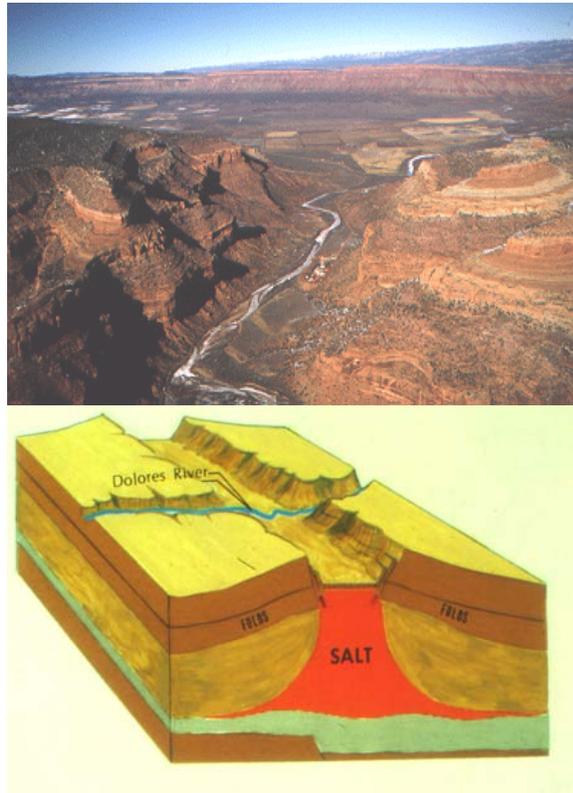


Figure 15 - Paradox Valley.

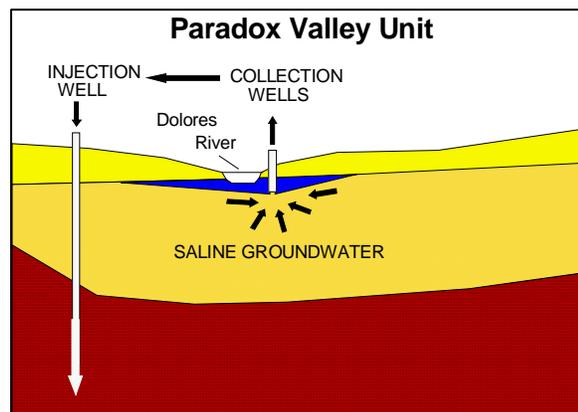


Figure 16 - Schematic of Paradox Project.

Facilities have been installed and mechanical tests performed. Over the years numerous mechanical and electrical problems with the facilities have been identified and solved. Several new technologies were developed to overcome the extremely high pressures created by the injection pumps. In fiscal year 2000, the Paradox Valley Seismic Network (PVSN) showed seismic activity at the injection site reached levels and frequencies that were unacceptably high. Restricting the maximum injection rate to 230 gpm in July 2000 has reduced seismic activity, but has also reduced the effectiveness of the injection facility to about 76,000 tons per year.

In January 2002, a test to inject 100 percent brine was implemented after temperature logs of the well showed that the area around the well bore and injection zone had cooled sufficiently to prevent precipitation problems near the well bore. Since January, facility disposal has increased by approximately 35,000 tons per year and there is no indication of apparent adverse effects from 100 percent brine injection. Reclamation will continue to carefully monitor injection pressures for buildups that might suggest plugging of the aquifer near the well bore. Seismic activity remained low during fiscal year 2002 and remains at a very low frequency and magnitude. Table 9 lists the number of seismic events measured on the Paradox Valley Seismic Network from 1998-2010 and the pressure and tons of salt injected.

The project continues to intercept and dispose of 100,000+ tons of salt annually, but the pressure necessary to inject the brine into the disposal formation at 14,000 feet is increasing. Modification of the current facility to operate at a higher injection pressure to extend the life of the current injection well is under way. Reclamation has also initiated a Plan of Study to investigate the feasibility of other salt removal alternatives to augment the project, including a second injection well. As part of the Plan of Study, an investigation of alternative salinity control methods was completed in June in 2008. The results of the investigation indicated a need for a current characterization of the regional groundwater flow to determine the appropriate strategy for future salinity control efforts. The groundwater study started in 2009 and is ongoing.

This project intercepts extremely saline brine (260,000 mg/l total dissolved solids) before it reaches the Dolores River and disposes of the brine by deep well injection (injection interval about 14,000 feet below ground surface). Seismicity associated with the injection process has diminished since the injection rate reduction in FY 2000 and remains at a low frequency and magnitude.

The project continues to intercept and dispose of 100,000+ tons of salt annually, but the pressure necessary to inject the brine into the disposal formation at 14,000 feet is increasing. Modification of the facility to operate at a higher injection pressure to extend the life of the current injection well was completed in 2009. Reclamation has initiated a Plan of Study to investigate the feasibility of other salt reduction alternatives to augment the project, including a second injection well. As part of the Plan of Study, an investigation of alternative salinity control methods was completed in June, 2008. The results of the investigation indicated a need for a current characterization of the regional groundwater flow to determine the appropriate strategy for future salinity control efforts. An interagency agreement was initiated with the USGS to conduct a hydro geologic study, and investigations for Phase I of the study began in the second quarter of FY 2009. Phase I was essentially completed in the third quarter of FY 2010, resulting in a

Table 9 - Paradox Well Injection Evaluation

Injection Period	Operational Days ¹	Pressure Start	Pressure End	Pressure Increase	Tons of Salt Injected ²	No. of Induced Seismic Events	Maximum Magnitude of Induced Seismic Events	Estimated Tons of Salt Entering the River ³
Jan-May '02 ⁴	148	1609	4432	2823	52,860	25	2.9	8,877
June-Dec '02 ⁵	178	929	4593	3664	58,953	34	2.2	9,801
Jan-May '03 ⁵	144	1172	4627	3455	53,173	27	2.1	18,077
June-Dec '03 ⁵	184	1154	4675	3521	59,530	106	2.3	11,055
Jan-May '04 ⁶	140	1201	4640	3439	51,449	47	2.4	19,484
June-Dec '04 ⁷	160	1091	4541	3450	51,589	57	3.9	6,515
Jan-May '05 ⁵	140	1038	4736	3698	55,024	69	2.4	12,571
June-Dec '05 ⁸	148	1203	4750	3547	46,551	31	2.6	38,163
Jan-June '06 ⁹	138	375	4680	4305	44,779	10 ¹⁰	2.4	50,148
July-Dec '06 ⁵	162	1084	4797	3713	56,920	13 ¹⁰	2.1	21,625
Jan-June '07 ⁵	159	1066	4796	3730	56,068	7 ¹⁰	1.1	18,777
July-Dec '07 ⁵	163	1232	4712	3480	57,395	31	2.6	10,571
Jan-June '08 ¹²	160	1152	4813	3661	54,720	47	1.3	14,933
July-Dec '08 ⁵	162	1263	4822	3559	56,734	61	2.1	15,874
*Jan-Mar '09 ⁵	84	1246	4756	3510	29,163	20	2.6	20,716
Apr-Sept '09 ¹³	160	1157	4891	3734	55,083	70	2.7	17,611
Oct '09-Mar '10 ⁵	153	970	4930	3960	51,589	91	2.9	32,260
Apr '10-Sep '10 ⁵	162	1347	4990	3643	55,747	75	2.7	14,364

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1. Operational days include partial days of operation which accounts for variations in tons of salt injected
 2. Tons of salt injected based on 260,000 mg/L. Brine concentration varies slightly due to seasonal and environmental fluctuations
 3. Tons of salt entering the river based on regression equations (Ken Watts, USGS Administrative Report – “Estimates of Dissolved Solids Load of the Dolores River in Paradox Valley, Montrose County, CO, 1988-2009, August 5, 2010”)
 4. Begin 100% brine injection
 5. No problems
 6. Down from 3/1/04 through 3/7/04 for mechanical problems
 7. Implemented quarterly 10-day shutdown schedule from 9/22 to 10/22; M3.9 earthquake on 11/7; plant shut down until 11/18; discontinued 10-day shutdown schedule
 8. Down from 11/13/05 through 12/31/05 for mechanical problems
 9. Down from 1/1/06 through 1/19/06 and 2/16/06 through 3/2/06 for mechanical problems
 10. Seismic data for 2006 and the first half of 2007 is likely incomplete due to seismic network problems
 11. Down from 4/16-17/08 for mechanical problems
 12. Down from 5/18-19/09 for mechanical problems

* Biannual shutdown schedule changed from winter/summer to spring/fall

preliminary conceptual flow model of groundwater flow in the stream-aquifer system in the Paradox Valley. The preliminary conceptual flow model indicates that alternatives to reduce the amount of brine being produced, identified in the 2008 investigation, may not be feasible. Some additional work is necessary to verify the results of Phase I. If the Phase I results are verified, Phase II of the study may not be implemented.

Price-San Rafael Rivers Unit

Huntington Cleveland Irrigation Company (HCIC) Project: The Project is located in northern Emery County, in and around the towns of Huntington, Lawrence, Cleveland, and Elmo. The Project was selected in the 2004 Request for Proposals (RFP) and awarded a cooperative agreement in September 2004. A new cooperative agreement was executed in November 2006 and was



Figure 17 - Salinity from Canal Seepage.

modified again in September 2009. Approximately 350 miles of open earthen canals and laterals are being replaced with a pressurized pipeline distribution system (Distribution System) to accommodate sprinkler irrigation on about 16,000 acres. Funding for this project is being shared between Reclamation's Basinwide Program, HCIC, NRCS's EQIP, the Parallel Program, and Rocky Mountain Power, formally known as Utah Power and Light. The last of Reclamation's share of \$17.1 million for the Off-farm Distribution System was obligated in 2008. Reclamation can provide up to an additional \$6.0 million in funding equally 50/50 with HCIC funds for completion of the Distribution System.

Since 2009 Reclamation has provided about \$2.0 million in additional funding. The Project, scheduled to be completed in 2012, will result in the annual reduction of 59,000 reportable tons of salt in the Colorado River at an anticipated cost of approximately less than \$100/ton. Of the 59,000 tons of salt, 13,000 are attributed to the Off-Farm



Figure 18 - Price-San Rafael Irrigation Improvements.

Distribution System and 46,000 tons are attributed to the On-Farm Distribution System and the on-farm salinity control measures (sprinklers).

Cottonwood Creek Irrigation Improvement Project: The \$6.5 million Cottonwood Creek Irrigation Improvement Project is located in Emery County, west of Castledale, Utah. It was selected from the applications received in the 2008 FOA. A Cooperative Agreement was executed in February 2010. Construction is expected to begin late in 2010. This project will replace approximately 31 miles of earthen canals and laterals with a pressurized pipeline system resulting in a reduction of 2,094 tons of salt in the Colorado River. It is expected that the pressurized pipeline will induce on-farm improvements resulting in the annual reduction of an additional 9,100 tons of salt. It is anticipated that the project will result in the total annual measurable reduction of 11,194 tons of salt in the Colorado River at an anticipated cost of approximately \$59 per ton of salt.

Uinta Basin Unit

The Uinta Basin Unit is located in northeastern Utah. The area includes portions of Duchesne and Uinta Counties and is situated between the Uinta Mountains on the north and the Tavaputs Plateau on the south. The principal communities within the area are Duchesne, Roosevelt, and Vernal.



Figure 19 - Salinity in Uinta Basin Unit Area.

Reclamation has conducted extensive studies in the area. Most of the salt pickup from the unit area is from the dissolution of salts from the soil and subsurface materials, principally from soils of marine origin that underlie most of the Uinta Basin. Seepage from conveyance systems and deep percolation resulting from irrigation are the primary processes that dissolve salts from the soils and shale and convey the salts through the groundwater system to natural drainages and ultimately to the Colorado River. The Uinta Basin contributes an estimated 450,000 tons of salt per year to the Colorado River.

Reclamation has a total of 14 projects in the Uinta Basin Unit area. The projects are funded jointly by Reclamation's Basinwide Program and cost sharing from the Basin States. The water conservation based projects include the Burns Bench, BIA-Ute Tribe, Duchesne County, Farnsworth, Lower Brush Creek, Western Uintah, South Lateral, River Canal, Union Canal, Hicken, Dry Gulch Class E, Dry Gulch Class C, Ouray Park, and Duchesne Water Conservancy District projects. These projects will reduce salinity by improving the efficiency of existing irrigation projects. Several will pipe selected canals and laterals to gain pressure to run high-efficiency sprinkler irrigation systems.

