FINAL REPORT

A REVIEW: FARMINGTON BAY

# Hydrology and Water Management

PREPARED FOR

**UTAH DEPARTMENT OF NATURAL RESOURCES, DIVISION OF FORESTRY, FIRE, & STATE LANDS**

PREPARED BY

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JANUARY 2012

*Final Report*

# A Review: Farmington Bay Hydrology and Water Management

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January 2012

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# Acronyms

| | |
|---|---|
| bgs | below ground surface |
| cfs | cubic feet per second |
| gpm | gallons per minute |
| SLCWRF | Salt Lake City Water Reclamation Facility |
| UDWR | Utah Division of Water Rights |
| UPDES | Utah Pollutant Discharge Elimination System |
| USGS | U.S. Geological Survey |

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# Abstract

Understanding a water body's hydrology and how it can influence its characteristics is critical to making meaningful management decisions. This study summarizes the available literature and provides recommendations for a path forward to better understanding the hydrology of Farmington Bay. A synthesis of available information describing the water balance is provided, along with a detailed summary of areas contributing surface water inflow and management practices that affect the sources, timing, and quantity of its delivery. Recommendations are made for augmenting ongoing monitoring programs and future research in the areas of flow monitoring, management practices, and developing a comprehensive water balance for Farmington Bay.

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# 1.0 Introduction

While the hydrologic characteristics that help define Farmington Bay are not typically at the forefront of management discussions, they are almost always a key factor that must be considered. Water quantity, flow velocities, timing, storage, management objectives, and location are all significant factors that shape the available habitat, food web, and water quality of Farmington Bay and its wetlands. Understanding the hydrologic drivers and how they can influence outcomes is critical not only to understanding the lake system but to making meaningful management decisions. This study summarizes the available literature and provides recommendations for a path forward to better understanding the hydrology of Farmington Bay.

## 1.1 Background

### 1.1.1 Great Salt Lake

Great Salt Lake is a uniquely dynamic terminal lake located adjacent to the rapidly growing metropolitan area of Salt Lake City (see Figure 1-1). It is the sixth-largest lake in the United States and the world's fourth-largest terminal lake. It varies significantly in size and depth as a result of changes in inflow from precipitation, tributaries, and groundwater, as well as from losses through evaporation. At a lake elevation of 4,200 feet, Great Salt Lake is about 75 miles long and 30 miles wide, and has about 335 miles of shoreline. It occupies more than 1,700 square miles and contains more than 15 million acre-feet (almost 5 trillion gallons) of water. Great Salt Lake's shallow depths (its maximum depth is about 35 feet) and its gradually sloping shoreline result in dramatic surface area variations with any increase or decrease in lake level. Lake levels flucturated more than 20 feet between 1873 and 1963, with elevations of 4,211.5 and 4,191.35 feet, respectively (Arnow and Stephens, 1987). The lake's surface area fluctuated between 938 and 2,500 square miles in that same period (Hahl and Handy, 1969). The lake level rose 20.5 feet after 1963 to reach its record high level of 4,211.85 feet on June 3, 1986. The net rise between 1982 and 1986 was 12.2 feet (Arnow and Stephens, 1987).

On average, 2.9 million acre-feet of water and 2.2 million tons of salt enter Great Salt Lake each year. The vast majority of lake inflow typically comes from three drainages: the Jordan River (9 percent), Weber River (13 percent), and Bear River (39 percent). Additional inflow comes from groundwater (3 percent), direct precipitation (31 percent), and other minor east-side streams (5 percent) (Arnow and Stephens, 1987). Because the lake's only substantial water loss mechanism is evaporation, minerals, salts, and sediments from the watershed accumulate in Great Salt Lake. This results in lake water that is typically three to five times more salty than sea water and creates a unique habitat for biota that have adapted to and rely on the Great Salt Lake ecosystem.

### 1.1.2 Farmington Bay

Farmington Bay is the southeastern arm of Great Salt Lake, extending between the lake's eastern coastline and the eastern side of Antelope Island (see Figure 1-1). The Davis County Causeway (also known as the Antelope Island-Syracuse causeway) links the eastern shore of Great Salt Lake to the northern tip of Antelope Island. With the exception of one bridge and one culvert, the causeway physically separates Farmington Bay from Great Salt Lake. The causeway was originally constructed in 1969 by the State of Utah but required frequent maintenance due to damage from wave action and rising lake levels. Davis County finally rebuilt the causeway to its present elevation and with the existing bridge and culvert in 1993 (Wikipedia, accessed April 21, 2011). Flow around the southern tip of Antelope Island is often restricted due to a southern causeway constructed by a ranching company in the 1960s (Sturm, 1986). The causeway has an elevation of approximately 4,202 feet; thus, for Great Salt Lake water elevations of less than 4,202 feet, there is no outlet around the southern tip of Antelope Island. The bridge at the Davis County Causeway is typically Farmington Bay's primary outlet to Great Salt Lake. The afore-mentioned culvert is located to the east and has an invert elevation that limits its use to instances when there are high water levels in Great Salt Lake.

Farmington Bay receives much of its water from the Jordan River drainage to the south. Almost all of the water from the Jordan River drainage must first travel through various duck clubs and preserves before reaching Farmington Bay. These areas serve primarily to conserve the water and wetlands habitat for waterfowl and shorebirds. Various east-side tributaries also contribute flow to Farmington Bay. These tributaries provide water to wetlands along the eastern shore of Farmington Bay; however, much of this water typically either evaporates or infiltrates into the mudflats before it reaches the open water of Farmington Bay.

The physical characteristics of Farmington Bay – the wetlands, mudflats, or open water that a visitor would encounter whether boating, wading through the shallows, or walking across the mudflats along the shore, as well as the habitat that is used by wildlife for resting, nesting, and foraging – all are directly linked to the hydrology of Farmington Bay. The water level of Great Salt Lake and the quantity, timing, and source of water entering Farmington Bay all have a profound effect upon these characteristics. An understanding of the hydrology of Farmington Bay is critical to understanding each facet of its ecosystem and making management decisions that balance the various interests. This information will serve as a foundation for future research and management efforts.

## 1.2 Objectives and Methods

When considering the characteristics of Farmington Bay and its wetlands, the flow quantities and patterns and how they might affect the ecosystem are crucial considerations. The overall goal of this study was to synthesize available information and make recommendations for future research to better define the hydrology of Farmington Bay. More specifically, the study's objectives were to review the available literature and data, identify data gaps, and recommend future research efforts.

To that end, CH2M HILL contacted numerous individuals responsible for managing the water resources in and around Farmington Bay. Each individual was queried as to available information, their understanding of the hydrology, and research they felt was important. These interviews were augmented by a review of available literature at the Utah Department of Natural Resources, a general internet search, the University of Utah library, as well as the individual libraries of several of the local water managers, agencies, and duck clubs. This study summarizes the information gathered during these efforts.

## 1.3 Document Organization

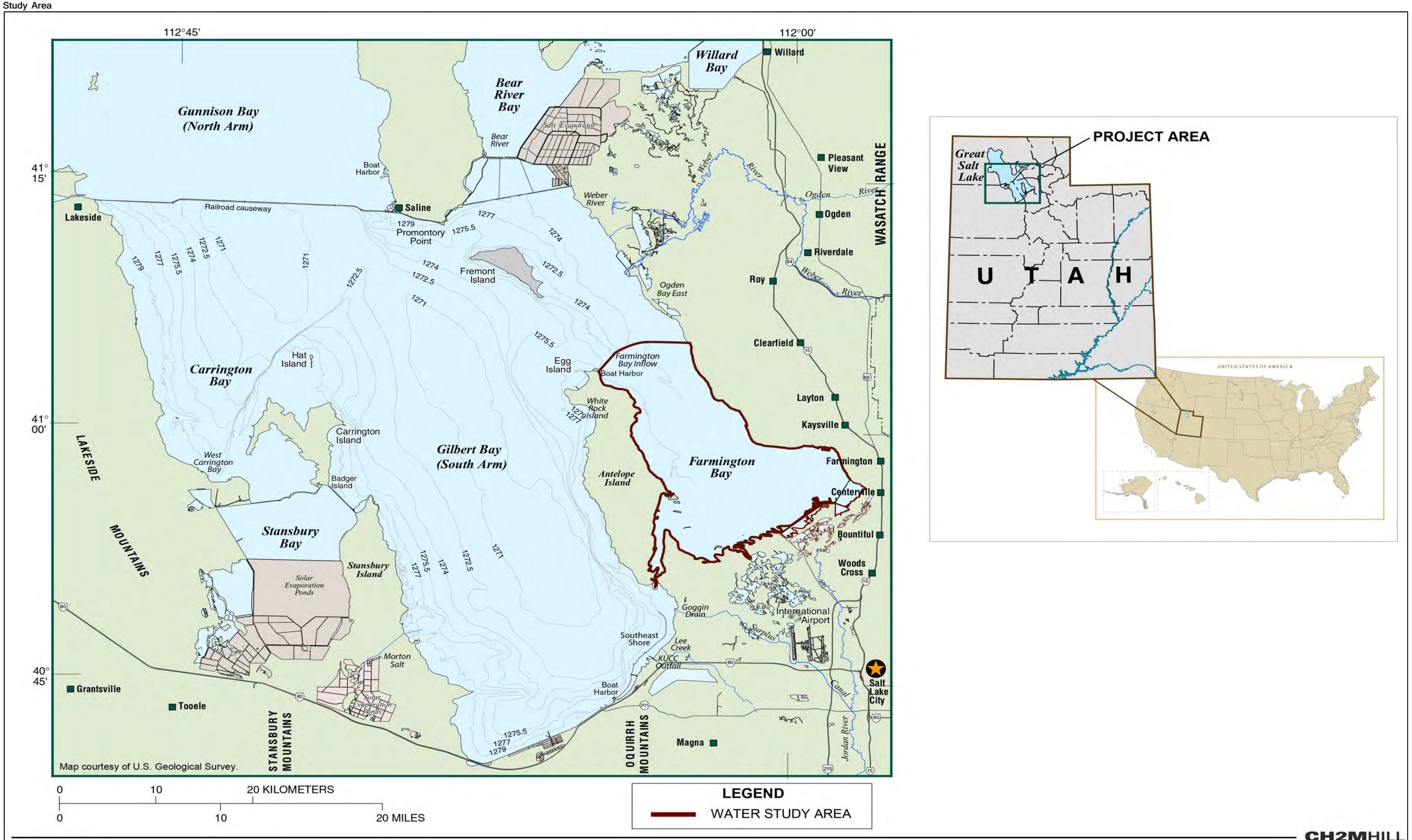
The remainder of this report is organized into the following sections:

- Section 2.0 provides a brief overview of previous efforts to understand the hydrology of Farmington Bay.
- Section 3.0 describes Farmington Bay's contributing areas and how water is managed in its watershed and along its shoreline.
- Section 4.0 provides a summary of recommended steps forward to better understand the hydrology of Farmington Bay.
- Section 5.0 provides references cited in this study.

## 1.4 Acknowledgements

Funding for this effort was provided by the Utah Division of Forestry, Fire & State Lands. The support, insight, and vision of Dave Grierson was critical to this project moving forward. He is missed. This work would not have been possible without the assistance of Jason Lillywhite, who converted the Jordan River water balance model into daily time steps and helped develop the current version of the GoldSim (GoldSim Technology Group) Farmington Bay water balance model. Thanks also to Layne Jensen, Rich Hansen, Adam Wright, and many others who provided insight into the hydrology and water management along Farmington Bay's shoreline.

FIGURE 1-1
Study Area

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CH2MHILL

# 2.0 Literature Review

Until the Southern Pacific Transportation Company completed the rock-fill causeway across Great Salt Lake in 1959, most hydrologic observations in the Great Salt Lake watershed focused on monitoring the lake level and flow in the key tributaries to Great Salt Lake: Bear River, Weber River, and the Jordan River. Monitoring of inflows was largely completed to evaluate and manage water resources and control flooding in the Great Salt Lake tributaries, not to predict the lake's dynamics. With completion of the causeway, the physical separation and resulting differential in water level and salinity between the north arm and south arm began to attract significant interest from local, state, and federal agencies. The hydrology of Great Sale Lake rapidly became an important topic as it served as the basis of the engineering studies to understand the impact of the railroad causeway, evaluate additional dikes in lake, and evaluate measures to mitigate rising lake levels. This section provides a literature review of Great Salt Lake hydrologic research, with an emphasis on Farmington Bay. A more detailed summary of available surface inflow data is included in Section 3.0.

## 2.1 Great Salt Lake Water Balance

Understanding the water balance of Great Salt Lake has been an important factor in many of the management decisions made regarding causeways, water storage, and flood control on Great Salt Lake since the 1960s. Some of the first published articles that addressed the hydrology of Great Salt Lake were focused on understanding the chemical and physical characteristics of the lake's water. Hahl and Langford (1964), Hahl and Handy (1969), and Madison (1970) investigated the sources of and chemical composition of Great Salt Lake's brine and how those were influenced by inflows and mixing within the lake. The 1970s brought an interest in how the railroad causeway was affecting the salt balance within Great Salt Lake, how lake salinity could be controlled for more efficient salt production, water storage and recreation, and factors influencing the change in the lake's water levels (Arnow and Mundorff, 1972; Steed and Glenne, 1972; Waddell and Bolke, 1973; Whelan, 1973; and Waddell and Fields, 1977. Whereas most research had previously focused on the unique biota of Great Salt Lake (Kirkpatrick, 1934; Relyea, 1937; Evans, 1960; and Carozzi, 1962], now the interest was in how the lake could be better utilized as a water resource. Understanding the hydrology of Great Salt Lake was central to this objective.

One of the first computerized water budgets for Great Salt Lake was published by Steed and Glenne (1972) using mean monthly flows for the 1944-1970 period. The Utah Division of Water Resources (Division) developed a Great Salt Lake water balance model in 1974 based on hydrologic input at annual time steps for the period 1901-1974. This model was later updated in 1977 to address a scenario of pumping water out of the lake and was extended to include the period 1851-1975. These models were largely based on the annual inflow from the Bear, Weber, and Jordan rivers, precipitation values from the Salt Lake Airport, and available elevation-area-volume data for Great Salt Lake.

The U.S. Geological Survey (USGS) and the Division began a 7-year study in 1971 to understand the parameters controlling the water and salt balance in Great Salt Lake. Waddell and Bolke (1973) provided a preliminary analysis from this program evaluating the effect of the railroad causeway on the lake's water and salt balance. Waddell and Fields (1977) later provided a detailed analysis of the work completed during this 7-year study. Their work is often the basis for subsequent work on the water and salt balance of Great Salt Lake. Waddell and Fields (1977) developed a water budget based on 1-month intervals for the period 1931-1973 using available flow data, additional flow measurements, and statistical analysis. The water budget incorporated surface and groundwater inflows and precipitation and evaporation over the lake. The analysis allowed for refinement of each of these variables, the ability to evaluate lake water levels and salinities, and the evaluation of several diking options. Waddell and Barton (1980) provided further calibration of this model for the period 1931-1976.

The Division and the Utah Water Research Laboratory developed a stochastic hydrologic simulation model in 1979 (James, et al., 1979) and coupled it with a damage simulation model to evaluate lake control alternatives. This model was updated again in 1984 (James, et al., 1984) as lake levels increased in the early 1980s. Stauffer (1985)

provides a useful summary of the work completed by the Division and the effect water development projects have had on lake levels.

Arnow (1984) completed a detailed review of Great Salt Lake water level fluctuations for the period 1847-1983 to better understand the record 5.2-foot lake level rise from 1982 to 1983. This work provides valuable historical information as well as a detailed summary of inflows and outflows to Great Salt Lake. Arnow (1984) concluded that while human use of water is a factor in the lake level, climatic factors seem to influence the greatest changes. Lake levels are governed by a balance of inflows and evaporation rates influenced by the lake-surface area and salinity. Arnow and Stephens (1990) provide an update to Arnow (1984) that discusses the flooding of 1982-1986 in more detail.

As described above, Wadell and Bolke (1973) developed one of the first models to evaluate Great Salt Lake's water and salt balance and describe how the railroad causeway influenced its characteristics. The model was calibrated for conditions during 1969-1972. Changes to the model were required due to changes to the causeway and its culverts in the 1980s. Wold, et al. (1997) modified this original model and recalibrated it for 1980-1986 to account for the modifications to the causeway and high lake levels that were experienced. The monthly water budget from Wadell and Fields (1977) was updated and extended through 1986. Loving, et al. (2000) expanded upon this model to account for additional changes in the causeway and water withdrawals by the West Desert Pumping Project. The monthly water budget for Great Salt Lake was updated and extended through 1998, and the new model was recalibrated for conditions from 1987 to 1998. . This water budget incorporated available flow data using similar regression analysis as used by Waddell and Fields (1977).

Some considerations from the literature pertaining to Farmington Bay are as follows:

- Farmington Bay was generally treated as part of the overall Great Salt Lake, i.e., it was not often evaluated as a distinct water body. For example, the unique characteristics that affect the salt balance in Farmington Bay are generally not addressed.
- The studies look at the water balance of the entire Great Salt Lake; thus, the input is often generalized for the lake as a whole rather than for the different parts of the lake. For example:
  - The studies generally evaluated the Jordan River inflow source as one input to Great Salt Lake and thus do not all provide the detail required to understand the split in Jordan River flows between Farmington Bay and the South Arm of Great Salt Lake (Gilbert Bay).
  - The studies generally evaluated Farmington Bay's east-side tributaries as one input to Great Salt Lake. This generalization makes it difficult to use these studies to evaluate particular conditions in distinct parts of Farmington Bay.
  - Precipitation and evaporation rates are often based on lake-wide averages rather than localized conditions (i.e., climate and salinities) in Farmington Bay.
- By virtue of the studies' objectives, flows are generally reported in terms of monthly or annual flow volumes.

## 2.2 Farmington Bay Water Balance

Significant interest in the specific water balance characteristics of Farmington Bay began in earnest in the 1970s and 1980s. Multiple proposals were made beginning in the 1970s to investigate the feasibility of building in-lake dikes for various reasons (Sturm, 1986; Chadwick, et al., 1986), including:

- To protect the populated eastern shores of Great Salt Lake from flooding from rising water levels in the lake.
- To freshen waters in these areas to enhance recreational opportunities and enable consumptive use of these waters.
- To optimize conditions along the eastern shoreline for wildlife preserves and provide opportunities for alternative north-south transportation that bypasses Salt Lake City.

This section provides a summary of various studies that included an investigation of Farmington Bay's hydrology as one objective and also discusses some of the key variables in its water budget.

Work began in the 1970s to document conditions in Farmington Bay, identify its sources of water, and investigate the possibility of controlling water flow to freshen its waters. These studies included:

- Carter, et al. (1971) presents one of the first efforts to investigate the possibility of controlling water flow to freshen the waters of Farmington Bay. This study included cross-sectional surveys, sediment coring, an evaluation of flow patterns in the bay, and an annual water budget. The water budget that was prepared included an evaluation of available Jordan River and wastewater treatment flow data, measurement of outflows through the causeway bridge, an estimate of flow in the Sewage Canal, and an estimate of groundwater and precipitation inflows and evaporation. Groundwater was used to balance the water budget.
- Richards (1980) completed a study of conditions in Farmington Bay and engineering recommendations to control water flow into and in Farmington Bay to freshen its waters. Annual water inflows from the Jordan River, Sewage Canal, effluent from four wastewater treatment plants, and various Davis County streams were measured in 1978 to estimate the annual inflow. Actual flow rates were not presented; however, the annual flow volume and salt load for 1978 is included in the report.

Many of the more serious proposals for diking were investigated in the early 1980s and focused on opportunities to minimize damage along the eastern coastline from rising lake levels. To that end, a detailed feasibility engineering study was completed by Montgomery Engineers (1984) to evaluate various on-shore diking alternatives to protect facilities such as wastewater treatment plants. This study also evaluated various in-lake diking options to compartmentalize the lake, including dikes linking Antelope Island and Fremont Island and the eastern shoreline, as well as dikes between islands. The proposals were deemed too costly but prompted the State of Utah to begin additional studies to evaluate inflows, water quality, and the economic benefits of these proposals. These studies included:

- Hansen (1981) presents one of the first hydrologic models prepared with the objective of managing water quantity and quality in Farmington Bay. Tributaries to Farmington Bay were identified, flows were measured (October 1980 to March 1981), and a water balance model was developed for Farmington Bay and the Farmington Bay Wildlife Management Area. The water balance model included estimated outflows from Farmington Bay; estimates for precipitation, evaporation, evapotranspiration, and groundwater inflows; and measured inflows to Farmington Bay. Of interest is the detailed measurement of flows for the various inflows and estimates of the water balance in the Farmington Bay Wildlife Management Area.
- Chadwick, et al. (1983) developed a mass balance model to describe the water budget of Farmington Bay that incorporated the preliminary water balance model in Hansen (1981) and the monthly flow record for the period October 1980 through December 1982 (Sturm, 1986). A stochastic model was also developed to simulate water elevations and salinity with various probability levels for different management options.
- Chadwick, et al. (1986) further augmented the models developed by Hansen (1981) and Chadwick, et al. (1983) to include East Bay (formed by proposed inter-island dikes north of Farmington Bay) and additional water quality considerations.
- Sturm (1986) summarizes efforts and data collected to support an investigation by the Utah Geological and Mineral Survey and Utah Water Research Laboratory beginning in 1980 to investigate the feasibility of turning Farmington Bay into a fresh-water reservoir. This document summarizes methods used to measure outflows from Farmington Bay through a bridge located on the Davis County Causeway and inflows from an unnamed ditch located below the North Davis Sewer District's outfall, Kays Creek, Holmes Creek, Snake Creek, and Baer Creek below Central Davis Wastewater Treatment Plant on a monthly basis for the period 1980-1982. Analytical results from water samples are also presented for salinity and nutrients. Additional activities described include salinity and depth measurements in Farmington Bay, as well as the establishment of a flow measurement station on the Sewage Canal on a bridge near the southwest corner of the Turpin Unit of

Farmington Bay Wildlife Management Area (gage was used by others). The data from this effort was the primary source of information for Hansen (1981) and Chadwick, et al. (1983 and 1986).

### 2.2.1 Surface Inflow Contributions

Numerous flow gages have been operated over the years by the USGS, State of Utah, and Salt Lake County Public Works. Figure 2-1 provides a summary of the flow gages and period of record that were identified in the vicinity of and contributing to Farmington Bay. Figure 2-2 illustrates the locations of many of the USGS flow gages on record. As a means of evaluating flows for average, wet, and dry water years, CH2M HILL (2005) proposed and used various decision rules for evaluating the available hydrologic record. Table 2-1 summarizes these decision rules. Refer to CH2M HILL (2005) for further discussion. A summary of the available flow data for surface inflow contributions to Farmington Bay is included in the discussion in Section 3.0 of this report.

FIGURE 2-1

**Available Flow Gage Stations and Period of Record**

| Site Name | Site Number | 1942 | 1943 | 1944 | 1945 | 1946 | 1947 | 1948 | 1949 | 1950 | 1951 | 1952 | 1953 | 1954 | 1955 | 1956 | 1957 | 1958 | 1959 | 1960 | 1961 | 1962 | 1963 | 1964 | 1965 | 1966 | 1967 | 1968 | 1969 | 1970 | 1971 | 1972 | 1973 | 1974 | 1975 | 1976 | 1977 | 1978 | 1979 | 1980 | 1981 | 1982 | 1983 | 1984 | 1985 | 1986 | 1987 | 1988 | 1989 | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | Years of record |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Davis County** | |||||||||||||||||||||||||||||||||||||||||||||||||||||||||||||||||||||| |
| Farminton Bay Outflow | 410401112134801 |||||||||||||||||||||||||||||||||||||||||||||||||||||||||||||||■|■|■|■|■|■|■|■|■| 9 |
| Kays Creek | |||||||||||||||||||||||||||||||||||||||||||||||||||||||||||||||||||||| 0 |
| Holmes Creek | 10141500 ||||||||■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|||||||||||||||||||||||||||||||||||||||||||||| 17 |
| Baer Creek | |||||||||||||||||||||||||||||||||||||||||||||||||||||||||||||||||||||| 0 |
| Haights Creek | |||||||||||||||||||||||||||||||||||||||||||||||||||||||||||||||||||||| 0 |
| Shepherd Creek | |||||||||||||||||||||||||||||||||||||||||||||||||||||||||||||||||||||| 0 |
| Farmington Creek | 10142000 |||||||■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■||||■|■|■|■|■|■||||||||||||||||||||||||||||■|■|■|■| 33 |
| Steed Creek | |||||||||||||||||||||||||||||||||||||||||||||||||||||||||||||||||||||| 0 |
| Davis Creek | |||||||||||||||||||||||||||||||||||||||||||||||||||||||||||||||||||||| 0 |
| Ricks Creek | 10142500 ||||||||■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|||||||||||||||||||||||||||||||||||||||||||||| 17 |
| Barnard Creek | |||||||||||||||||||||||||||||||||||||||||||||||||||||||||||||||||||||| 0 |
| Parrish Creek | 10143000 |||||||■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|||||||||||||||||||||||||||||||||||||||||||| 20 |
| Deuel Creek | 10143500 |||||||■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|||||||||||||||||||■|■|■|■|■|■|■|■|■|■|■|■|■| 45 |
| Stone Creek | ||||||||■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|||||||||||||||||||||||||||||||||||||||||||||| 17 |
| Barton Creek | 10144000 |||||||||||||||||||||||||||||||||||||||||||||||||||||||||||||||||||||| 0 |
| Mill Creek | 10145000 ||||||||■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|||||||||||||||||||||||||||||||||||||||||||| 19 |
| North Canyon Creek | |||||||||||||||||||||||||||||||||||||||||||||||||||||||||||||||||||||| 0 |
| Hooper Draw | |||||||||||||||||||||||||||||||||||||||||||||||||||||||||||||||||||||| 0 |
| Jordan River @ Cudahy Lane @ SLC | 10172600 & DWR |||||||||||||||||||||■|■|■|■|■|■||||||||||||||||||||||■|■|■|■||||||||■|■|■|■|■|■|■|■|■|■| 20 |
| **Salt Lake County** | |||||||||||||||||||||||||||||||||||||||||||||||||||||||||||||||||||||| |
| Jordan River @ 1700 South | 10171000 |■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■| 69 |
| Red Butte Creek @ Fort Douglas Near SLC | 10172200 |||||||||||||||||||||■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■| 48 |
| Red Butte Cr Blw Reservoir Near SLC | 10172220 |||||||||||||||||||||||||||||||||||||■|■|■|■|■|■|■|■|■|■||||||||||||||||||||||| 10 |
| Red Butte Cr @ 1600 @ SLC | Salt Lake County 740 ||||||||||||||||||||||||||||||||||||||||||■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■| 27 |
| Emigration Creek Near SLC | 10172000 |||||||||||||||||||||■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|||||||||||||||||||||||||| 24 |
| Emigration Creek @ Rotary Park | Salt Lake County 620 |||||||||||||||||||||||||||||||||||||■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■| 32 |
| Parley's Creek @ Suicide Rock | Salt Lake County 520 |||||||||||||||||||||||||||||||||||||■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■| 32 |
| 1300 South Conduits @ Jordan River Combined Flows | 10172350 ||||||||||||||||||||||||||||||||||||||■|■|■|■|■|■|■|■|■||||||||||||||||||||||| 9 |
| So Conduit of 1300 South Conduits @ Jordan River | 10172351 ||||||||||||||||||||||||||||||||||||||■|■|■|■|■|■|■|■|■||||||||||||||||||||||| 9 |
| No Conduit of 1300 South Conduits @ Jordan River | 10172352 ||||||||||||||||||||||||||||||||||||||■|■|■|■|■|■|■|■|■||||||||||||||||||||||| 9 |
| Eighth South Conduit @ Jordan River @ SLC | 10172370 ||||||||||||||||||||||||||||||||||||||■|■|■||||||||||||||||||||||||||||| 4 |
| So Conduit of 8th South Conduits @ Jordan River | 10172371 ||||||||||||||||||||||||||||||||||||||■|■|||||||||||||||||||||||||||||| 3 |
| Mid Conduit of 8th South Conduits @ Jordan River | 10172372 ||||||||||||||||||||||||||||||||||||||■|■|||||||||||||||||||||||||||||| 3 |
| No Conduit of 8th South Conduits @ Jordan River | 10172373 ||||||||||||||||||||||||||||||||||||||■|■|||||||||||||||||||||||||||||| 3 |
| City Creek @ Memory Grove | Salt Lake County 820 |||||||||||||||||||■|■|■||||||■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■| 45 |
| North Temple Conduit @ Jordan River @ SLC | 10172520 ||||||||||||||||||||||||||||||||||||||■|■|■||||||||||||||||||||||||||||| 3 |
| Jordan River @ 500 N @ SLC | Salt Lake County 960 |||||||||||||||||||||||||||||||||■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■| 36 |
| North Canyon Channel | Legacy Nature Preserve |||||||||||||||||||||||||||||||||||||||||||||||||||||||||||||||||||■|■|■| 3 |
| State Canal | DWR staff gauge |||||||||||||||||||||||||||||||||||||||||||||||||||■|||||||||||||||||| 1 |
| Surplus Canal @ Salt Lake City | 10170500 |■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■| 69 |
| Surplus Canal @ North Temple @ SLC | 404614111582801 ||||||||||||||||||||||||||||||||||■|||||||||||||||||||||||||||||||||||| 1 |
| Husted Dam (Surplus Canal) | DWR staff gauge ||||||||||||||||||||||||||||■|||||||||||||||||||||■|■|■|■||||||||■|■|■|■|■|■|■|■|■|■| 15 |
| Past Husted Dam (Surplus Canal) | DWR staff gauge ||||||||||||||||||||||||||||||||||||||||||||||||||||||||||||||||■|||||||| 1 |
| Ambassador Cut (Surplus Canal) | DWR staff gauge |||||||||||||||||||||||||||||||||||||||||||||||||||■|||||||||||||||||| 1 |
| Utah Club (Surplus Canal) | DWR staff gauge ||||||||||||||||||||||||||||||||||||||||||||||||||||||||||||■|||||||||| 1 |
| North Point Consolidated Canal @ SLC | 10170700 (*is DWR) |||||||||||||||||||||||||■ *||||||||||||■|■|■|■|■|||||||||||||||||||||||||||| 6 |
| Goggin Drain @ Magna | 10172630 |||||||||||||||||||||■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■|■| 48 |
| Note: All site numbers are USGS unless otherwise noted. | |||||||||||||||||||||||||||||||||||||||||||||||||||||||||||||||||||||| |

FIGURE 2-2
**Location of USGS Flow Gage Stations**

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TABLE 2-1
Decision Rules Used for Evaluating the Historical Record for Average, Wet, and Dry Period Years

| Priority | Average Year | Wet Year | Dry Year |
|---|---|---|---|
| 1 | Average of more than 20 years of data | 1998 | 2003 or 2004 |
| 2 | Average of more than 5 years of data | 1983, 1984, or 1986 | 1961, 1990, 1988, or 2002 |
| 3 | 1981 | Wet factor applied to average or used other year | Dry factor applied to average or used other year |

Source: CH2M HILL, 2005.

### 2.2.2 Groundwater Inflow Contributions

Various methods were used by investigators to estimate groundwater inflow to Farmington Bay, including:

- Carter, et al. (1971) and Dicataldo (2008) used the groundwater contribution to balance the water budget. Carter, et al. (1971) estimated the annual groundwater contribution to Farmington Bay at 58,000 acre-feet using this method.
- Numerous authors (Waddell and Burton, 1980; Hansen, 1981; Loving, et al., 2000) referred to and used groundwater inflow contributions estimated by Waddell and Fields (1977). Waddell and Fields (1977) provided estimates for groundwater inflow in Farmington Bay from three areas: Antelope Island (125 acre-feet), Salt Lake County (165 acre-feet), and the east shore of the Great Salt Lake (2,000 acre-feet). Thus, the total estimated monthly groundwater inflow contribution to Farmington Bay was 2,300 acre-feet, and the annual contribution was 27,600 acre-feet.
- Chadwick, et al. (1983) estimated and used a value of 1,667 acre-feet per month of groundwater inflow to Farmington Bay.
- Arnow (1984) and Arnow and Stephens (1990) refer to and used a groundwater analysis completed by Arnow and Stephens (1975) that we were not able to locate. Arnow and Stephens (1975) estimated a total annual groundwater inflow to Great Salt Lake of 75,000 acre-feet, including 4,000 acre-feet from Salt Lake Valley and 48,000 acre-feet from the eastern shore of Great Salt Lake.
- Bowles, et al. (1985) proposed the use of a relationship to estimate annual groundwater flows to Great Salt Lake using the sum of inflows of the Bear, Weber, and Jordan Rivers. Chadwick, et al. (1986) modified this method by developing a new coefficient for Farmington Bay from groundwater estimates in Wadell and Fields (1977) and applying it to a relationship using only inflows from the Jordan River.
- Bishop, et al. (2009) estimated that the annual groundwater inflow to the wetlands along the eastern shoreline of Farmington Bay in Davis County was 16,000 acre-feet.

### 2.2.3 Precipitation

Estimates of the water contribution from precipitation were generally based on regression analysis of precipitation at nearby gage sites. These studies included:

- Waddell and Fields (1977) compiled annual average precipitation data for 1931-1973 for 68 nearby sites surrounding Great Salt Lake. A multiple regression equation was used to map lines of equal average annual precipitation across the lake. Monthly precipitation was estimated using a fraction of the annual total. A fraction for each month was defined. Because precipitation volume depends on the surface area of the lake, Wadell and Fields (1977) assumed four different lake levels for their precipitation inflow estimates. This method was used by Waddell and Barton (1980), Arnow (1984), Arnow and Stephens (1990), Wold, et al. (1997), and Loving, et al. (2000) to estimate precipitation inflows for Great Salt Lake.

- Hansen (1981), Chadwick, et al. (1983), and Chadwick, et al. (1986) used an equation developed using three nearby gages for estimating precipitation over Farmington Bay. It was assumed that a portion of precipitation falling on the mudflats entered Farmington Bay. It was assumed that this portion ranged linearly from 50 percent in January to 0 percent in July.

### 2.2.4 Evaporation

Estimates of evaporation generally are based upon modification of observed freshwater evaporation rates to account for actual salinity. These studies included:

- Waddell and Fields (1977) developed estimates of evaporation from Great Salt Lake using available evaporation pan data and extending the data set to include monthly data for the period 1931-1970. Pan coefficients were used to convert the data to freshwater evaporation rates and as a function of latitude, longitude, and water surface elevation. These values were then adjusted for salinity using an equation from Waddell and Bolke (1973). Waddell and Fields (1977) estimated the annual evaporation rate at Farmington Bay Wildlife Management Area to be 50.2 inches. This method was similarly used by Waddell and Barton (1980), Wold, et al. (1997), and Loving, et al. (2000) with adjustments to account for different evaporation pans.
- Hansen (1981), Chadwick, et al. (1983), and Chadwick, et al. (1986) used an annual freshwater evaporation for Farmington Bay of 52 inches. Annual and seasonal variability was adjusted using the evaporation pan at the Bear River Migratory Bird Refuge and adjusted for salinity using an equation from Waddell and Bolke (1973). It was assumed the mudflats exhibited the same evaporation rate as open water if the water level was less than 1.5 feet from ground surface. Evaporation rates reduced linearly to zero to a depth of 3.0 feet below ground surface (bgs). Evapotranspiration was estimated using monthly coefficients taken from Riley (1967) and assuming that 50 percent of the marshlands was open water and 50 percent was covered with vegetation.
- Christiansen and Low (1970) completed detailed measurements of surface and groundwater inflow and outflow to determine evapotranspiration rates for managed waterfowl wetland areas. Several different methods were evaluated, and recommendations were made.

### 2.2.5 Outflow Through the Davis County Causeway

As previously described, the Davis County Causeway physically separates Farmington Bay from Great Salt Lake. No flow measurements or flow capacity discussion was found in the literature for the culvert near the east side of the causeway; however, there has been significant work completed to understand flow through the bridge near the west side of the causeway.

Carter, et al. (1971) contained the first mention found of bi-directional flow through the bridge in the causeway. Coburn and Eckhoff (1972), