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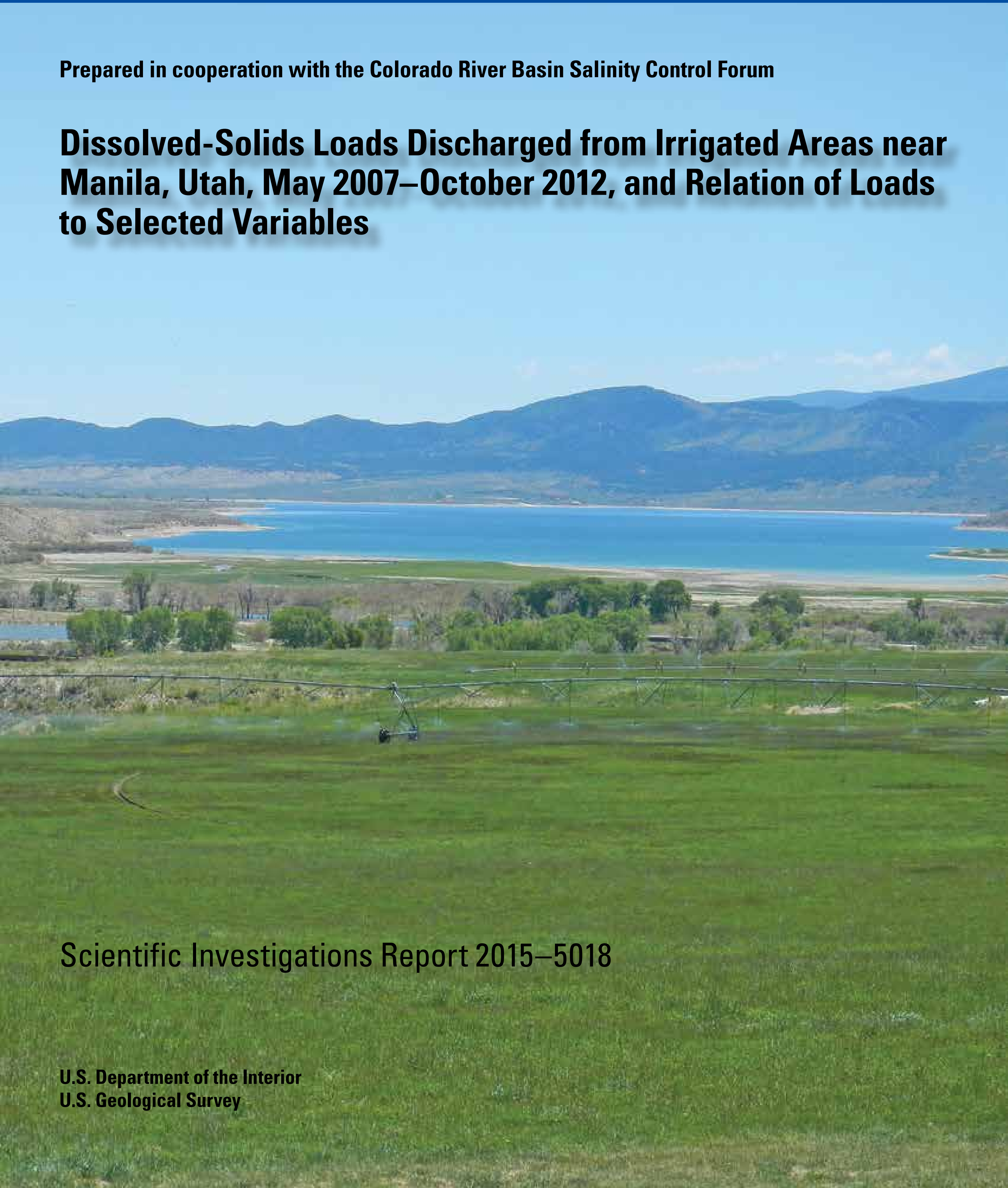
Dissolved-Solids Loads Discharged from Irrigated Areas near Manila, Utah, May 2007–October 2012, and Relation of Loads to Selected Variables



Scientific Investigations Report 2015–5018

U.S. Department of the Interior
U.S. Geological Survey

Cover photograph: View from Lucerne Valley, Utah/Wyoming, with Flaming Gorge Reservoir to the southeast, June 2013. Photograph by Susan Thiros, U.S. Geological Survey.

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SALLY JEWELL, Secretary

U.S. Geological Survey
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Conversion Factors, Datums, and Water-Quality Units

Inch/Pound to SI

Multiply	By	To obtain
	Length	
inch (in.)	25.4	millimeter (mm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
	Area	
acre	4,047	square meter (m^2)
acre	0.004047	square kilometer (km^2)
	Volume	
acre-foot (acre-ft)	1,233	cubic meter (m^3)
acre-foot (acre-ft)	0.001233	cubic hectometer (hm^3)
	Flow rate	
acre-foot per year (acre-ft/yr)	1,233	cubic meter per year (m^3/yr)
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)
inch per year (in/yr)	25.4	millimeter per year (mm/yr)
	Mass	
ton, short (2,000 lb)	0.9072	megagram (Mg)
ton per year (ton/yr)	0.9072	megagram per year (Mg/yr)

Temperature in degrees Celsius (°C) may be converted to degrees Fahrenheit (°F) as follows:

°F=(1.8×°C)+32

Vertical coordinate information is referenced to the North American Vertical Datum of 1988 (NAVD 88).

Horizontal coordinate information is referenced to the North American Datum of 1983 (NAD 83).

Altitude, as used in this report, refers to distance above the vertical datum.

Specific conductance is given in microsiemens per centimeter at 25 degrees Celsius (µS/cm at 25 °C).

Concentrations of dissolved-solids in water are given in milligrams per liter (mg/L).

Dissolved-Solids Loads Discharged from Irrigated Areas near Manila, Utah, May 2007–October 2012, and Relation of Loads to Selected Variables

By Susan A. Thiros and Steven J. Gerner

Abstract

The Manila/Washam Salinity Project (MWSP) is a cooperative effort by the Natural Resources Conservation Service (NRCS) and local farmers and ranchers to reduce the transport of dissolved solids to Flaming Gorge Reservoir from irrigated agricultural lands near Manila, Utah. To estimate dissolved-solids loads from the MWSP area, discharge and water quality from Birch Spring Draw and other selected outflows and inflows were monitored from May 2007 to October 2012. An average annual May–April streamflow of 5,960 acre-feet discharged from Birch Spring Draw at site BSD-2 to Flaming Gorge Reservoir during 2007–12, containing an average dissolved-solids load of 14,660 tons. An average May–April net dissolved-solids load of 24,300 tons per year discharged from the MWSP area, estimated from the relation between streamflow and dissolved-solids concentration at site BSD-2 and other measured inflows and outflows.

The amount of precipitation and water available for irrigation are important factors affecting the dissolved-solids load in outflow from the MWSP area. Net dissolved-solids load discharged from the MWSP area increased with increasing canal streamflow and precipitation measured at Manila during the irrigation season, from May to October, each year. The net tons of dissolved solids discharged from the MWSP area per acre-foot of canal water increased with increasing irrigation season precipitation during May 2007–October 2012.

Irrigation improvements began to be implemented in 2007 to reduce dissolved-solids loads discharged from the MWSP area. The theoretical annual net dissolved-solids load where the cumulative NRCS calculated dissolved-solids load reduction is added to the net MWSP dissolved-solids load is what would be expected if there was no irrigation improvement in the area associated with the MWSP. The theoretical data points lie very near the baseline representing the pre-MWSP dissolved-solids load to canal streamflow relation. The proximity of the theoretical data points to the baseline shows that the NRCS calculations of reduction in dissolved-solids load are generally supported by the data collected during this study.

Introduction

Irrigated agriculture has been the focus of many salinity control projects in the Colorado River Basin because changes to infrastructure and irrigation practices can yield substantial reductions in the transport of dissolved solids to streams (Natural Resources Conservation Service, 2013). Public laws enacted in 1974 and 1984 established the Colorado River Basin Salinity Control Program, which authorized the planning and construction of numerous salinity-control projects in the basin to improve or prevent further degradation in the quality of Colorado River water used by the United States and Mexico (Natural Resources Conservation Service, 2013). The overarching goal of the Colorado River Basin Salinity Control Program and its participating federal agencies—the Bureau of Reclamation (Reclamation) and Bureau of Land Management of the U.S. Department of the Interior, and the Natural Resources Conservation Service (NRCS) of the U.S. Department of Agriculture—is the cost-effective reduction of salinity in the Colorado River. The NRCS has been actively working to reduce dissolved-solids loads through promotion of improved irrigation methods.

The Manila/Washam Salinity Project (MWSP) is a cooperative effort by the NRCS and local farmers and ranchers to reduce the transport of dissolved solids derived from agricultural practices near Manila, Utah, into Flaming Gorge Reservoir, an impoundment on a tributary to the Colorado River (fig. 1). Implementation of the MWSP began in 2007 and calls for about 7,780 acres of land that was flood irrigated to be converted to use more efficient pressurized sprinkler-irrigation systems (Natural Resources Conservation Service, 2006). Irrigation improvements resulting from the MWSP are projected to reduce the loading of dissolved solids into Flaming Gorge Reservoir by 18,000 tons per year (ton/yr). The U.S. Geological Survey (USGS), in cooperation with the Colorado River Basin Salinity Control Forum (an organization of the seven Colorado River Basin states—Arizona, California, Colorado, Nevada, New Mexico, Utah, and Wyoming), initiated a study to estimate dissolved-solids loading from Birch Spring Draw at site BSD-2 and other selected outflow and inflow sites within the MWSP area (fig. 1) from May 2007 to October 2012.

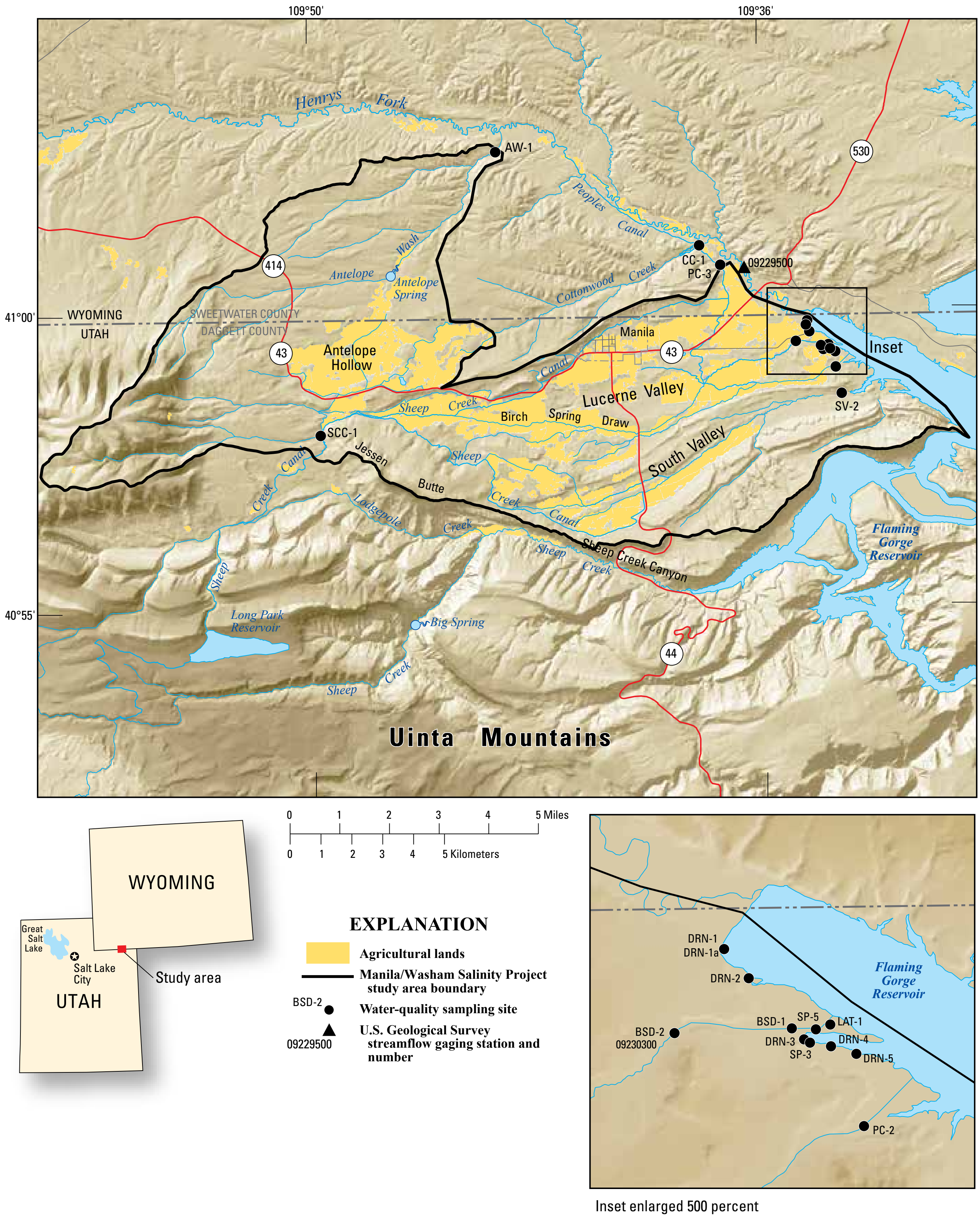

Figure 1. Location of water-quality sampling sites and agricultural lands in the Manila/Washam Salinity Project area.

Purpose and Scope

This report describes the loading of dissolved solids into Flaming Gorge Reservoir from the MWSP area on the basis of data collected from May 2007 to October 2012, and the statistical relation between calculated loads and data pertaining to irrigation diversions, precipitation, and streamflow in the area. The relation between dissolved-solids loads and these variables was evaluated for irrigation and nonirrigation seasons and annually from May to April to better understand the effect of irrigation improvements on dissolved-solids loading from the MWSP area. Water-quality and discharge data collected from May 2004 to October 2005 in the MWSP area and reported by Gerner and others (2007) also were used to help evaluate whether dissolved-solids loading to Flaming Gorge Reservoir has been affected by irrigation improvements.

Birch Spring Draw drains much of Lucerne Valley (fig. 1), which contains most of the agricultural land in the MWSP area. To estimate dissolved-solids load from Birch Spring Draw to Flaming Gorge Reservoir, streamflow (discharge) and specific conductance were measured at site BSD-2 and dissolved-solids concentration was determined by laboratory analysis of water samples from the site. Streamflow and specific conductance also were measured and dissolved-solids concentration determined for several sites representing inflow to and outflow from the MWSP area. Relations between these data were used to extrapolate dissolved-solids loads from Birch Spring Draw to the broader MWSP area.

Description of Study Area

The MWSP area described in this report includes about 10,100 acres of irrigated agricultural lands (Natural Resources Conservation Service, 2013) in the northern part of Daggett County, Utah, and the southern part of Sweetwater County, Wyoming (fig. 1). The town of Manila, Utah, is in the MWSP area and Flaming Gorge Reservoir is at its eastern boundary. Descriptions of the environmental setting, geology and soils, land cover/use, and hydrology in the MWSP area are presented by Gerner and others (2007); this report also characterized the occurrence and distribution of dissolved solids in the area's water resources during 2004–05. The dissolved-solids load in Henrys Fork upstream from Antelope Wash in Wyoming and near Manila is described by Foster and Kenney (2010).

Streams and Canals

Both Henrys Fork and Sheep Creek (fig. 1), perennial streams that are the source of irrigation water to the MWSP area, originate in the Uinta Mountains and discharge to Flaming Gorge Reservoir. USGS streamflow gaging station 09229500, Henrys Fork near Manila, Utah (fig. 1), is about 1.3 miles (mi) upstream from the normal high-water line of Flaming Gorge Reservoir at an altitude of 6,045 feet (ft) above sea level, and 3.0 mi northeast of Manila. Gaging station 09229500 has recorded streamflow from 1928 to 1993 and from 2001 to present (2014) (data are accessible from the USGS National Water Information System (NWIS) database at *http://waterdata.usgs.gov/nwis*). Annual streamflow at this gaging station for water years (WY) 1929–2013 has ranged from 11,900 acre-feet (acre-ft) in 1934 to 197,500 acre-ft in 1983, with a mean of 58,200 acre-ft. The mean annual streamflow for WY 2007–12 was 58,300 acre-ft, and the median was 43,200 acre-ft. Streamflow at the Henrys Fork gaging station is affected by diversions for irrigation along the river's floodplain. Peoples Canal diverts water from Henrys Fork 5.9 mi upstream from gaging station 09229500 (fig. 1), typically from April to November (Gerner and others, 2007). Water in Peoples Canal is used to irrigate about 2,000 acres in the northeastern (lower) part of Lucerne Valley.

The upper part of Sheep Creek Canal (fig. 1) collects runoff from along the crest of the north slope of the Uinta Mountains. Streamflow from the upper reaches of Sheep Creek and other streams in the area is transported by the canal to the offstream Long Park Reservoir and stored for irrigation use in areas near Manila. Downstream from the Sheep Creek Canal diversion, streamflow in Sheep Creek is supplemented by Big Spring before discharging into Flaming Gorge Reservoir in Sheep Creek Canyon. Sheep Creek Canal below Long Park Reservoir transports water to the head of Lucerne Valley (fig. 1, site SCC-1) where it is split into laterals that flow along the north and south sides of the valley, to the Antelope Hollow irrigated area to the northeast, and to South Valley to the southeast. South Valley is a narrow strip of agricultural land bounded on the north and south by bedrock ridges, just north of the Sheep Creek Canyon arm of Flaming Gorge Reservoir. Sheep Creek Canal typically diverts water from Long Park Reservoir from May to September (Gerner and others, 2007) and provides irrigation water to about 8,000 acres.

Water brought to the MWSP area by Peoples Canal and Sheep Creek Canal is applied to crops by flood and sprinkler irrigation. Percolation of water from unlined sections of the canals and from excess water applied to fields—unconsumed irrigation water— becomes groundwater recharge and potentially causes a rise in the shallow groundwater table. The Mancos Shale underlies most of Lucerne Valley and is a major source of dissolved solids to groundwater and surface water in the Colorado River Basin (Anning and others, 2007). Shallow groundwater associated with unconsumed irrigation water in Lucerne Valley dissolves salt derived from the Mancos Shale that eventually drains to Flaming Gorge Reservoir. Peoples Canal was piped in 2010 (Natural Resources Conservation Service, 2013) in part to help control salt mobilization in the area. Piping the canal reduced the amount of seepage from the canal to the shallow groundwater system and, should theoretically reduce the dissolved-solids load from the area to the reservoir.

Antelope Wash receives streamflow from unconsumed irrigation water in the Antelope Hollow area and from Antelope Spring, and drains northeast to Henrys Fork, approximately 1.7 mi upstream from the Peoples Canal diversion (fig. 1).

Birch Spring Draw drains the center of Lucerne Valley and is sustained by shallow groundwater discharge, surface runoff from precipitation, and tail water—runoff from agricultural lands irrigated with water transported by Peoples Canal and Sheep Creek Canal and (or) water that passes through the canal distribution system without being applied for irrigation.

Precipitation

The average annual precipitation at the Manila weather station was 8.20 inches (in.) during WY 2007–12 and 8.98 in. for the 1910–2012 period of record (Western Regional Climate Center, 2013). The Manila weather station is located in town at an altitude of about 6,400 ft above sea level. WY 2011 (October 1, 2010 to September 30, 2011) was the wettest (11.66 in.) during 2007–12, with 4.29 in. falling in May 2011. WY 2012 was the driest (3.62 in.) during this period. About two-thirds of the months in WY 2007–12 had less than the weather station's period of record mean monthly precipitation (fig. 2). Mean precipitation during the WY 2007–12 irrigation seasons (May–October) was 5.40 in. compared to 2.81 in. during the nonirrigation seasons (November–April). The mean monthly temperature at the Manila weather station is below freezing in December, January, and February, resulting in little surface runoff during these months.

Precipitation also is recorded at USGS streamflow gaging station 09229500 on Henrys Fork (MesoWest, 2013), with a WY 2007–12 annual average of 8.63 in. However, precipitation was not recorded from July 2010 through April 2011. Monthly precipitation recorded during WY 2007–12 at the Henrys Fork gaging station and the Manila weather station was generally similar. Exceptions occurred in March 2010 when 5.01 in. was recorded at Henrys Fork compared to 1.20 in. in Manila, and in October 2011 when 2.25 in. was recorded at Henrys Fork compared to 0.43 in. in Manila.

Estimation of Dissolved-Solids Load

Dissolved-solids load is defined as the mass of dissolved solids flowing past a sampling site during a specific time interval and is expressed in units of mass/time. The term "dissolved solids" is synonymous with the terms "salinity" and "salt" in this report and refers to the mass of all cations and anions dissolved in the water.

To estimate dissolved-solids load from Birch Spring Draw to Flaming Gorge Reservoir, streamflow and specific conductance of water were monitored continuously from May 2007 to September 2012 at site BSD-2 (fig. 1). Dissolved-solids concentrations determined from water samples were used with the continuous specific-conductance and streamflow data to calculate the dissolved-solids load discharged at site BSD-2. Measurements of streamflow, specific conductance, and dissolved-solids concentration also were made periodically

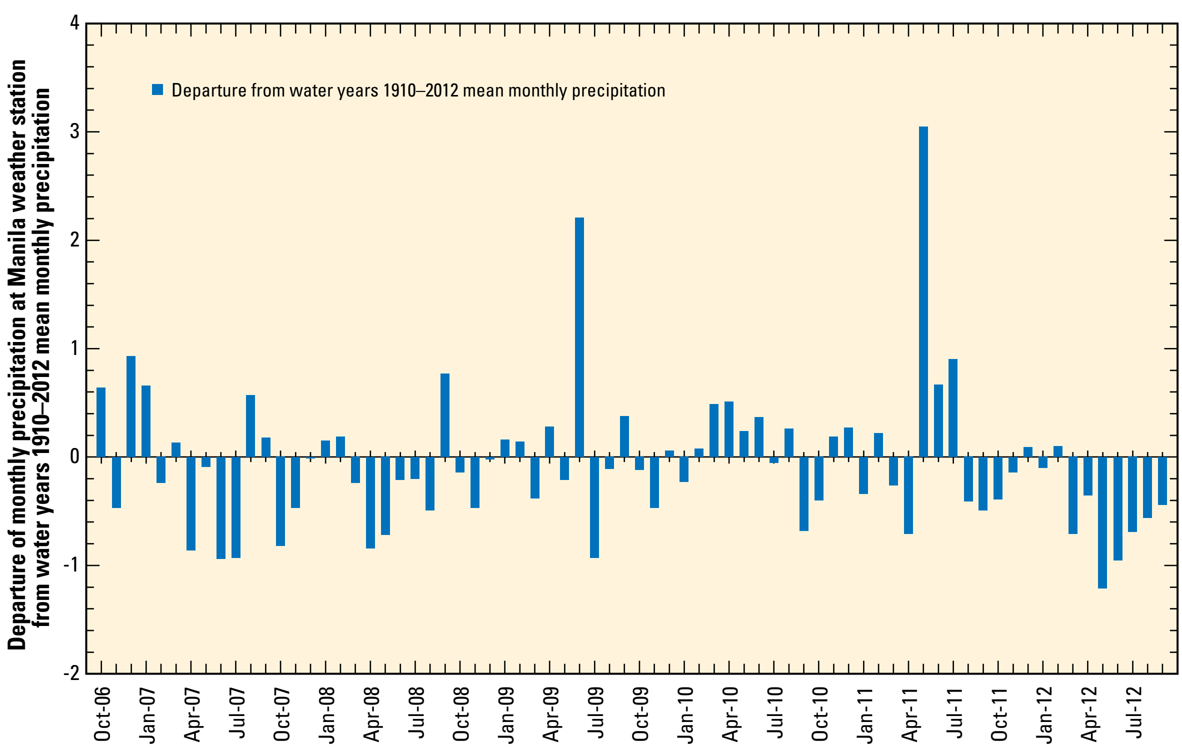

Figure 2. Departure of monthly precipitation for water years 2007–12 from the mean monthly precipitation for water years 1910–2012 at the Manila weather station.

at 15 other sites representing inflow and outflow from the MWSP area during May 2004 to October 2012 (table A-1 in appendix). The net dissolved-solids load discharged from the MWSP area (the load derived only from within the MWSP area) was determined for 36 sets of streamflow and concentration measurements, and estimates made at these outflow and inflow sites from June 2004 to August 2012 (table A-2 in appendix). The term “net dissolved-solids load” in this report refers to the difference between the outflow of dissolved solids from the MWSP area to Flaming Gorge Reservoir and the inflow of dissolved solids to the MWSP area from Peoples and Sheep Creek Canals (monitored at sites PC-3 and SCC-1, respectively).

Birch Spring Draw Streamflow

Stage, specific conductance, and water temperature were monitored at 15-minute increments from May 11, 2007, to September 30, 2012, at site BSD-2 (USGS streamflow gaging station 09230300), located near the outflow of Birch Spring Draw (fig. 1). These data can be accessed from the USGS NWIS database at *http://waterdata.usgs.gov/nwis*. Streamflow at the site was determined from the stage-discharge relation method (Rantz and others, 1982), where area-velocity discharge (streamflow) measurements are associated with stage (height of stream surface above a reference point) to calculate a time series of streamflow values based on a time series of stage measurements. These instantaneous streamflow values were aggregated to determine daily mean streamflow (fig. 3) and monthly mean streamflow values (fig. 4). Stage values and specific-conductance measurements were affected by ice several days each winter, which caused missing data and streamflow and (or) specific conductance to be estimated on those days.

The average annual (May–April) streamflow at site BSD-2 was 5,960 acre-ft during May 2007–April 2012. Streamflow at site BSD-2 from May through October, when most of the irrigation occurs in the MWSP area, averaged 4,630 acre-ft during 2007–12. Streamflow at site BSD-2 from November through April, the nonirrigation season, averaged 900 acre-ft.

Irrigation season (May–October) streamflow in Birch Spring Draw is affected primarily by tail water and unconsumed irrigation water from canal diversions. Monthly mean streamflow at site BSD-2 during the irrigation seasons from May 2007 to September 2012 ranged from 2.3 cubic feet per second (ft^3/s) in July 2007 to 31.4 ft^3/s in July 2011 (fig. 4), with an average of 13.1 ft^3/s. The highest monthly mean streamflows occurred in June, July, or August, primarily the result of irrigation diversions and precipitation. A record 4.29 in. of precipitation for the month of May (period of record WY1910–2012) was recorded at the Manila weather station in 2011. Higher than average monthly mean streamflow at site BSD-2 followed in June and July of that year. These high flows at site BSD-2 were likely affected by greater than normal diversions into Peoples Canal in June and July, leading

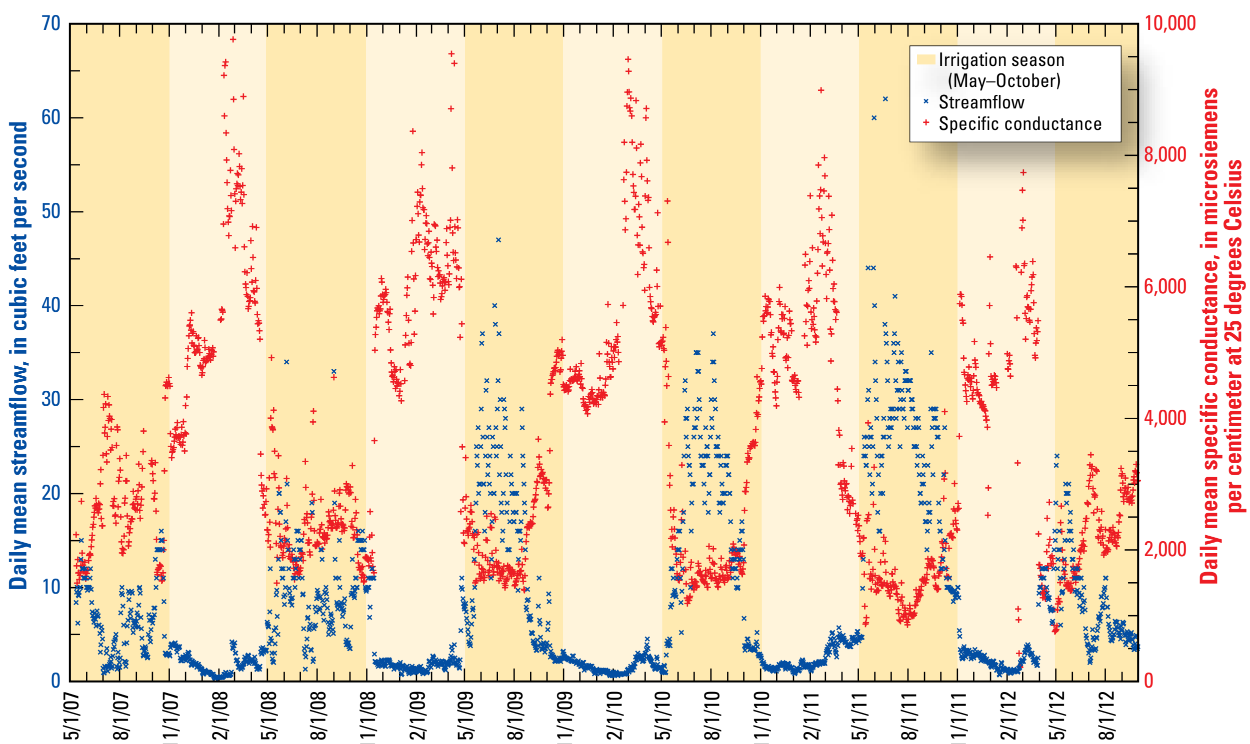

Figure 3. Daily mean streamflow and specific conductance at Birch Spring Draw site BSD-2, May 11, 2007 to September 30, 2012.

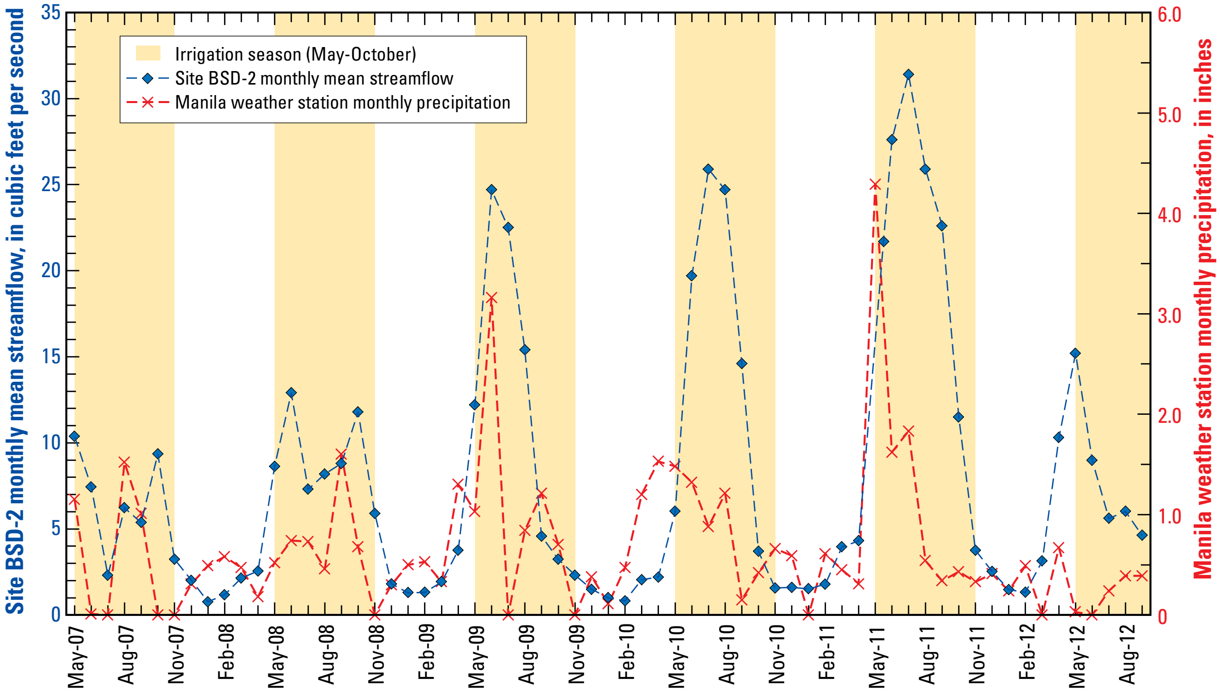

Figure 4. Monthly mean streamflow at Birch Spring Draw site BSD-2 and monthly precipitation at the Manila weather station, May 2007–September 2012.

to greater than average amounts of tail water diverted to Birch Spring Draw. Low monthly mean streamflow at site BSD-2 during the irrigation seasons occurred in October 2010 and 2011 (3.2 and 3.7 ft^3/s, respectively). These streamflow rates are more similar to those in November–April than May–October and indicate that October is a transition month from the irrigation season to the nonirrigation season.

Streamflow at site BSD-2 during the nonirrigation season consists primarily of groundwater discharge (base flow). Monthly mean streamflows at site BSD-2 during the nonirrigation seasons from November 2007 to April 2012 were generally less than 4 ft^3/s (fig. 4), with an average of 2.8 ft^3/s. The two high nonirrigation season streamflow outliers during this period were 10.4 ft^3/s in April 2012 and 6.0 ft^3/s in November 2008. These streamflow rates are likely affected by freezing and thawing temperatures that influence the transition between irrigation and nonirrigation seasons.

Canal Streamflow

Canal diversions during the May–October irrigation season were totaled from monthly estimates of streamflow on the basis of instantaneous measurements made from May 2007 to October 2012 (table A-1 in appendix) and estimates made from measurements of and trends in streamflow (table A-3 in appendix). Canal streamflow measurements were not available for May and June 2007, so the diversion amounts for those months were estimated from measurements and trends observed during other irrigation seasons. Estimated streamflow diverted into Sheep Creek Canal (site SCC-1 in table A-1) during the 2007–12 irrigation seasons ranged from 18,900 acre-ft in 2007 to 23,400 acre-ft in 2009 and 2010 (fig. 5), with an average of 21,700 acre-ft. Estimated streamflow diverted into Peoples Canal (site PC-3 in table A-1) ranged from 6,000 acre-ft in 2012 to 10,700 acre-ft in 2011, with an average of 7,600 acre-ft. Peoples Canal was enclosed in a high-density polyethylene pipeline in 2010 to stop seepage losses from the canal of approximately 1,100 acre-feet per year (acre-ft/yr) (Bureau of Reclamation, 2009). Prior to piping, the capacity of the canal was reduced by sediment deposition. A screening structure installed near the head of Peoples Canal during piping resulted in much less sediment in the canal, allowing more water to be delivered to the fields for irrigation (Bureau of Reclamation, 2009).

An average combined flow of 29,300 acre-ft/yr was estimated to be transported by Peoples and Sheep Creek Canals during May 2007–October 2012, with flow ranging from 25,400 acre-ft in 2012 to 33,400 acre-ft in 2011. Measurements of streamflow in Peoples and Sheep Creek Canals made during June–October 2004 and May–June 2005 by Gerner and others (2007) were used to calculate an irrigation season canal streamflow of 32,600 acre-ft for 2004/05 (fig. 5; table A-3). Streamflow measurements for 2004/05 at Peoples Canal site PC-1 are listed in table 2 of Gerner and others (2007) and Sheep Creek Canal site SCC-1 in table A-1. The estimate of canal streamflow for 2004/05 uses streamflow data that straddle two irrigation seasons. Therefore, caution should be used when comparing estimated irrigation season canal

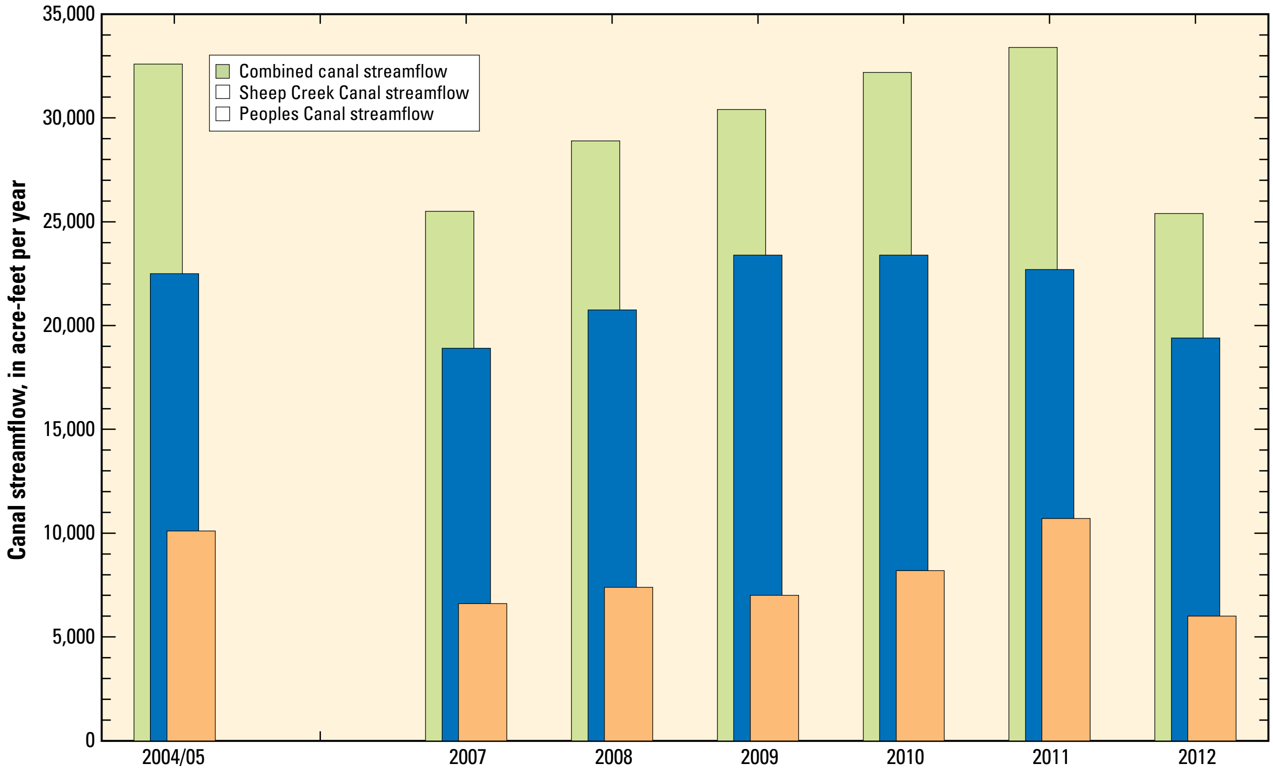

Figure 5. Canal streamflow diverted into the Manila/Washam Salinity Project (MWSP) area, 2004/05 and 2007–12. The irrigation season represented by the period 2004/05 uses measurements and estimates of canal streamflow made during June–October 2004 and May–June 2005.

streamflow for 2004/05 to streamflow for May 2007–October 2012. The 2004/05 estimate of canal streamflow represents an irrigation season before irrigation improvements began in the MWSP area.

Much of the water transported by the Sheep Creek and Peoples Canals is consumed by crops and evaporation in an average irrigation season. About 33 in. of water per acre per year is estimated to be applied for irrigation from Sheep Creek Canal (average of 21,700 acre-ft/yr diverted for 8,000 irrigated acres) and 46 in. of water per acre per year from Peoples Canal (average of 7,600 acre-ft/yr diverted for 2,000 irrigated acres). These estimates assume that all of the diverted water is applied for irrigation, although some water generally remains in the canals and flows to a drain as tail water. Potential evapotranspiration in the MWSP area exceeds precipitation, with an average May–October (1952–2005) pan evaporation rate at the Manila weather station of 45 inches per year (in/yr) or about 31 in/yr from wet soil (Western Regional Climate Center, 2014).

Dissolved-Solids Concentrations

Canal streamflow diverted for irrigation, and precipitation in the MWSP area are the sources of water flowing over the land surface and through the subsurface. Shallow groundwater recharged from precipitation and unconsumed irrigation water can dissolve minerals as it moves through the soil and underlying geologic formations. The Mancos Shale underlies irrigated fields in the MWSP area and is a source of sediment and dissolved solids in the soil. Unconsumed irrigation water and tail water from canal diversions in areas of the upper Colorado River Basin underlain by Mancos Shale add substantial amounts of dissolved solids to streams and rivers (Anning and others, 2007).

Springs, seeps, and drains intercept and drain shallow groundwater from the soil. Evapotranspiration causes water near the soil surface to become more concentrated in dissolved constituents. In some places, evaporation results in the precipitation of salts and the formation of an efflorescent salt crust at land surface. In the spring, surface runoff coupled with excess irrigation water dissolves the efflorescent salt crust. Runoff and groundwater downgradient from irrigated fields potentially become more concentrated in dissolved solids as a result of the dissolution of minerals precipitated in the soil.

Birch Spring Draw Dissolved-Solids Concentrations

Periodic site visits were made to site BSD-2 to maintain and calibrate the stage and specific-conductance instrumentation and to collect samples for analysis of dissolved-solids concentration as residue on evaporation (ROE) at 180 degrees Celsius (table A-1). The linear relation between 32 pairs of dissolved-solids concentration and specific-conductance values for site BSD-2 during June 2007–March 2012 (table 1; fig. 6) allowed dissolved-solids concentrations to be estimated from the continuous specific-conductance data.

Dissolved-solids concentrations in water at site BSD-2 are related to streamflow—lower concentrations at higher streamflows and higher concentrations at lower streamflows (fig. 7). Lower monthly mean dissolved-solids concentrations (calculated from specific-conductance values) and higher streamflows mostly occur during the May–October irrigation season. Higher concentrations and lower streamflows mostly occur during the November–April nonirrigation season.

Monthly mean dissolved-solids concentrations calculated from specific conductance measured at site BSD-2 during May 2007–September 2012 were generally less than 2,500 milligrams per liter (mg/L) during the irrigation season from May to October (fig. 8*A*). Monthly mean dissolved-solids concentrations during the irrigation season ranged from 830 mg/L in July and August 2011 to 3,860 mg/L in October 2009. There is a large range in streamflow at site BSD-2 during the irrigation season (fig. 8*B*) primarily because of tail water inflow from the canals and irrigated fields, precipitation runoff, and return flow from unconsumed irrigation water. The lowest average monthly mean dissolved-solids concentrations in streamflow at site BSD-2 occurred in June, July, and August—the months with the highest average monthly mean streamflow.

The monthly mean dissolved-solids concentration at site BSD-2 during the nonirrigation season from November through April was typically between 3,000 and 7,000 mg/L (fig. 8*A*) with an average of 4,550 mg/L. High dissolved-solids concentrations in the nonirrigation season are the result of groundwater discharge being a larger component of streamflow. In April 2012, however, a greater than normal nonirrigation season streamflow at site BSD-2 (10.4 ft^3/s; fig. 8*B*) corresponded with a lower than normal mean dissolved-solids concentration (1,190 mg/L; fig. 8*A*). The April 2012 outlier was potentially caused by diversions starting earlier than normal or earlier than normal snowmelt runoff.

High monthly mean dissolved-solids concentrations in February, March, and April at site BSD-2 during May 2007–September 2012 likely indicate the addition of runoff and (or) shallow groundwater that has dissolved efflorescent salts. The highest dissolved-solids concentration in water samples collected during this study was 8,030 mg/L in April 2009 at site BSD-2 (table A-1). The specific conductance of this sample was 8,980 microsiemens per centimeter (µS/cm). Specific-conductance values of water at upstream road crossings and several inflows indicate the probable source of the additional dissolved solids to the April 2009 sample was runoff from an area with extensive efflorescent salt deposits; the specific conductance of water draining this area was 22,500 µS/cm, higher than other measurements made at sites upgradient of site BSD-2.

Table 1. Relation between specific conductance and dissolved-solids concentration at selected water-quality sampling sites in the Manila/Washam Salinity Project area.

[Site identifier, see figure 1 for location; UT, Utah; FGNRA, Flaming Gorge National Recreation Area; WY, Wyoming]

Site identifier	Site number	Site name	Number of samples	Relation of specific conductance (SC) to dissolved-solids concentration (DS)	Relation coefficient of regression (R^2)
BSD-1	405925109383901	Birch Spring Draw near Manila, UT	6	Used relation for BSD-2	0.998
BSD-2	09230300	Birch Spring Draw at FGNRA Boundary near Manila, UT	32	DS = 0.9429(SC) – 324.19	0.998
PC-2	405902109381801	Peoples Canal near mouth near Manila, UT	18	DS = 1.0435(SC) – 402.81	0.994
SV-2	405832109381401	South Valley Canal at mouth near Manila, UT	11	DS = 0.8640(SC) – 222.51	0.983
DRN-1	405945109390001	Drain No. 1 near Manila, UT	5	DS = 1.2009(SC) – 834.91	0.997
DRN-1a	405945109390002	Drain No. 1a near Manila, UT	6	DS = 0.9501(SC) – 126.87	0.962
DRN-2	405938109385301	Drain No. 2 near Manila, UT	14	DS = 0.9918(SC) – 303.56	0.996
DRN-3	405923109383601	Drain No. 3 near Manila, UT	4	DS = 1.1057(SC) – 515.16	0.998
DRN-4	405921109382801	Drain No. 4 near Manila, UT	5	DS = 1.0578(SC) – 389.7	0.997
LAT-1	405926109382801	Lateral No. 1 near Manila, UT	2	Used relation for all sites	0.985
AW-1	410244109454901	Antelope Wash at County Road 13 near Manila, UT	13	DS = 0.9574(SC) + 144.39	0.872
DRN-5	405919109382001	Drain No. 5 near Manila, UT	0	Used relation for all sites	0.985
SP-3	405922109383501	Seep No. 3 near Manila, UT	3	Used relation for all sites	0.985
CC-1	410104109412001	Cottonwood Creek at County Road 13 near Manila, UT	2	Used relation for all sites	0.985
SCC-1	405800109494601	Sheep Creek Canal near Manila, UT	5	DS = 0.5528(SC) + 7.629	0.634
PC-3	410044109405601	Peoples Canal at Washam, WY	6	DS = 0.8398(SC) – 84.338	0.996
		All sites	132	DS = 0.9487(SC) – 180.13	0.985

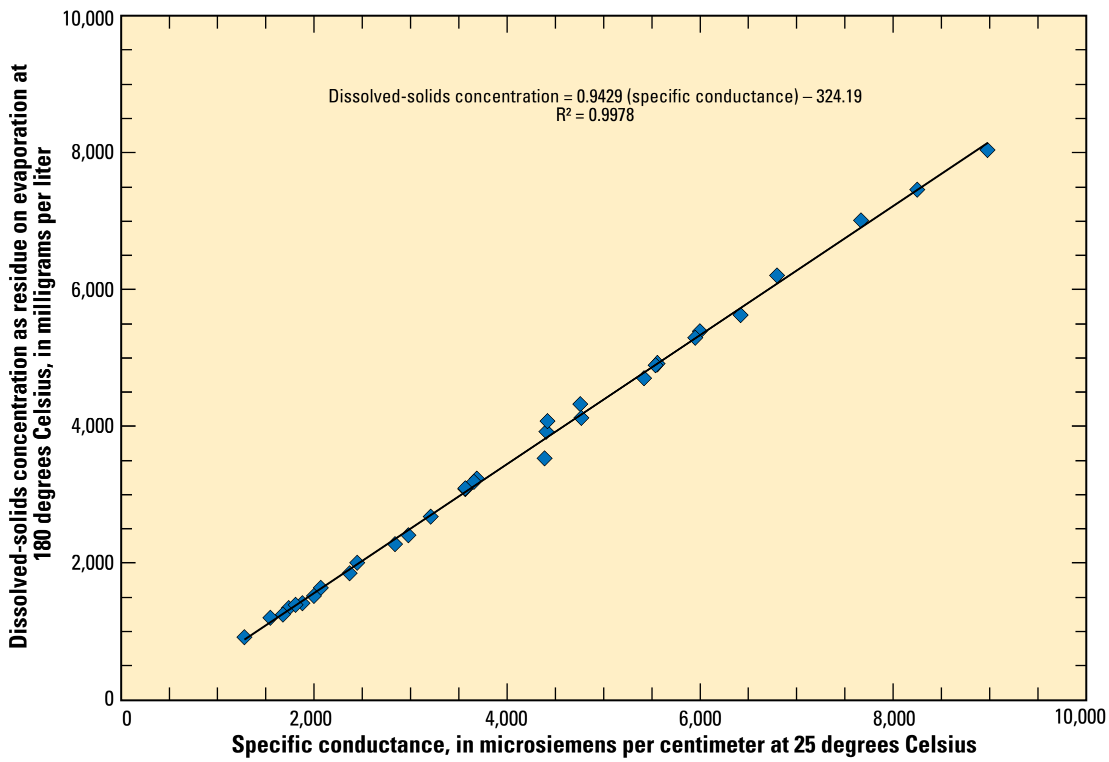

Figure 6. Relation between dissolved-solids concentration and specific conductance in water samples collected at Birch Spring Draw site BSD-2, June 2007–March 2012.

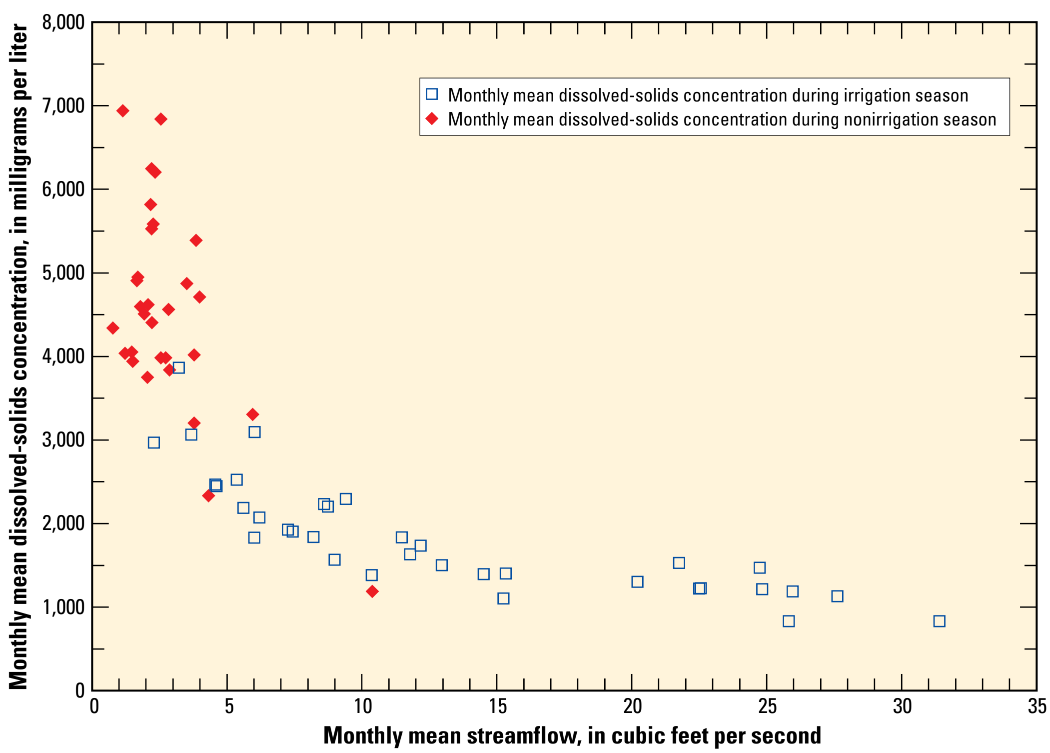

Figure 7. Monthly mean streamflow and monthly mean dissolved-solids concentration at Birch Spring Draw site BSD-2 during the May–October irrigation season and the November–April nonirrigation season, May 2007–September 2012.

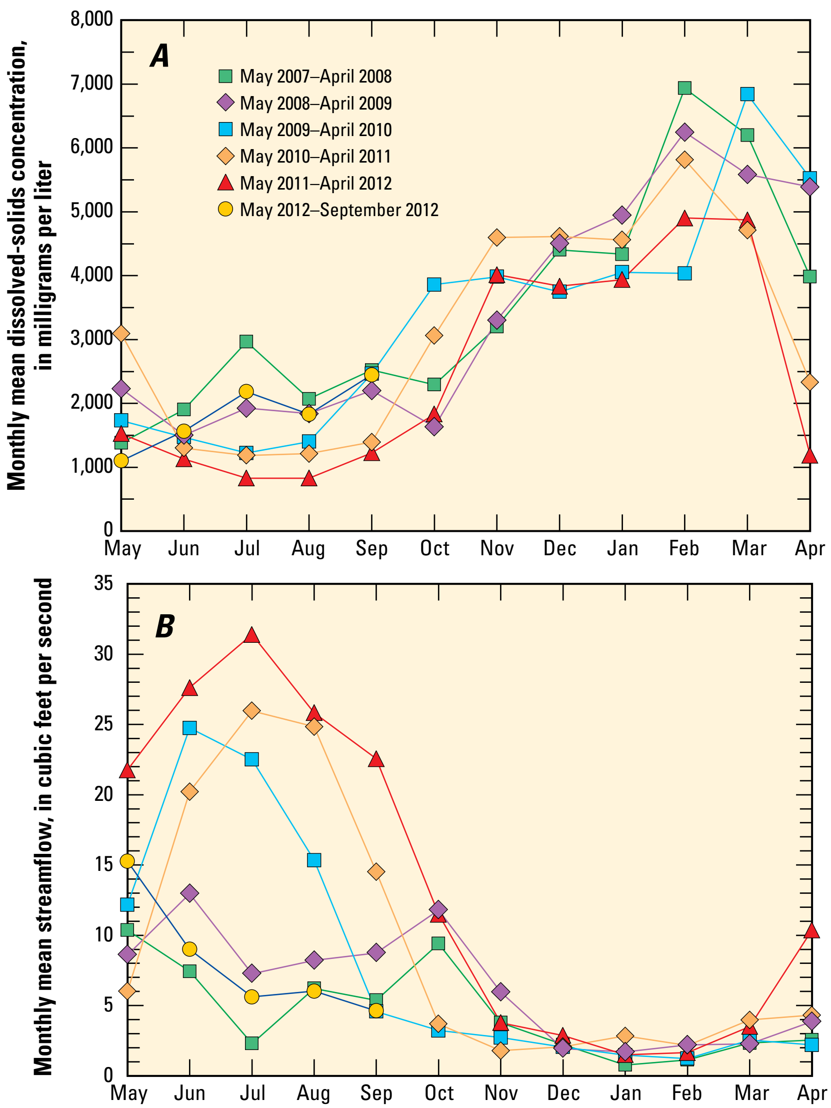

Figure 8. *A*, monthly mean dissolved-solids concentration and *B*, monthly mean streamflow at Birch Spring Draw site BSD-2, May 2007–September 2012.

Dissolved-Solids Concentrations at Other Outflow and Inflow Sites

In addition to Birch Spring Draw, several other outflows discharge dissolved solids to Flaming Gorge Reservoir. Water samples from major outflows (see list in table A-2) and inflows (Peoples Canal at site PC-3 and Sheep Creek Canal at site SCC-1) in the MWSP area were periodically collected from June 2007 to March 2012 and analyzed for dissolved-solids concentrations (table A-1). Discharge and specific conductance were typically measured at these sites several more times during May 2007–October 2012 (table A-1). Data collected from May 2004 to June 2005 by Gerner and others (2007) were used to expand this study's data set and are included in table A-1. A linear relation between dissolved-solids concentration and specific conductance was determined for each site (table 1), if possible, and was used to estimate the dissolved-solids concentration when only specific-conductance data were available.

Dissolved-solids concentrations in outflow from drains and seeps in the lower part of Lucerne Valley ranged from 900 mg/L at site DRN-4 in June 2005, to 6,450 mg/L at site DRN-2 in March 2012 (table A-1). Outflow from Antelope Hollow, derived from Antelope Spring and unconsumed irrigation water, discharges dissolved solids to Henrys Fork, which in turn is diverted into Peoples Canal or discharges to Flaming Gorge Reservoir. The dissolved-solids concentration at site AW-1 averaged 3,930 mg/L (13 samples; table A-1). A mean dissolved-solids concentration of 3,820 mg/L at site AW-1 and a median concentration of 3,860 mg/L were calculated from 55 specific-conductance measurements made in 2004–12 (table A-1) and the relation between dissolved-solids concentration and specific conductance for 13 samples (table 1).

Dissolved solids are transported into the MWSP area by water in Sheep Creek and Peoples Canals for distribution to agricultural fields during the irrigation season. The calculated dissolved-solids concentration in water from Sheep Creek Canal at the head of Lucerne Valley (site SCC-1) ranged from 34 to 1,140 mg/L, with a mean of 145 mg/L and a median of 41 mg/L, on the basis of 32 specific-conductance measurements made in 2004–12 (table A-1) and the relation between dissolved-solids concentration and specific conductance for 5 samples (table 1). Higher specific-conductance values, and therefore dissolved-solids concentrations, correspond with low flows in the canal (less than 1 ft^3/s) during the nonirrigation season and account for the large difference between the mean and median calculated dissolved-solids concentrations. Low dissolved-solids concentrations in Sheep Creek Canal water during the irrigation season is a result of high-altitude streamflow associated with snowmelt and precipitation events.

The calculated dissolved-solids concentration in water transported into the MWSP area by Peoples Canal at site PC-3 ranged from 215 mg/L in May 2009, to 1,140 mg/L in August 2008, with a mean and median value of 698 mg/L, on the basis of 27 specific-conductance measurements made in 2007–12 (table A-1) and the relation between dissolved-solids concentration and specific conductance for 6 samples (table 1). The water diverted into Peoples Canal originates in the headwaters of Henrys Fork and should have a dissolved-solids concentration similar to Sheep Creek Canal, but Henrys Fork water at the diversion contains dissolved solids from groundwater discharge, irrigation return flow, and runoff from nonirrigated areas.

Dissolved-Solids Loads

Dissolved-solids loads were calculated for water flowing into the MWSP area and flowing out of the area to Flaming Gorge Reservoir to characterize the net load from the MWSP area. Dissolved-solids loads were computed using the following equation:

$$Load = (Conc)\ (Flow)\ (CF) \tag{1}$$

where

Load is the dissolved-solids load in tons,
Conc is the dissolved-solids concentration in milligrams per liter,
Flow is the streamflow in cubic feet per second, and
CF is a conversion factor used to determine a load at a specific time interval.

The conversion factor used in this report to calculate daily dissolved-solids loads in tons per day is 0.002697, and the conversion factor used to calculate 15-minute dissolved-solids loads is 0.0000281.

Birch Spring Draw Dissolved-Solids Loads

Dissolved-solids loads at site BSD-2 were calculated primarily from 15-minute streamflow and dissolved-solids concentration values (determined from the relation to specific conductance), and were aggregated to determine daily, monthly, seasonal, and annual dissolved-solids loads. Dissolved-solids loads on days when specific-conductance data were missing were estimated by determining the relation of streamflow to dissolved-solids load for the previous 20 days, using least-squares linear regression. Stage values were affected by ice many days each winter, and streamflow was estimated on those days. Consequently, the dissolved-solids load on days with estimated daily streamflow (but measured specific conductance) was calculated by using the daily streamflow and the average dissolved-solids concentration.

Annual and seasonal variations in dissolved-solids load at site BSD-2 are affected mainly by streamflow. Periods with higher streamflow have larger dissolved-solids loads than periods with lower streamflow. Annual (May–April) dissolved-solids loads during May 2007–April 2012 ranged from 10,590 tons in 2007–08 to 18,770 tons in 2011–12 and averaged 14,660 tons (table 2). Dissolved-solids loads were larger during the irrigation season than the nonirrigation season because more water was available to mobilize salts from the soil and transport them to Birch Spring Draw. Streamflow at site BSD-2 during the irrigation season (May–October) was consistently higher than the nonirrigation season (November–April). Irrigation season dissolved-solids loads at site BSD-2 ranged from 6,045 tons in 2012 to 13,720 tons in 2011 (table 2).

The large range in monthly mean streamflow at site BSD-2 during the irrigation season combined with low dissolved-solids concentrations, corresponds to a monthly dissolved-solids load that ranged from 520 tons in July 2007 to 3,027 tons in May 2011 (table 2; fig. 9). The small dissolved-solids load in July 2007 corresponds to a mean streamflow of 2.3 ft^3/s, similar to mean streamflow rates in nonirrigation season months, and an average dissolved-solids concentration of 2,966 mg/L. In contrast, the mean streamflow and average dissolved-solids concentration in May 2011 at site BSD-2 was 21.7 ft^3/s and 1,527 mg/L, respectively. Dissolved-solids load generally increased with monthly mean streamflow and averaged 1,570 tons per month during the irrigation seasons from May 2007 to September 2012.

Table 2. Dissolved-solids load, in tons, discharged at Birch Spring Draw site BSD-2, May 2007–September 2012.

[—, no data]

	2007–08	2008–09	2009–10	2010–11	2011–12	2012
May	1,135	1,415	1,601	1,114	3,027	1,299
June	1,084	1,663	3,026	1,955	2,620	1,068
July	520	1,053	2,291	2,568	2,212	947
August	1,005	1,259	1,675	2,555	1,746	910
September	1,074	1,707	922	1,605	2,234	911
October	1,392	1,530	951	927	1,876	—
November	836	995	743	581	1,124	—
December	737	687	469	622	802	—
January	277	521	338	594	496	—
February	707	613	343	794	538	—
March	1,096	901	1,143	1,513	1,162	—
April	725	1,429	1,037	824	933	—
May-April total	10,590	13,770	14,540	15,650	18,770	—
Irrigation season	6,210	8,625	10,470	10,720	13,720	[1]6,045
Nonirrigation season	4,380	5,145	4,070	4,930	5,050	—

[1]Because the instrumentation recording stage and specific conductance at site BSD-2 was removed at the end of September 2012, the irrigation season dissolved-solids load for 2012 assumes that the dissolved-solids load in October is the same as it was in August and September.

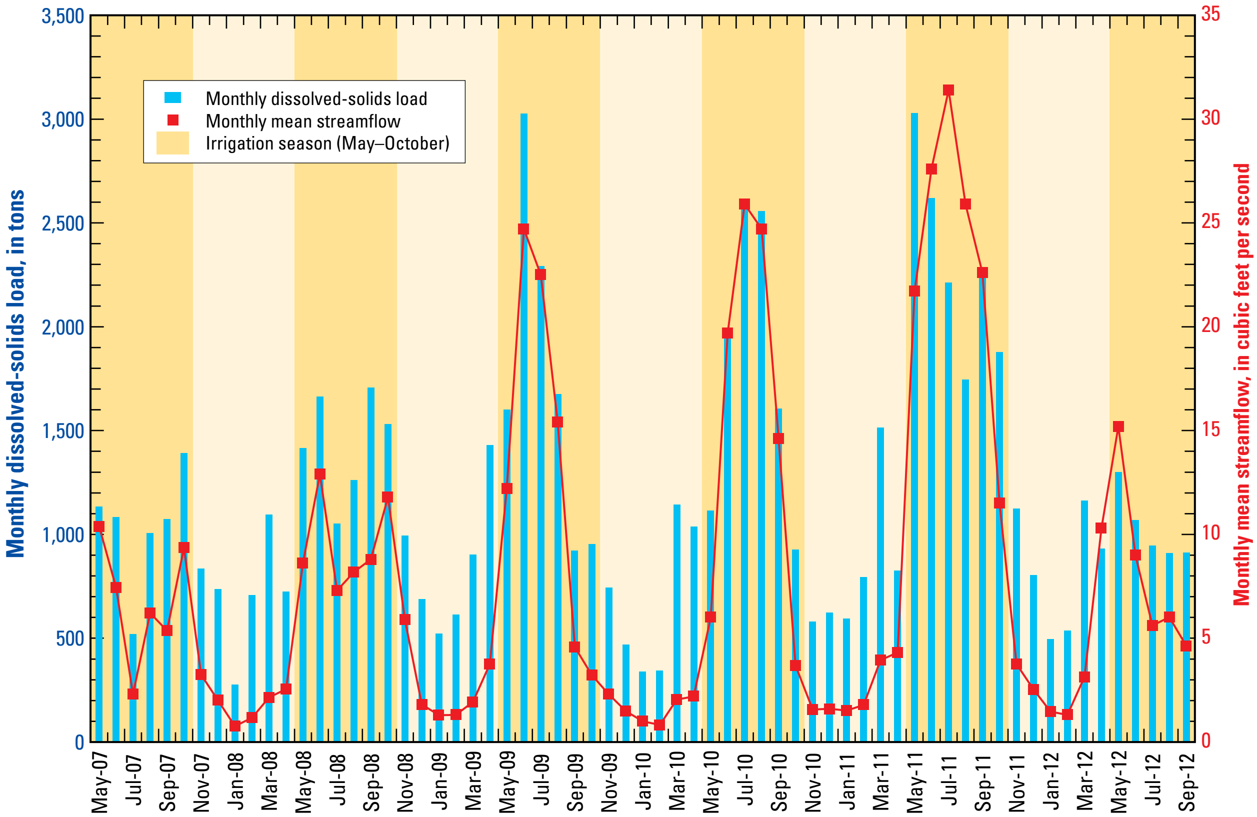

Figure 9. Monthly dissolved-solids load and monthly mean streamflow at Birch Spring Draw site BSD-2, May 2007–September 2012.

The small range in monthly mean streamflow at site BSD-2 during the nonirrigation season combined with elevated dissolved-solids concentrations equates to a monthly dissolved-solids load that ranged from 277 tons in January 2008 to 1,513 tons in March 2011. The average monthly November–April dissolved-solids load at site BSD-2 during November 2007–April 2012 was 785 tons, about half as much as the average monthly May–October dissolved-solids load. Dissolved-solids load at site BSD-2 during the nonirrigation season ranged from 5,145 tons in 2008–09 to 4,070 tons in 2009–10.

Manila/Washam Salinity Project Area Dissolved-Solids Loads

Dissolved-solids loads were estimated for all of the major inflows and outflows in the MWSP area. Water-quality and streamflow measurements made periodically at inflow and outflow sites were used to develop a relation between the dissolved-solids load at site BSD-2 and the net dissolved-solids load discharged from the MWSP area. The net dissolved-solids load discharged from the MWSP area (the load derived only from within the MWSP area) was determined for each of 36 sets of streamflow and dissolved-solids concentration data for inflow and outflow sites (table A-2). Each set of measurements represents a single visit to the MWSP area. The net dissolved-solids load associated with each visit was determined by summing the dissolved-solids loads from outflow sites, including site BSD-2, and then subtracting the estimated dissolved-solids loads from Peoples Canal at site PC-3 and Sheep Creek Canal at site SCC-1.

Net MWSP area dissolved-solids loads from May 2007 to September 2012 were estimated from the relation between the dissolved-solids load determined from continuous data collected at site BSD-2 and the net MWSP dissolved-solids load estimated from the 36 sets of inflow and outflow measurements (table A-2). The relation between site BSD-2 dissolved-solids load and net dissolved-solids load from the MWSP area is different during the irrigation and nonirrigation seasons as shown in figure 10 and described in equations 2a and 2b:

$$\text{Net MWSP load during irrigation season} = \text{BSD-2 load}\,(1.4521) - 0.5325 \quad (2a)$$

$$\text{Net MWSP load during nonirrigation season} = \text{BSD-2 load}\,(1.5983) + 12.365 \quad (2b)$$

where

Net MWSP load is the net dissolved-solids load from the MWSP area, in tons per day, and

BSD-2 load is the monitored dissolved-solids load at site BSD-2, in tons per day.

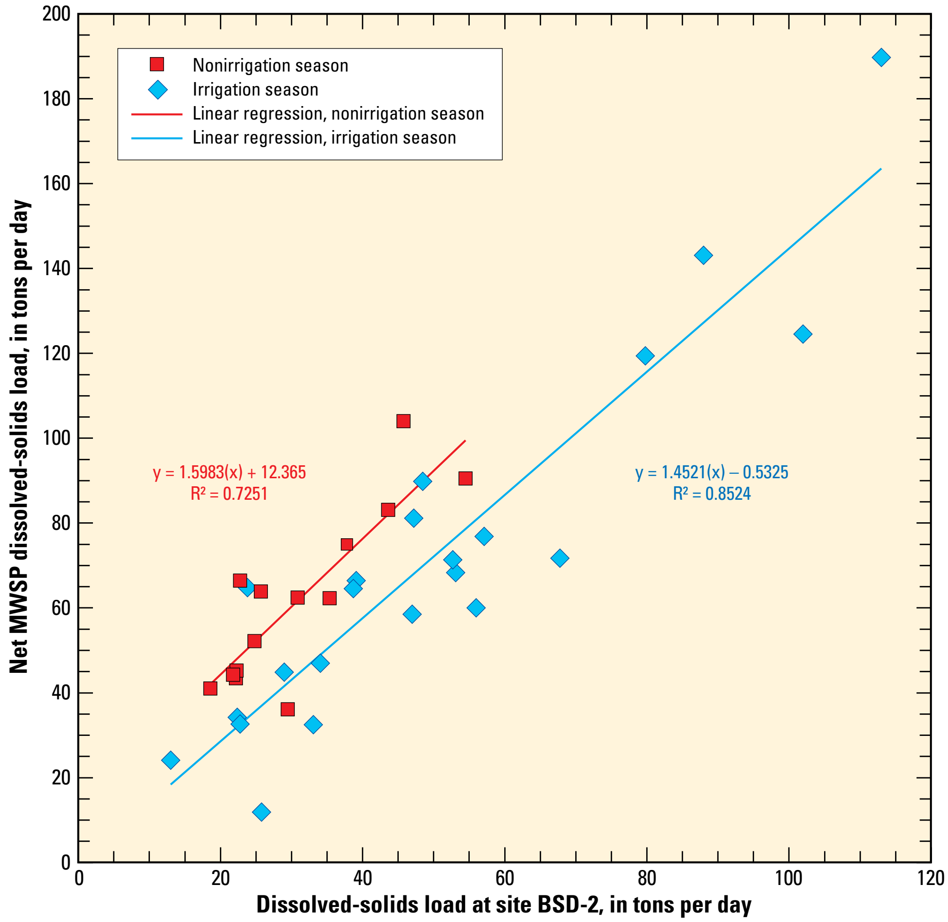

Figure 10. Relation between dissolved-solids load at Birch Spring Draw site BSD-2 and the net dissolved-solids load discharged from the Manila/Washam Salinity Project (MWSP) area.

From these relations, the calculated net MWSP area dissolved-solids load is about 31 percent larger than the corresponding dissolved-solids load at site BSD-2 during the irrigation season, and ranged from 45 to 55 percent larger during the nonirrigation season.

Annual May–April net dissolved-solids loads from the MWSP area (table 3) varied similarly to those calculated for site BSD-2 (table 2) and averaged 24,300 tons. May–April net loads ranged from 18,310 tons in 2007–08 to 30,190 tons in 2011–12. Net MWSP area dissolved-solids loads during the irrigation season ranged from 8,680 tons in 2012 to 19,940 tons in 2011 and averaged 15,300 tons. Monthly net dissolved-solids loads discharged from the MWSP area ranged from 738 tons in July 2007 to 4,507 tons in May 2011 (table 3; fig. 11).

An average irrigation season dissolved-solids load of 1,400 tons from Sheep Creek Canal at site SCC-1 was estimated from 25 instantaneous streamflow and specific-conductance measurements made from July 2007 to October 2012 (table A-1) and the relation between specific conductance and dissolved-solids concentration for 5 samples (table 1). An average irrigation season dissolved-solids load of 7,400 tons from Peoples Canal at site PC-3 was estimated from 27 instantaneous streamflow and specific-conductance measurements made from July 2007 to October 2012 (table A-1) and the relation between specific conductance and dissolved-solids concentration for 6 samples (table 1). For comparison, in 2004/05, before improvements to irrigation systems began, the estimated dissolved-solids load from canal inflow to the MWSP area was 14,500 tons—1,300 tons from Sheep Creek Canal and 13,200 tons from Peoples Canal (Gerner and others, 2007).

An average annual dissolved-solids load of 8,100 tons from Antelope Wash was estimated from 47 instantaneous streamflow and specific-conductance measurements made from June 2007 to September 2012 at site AW-1 (table A-1) and the relation between specific conductance and dissolved-solids concentration for 13 samples (table 1). Part of the dissolved-solids load at site AW-1 is derived from Antelope Spring and part from unconsumed irrigation water in Antelope Hollow. Geochemical data indicate that Antelope Spring discharges from a regional groundwater flow system that is not affected by agricultural activities (Gerner and others, 2007). A mass-balance model of dissolved-solids load in the upper Henrys Fork Basin predicted an annual dissolved-solids load of 2,700 tons from Antelope Wash (Foster and Kenney, 2010).

Table 3. Net dissolved-solids load, in tons, discharged from the Manila/Washam Salinity Project area, May 2007–September 2012.

[—, no data]

	2007–08	2008–09	2009–10	2010–11	2011–12	2012
May	1,824	2,037	2,308	1,837	4,507	1,870
June	1,558	2,399	4,378	2,822	3,788	1,535
July	738	1,512	3,310	3,712	3,196	1,359
August	1,444	1,812	2,416	3,694	2,519	1,305
September	1,544	2,462	1,323	2,314	3,228	1,306
October	2,162	2,205	1,791	1,848	2,708	—
November	1,707	1,697	1,559	1,299	2,141	—
December	1,561	1,482	1,133	1,378	1,663	—
January	827	1,216	923	1,333	1,201	—
February	1,488	1,326	894	1,616	1,175	—
March	2,136	1,823	2,210	2,802	2,251	—
April	1,321	2,555	2,029	1,689	1,810	—
May-April total	18,310	22,530	24,270	26,340	30,190	—
Irrigation season	9,270	12,430	15,530	16,230	19,940	[1]8,680
Nonirrigation season	9,040	10,100	8,740	10,110	10,250	—

[1]Because the instrumentation recording stage and specific conductance at site BSD-2 was removed at the end of September 2012, the irrigation season dissolved-solids load for 2012 assumes that the dissolved-solids load in October is the same as it was in August and September.

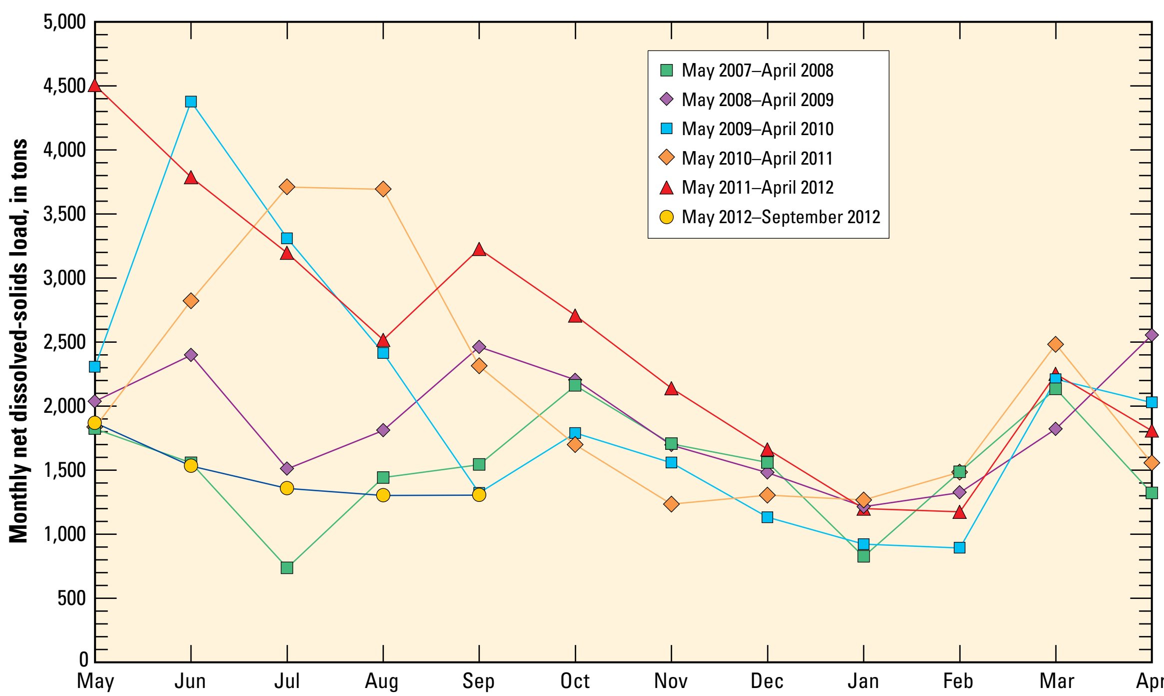

Figure 11. Monthly net dissolved-solids load discharged from the Manila/Washam Salinity Project area, May 2007–September 2012.

The difference of 5,400 ton/yr between the estimated and predicted dissolved-solids load for Antelope Wash is attributed to Antelope Spring. The dissolved-solids load from Antelope Spring is included in estimates of net dissolved-solids load in the MWSP area presented in this report.

The estimate of net dissolved-solids load discharging from the MWSP area accounts for all of the major components involved in transporting dissolved solids into and out of the MWSP area. Precipitation is an additional source of dissolved solids to the MWSP area, but contributions are considered negligible relative to canal inflows. In addition, there was little drain water or seepage of groundwater observed beyond what was measured during this study. During the low water levels of Flaming Gorge Reservoir in 2004–05, diffuse seepage was not observed, and the dissolved-solids load discharging from seeps that were visited was generally less than 0.5 ton per day (Gerner and others, 2007).

Relation of Dissolved-Solids Loads to Selected Variables

The amount of precipitation and water available for irrigation are important factors affecting the dissolved-solids load in outflow from the MWSP area. The net dissolved-solids load discharged from the MWSP area is positively correlated to the amount of canal water diverted into the study area. The relation between net dissolved-solids load (annual period from May to April) and canal streamflow was separated into two groups (fig. 12). The first group of data is from 2004/05 and 2007–08, and forms a baseline that is assumed to represent conditions prior to or during 2007, before changes to irrigation systems and improved irrigation practices were implemented to reduce the dissolved-solids load discharged from the MWSP area. Streamflow and specific-conductance data collected from July 2004 through June 2005 at site BSD-1 (Gerner and others, 2007; table A-1) and the relations between load at sites BSD-1 and BSD-2, and net MWSP area load were used to estimate a May–April net MWSP dissolved-solids load of 35,500 tons in 2004/05. A limitation of the 2004/05 estimate is that the data collected for this period straddle parts of two irrigation seasons.

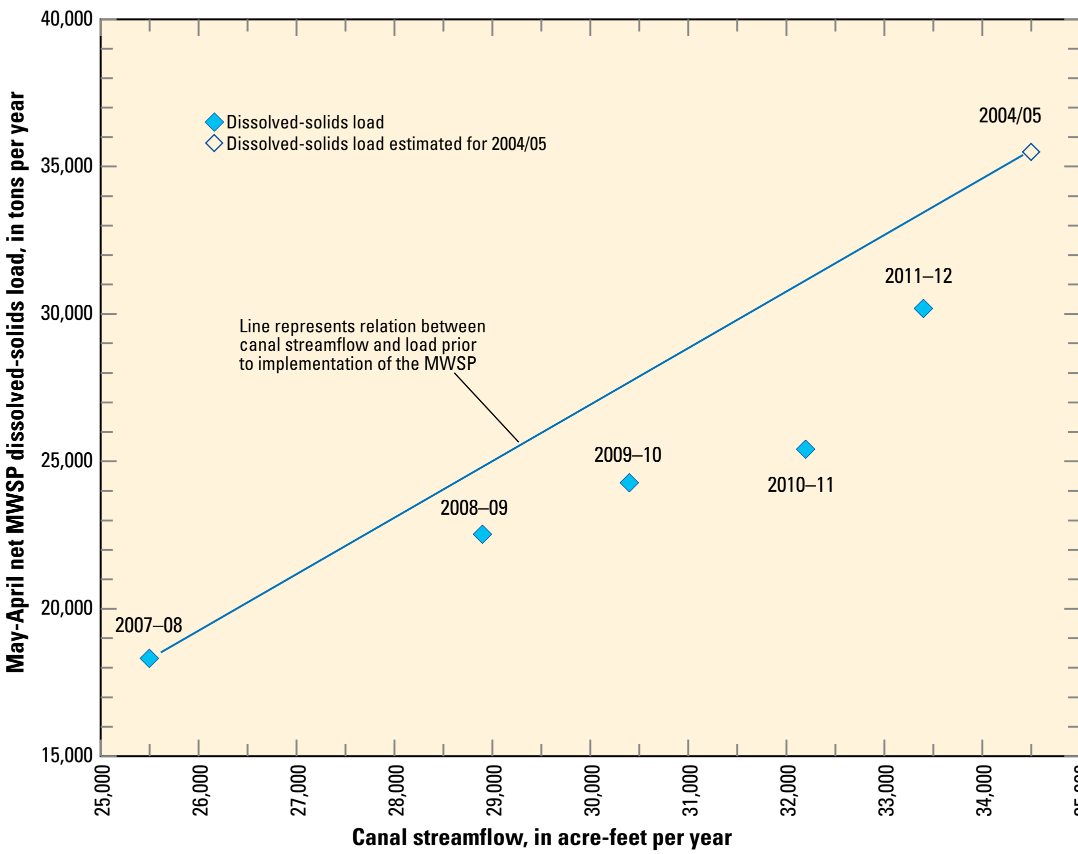

Figure 12. Relation between annual May–April net dissolved-solids load from the Manila/Washam Salinity Project (MWSP) area and canal streamflow diverted into the area, 2004/05 and May 2007–April 2012. The period 2004/05 uses measurements and estimates of streamflow and specific conductance made during June 2004–June 2005.

The second group of data is from May 2007 to April 2012, a period when a cumulatively increasing reduction in loads should result from the incremental implementation of irrigation improvements in the MWSP area. The offset between the two groups is caused by variations in precipitation and the resulting amount of canal streamflow diverted into the area in addition to changes in irrigation systems and practices, and is discussed in the "Effects of Improved Irrigation Practices on Dissolved-Solids Loads" section of this report.

An increase in combined canal streamflow diverted into the MWSP area during the 2007–11 irrigation seasons corresponds to an increase in the May–April net MWSP dissolved-solids load during May 2007–April 2012 (fig. 13). Canal streamflow during the 2012 irrigation season was excluded from this comparison because streamflow was less than the previous irrigation season and data were not collected after September 2012; therefore, a May 2012–April 2013 dissolved-solids load could not be calculated. Combined streamflow in Peoples and Sheep Creek Canals was smallest in 2012 (25,400 acre-ft) and corresponds to an estimated net MWSP dissolved-solids load for the May–October 2012 irrigation season that was smaller than in all of the previous years (fig. 13).

Combined streamflow in Peoples and Sheep Creek Canals also was small in 2007 (25,500 acre-ft) and corresponds to the smallest net annual (May–April) MWSP dissolved-solids load during May 2007–April 2012 (fig. 13). Below normal precipitation in 2007 resulted in less water available for diversion to the canals, and therefore, less water flowing through the area as unconsumed irrigation water and tail water. Similar streamflow amounts diverted by Peoples and Sheep Creek Canals in 2004/05 and 2011 correspond to net annual (May–April) dissolved-solids loads discharged from the MWSP area that are not similar (fig. 13). The smaller net dissolved-solids load estimated for May 2011–April 2012 is likely affected by greater than normal tail water in the canals, irrigation improvements, and the piping of Peoples Canal in 2010, which should have reduced the dissolved-solids load contributed by seepage from the canal in 2011 as compared to 2004/05.

Like canal streamflow, streamflow at site BSD-2 during the irrigation season was smallest in 2012 (2,460 acre-ft) and largest in 2011 (8,550 acre-ft), corresponding to the amount of precipitation measured at the Manila weather station (fig. 14). In 2012, only 1.23 in. of precipitation fell at Manila during the irrigation season and 3.62 in. fell during the water year

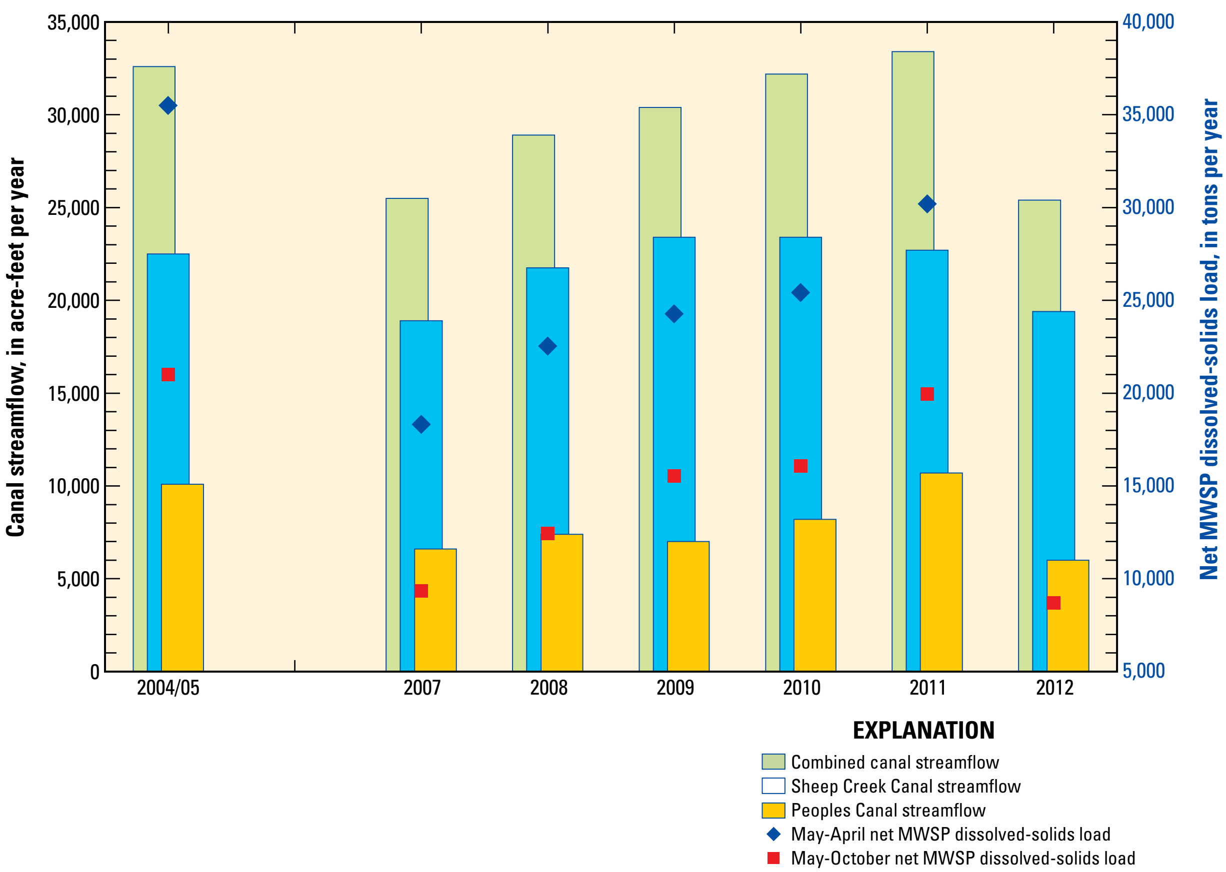

Figure 13. Estimated canal streamflow diverted into the Manila/Washam Salinity Project (MWSP) area, 2004/05 and 2007–12, and annual May–April and May–October net MWSP area dissolved-solids load, 2004/05 and May 2007–October 2012. The period 2004/05 uses measurements and estimates of streamflow and specific conductance made during June 2004–June 2005.

(October 2011–September 2012). Only slightly less water was estimated to be diverted for irrigation in 2012 (25,400 acre-ft) compared to 2007 (25,500 acre-ft), when more precipitation fell, possibly to meet soil moisture and crop requirements. In 2011, 9.05 in. of precipitation fell at Manila during the irrigation season (May to October 2011) and 11.66 in. fell during the water year (October 2010–September 2011). Above average precipitation that year allowed excess streamflow to be diverted into the canals, some of which flowed as tail water to Birch Spring Draw. The second largest irrigation season streamflow measured at site BSD-2 from May 2007 to October 2012 occurred in 2010, also likely affected by above average canal streamflow.

The net irrigation season dissolved-solids load discharged from the MWSP area increased with increasing irrigation season precipitation, as measured at the Manila weather station from May 2007 to October 2011 (fig. 15). This is similar to the relation between site BSD-2 streamflow and precipitation (fig. 14) because net MWSP dissolved-solids load is determined from streamflow and dissolved-solids concentrations at site BSD-2 and other outflow and inflow sites in the MWSP area. However, the same relation does not hold true for the nonirrigation season (November–April) dissolved-solids load and precipitation that fell during the preceding irrigation season (fig. 15). The nonirrigation season streamflow and dissolved-solids load calculated for site BSD-2 and the MWSP area are primarily influenced by groundwater discharge.

The relation between net MWSP dissolved-solids load and precipitation during the irrigation season ($R^2 = 0.8872$, fig. 15) is stronger when the canal flow variable is included; the net tons of dissolved solids per acre-ft of canal flow regressed against precipitation has an $R^2 = 0.9256$. The net tons of dissolved solids discharged from the MWSP area per acre-ft of canal water increased with increasing May–October precipitation as greater outflow (tail water and unconsumed irrigation water) transported a larger load.

Net dissolved-solids load discharged from the MWSP area also increased with Henrys Fork streamflow during the irrigation season (fig. 16). Henrys Fork streamflow is largely dependent on climatic factors, such as precipitation and temperature in its drainage basin, and integrates the effects of these factors from a larger area than the Manila weather station. During the irrigation season, water is diverted into Peoples Canal from Henrys Fork upstream from USGS streamflow gaging station 09229500 near Manila (fig. 1). Although higher irrigation season streamflow in Henrys Fork in 2010 and 2011 corresponds to higher streamflow in Peoples Canal, the relations between increasing Henrys Fork streamflow and increasing site BSD-2 and net MWSP dissolved-solids loads flattens out (fig. 16). This nonlinear relation could result from more tail water in the canal that is discharged directly to Birch Spring Draw, rather than applied to fields, which would likely result in a smaller increase in dissolved-solids load.

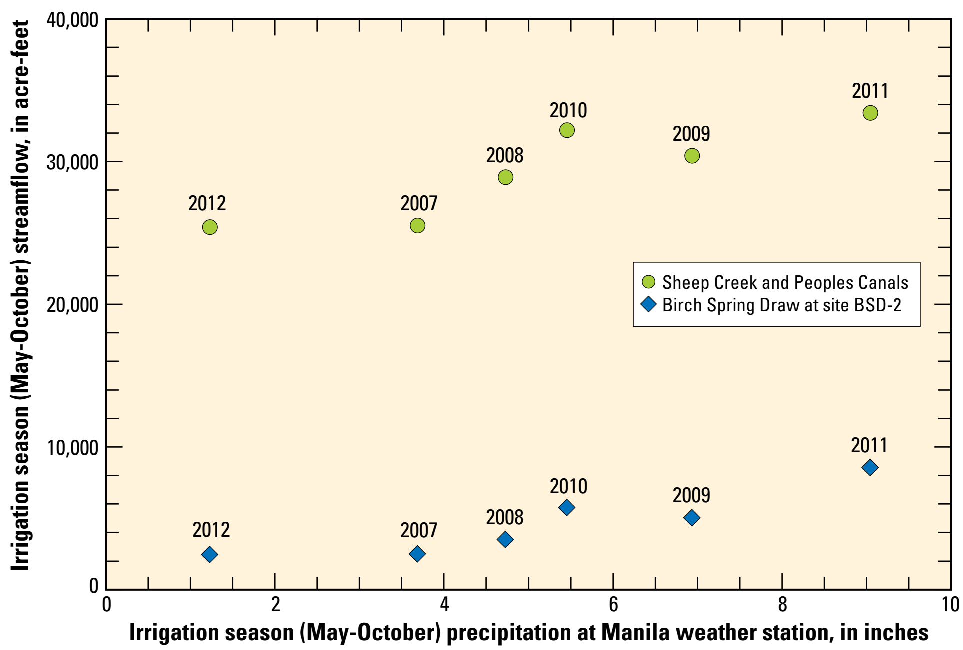

Figure 14. Relations between irrigation season streamflow in Sheep Creek and Peoples Canals and Birch Spring Draw site BSD-2, and irrigation season precipitation at the Manila weather station, May 2007–October 2012.

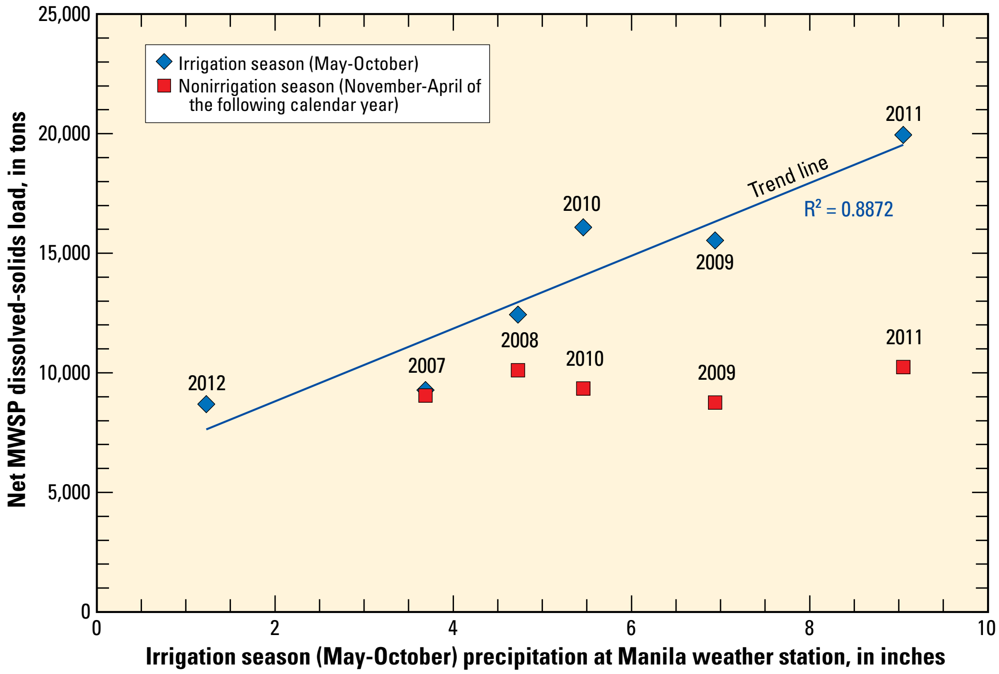

Figure 15. Relations between net dissolved-solids load discharged from the Manila/Washam Salinity Project (MWSP) area during the irrigation and nonirrigation seasons, and irrigation season precipitation at the Manila weather station, May 2007–October 2012.

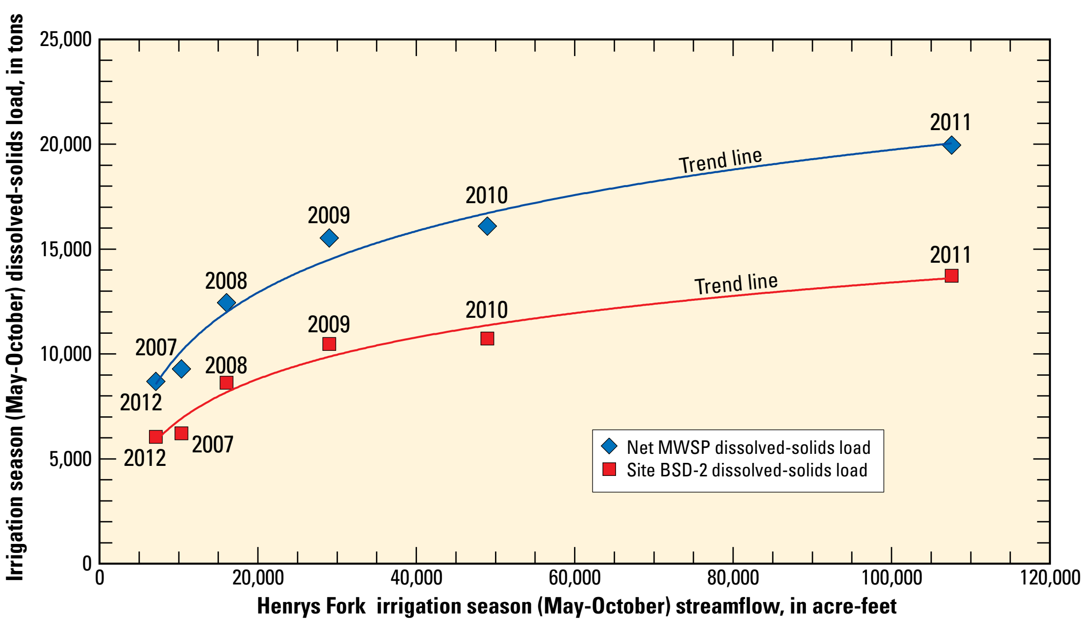

Figure 16. Relations among irrigation season dissolved-solids load at Birch Spring Draw site BSD-2, irrigation season net dissolved-solids load discharged from the Manila/Washam Salinity Project (MWSP) area, and irrigation season streamflow in Henrys Fork (USGS streamflow gaging station 09229500), May 2007–October 2012.

Effects of Improved Irrigation Practices on Dissolved-Solids Loads

The NRCS began coordinating irrigation improvements in 2007 as part of the MWSP to reduce the transport of dissolved solids to Flaming Gorge Reservoir from the agricultural areas surrounding Manila. About 7,780 acres of land that was flood irrigated in the MWSP area prior to 2007 is planned to be converted to use more efficient pressurized sprinkler-irrigation systems (Natural Resources Conservation Service, 2006). The NRCS estimated that on-farm agricultural activities prior to 2007 generated a dissolved-solids load of 27,000 ton/yr from 10,100 acres of irrigated land in the MWSP area, equating to an irrigation related dissolved-solids load of 2.67 tons per acre. Conversion from flood irrigation to wheel-line sprinklers or to a center-pivot sprinkler system is estimated to reduce the dissolved-solids load from the area by 84 and 90 percent, respectively. The NRCS calculated the annual reduction in dissolved-solids load in the MWSP area to be the number of acres converted in a year multiplied by the pre-MWSP implementation irrigation load (2.67 tons per acre) and the percent load reduction based on the change in irrigation practice (Natural Resources Conservation Service, 2011 and 2013). Improvements to irrigation delivery and application systems have been applied incrementally since 2007. By 2012, the NRCS had coordinated irrigation improvements on 3,400 acres, resulting in a calculated cumulative reduction in dissolved-solids load of 8,150 tons in 2012 (Natural Resources Conservation Service, 2013; table 4).

The May–April reporting year was used to evaluate the possible effects of irrigation improvements on the net dissolved-solids load discharged from the MWSP area. It was shown in the previous section that annual dissolved-solids loads are correlated to canal flow, precipitation, and streamflow in Henrys Fork. These factors are all related, but canal flow appears to have the largest influence on dissolved-solids loads discharging from the MWSP area. Therefore, annual net dissolved-solids loads were compared to annual estimates of canal flow to determine if that relation had changed as a result of irrigation improvements.

No reduction in dissolved-solids load associated with the MWSP had occurred during 2004/05, and only a minor reduction (72 tons) was calculated by the NRCS during May 2007–April 2008, the first year of salinity control projects in the area. The observed dissolved-solids loads associated with these periods, and their relation to irrigation season canal streamflow, are shown in figure 17. The line connecting the 2004/05 and 2007–08 points approximates the relation of canal flow to net dissolved-solids load discharged to Flaming Gorge Reservoir prior to implementation of the MWSP. Data points representing the relation between annual dissolved-solids loads from May 2008 to April 2012 and canal streamflow lie below the baseline established for pre-MWSP loads, indicating that from May 2008 to April 2012, less dissolved-solids loading occurred for an equal amount of canal streamflow. This could be reflective of irrigation improvements, resulting in less deep percolation and runoff of excess irrigation water. The shift in the relation of dissolved-solids load to canal streamflow with time could result if less of the water being diverted at the head of the canals was being applied because of improved irrigation practices and efficiencies. As evidence of this, monthly mean streamflow for July and August at site BSD-2 increased each year from 2008 through 2011 (fig. 8*B*), indicating that there was progressively more tail water in Peoples and Sheep Creek Canals draining to the site.

The effect of MWSP irrigation improvements on dissolved-solids load was approximated by adding the cumulative NRCS estimate of reduction in dissolved-solids load to the net May–April MWSP load for each year monitored from May 2007 to April 2012. The theoretical annual net MWSP dissolved-solids load where the cumulative NRCS calculated dissolved-solids load reduction is added to the net dissolved-solids load is what would be expected if there were no irrigation improvements in the area associated with the MWSP. The data points

Table 4. Theoretical annual dissolved-solids load where the reduction in dissolved-solids load calculated by the Natural Resources Conservation Service (NRCS) is added to the net May–April load from the Manila/Washam Salinity Project (MWSP) area, 2004/05 and May 2007–October 2012.

[—, no data]

Period (May–April)	Canal flow (in acre-feet per year)	Net MWSP dissolved-solids load (in tons per year)	Area with new irrigation improvements (in acres)	Cumulative NRCS calculated dissolved-solids load reduction (in tons per year)	Theoretical dissolved-solids load with NRCS calculated load reduction added to the net MWSP load (in tons per year)
[1]2004/05	32,600	35,500	0	0	35,500
2007–08	25,500	18,310	32	72	18,382
2008–09	28,900	22,528	857	2,118	24,646
2009–10	30,400	24,273	1,566	5,882	30,155
2010–11	32,200	26,345	497	7,087	33,432
2011–12	33,400	30,186	368	7,960	38,146
2012–13	25,400	—	84	8,149	—

[1]The period 2004/05 uses measurements and estimates of streamflow and specific conductance made during June 2004–June 2005.

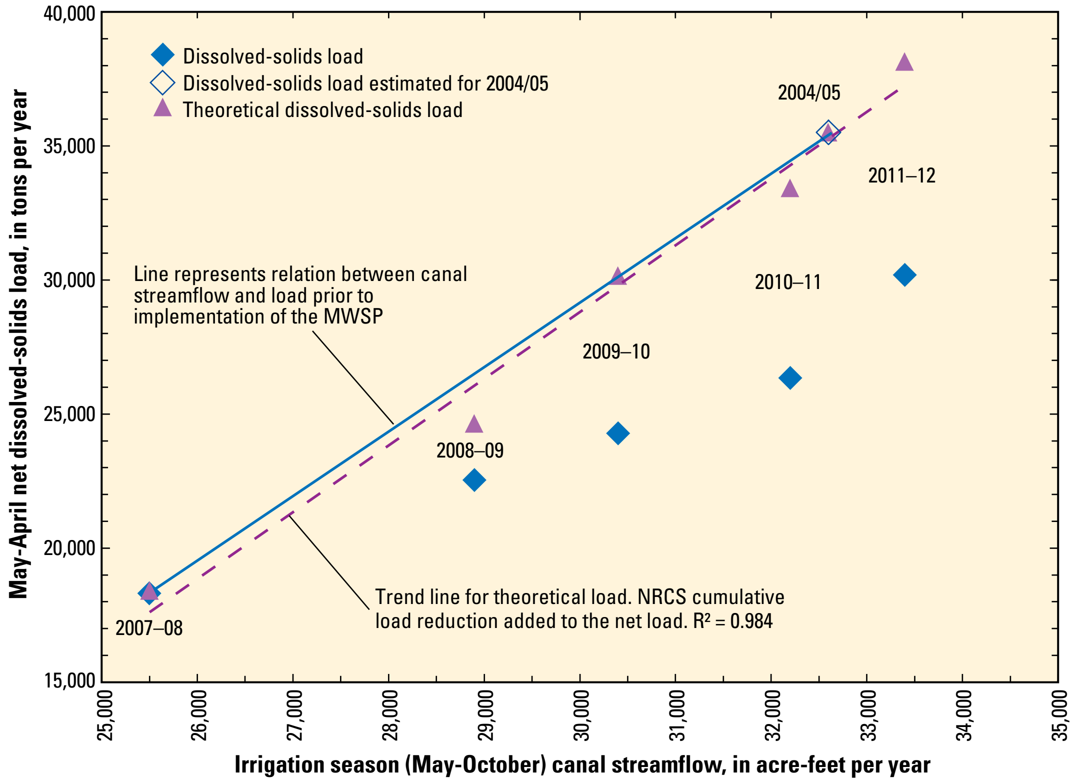

Figure 17. Relations among net dissolved-solids load discharged from the Manila/Washam Salinity Project (MWSP) area, theoretical annual dissolved-solids load where the cumulative Natural Resources Conservation Service (NRCS) calculated dissolved-solids load reduction is added to the net dissolved-solids load, and canal streamflow diverted into the MWSP area, 2004/05 and May 2007–October 2012. The period 2004/05 uses measurements and estimates of streamflow and specific conductance made during June 2004–June 2005.

representing the theoretical dissolved-solids load to canal streamflow relation lie very near the baseline representing the pre-MWSP dissolved-solids load to canal streamflow relation (fig. 17). The proximity of the theoretical data to the baseline constructed from 2004/05 and 2007–08 data shows that the NRCS calculations of load reduction are generally supported by the data collected during this study.

Of the 7,780 acres projected to receive irrigation improvements associated with the MWSP, less than half had received improvements at the conclusion of data collection by this study (October 2012). As more acres receive improvements, there could be a greater shift in the dissolved-solids load to canal streamflow relation from the baseline. Additional study in subsequent years that includes an annual assessment of dissolved-solids load discharged from the MWSP area and measurement of canal streamflow into the area would be useful to verify the persistence or increase of reductions in dissolved-solids loads as additional irrigation improvements are implemented by the MWSP.

Summary

The Manila/Washam Salinity Project (MWSP) is a cooperative effort between local ranchers and farmers and the NRCS to reduce the transport of dissolved solids to Flaming Gorge Reservoir from about 10,100 acres of irrigated agricultural land near Manila, Utah. Water brought to the MWSP area by Peoples Canal and Sheep Creek Canal is applied to crops by flood and sprinkler irrigation. Percolation of water from unlined sections of the canals and from excess water applied to fields (unconsumed irrigation water) becomes groundwater recharge. Birch Spring Draw is a major drain in the MWSP area and is sustained by shallow groundwater discharge, surface runoff from precipitation, and tail water—runoff from agricultural lands irrigated with water transported by Peoples Canal and Sheep Creek Canal and (or) water that passes through the canal distribution system without being applied for irrigation.

To estimate dissolved-solids loads from the MWSP area, the discharge and water quality from Birch Spring Draw and other selected outflows and inflows were monitored from May 2007 to October 2012. An average annual (May–April) streamflow of 5,960 acre-ft discharged from Birch Spring Draw at site BSD-2 to Flaming Gorge Reservoir during 2007–12, containing an average dissolved-solids load of 14,660 tons. Annual dissolved-solids loads at site BSD-2 ranged from 10,590 tons in May 2007–April 2008, to 18,770 tons in May 2011–April 2012. Dissolved-solids loads were larger during the irrigation season than the nonirrigation season because more water was available to mobilize salts from the soil and transport them to Birch Spring Draw. Irrigation season dissolved-solids loads at site BSD-2 ranged from 6,045 tons in 2012 to 13,720 tons in 2011.

The net dissolved-solids load discharged from the MWSP area (the load derived only from within the MWSP area) was determined for each of 36 sets of streamflow and dissolved-solids concentration measurements and estimates by summing the loads from outflow sites and then subtracting the input dissolved-solids loads estimated from the inflow sites on Peoples Canal and Sheep Creek Canal. An average net MWSP dissolved-solids load of about 24,300 ton/yr (May–April) was estimated from the relation between streamflow and dissolved-solids concentration at site BSD-2 and other measured inflows and outflows in the MWSP area. Annual net MWSP dissolved-solids loads (May–April) ranged from 18,310 tons in 2007–08 to 30,190 tons in 2011–12. Net MWSP dissolved-solids loads during the irrigation season ranged from 8,680 tons in 2012 to 19,940 tons in 2011.

The amount of precipitation and water available for irrigation are important factors that affect the net dissolved-solids load in outflow from the MWSP area. Net dissolved-solids load discharged from the MWSP area increased with increasing canal streamflow and precipitation measured at Manila during the irrigation season. The net tons of dissolved solids discharged from the MWSP area per acre-ft of canal water increased with increasing May–October precipitation. Net dissolved-solids load discharged from the MWSP area also increased with Henrys Fork streamflow during the irrigation season.

Irrigation improvements began to be implemented in 2007 to reduce dissolved-solids loads discharged from the MWSP area. Dissolved-solids loads estimated for May–April 2004/05 and 2007–08 were related to canal streamflow and form a baseline that is assumed to represent conditions prior to or during 2007, before changes to irrigation systems and improved irrigation practices were implemented in the MWSP area. Data points representing the relation between annual dissolved-solids loads from May 2008 to April 2012 and canal streamflow lie below the baseline established for pre-MWSP loads, indicating that from May 2008–April 2012, less dissolved-solids loading occurred for an equal amount of canal streamflow. This could be reflective of irrigation improvements, resulting in less deep percolation and runoff of excess (unconsumed) irrigation water.

The effect of MWSP irrigation improvements on dissolved-solids load was approximated by adding the cumulative NRCS estimate of reduction in dissolved-solids load to the net May–April MWSP load for each year monitored from May 2007 to April 2012. The theoretical annual net dissolved-solids load where the cumulative NRCS calculated dissolved-solids load reduction is added to the net dissolved-solids load is what would be expected if there were no irrigation improvements in the area associated with the MWSP. The theoretical data points lie very near the baseline representing the pre-MWSP dissolved-solids load to canal streamflow relation. The proximity of the theoretical data points to the baseline constructed from 2004/05 and 2007–08 data shows that the NRCS calculations of reduction in dissolved-solids load are generally supported by the data collected during this study.

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Appendix

Table A-1. Data collected at water-quality sampling sites in the Manila/Washam Salinity Project area.

[Site identifier: see figure 1 and table 1 for more site information. E, estimated; —, no measurement; <, less than]

Site identifier	Date	Time	Discharge, instantaneous, cubic feet per second	Specific conductance, microsiemens per centimeter at 25 degrees Celsius	Dissolved-solids concentration, residue on evaporation at 180 degrees Celsius, milligrams per liter	Used to determine relation of specific conductance to dissolved-solids concentration (see table 1)
BSD-1	5/27/04	1400	E20	1,890	—	
BSD-1	6/30/04	0855	22	2,290	1,860	
BSD-1	8/11/04	1035	8.1	2,340	1,790	
BSD-1	9/15/04	1105	9.2	2,640	2,300	
BSD-1	10/27/04	1050	17	2,340	—	
BSD-1	11/23/04	1015	3.5	5,430	4,850	
BSD-1	1/20/05	1145	2.9	5,900	—	
BSD-1	2/24/05	1100	3.4	6,890	5,940	
BSD-1	4/6/05	0950	2.2	6,060	—	
BSD-1	5/31/05	1930	24	2,120	1,580	
BSD-2	6/12/07	1500	7.7	2,370	1,840	X
BSD-2	7/10/07	1525	1.2	4,390	3,520	X
BSD-2	8/13/07	1430	1.4	3,210	2,670	X
BSD-2	9/27/07	1410	4.7	3,690	3,230	X
BSD-2	10/16/07	1350	14	1,740	1,340	X
BSD-2	11/7/07	1350	3.5	3,660	3,180	X
BSD-2	12/12/07	1230	2.1	5,560	4,910	X
BSD-2	1/14/08	1150	0.94	4,760	4,320	X
BSD-2	2/13/08	1600	0.93	8,250	7,450	X
BSD-2	3/18/08	1320	1.4	6,800	6,200	X
BSD-2	4/10/08	1515	1.7	6,000	5,380	X
BSD-2	5/20/08	1545	4.3	2,840	2,270	X
BSD-2	6/9/08	1415	13	1,880	1,410	X
BSD-2	7/17/08	1405	5.8	2,070	1,630	X
BSD-2	8/25/08	1540	5.2	2,450	2,000	X
BSD-2	10/1/08	0800	3.6	2,980	2,400	X
BSD-2	10/16/08	1420	16	1,810	1,390	X
BSD-2	12/2/08	1415	1.9	5,540	4,880	X
BSD-2	1/9/09	1400	1.4	4,770	4,120	X
BSD-2	2/18/09	1400	1.0	6,420	5,620	X
BSD-2	4/6/09	1150	2.6	8,980	8,030	X
BSD-2	4/29/09	1156	8.0	2,290	—	
BSD-2	5/20/09	0755	9.8	2,000	1,510	X
BSD-2	6/4/09	1355	25	1,680	1,240	X
BSD-2	8/4/09	1030	17	1,550	1,190	X
BSD-2	9/2/09	1530	4.8	2,380	—	
BSD-2	10/7/09	1550	2.5	4,410	3,920	X
BSD-2	11/10/09	1345	2.4	4,260	—	
BSD-2	12/28/09	1400	1.2	4,250	—	
BSD-2	2/22/10	1300	0.76	7,670	7,000	X
BSD-2	3/17/10	1600	2.5	6,480	—	
BSD-2	4/8/10	1240	2.4	5,950	5,290	X
BSD-2	5/10/10	1550	2.6	4,640	—	

Table A-1. Data collected at water-quality sampling sites in the Manila/Washam Salinity Project area.—Continued

[Site identifier: see figure 1 and table 1 for more site information. E, estimated; —, no measurement; <, less than]

Site identifier	Date	Time	Discharge, instantaneous, cubic feet per second	Specific conductance, microsiemens per centimeter at 25 degrees Celsius	Dissolved-solids concentration, residue on evaporation at 180 degrees Celsius, milligrams per liter	Used to determine relation of specific conductance to dissolved-solids concentration (see table 1)
BSD-2	6/23/10	1430	27	1,280	915	X
BSD-2	7/14/10	1300	24	1,660	—	
BSD-2	8/18/10	1245	21	1,560	—	
BSD-2	9/10/10	1000	12	1,980	—	
BSD-2	10/14/10	1230	2.8	3,570	3,080	X
BSD-2	10/14/10	1231	—	3,570	3,090	X
BSD-2	11/17/10	1230	1.4	5,580	—	
BSD-2	1/5/11	1310	1.0	4,420	4,070	X
BSD-2	1/20/11	1220	—	7,700	—	
BSD-2	3/4/11	1200	4.7	6,460	—	
BSD-2	4/5/11	1234	—	2,880	—	
BSD-2	4/25/11	1305	—	2,660	—	
BSD-2	5/23/11	1116	—	1,530	—	
BSD-2	7/7/11	1823	—	1,820	—	
BSD-2	8/23/11	1340	22	1,310	—	
BSD-2	9/16/11	1036	24	1,820	—	
BSD-2	10/4/11	1500	14	2,130	—	
BSD-2	10/4/11	1519	—	2,130	—	
BSD-2	11/9/11	1534	2.4	5,580	—	
BSD-2	2/1/12	1230	1.3	4,570	—	
BSD-2	3/28/12	1340	1.7	5,420	4,700	X
BSD-2	5/10/12	1329	5.7	2,590	—	
BSD-2	6/20/12	1310	8.8	2,210	—	
BSD-2	7/26/12	1315	8.1	2,240	—	
BSD-2	8/21/12	1535	6.2	2,070	—	
BSD-2	9/20/12	1317	4.5	2,770	—	
BSD-2	10/31/12	1130	4.6	3,200	—	
PC-2	6/16/04	1420	E9.0	1,890	—	
PC-2	6/30/04	1740	15	2,030	1,700	X
PC-2	8/12/04	0845	3.2	1,920	1,640	X
PC-2	9/16/04	0930	4.6	2,080	1,830	X
PC-2	10/27/04	1641	4.0	2,070	—	
PC-2	11/23/04	1550	0.47	3,000	2,800	X
PC-2	1/20/05	1030	0.25	3,190	—	
PC-2	2/24/05	0920	0.13	3,300	—	
PC-2	4/6/05	1255	0.08	3,350	—	
PC-2	4/19/05	1255	0.15	2,930	—	
PC-2	5/31/05	1540	9.2	1,650	1,310	X
PC-2	7/11/07	0910	2.1	2,080	1,700	X
PC-2	8/14/07	0830	2.6	2,220	—	
PC-2	9/27/07	1630	2.5	2,220	1,930	X
PC-2	10/16/07	1555	5.4	1,880	1,610	X
PC-2	11/7/07	1540	0.51	2,750	—	
PC-2	12/12/07	1500	0.37	2,940	2,610	X
PC-2	2/13/08	1150	0.08	3,110	2,820	X

Table A-1. Data collected at water-quality sampling sites in the Manila/Washam Salinity Project area.—Continued

[Site identifier: see figure 1 and table 1 for more site information. E, estimated; —, no measurement; <, less than]

Site identifier	Date	Time	Discharge, instantaneous, cubic feet per second	Specific conductance, microsiemens per centimeter at 25 degrees Celsius	Dissolved-solids concentration, residue on evaporation at 180 degrees Celsius, milligrams per liter	Used to determine relation of specific conductance to dissolved-solids concentration (see table 1)
PC-2	3/18/08	1530	0.06	3,130	—	
PC-2	4/11/08	0850	0.08	3,220	—	
PC-2	5/20/08	1200	1.3	1,900	1,560	X
PC-2	6/9/08	1830	7.4	1,760	1,360	X
PC-2	7/17/08	1240	9.1	1,860	1,530	X
PC-2	8/25/08	1250	3.3	2,130	—	
PC-2	9/30/08	1300	1.2	2,690	2,520	X
PC-2	12/2/08	1110	0.19	3,100	2,830	X
PC-2	2/18/09	1530	0.02	3,310	3,010	X
PC-2	5/19/09	1440	10	1,460	1,110	X
PC-2	6/4/09	1700	4.5	1,620	—	
PC-2	9/2/09	0910	3.7	2,200	—	
PC-2	11/10/09	1125	0.31	3,020	—	
PC-2	3/17/10	1200	0.07	3,360	—	
PC-2	5/10/10	1330	0.08	3,180	—	
PC-2	6/23/10	1830	1.4	1,820	—	
PC-2	7/14/10	1630	2.6	1,860	—	
PC-2	9/9/10	1225	3.3	2,100	—	
PC-2	10/4/11	1215	1.6	1,790	—	
PC-2	3/28/12	1615	0.08	3,330	3,040	X
PC-2	8/21/12	1400	0.84	1,820	—	
SV-2	6/30/04	1455	9.7	1,420	1,020	X
SV-2	8/12/04	0950	6.5	935	639	X
SV-2	9/16/04	1050	5.1	1,080	751	X
SV-2	10/28/04	1050	8.3	1,910	—	
SV-2	11/24/04	1010	2.1	2,030	1,460	X
SV-2	1/20/05	0945	1.1	2,480	—	
SV-2	4/6/05	1355	0.72	2,070	—	
SV-2	5/31/05	1445	0.56	2,120	1,490	X
SV-2	7/11/07	1010	3.0	1,360	—	
SV-2	8/14/07	0945	2.1	1,460	1,030	X
SV-2	9/27/07	1720	2.2	1,370	—	
SV-2	10/16/07	1720	2.2	1,370	—	
SV-2	11/7/07	1640	0.64	1,930	—	
SV-2	12/12/07	1550	1.1	2,190	1,560	X
SV-2	2/13/08	1215	0.83	2,090	1,550	X
SV-2	3/18/08	1640	1.1	2,360	—	
SV-2	4/11/08	0940	1.0	2,170	—	
SV-2	6/9/08	1915	3.5	1,250	—	
SV-2	7/17/08	1300	7.1	1,330	—	
SV-2	8/25/08	1400	5.2	1,010	—	
SV-2	9/30/08	1340	1.9	1,500	—	
SV-2	12/2/08	1205	1.9	2,030	1,480	X
SV-2	2/18/09	1640	0.89	2,070	—	
SV-2	5/19/09	1530	13	506	310	X

Table A-1. Data collected at water-quality sampling sites in the Manila/Washam Salinity Project area.—Continued

[Site identifier: see figure 1 and table 1 for more site information. E, estimated; —, no measurement; <, less than]

Site identifier	Date	Time	Discharge, instantaneous, cubic feet per second	Specific conductance, microsiemens per centimeter at 25 degrees Celsius	Dissolved-solids concentration, residue on evaporation at 180 degrees Celsius, milligrams per liter	Used to determine relation of specific conductance to dissolved-solids concentration (see table 1)
SV-2	6/4/09	1750	14	969	—	
SV-2	9/2/09	1005	3.2	1,070	—	
SV-2	11/10/09	1210	1.1	2,020	—	
SV-2	3/17/10	1320	2.1	3,500	2,990	X
SV-2	5/10/10	1415	0.51	2,200	—	
SV-2	6/24/10	0800	5.5	790	—	
SV-2	7/14/10	1730	8.2	743	—	
SV-2	9/9/10	1320	7.2	771	—	
SV-2	10/4/11	1115	0.99	2,050	—	
SV-2	8/21/12	1255	2.0	938	—	
DRN-1	6/29/04	1635	2.7	2,400	2,070	X
DRN-1	8/11/04	1650	0.25	2,910	2,710	X
DRN-1	9/15/04	1800	0.03	3,870	3,800	X
DRN-1	10/27/04	1535	0.11	4,340	—	
DRN-1	10/27/04	1555	0.11	3,890	—	
DRN-1	11/23/04	1500	0.1	3,800	3,740	X
DRN-1	1/19/05	1610	<0.01	4,320	—	
DRN-1	4/5/05	1610	E0.20	4,140	—	
DRN-1	4/24/05	1700	0.13	7,880	—	
DRN-1	6/1/05	1240	E0.05	3,740	—	
DRN-1	6/9/08	1120	4.7	802	—	
DRN-1	7/18/08	1030	2.0	1,150	—	
DRN-1	8/26/08	1030	1.4	1,380	—	
DRN-1	10/1/08	1345	0.28	1,520	—	
DRN-1	12/3/08	0910	0.02	2,720	2,360	X
DRN-1	2/19/09	0940	0.18	2,650	—	
DRN-1	5/20/09	1000	E0.07	2,090	—	
DRN-1	6/4/09	1510	E0.01	2,850	—	
DRN-1	9/3/09	1100	E0.07	1,850	—	
DRN-1	3/18/10	0800	E0.01	2,710	—	
DRN-1	6/24/10	1200	0.79	865	—	
DRN-1	7/15/10	1100	0.68	1,120	—	
DRN-1	9/10/10	1230	E0.10	1,500	—	
DRN-1	10/5/11	1115	0.7	1,840	—	
DRN-1	8/22/12	1010	0.25	1,370	—	
DRN-1a	8/11/04	1640	0.27	3,100	2,820	X
DRN-1a	9/15/04	1810	0.09	3,630	3,480	X
DRN-1a	10/27/04	1535	0.11	4,340	—	
DRN-1a	11/23/04	1440	0.07	4,950	4,680	X
DRN-1a	1/19/05	1630	0.02	4,520	—	
DRN-1a	4/5/05	1545	0.02	6,800	—	
DRN-1a	6/1/05	1220	0.2	4,350	3,840	X
DRN-1a	5/10/07	1650	0.02	6,310	—	
DRN-1a	6/13/07	1110	0.04	4,080	3,610	X
DRN-1a	9/28/07	0740	0.24	2,920	—	

Table A-1. Data collected at water-quality sampling sites in the Manila/Washam Salinity Project area.—Continued

[Site identifier: see figure 1 and table 1 for more site information. E, estimated; —, no measurement; <, less than]

Site identifier	Date	Time	Discharge, instantaneous, cubic feet per second	Specific conductance, microsiemens per centimeter at 25 degrees Celsius	Dissolved-solids concentration, residue on evaporation at 180 degrees Celsius, milligrams per liter	Used to determine relation of specific conductance to dissolved-solids concentration (see table 1)
DRN-1a	9/28/07	1035	E0.50	1,510	—	
DRN-1a	10/16/07	1415	0.05	3,760	—	
DRN-1a	11/8/07	0835	0.04	4,340	—	
DRN-1a	12/13/07	1000	0.02	4,620	—	
DRN-1a	4/10/08	1650	0.03	4,520	—	
DRN-1a	5/20/08	1315	0.03	5,100	—	
DRN-1a	6/9/08	1710	0.09	3,540	—	
DRN-1a	7/17/08	1656	0.23	2,080	—	
DRN-1a	8/25/08	1815	0.04	3,740	—	
DRN-1a	9/30/08	1510	0.04	3,920	—	
DRN-1a	12/3/08	0850	0.03	4,720	4,400	X
DRN-1a	2/18/09	1720	0.02	5,030	—	
DRN-1a	5/19/09	1615	0.03	6,970	—	
DRN-1a	6/4/09	1450	0.07	4,410	—	
DRN-1a	9/2/09	1145	0.05	3,860	—	
DRN-1a	11/10/09	1455	0.19	4,150	—	
DRN-1a	3/18/10	0810	0.02	3,710	—	
DRN-1a	5/10/10	1800	0.02	5,560	—	
DRN-1a	6/23/10	1600	0.04	2,280	—	
DRN-1a	7/15/10	1010	0.5	2,690	—	
DRN-1a	9/9/10	1520	0.3	2,340	—	
DRN-1a	10/4/11	1245	0.08	3,280	—	
DRN-1a	8/21/12	1700	0.01	4,970	—	
DRN-2	6/29/04	1740	5.8	2,170	1,830	X
DRN-2	8/11/04	1540	1.7	2,710	2,420	X
DRN-2	9/15/04	1700	0.57	3,240	3,080	X
DRN-2	10/27/04	1443	0.2	5,100	—	
DRN-2	11/23/04	1410	0.12	5,140	4,780	X
DRN-2	1/19/05	1700	0.06	5,540	—	
DRN-2	2/25/05	1446	0.07	5,620	—	
DRN-2	4/6/05	1140	0.07	5,950	—	
DRN-2	6/1/05	1350	1.7	3,080	2,610	X
DRN-2	5/10/07	1640	4.3	2,980	—	
DRN-2	6/13/07	1050	1.9	1,770	1,450	X
DRN-2	7/10/07	1630	0.02	5,680	5,140	X
DRN-2	9/28/07	0840	4.9	2,380	2,060	X
DRN-2	10/16/07	1720	0.49	3,440	—	
DRN-2	11/8/07	0825	0.19	3,850	—	
DRN-2	12/13/07	0940	0.07	4,190	4,030	X
DRN-2	3/19/08	0915	0.05	5,170	—	
DRN-2	4/10/08	1700	0.04	5,300	5,040	X
DRN-2	5/20/08	1330	0.41	3,340	2,890	X
DRN-2	6/9/08	1700	2.5	2,410	—	
DRN-2	7/17/08	1640	3.6	1,700	1,400	X
DRN-2	8/25/08	1830	0.49	2,910	—	

Table A-1. Data collected at water-quality sampling sites in the Manila/Washam Salinity Project area.—Continued

[Site identifier: see figure 1 and table 1 for more site information. E, estimated; —, no measurement; <, less than]

Site identifier	Date	Time	Discharge, instantaneous, cubic feet per second	Specific conductance, microsiemens per centimeter at 25 degrees Celsius	Dissolved-solids concentration, residue on evaporation at 180 degrees Celsius, milligrams per liter	Used to determine relation of specific conductance to dissolved-solids concentration (see table 1)
DRN-2	9/30/08	1500	1.2	2,760	2,390	X
DRN-2	12/2/08	1600	0.08	4,630	—	
DRN-2	2/18/09	1710	0.02	5,560	—	
DRN-2	5/19/09	1640	1.2	3,190	—	
DRN-2	6/4/09	1555	1.7	2,850	—	
DRN-2	9/2/09	1113	3.1	2,410	—	
DRN-2	11/10/09	1447	0.47	4,230	—	
DRN-2	3/18/10	0830	0.03	5,530	—	
DRN-2	5/10/10	1815	0.05	6,590	—	
DRN-2	6/23/10	1545	3.6	1,780	—	
DRN-2	7/15/10	0945	4.9	2,040	—	
DRN-2	9/9/10	1550	4.4	2,060	—	
DRN-2	10/4/11	1315	1.9	2,460	—	
DRN-2	3/28/12	1210	0.09	6,770	6,450	X
DRN-2	8/21/12	1650	0.33	2,800	—	
DRN-3	6/30/04	1000	1.9	2,070	1,720	X
DRN-3	8/11/04	1025	0.1	2,820	2,630	X
DRN-3	9/15/04	1120	1.7	1,970	1,700	X
DRN-3	10/27/04	1140	0.31	2,850	—	
DRN-3	11/23/04	1030	0.05	3,650	3,510	X
DRN-3	1/20/05	1220	<0.01	3,690	—	
DRN-3	2/24/05	1010	E0.01	3,710	—	
DRN-3	4/6/05	1010	E0.05	3,730	—	
DRN-3	6/1/05	1500	<0.01	3,960	—	
DRN-3	6/9/08	1530	0.16	1,530	—	
DRN-3	7/18/08	0920	0.17	1,810	—	
DRN-3	8/26/08	0910	0.03	3,740	—	
DRN-3	10/1/08	1246	0.26	2,000	—	
DRN-3	12/2/08	1520	0	3,630	—	
DRN-3	6/5/09	0900	1.4	1,310	—	
DRN-3	9/3/09	1015	0.76	1,750	—	
DRN-3	3/18/10	0900	E0.01	3,460	—	
DRN-3	5/11/10	0930	0	3,650	—	
DRN-3	6/24/10	0955	0.04	3,390	—	
DRN-3	7/15/10	0850	0.04	4,230	—	
DRN-3	9/9/10	1145	0.1	2,730	—	
DRN-3	8/22/12	0934	0.02	3,950	—	
DRN-4	6/30/04	1100	0.33	3,330	3,050	X
DRN-4	8/11/04	1220	<0.01	2,960	2,730	X
DRN-4	9/15/04	1245	0.08	2,460	—	
DRN-4	10/27/04	1240	E0.30	3,040	—	
DRN-4	11/23/04	1100	0.02	3,220	3,090	X
DRN-4	1/20/05	1240	<0.01	3,250	—	
DRN-4	2/24/05	1023	<0.01	2,000	—	
DRN-4	6/1/05	1530	0.31	1,220	900	X

Table A-1. Data collected at water-quality sampling sites in the Manila/Washam Salinity Project area.—Continued

[Site identifier: see figure 1 and table 1 for more site information. E, estimated; —, no measurement; <, less than]

Site identifier	Date	Time	Discharge, instantaneous, cubic feet per second	Specific conductance, microsiemens per centimeter at 25 degrees Celsius	Dissolved-solids concentration, residue on evaporation at 180 degrees Celsius, milligrams per liter	Used to determine relation of specific conductance to dissolved-solids concentration (see table 1)
DRN-4	7/18/08	0940	0.24	2,810	—	
DRN-4	8/26/08	0925	0.14	3,090	—	
DRN-4	10/1/08	1300	0.19	2,800	—	
DRN-4	12/2/08	1530	0.01	3,560	—	
DRN-4	5/19/09	0910	0	3,740	—	
DRN-4	6/5/09	0910	0	3,770	—	
DRN-4	9/3/09	1025	0.55	2,270	—	
DRN-4	5/11/10	0945	0	3,870	—	
DRN-4	6/24/10	1000	0.37	1,730	—	
DRN-4	7/15/10	0900	0.09	2,450	—	
DRN-4	9/10/10	1150	E2.0	1,960	—	
DRN-4	10/5/11	1010	0.32	1,980	—	
DRN-4	3/28/12	1535	0	3,440	3,270	X
DRN-4	8/22/12	0940	0.17	3,500	—	
LAT-1	8/11/04	1400	0.07	1,980	1,630	X
LAT-1	9/15/04	1405	0.74	1,970	—	
LAT-1	10/27/04	1320	E0.10	6,100	—	
LAT-1	11/23/04	1315	0.01	7,160	—	
LAT-1	5/31/05	2000	0.14	1,950	—	
LAT-1	6/9/08	1520	1.2	1,280	—	
LAT-1	7/18/08	0900	0	1,560	—	
LAT-1	8/26/08	1000	0.02	2,020	—	
LAT-1	10/1/08	1240	0.42	1,870	—	
LAT-1	5/20/09	0900	0.48	1,210	—	
LAT-1	6/5/09	0930	0.96	1,520	—	
LAT-1	9/3/09	1100	2.4	1,760	—	
LAT-1	5/11/10	1015	0.58	2,150	—	
LAT-1	6/24/10	0915	3.6	1,300	1,010	X
LAT-1	7/15/10	0800	3.3	1,330	—	
LAT-1	9/9/10	1610	2.1	1,550	—	
LAT-1	10/5/11	1050	1.0	1,500	—	
LAT-1	8/21/12	1640	0.61	1,730	—	
AW-1	8/10/04	1430	4.3	3,640	3,580	X
AW-1	9/14/04	1610	3.0	4,160	4,080	X
AW-1	10/26/04	1300	4.1	4,140	—	
AW-1	11/22/04	1345	3.8	4,320	4,450	X
AW-1	1/19/05	1135	2.6	4,150	—	
AW-1	2/24/05	1600	2.3	4,030	4,080	X
AW-1	4/5/05	1325	1.6	4,560	—	
AW-1	6/1/05	0930	1.3	4,470	4,250	X
AW-1	6/13/07	1250	1.9	3,690	—	
AW-1	7/10/07	1840	1.2	3,670	—	
AW-1	8/14/07	1345	2.2	3,840	3,950	X
AW-1	9/27/07	1855	2.2	3,860	—	
AW-1	11/8/07	1130	2.1	4,100	—	

Table A-1. Data collected at water-quality sampling sites in the Manila/Washam Salinity Project area.—Continued

[Site identifier: see figure 1 and table 1 for more site information. E, estimated; —, no measurement; <, less than]

Site identifier	Date	Time	Discharge, instantaneous, cubic feet per second	Specific conductance, microsiemens per centimeter at 25 degrees Celsius	Dissolved-solids concentration, residue on evaporation at 180 degrees Celsius, milligrams per liter	Used to determine relation of specific conductance to dissolved-solids concentration (see table 1)
AW-1	12/13/07	1115	1.5	4,310	—	
AW-1	2/13/08	1400	1.4	3,930	3,970	X
AW-1	3/19/08	1020	1.9	3,750	—	
AW-1	4/10/08	1810	1.6	3,870	—	
AW-1	5/20/08	1709	0.96	4,180	—	
AW-1	6/9/08	1300	1.4	4,020	—	
AW-1	7/17/08	1800	3.4	3,460	3,450	X
AW-1	8/25/08	1630	3.1	3,750	—	
AW-1	9/30/08	1600	1.8	3,900	3,990	X
AW-1	12/3/08	1023	2.5	4,020	—	
AW-1	2/19/09	1050	1.5	4,190	4,090	X
AW-1	4/6/09	1600	3.1	3,810	—	
AW-1	5/20/09	1236	1.2	4,220	—	
AW-1	6/4/09	1145	1.6	3,980	—	
AW-1	7/9/09	1648	7.5	2,890	—	
AW-1	8/4/09	1445	4.2	3,270	—	
AW-1	9/3/09	1240	2.3	3,720	—	
AW-1	10/8/09	1130	2.4	3,960	3,940	X
AW-1	11/10/09	1530	3.0	3,640	—	
AW-1	12/28/09	1450	2.4	3,660	—	
AW-1	2/22/10	1520	1.7	3,580	—	
AW-1	3/17/10	1745	2.5	3,370	—	
AW-1	4/8/10	1430	2.3	3,770	3,670	X
AW-1	5/10/10	1730	1.2	3,880	—	
AW-1	6/23/10	1700	2.8	3,310	—	
AW-1	7/15/10	1215	1.8	3,600	—	
AW-1	8/18/10	1445	2.4	3,600	—	
AW-1	9/9/10	1455	2.2	3,930	—	
AW-1	10/14/10	1500	1.9	4,030	—	
AW-1	11/17/10	1400	2.7	4,040	—	
AW-1	1/5/11	1430	1.8	3,950	—	
AW-1	3/4/11	1300	1.4	3,950	—	
AW-1	8/23/11	1430	5.9	3,050	—	
AW-1	10/4/11	1630	3.0	4,080	—	
AW-1	12/28/11	1530	2.7	3,660	—	
AW-1	2/1/12	1330	3.5	3,830	—	
AW-1	3/28/12	1055	1.7	3,680	3,540	X
AW-1	5/10/12	1455	3.2	2,500	—	
AW-1	6/20/12	1420	0.58	4,080	—	
AW-1	7/26/12	1440	0.94	3,840	—	
AW-1	8/22/12	1115	0.55	4,060	—	
AW-1	9/20/12	1435	0.8	4,100	—	
CC-1	7/1/04	0955	0.87	3,300	3,120	X
CC-1	8/10/04	1530	E0.06	3,200	3,070	X
CC-1	9/15/04	1725	0.05	3,890	—	

Table A-1. Data collected at water-quality sampling sites in the Manila/Washam Salinity Project area.—Continued

[Site identifier: see figure 1 and table 1 for more site information. E, estimated; —, no measurement; <, less than]

Site identifier	Date	Time	Discharge, instantaneous, cubic feet per second	Specific conductance, microsiemens per centimeter at 25 degrees Celsius	Dissolved-solids concentration, residue on evaporation at 180 degrees Celsius, milligrams per liter	Used to determine relation of specific conductance to dissolved-solids concentration (see table 1)
CC-1	10/26/04	1620	0.32	4,040	—	
CC-1	1/19/05	1350	0.6	4,240	—	
CC-1	4/5/05	1440	0.24	4,070	—	
CC-1	6/1/05	1000	0.05	3,100	—	
CC-1	12/3/08	0940	0.45	4,240	—	
CC-1	2/19/09	1000	E0.31	4,380	—	
DRN-5	6/30/04	1130	E0.01	2,790	—	
DRN-5	8/11/04	1205	<0.01	2,350	—	
DRN-5	9/15/04	1310	<0.01	2,970	—	
DRN-5	10/27/04	1230	E0.10	3,240	—	
DRN-5	11/23/04	1130	<0.01	3,160	—	
SP-3	6/30/04	1030	<0.01	3,850	—	
SP-3	8/11/04	1220	<0.01	3,730	—	
SP-3	9/15/04	1230	<0.01	3,960	—	
SP-3	10/27/04	1150	<0.01	3,030	—	
SP-3	11/23/04	1100	<0.01	3,980	—	
SP-3	6/10/08	0945	—	3,100	3,000	X
SP-3	12/3/08	0840	0.02	2,930	2,760	X
SP-3	6/24/10	1045	0.03	3,590	3,470	X
PC-3	7/10/07	1800	4.8	1,190	—	
PC-3	8/14/07	1250	13	1,040	772	X
PC-3	9/27/07	1740	20	1,210	—	
PC-3	10/16/07	1450	27	902	661	X
PC-3	11/7/07	1710	2.6	840	—	
PC-3	12/13/07	1030	0.05	943	—	
PC-3	5/20/08	1810	39	463	326	X
PC-3	6/10/08	1200	40	641	—	
PC-3	7/17/08	1900	28	1,060	784	X
PC-3	8/25/08	1800	15	1,460	1,170	X
PC-3	9/30/08	1645	14	1,250	—	
PC-3	4/29/09	0945	7.2	796	—	
PC-3	5/19/09	1910	24	357	—	
PC-3	6/5/09	1200	32	537	368	X
PC-3	7/9/09	1522	26	932	—	
PC-3	8/4/09	1300	25	1,270	—	
PC-3	9/1/09	1845	21	1,420	—	
PC-3	7/15/10	1200	36	925	—	
PC-3	9/9/10	1400	E22	1,230	—	
PC-3	8/23/11	1340	33	628	—	
PC-3	10/4/11	1604	—	1,090	—	
PC-3	5/10/12	1400	37	401	—	
PC-3	6/20/12	1330	17	997	—	
PC-3	7/26/12	1346	32	824	—	
PC-3	8/22/12	1020	—	911	—	
PC-3	9/20/12	1340	12	954	—	

Table A-1. Data collected at water-quality sampling sites in the Manila/Washam Salinity Project area.—Continued

[Site identifier: see figure 1 and table 1 for more site information. E, estimated; —, no measurement; <, less than]

Site identifier	Date	Time	Discharge, instantaneous, cubic feet per second	Specific conductance, microsiemens per centimeter at 25 degrees Celsius	Dissolved-solids concentration, residue on evaporation at 180 degrees Celsius, milligrams per liter	Used to determine relation of specific conductance to dissolved-solids concentration (see table 1)
PC-3	10/31/12	1408	14	889	—	
SCC-1	5/27/04	1300	E100	62	—	
SCC-1	7/1/04	1225	97	60	35	X
SCC-1	8/10/04	1125	60	66	39	X
SCC-1	9/14/04	1250	34	90	58	X
SCC-1	10/26/04	1140	0.22	1,070	—	
SCC-1	4/5/05	1130	E0.10	1,930	—	
SCC-1	6/1/05	1750	126	61	—	
SCC-1	7/10/07	1240	89	54	—	
SCC-1	8/13/07	1200	69	60	45	X
SCC-1	5/21/08	1045	113	63	—	
SCC-1	6/10/08	1420	111	53	—	
SCC-1	7/18/08	1140	98	48	—	
SCC-1	8/26/08	1200	61	65	—	
SCC-1	9/30/08	1130	0.19	1,020	—	
SCC-1	5/19/09	1240	108	60	—	
SCC-1	6/5/09	1330	99	56	—	
SCC-1	7/9/09	1147	104	57	—	
SCC-1	8/3/09	1720	85	61	—	
SCC-1	9/1/09	1730	47	68	—	
SCC-1	5/10/10	1215	3.2	234	—	
SCC-1	6/23/10	1230	99	62	48	X
SCC-1	7/14/10	1130	107	63	—	
SCC-1	8/18/10	1100	79	57	—	
SCC-1	9/9/10	1100	66	61	—	
SCC-1	8/23/11	1115	92	55	—	
SCC-1	9/16/11	1200	71	60	—	
SCC-1	10/4/11	1015	0.68	2,050	—	
SCC-1	5/10/12	1100	96	51	—	
SCC-1	6/20/12	1045	105	59	—	
SCC-1	7/26/12	1115	67	62	—	
SCC-1	8/21/12	1145	59	65	—	
SCC-1	9/20/12	1045	47	47	—	

Table A-2. Dissolved-solids loads, in tons per day, at water-quality sampling sites in the Manila/Washam Salinity Project area.

[Sites shown on figure 1, see table 1 for more site information; load values were determined from instantaneous measurements made in the month and year listed or were estimated from other values; —, no measurement; <, less than]

		Outflow sites											Inflow sites				
		BSD-2[1]	PC-2	SV-2	DRN-1	DRN-1a	DRN-2	DRN-3	DRN-4	LAT-1	AW-1	Other drains and seeps[2]	PC-3	SCC-1	Total outflow load	Total inflow load	Net outflow load[3]
June/July	[4]2004	113	69	27	15	7.0	29	8.8	—	—	37	2.9	109	9.2	308	118	190
August		39	14	11	1.8	2.0	11	0.7	—	0.3	42	0.5	50	6.3	122	56	66
September		57	23	1.3	0.3	0.8	4.7	7.8	—	3.2	33	1.0	50	5.3	132	55	77
October		88	19	30	1.1	1.2	2.4	2.1	—	1.4	46	3.5	51	0.5	195	52	143
November		46	3.6	8.3	1.0	0.9	1.6	0.5	—	0.2	46	0.4	3.9	0	108	3.9	104
January	[4]2005	38	1.8	5.2	<0.1	0.2	0.8	<0.1	—	0	29	0.1	0	0	75	0	75
February		55	1.0	7.5	1.0	0.1	0.9	0.1	—	0	25	0.1	0	0	91	0	91
April		30	0.6	2.8	2.1	0.3	1.0	0.5	—	0	20	0	20	0.4	57	20	36
May/June		102	33	2.2	0.5	2.1	11	<0.1	—	0.6	15	—	29	13	166	42	125
July	2007	13	9.6	7.8	0	0	0.3	<0.1	—	—	12	0.4	11	7.9	43	19	24
August		22	14	5.8	0.7	0.3	1.6	1.5	—	—	23	0.7	27	8.4	70	36	34
September		39	13	5.7	1.3	1.7	27	—	—	3.2	23	1.0	50	0	115	50	65
October		53	23	5.8	3.7	0.5	4.1	0.1	—	1.1	23	1.2	48	0	116	48	68
November		31	3.4	2.4	3.7	0.4	1.8	0.09	—	0	23	1.0	4.4	0	67	4.4	62
December		25	2.6	4.6	1.1	0.2	0.8	0.1	—	0	17	0.7	0.1	0	52	0.1	52
April	2008	22	0.6	3.4	0.65	0	0.88	—	—	0	15	0.7	0	0	43	0	43
March		35	0.5	5.1	0.64	0	0.6	0.06	—	0	19	0.63	0	0	62	0	62
April		22	0.6	4.2	0.34	0.3	0.5	—	—	0	17	0.3	0	0	45	0	45
June		47	27.1	8.3	1.6	0.8	14.1	0.5	—	3.4	15	0.3	49.4	10.3	118	60	59
July		24	37.6	17.9	2.9	1.1	13.6	0.7	1.7	—	32	1.25	59	8	132	67	65
August		34	16.2	9.8	3.1	0.4	3.4	0.3	1.1	0	32	1.28	47	7	101	54	47
October		23	7.5	5.5	0.7	0.39	7.7	1.2	1.3	1.7	19	1.23	37	0	69	37	33
December		26	1.5	7.6	0.1	0.4	0.9	<0.1	0.1	0	27	0.44	0	0	64	0	64
February	2009	19	0.2	3.6	1.1	0.3	0.3	0	0	0	17	0.37	0	0	41	0	41
May		49	29.9	10.9	0.3	0.5	9.3	0	0	1.3	14	0.68	14	11	115	25	90
June		80	15.6	25.1	0.1	0.8	11.6	3.5	0	3.2	17	4	32	9.7	161	42	119
September		29	18.9	6.4	0.3	0.5	17.5	2.9	3.0	9.3	23	2.11	63	5.5	113	68	45
November		23	2	4	—	2	5	—	—	0	30	0.39	0	0	66	0	66
March	2010	44	0.6	14.6	0	0	0.4	<0.1	0	0	24	0.17	0	0	83	0	83
May		33	0.6	2.2	0	0.3	0.8	<0.1	<0.1	2.8	13	0.37	19	1.3	53	20	32
June		53	0.7	7.9	5.2	0	14.4	0.4	1.8	10.4	26	1.0	38	11	120	49	71
July		68	10.8	11.1	2.2	3	22.6	0.5	0.6	9.6	18	3.4	66	12	150	78	72
September		47	15.9	10.2	0.3	2	20.7	0.7	9.1	6.9	23	8.5	56	7	144	63	81
October		56	6.3	3.9	2.6	1	11.0	0.3	1.5	3.2	33	2.7	59	2	121	61	60
March	2012	22	0.7	2.7	<0.2	0.3	1.6	<0.1	<0.1	0	17	0.2	0	0	44	0	44
August		26	3.4	3.5	0.6	0	2.2	0.2	1.5	2.3	6	0.6	28	7	46	34	12

[1]Load values were determined from the average daily specific conductance and flow for those days that other sites were measured.

[2]Includes sites DRN-5, SP-3, and numerous small seeps and drains between site BSD-2 and Flaming Gorge Reservoir.

[3]Net outflow load = total outflow load minus total inflow load.

[4]The load listed for site BSD-2 was determined at site BSD-1 from instantaneous measurements.

Table A-3. Estimates of monthly and irrigation season canal streamflow in the Manila/Washam Salinity Project area, 2004/05 and 2007–12.

[Estimated combined streamflow was determined by extrapolating a monthly instantaneous measurement of canal streamflow, in cubic feet per second, to monthly streamflow, in acre-feet. Canal streamflow was estimated to occur about half of the month in May and October because of the variable onset or cessation of irrigation during the year. ft^3/s, cubic feet per second; —, not applicable]

Irrigation season		May	June	July	August	September	October	Irrigation season total, in acre-feet
[1]2004/05	Sheep Creek Canal streamflow, in ft^3/s	123	126	97	60	34	0.22	22,500
	Peoples Canal streamflow, in ft^3/s	40	41	50	23	24	24	10,100
	Combined streamflow, in ft^3/s	163	167	147	83	58	24.2	—
	Combined streamflow, in acre-feet	4,850	9,937	8,747	4,939	3,451	721	32,600
2007	Sheep Creek Canal streamflow, in ft^3/s	111	101	89	69	0.1	0.1	18,900
	Peoples Canal streamflow, in ft^3/s	39	39	4.8	13	20	26.6	6,600
	Combined streamflow, in ft^3/s	150	140	93.8	82	20.1	26.7	—
	Combined streamflow, in acre-feet	4,760	8,331	5,582	4,879	1,196	794	25,500
2008	Sheep Creek Canal streamflow, in ft^3/s	113	111	97.9	61.4	30.5	0.2	21,500
	Peoples Canal streamflow, in ft^3/s	39.2	39.6	28.3	14.6	14.5	14.5	7,400
	Combined streamflow, in ft^3/s	152.2	150.6	126.2	76.0	45.0	14.7	—
	Combined streamflow, in acre-feet	4,830	8,961	7,510	4,522	2,678	437	28,900
2009	Sheep Creek Canal streamflow, in ft^3/s	108	99	104	85.1	47	0.52	23,400
	Peoples Canal streamflow, in ft^3/s	24	32	26.4	25.2	21	0	7,000
	Combined streamflow, in ft^3/s	132	131	130.4	110.3	68	0.52	—
	Combined streamflow, in acre-feet	4,189	7,795	7,759	6,563	4,046	15	30,400
2010	Sheep Creek Canal streamflow, in ft^3/s	98	98	107	79	66.4	0	24,000
	Peoples Canal streamflow, in ft^3/s	10	36	36	28.1	22	20	8,200
	Combined streamflow, in ft^3/s	108	134	143	107.1	88.4	20	—
	Combined streamflow, in acre-feet	3,427	7,974	8,509	6,373	5,260	595	32,200
2011	Sheep Creek Canal streamflow, in ft^3/s	78	77.7	98	92.2	70.8	0.68	22,700
	Peoples Canal streamflow, in ft^3/s	[2]38	28.8	36	32.5	30	26	10,700
	Combined streamflow, in ft^3/s	116	106.5	134	124.7	100.8	26.7	—
	Combined streamflow, in acre-feet	4,857	6,337	7,974	7,420	5,998	794	33,400
2012	Sheep Creek Canal streamflow, in ft^3/s	96.4	104.5	66.9	59.3	47.3	0	19,400
	Peoples Canal streamflow, in ft^3/s	37	17.2	31.5	15.1	11.9	13.6	6,000
	Combined streamflow, in ft^3/s	133.4	121.7	98.4	74.4	59.2	13.6	—
	Combined streamflow, in acre-feet	3,969	7,242	5,855	4,425	3,524	405	25,400

[1]The irrigation season represented by the period 2004/05 uses measurements and estimates of canal streamflow made during June–October 2004 and May–June 2005.

[2]Peoples Canal streamflow in May 2011 was from totalizer.

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