Verification Studies - In their “National Water Summary 1990-91, Water Supply Paper 2400”, the USGS reported a downward trend in dissolved solids concentration (salinity) in the Duchesne River, immediately downstream of the project area. They pointed out that much of the base flow of the river was from irrigation return flows. Salinity discharge has dropped from 206,000 tons in 1981 when USDA first started irrigation improvements to 169,000 tons in 1993 - a 37,000-ton reduction. Based on the amount of irrigation improvements installed, USDA estimates that irrigation improvements through 1992 have reduced the salinity discharge by about 55,500 tons per year (*1993 Joint Evaluation Report*). Recent studies have also shown a downward shift in the salt/flow relationship (for a given flow, salinity is lower). These data support the theory that onfarm irrigation practices can be effective at reducing salt loading. Monitoring and analysis will continue.

Uinta Basin Unit, Utah

The Duchesne County II Salinity Reduction Project is located in Duchesne County, in and around Roosevelt, Utah. A total of 51.9 canal miles serving 13,350 acres is being replaced to accommodate pressurized pipeline systems, in order to facilitate sprinkler irrigation. The K2 and Pleasant Valley phases of the project are completed, but land easements from the Business Committee of the Ute Tribe of the Uintah and Ouray Agency need to be obtained in order to complete the last and final phase (TN Dodd) of the project. It is anticipated that the off-farm portion of this project will result in the annual reduction of 42,800 tons of salt in the Colorado River at \$25 per ton of salt.

The Moffat-Ouray Pipeline Salinity Project near Gusher, Utah was completed in 2008. This project replaces approximately 30.2 miles of canals with pipelines and 15,900 tons of salt will be reduced annually to the Colorado River at a cost of \$28 per ton. The abandoned canals have been replaced by pipelines which provide a pressurized irrigation system.

Colorado River Basin Salinity Control Program Summary Data

Table 10 – Summary of Federal Salinity Control Programs (2010)

Salinity Unit		Tons / Year Removed
MEASURES IN PLACE BY RECLAMATION		
Basinwide Program		176,000
Basin States Program	1/	7,000
Meeker Dome		48,000
Las Vegas Wash Pitman		4,000
Grand Valley		122,000
Paradox Valley	2/	113,000
Lower Gunnison Winter Water (USBR)		41,000
Dolores		23,000
Reclamation Subtotal		534,000

MEASURES IN PLACE BY USDA/BSP	3/	
Grand Valley		144,000
Price-San Rafael		76,000
Uinta Basin		149,000
Big Sandy River		57,000
Lower Gunnison		106,000
McElmo Creek		26,000
Mancos		4,000
Muddy Creek		0
Manila		7,000
Silt		4,000
Green River		0
USDA/BSP Subtotal		573,000
MEASURES IN PLACE BY BLM		
Nonpoint Sources	4/	85,000
Well-Plugging		15,000
BLM Subtotal		100,000
Measures in Place Total		1,207,000
GOALS TO REACH TARGET		
Reclamation Basinwide Program		368,000
Price-San Rafael (USDA/BSP)		71,000
Grand Valley (USDA/BSP)	5/	0
Uinta Basin (USDA/BSP)	6/	11,000
Big Sandy River (USDA/BSP)		27,000
Lower Gunnison (USDA/BSP)		80,000
McElmo Creek (USDA/BSP)		20,000
Mancos River (USDA/BSP)		8,000
Muddy Creek (USDA/BSP)		12,000
Manila (USDA/BSP)		10,000
Silt (USDA/BSP)	5/	0
Green River (USDA/BSP)		7,000
Tier 2 (USDA)	7/	20,000
New Well Plugging and Nonpoint Source (BLM)		10,000
Goals Subtotal		644,000
Target Total		1,851,000
<p>1/ Off-farm projects funded by Basin States Program</p> <p>2/ Paradox injection well capacity estimated to decline beginning in 2020; assumed continuation of well or alternative control methods after 2020</p> <p>3/ May include off-farm controls that were not goaled.</p> <p>4/ BLM Non-point source are estimates.</p> <p>5/ Original goal attained</p> <p>6/ Estimated Original goal attained.</p> <p>7/ Potential new measures in areas outside approved projects</p>		

Table 11 – Summary of Colorado River Basin Salinity Control Program
Funding for Federal Agencies (In 1,000 Dollars)

Federal Fiscal Year	Bureau of Reclamation	USDA - NRCS	Upfront Cost Sharing from Basin Funds¹	Bureau of Land Management²	Total
1988	20,783	3,804		500	25,087
1989	16,798	5,452		500	22,750
1990	14,185	10,341		700	25,226
1991	24,984	14,783		873	40,640
1992	34,566	14,783		873	50,222
1993	33,817	13,783		866	48,466
1994	32,962	13,783		800	47,545
1995	13,622	4,500		800	18,922
1996	17,420	9,561	0	800	27,781
1997	3,464	3,100	4,197	800	11,561
1998	12,306	2,894	5,749	800	21,749
1999	15,651	4,016	7,432	800	30,948
2000	16,637	3,805	16,372	800	37,614
2001	14,136	5,785	1,100	800	21,821
2002	14,944	10,451	8,196	800	34,391
2003	11,315	12,714	11,845	800	36,674
2004	12,409	19,488	13,064	800	45,761
2005	11,301	19,798	8,523	800	40,422
2006	11,953	19,661	14,465	751	46,830
2007	12,223	19,667	14,685	800	47,375
2008	11,630	17,611	12,184	800	42,225
2009	21,363	18,551	16,601	800	57,315
2010	12,015	14,697	7,405	800	34,917

1. Prior to 1996 Basin Funds were used to repay the reimbursable portion of Reclamation's Salinity Control Projects within a fifty-year period or within a period equal to the estimated life of the project, whichever is less.

2. Funds expended by BLM for salinity control cannot accurately be determined. This amount reflects what has been reported as having been designated within the BLM budget.

Table 12 – Reclamation Salinity Control Unit Summary (P.L. 93-320 and 98-569)

Unit/Study	Implementation	Controls (tons/y)	Reclamation Capital Cost	Annual O&M Costs	Cost per Ton ¹
Meeker Dome	1980-1983	48,000	\$3,100,000	\$0	\$5
Las Vegas Wash	1978-1985	3,800	\$1,757,000	\$0	\$28
Grand Valley	1980-1998	127,500	\$160,900,000	\$1,417,000	\$83
Paradox Valley	1988-1996	110,000	\$66,199,000	\$2,497,000	\$60
Dolores Project	1990-1996	23,000	\$44,700,000	\$613,000	\$185
Lower Gunnison	1991-1995	41,380	\$24,000,000	\$0	\$35
Total		353,680	\$300,656,000	\$4,016,000	\$66

1. Cost per ton based on amortization over 50 years at the project authorized interest rate.

Table 13 - UCRB Agriculture Salinity Control Summary (tons) - 2010

Project Area	Total Salt Load	Total Ag. Load	Total Controls	Remaining Ag. Load
Big Sandy	157,500	124,900	68,357	56,543
Grand Valley	580,000	559,100	270,641	288,459
Green River	15,700	15,700	0	15,700
Lower Gunnison	1,440,000	840,000	166,701	673,299
Mancos	43,000	26,000	4,045	21,955
Manila	49,000	40,000	12,640	27,360
McElmo	164,075	99,960	49,815	50,145
Muddy Creek	90,000	14,980	0	14,980
Price-San Rafael	430,000	244,000	126,354	117,646
Rifle - Silt	NA	24,700	4,038	20,662
San Juan ¹	NA	62,530	48,329	14,201
Uinta	500,000	328,120	178,938	149,182
Paria (Tropic) ^{1,2}	NA	1,829	1,829	0
Total	3,469,275	2,381,819	931,687	1,450,132

1. Off-farm load shown only. On-farm loads have not been estimated for the San Juan and Paria areas
2. Agricultural load for Paria only represents the conveyance systems which were piped as part of the Tropic Project

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APPENDIX A – SALINITY DATA

The historical flow and quality of water data have been calculated using the U.S. Geological Survey (USGS) database and computer techniques developed jointly by the Bureau of Reclamation (Reclamation) and USGS. The purpose of the analysis was to develop a consistent, documented methodology for the calculation of monthly salt loads in the Colorado River Basin.

The salinity computation method was originally developed for the trend studies conducted by Reclamation and USGS (Liebermann, et al., 1986). Several procedures were evaluated. A 3 year moving regression was determined to be the best overall method in terms of providing the most complete record, preserving short-term fluctuations, and being insensitive to minor errors in the data. Using this method, daily salt load (L) was computed from discharge (Q) and when available, conductivity (S): $L = aQ^bS^c$. For days without specific conductivity data, a slight variation of the equation for load as a function of discharge was used: $L = a'Q^{b'}$.

The coefficients a, b, and c for each year of record were typically estimated by regression analysis using data from a 3 year period surrounding the year of interest. For example, coefficients for 1990 were derived with data from 1989 through 1991. The last year of salinity data computed for this report uses two years of data for obvious reasons. It is subject to change and will be updated in the next report as data become available to complete the analysis for that year.

Daily loads were added to yield the monthly values given. Monthly values were then added to yield annual values. All values shown are rounded but were computed using unrounded values.

For this analysis, salt-load data were based on total dissolved solids (TDS) as the sum of constituents, whenever possible. Sum of constituents was defined to include calcium, magnesium, sodium, chloride, sulfate, a measure of the carbonate equivalent of alkalinity and, if measured, silica and potassium. If a sum-of-constituents value could not be computed, TDS as residue on evaporation (at 180 degrees Celsius) was substituted.

Extensive error analyses were performed on the data. Suspect values were corrected according to published records or deleted. The resultant data set is considered by Reclamation and USGS to be the best available for stations in the Colorado River Basin. Annual values based on the new method were compared to values in previous Quality of Water Colorado River Basin Progress Reports for selected stations. The observed differences were between plus or minus five percent, with mean differences approximately zero. Changes in the progress report database can, therefore, be considered generally insignificant and unbiased.

MONITORING STATIONS

- 1 Green River near Green River, WY
- 2 Green River near Greendale, UT
- 3 Yampa River near Maybell, CO
- 4 Duchesne River near Randlett, UT
- 5 White River near Watson, UT
- 6 Green River near Green River, UT
- 7 San Rafael River nr Green River, UT
- 8 Colorado River nr Glenwood Springs, CO
- 9 Colorado River near Cameo, CO
- 10 Gunnison River near Grand Jct, CO
- 11 Dolores River near Cisco, UT
- 12 Colorado River near Cisco, UT
- 13 San Juan River near Archuleta, NM
- 14 San Juan River near Bluff, UT
- 15 Colorado River at Lees Ferry, AZ
- 16 Colorado River near Grand Canyon, AZ
- 17 Virgin River at Littlefield, AZ

Numeric Criteria Stations:

- 18 Colorado River below Hoover Dam
- 19 Colorado River below Parker Dam
- 20 Colorado River at Imperial Dam

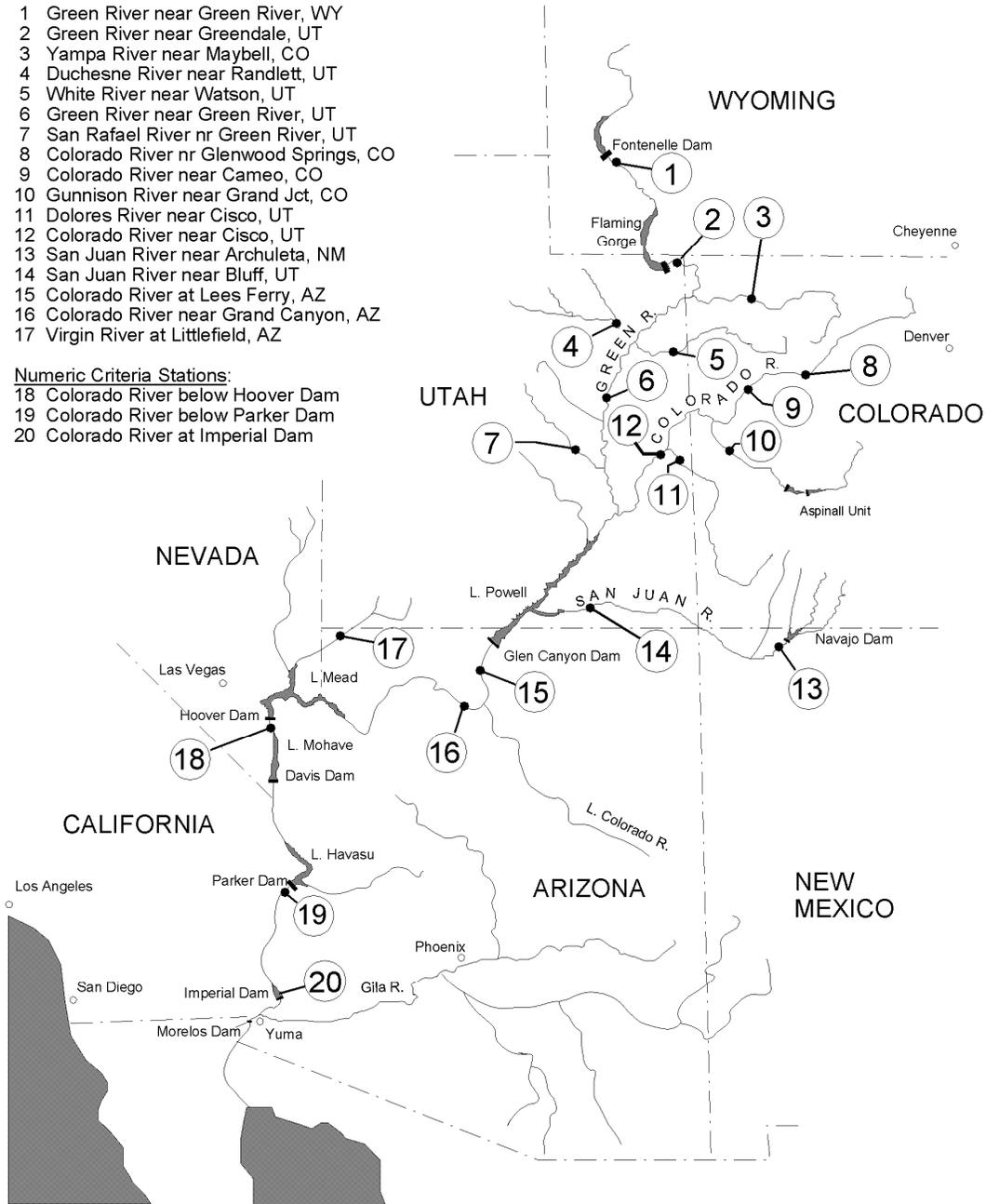
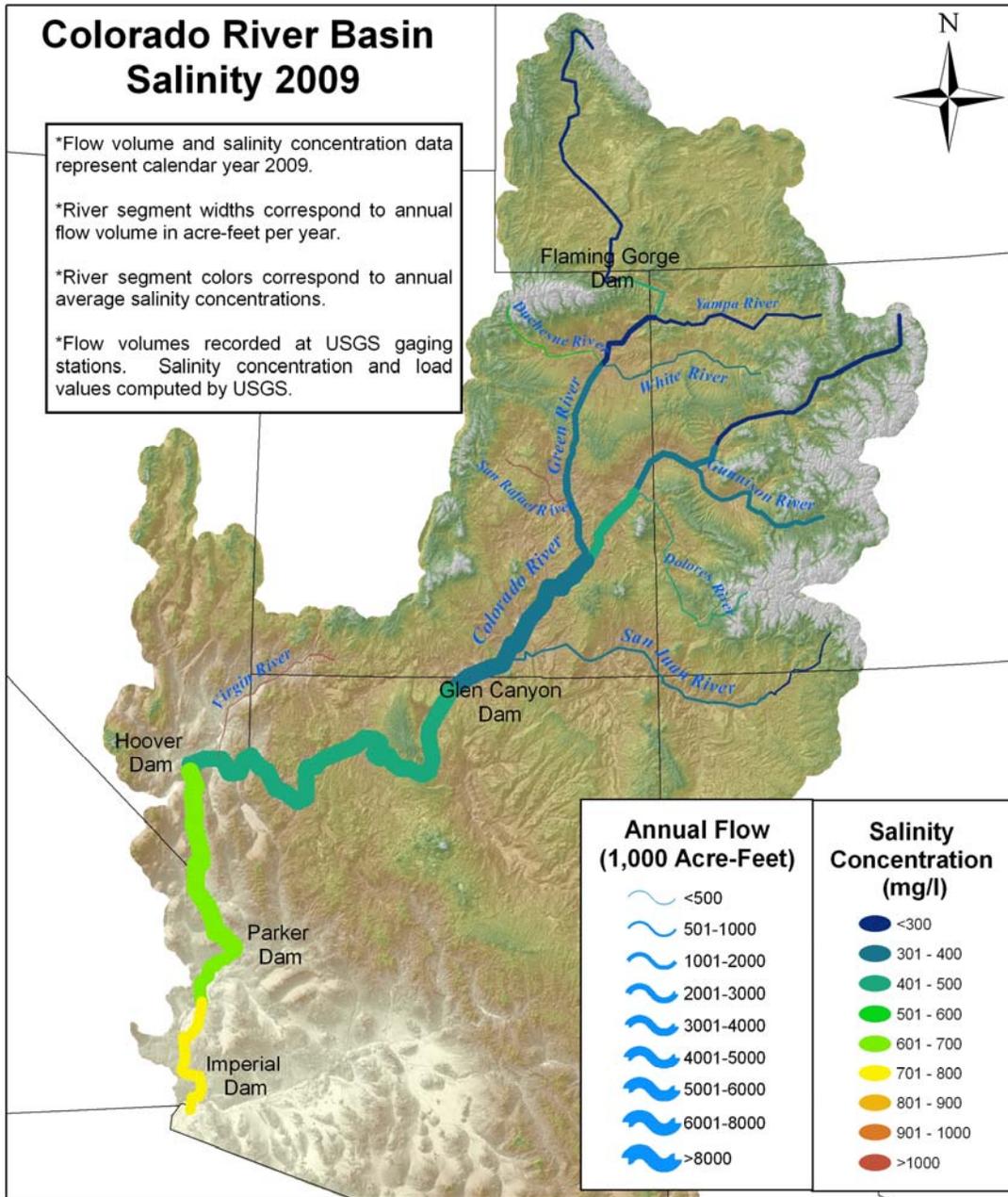


Figure A1 - Colorado River Water Quality Monitoring Stations.



RECLAMATION

Managing Water in the West

Figure A2 – Colorado River Flow and Salinity

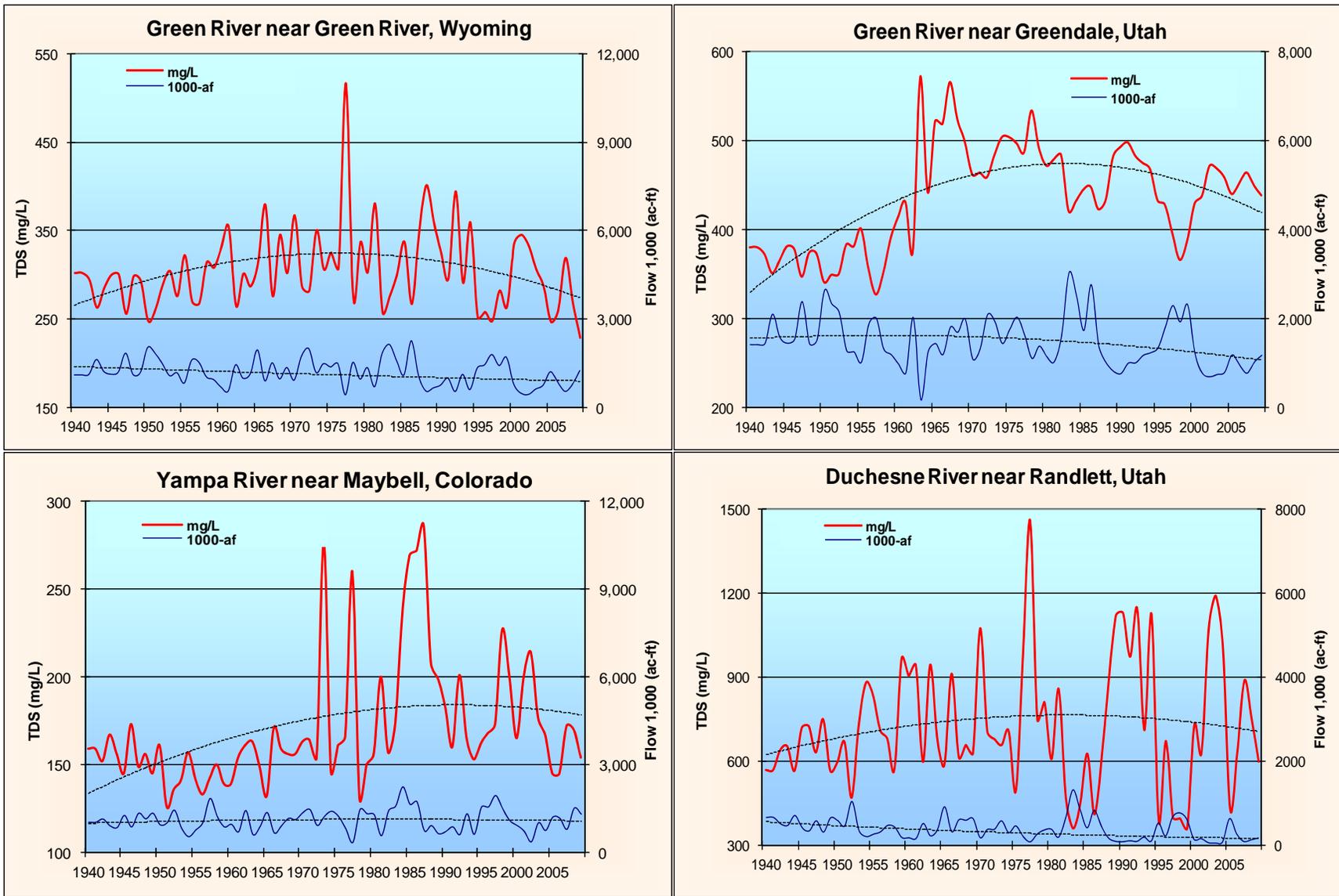


Figure A3 – Flow and TDS over time for sites 1-4. Site locations shown in Figure A1.

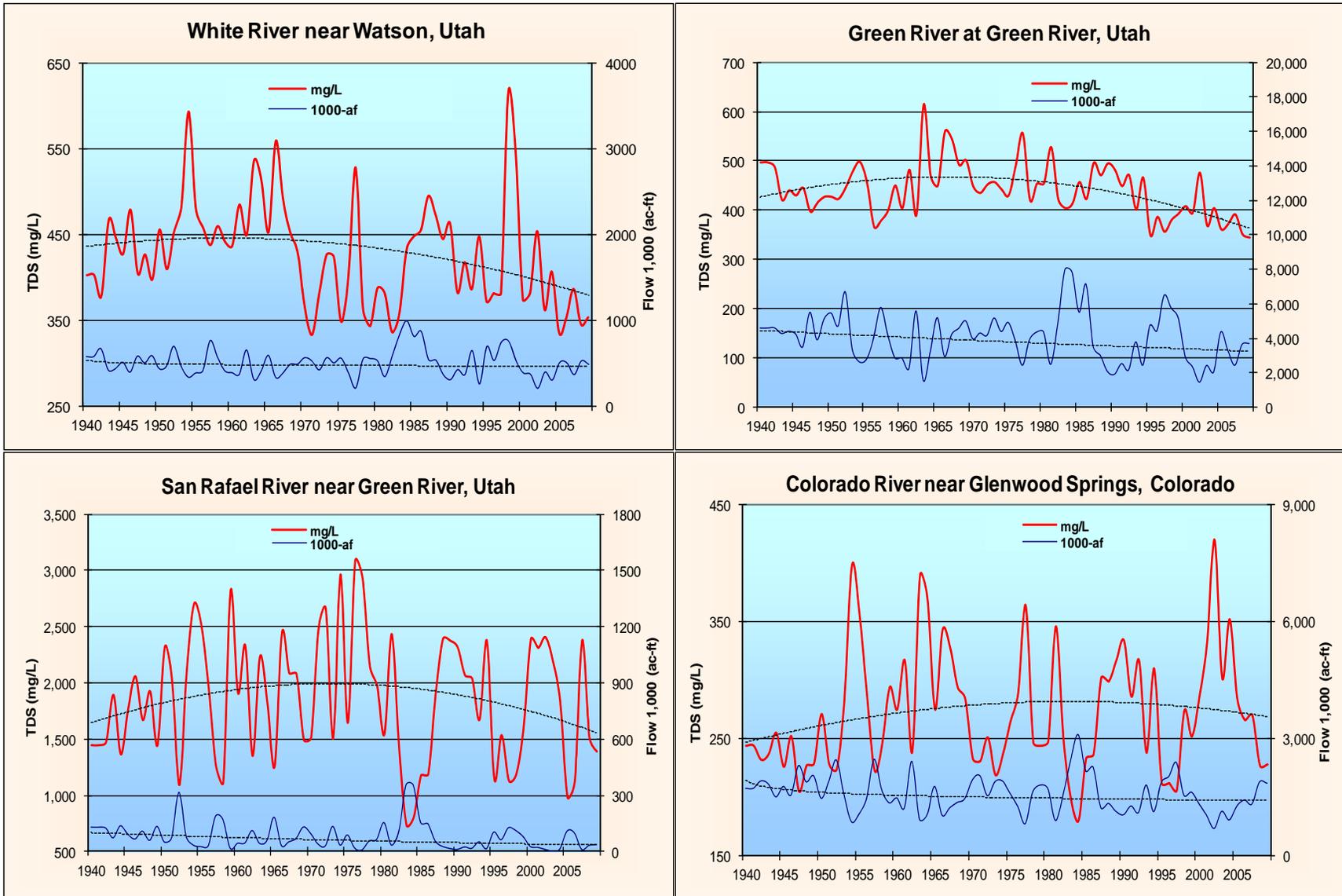


Figure A4 - Flow and TDS over time for sites 5-8. Site locations shown in Figure A1.

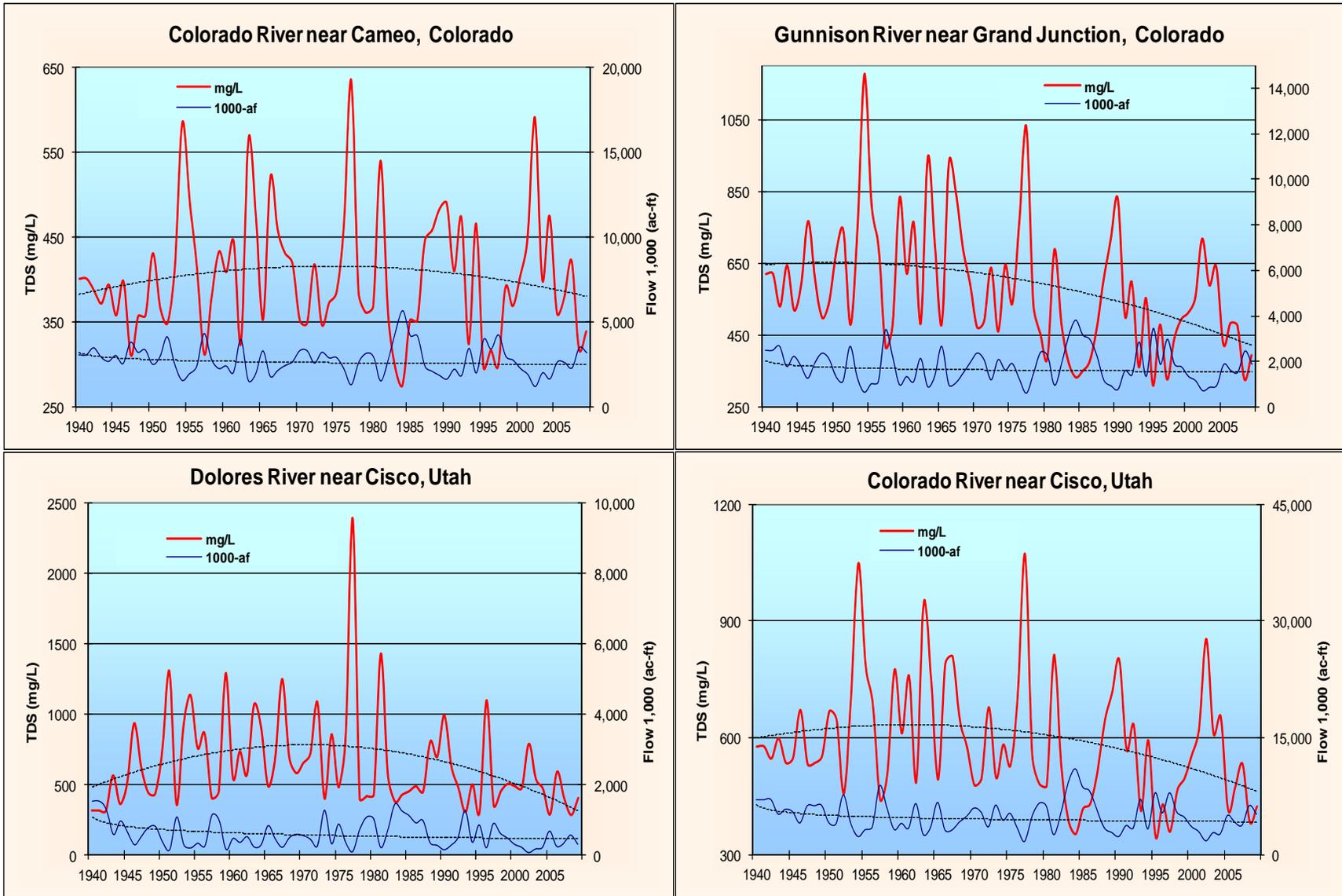


Figure A5 - Flow and TDS over time for sites 9-12. Site locations shown in Figure A1.

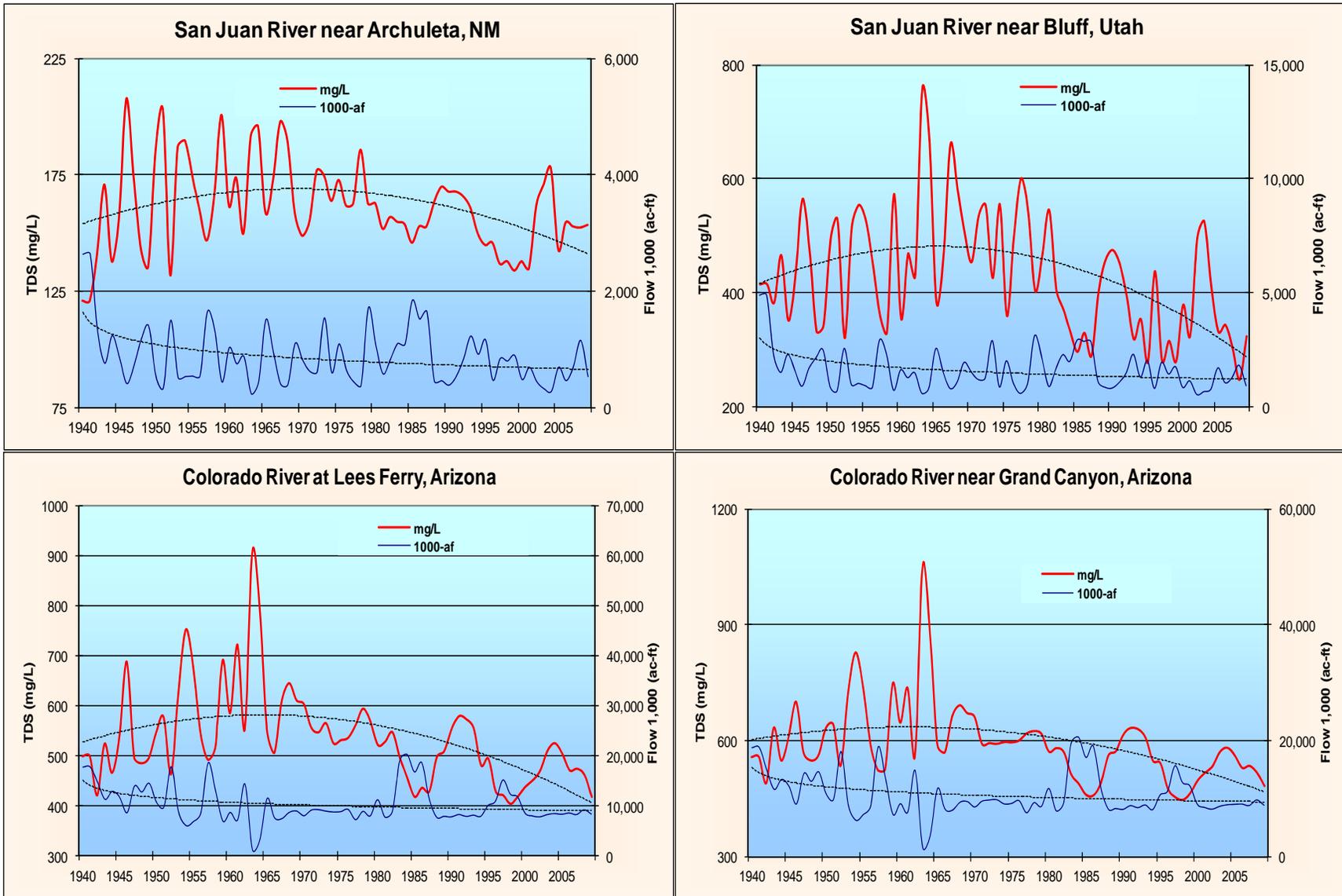


Figure A6 - Flow and TDS over time for sites 13-16. Site locations shown in Figure A1.

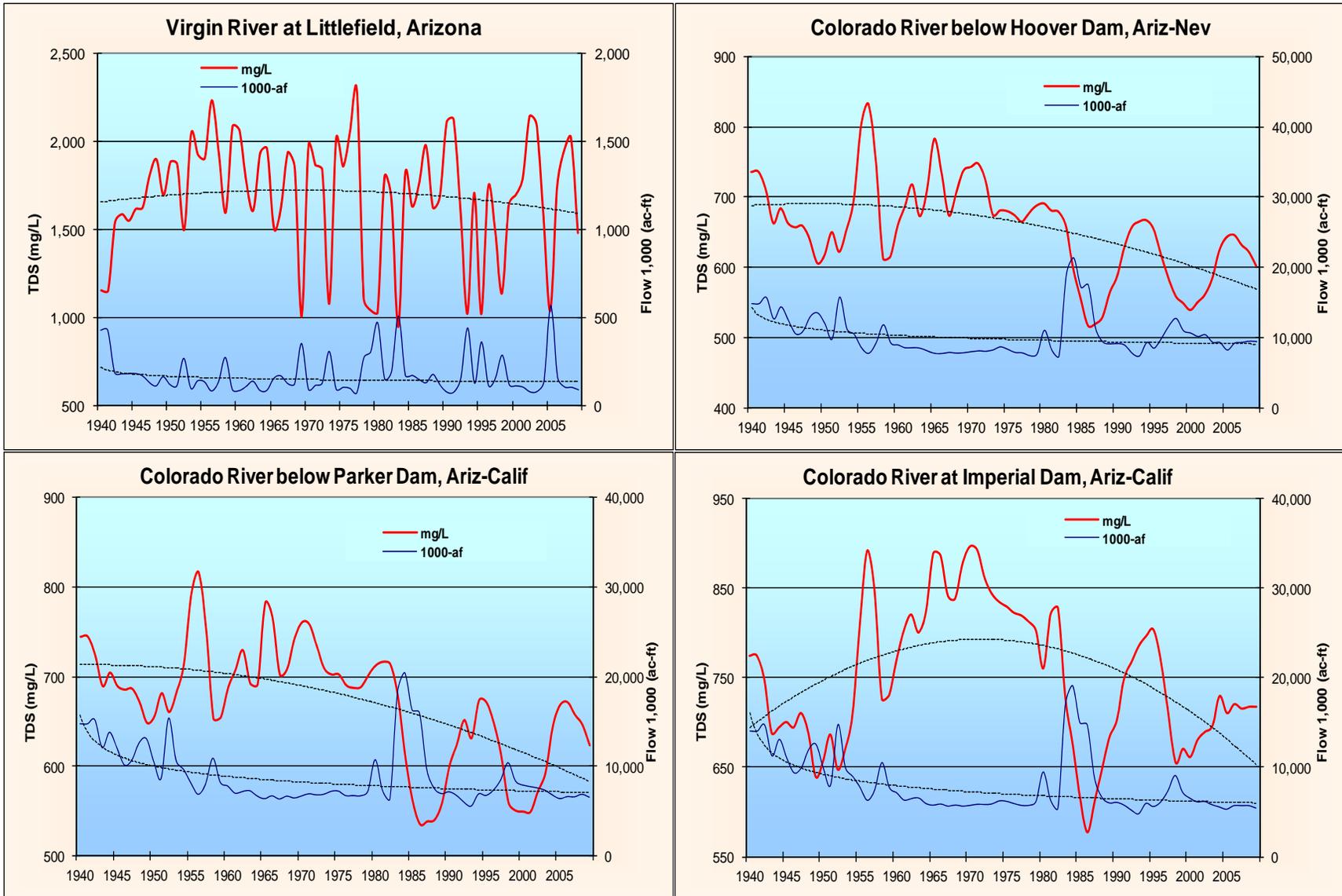


Figure A7 - Flow and TDS over time for sites 17-20. Site locations shown in Figure A1.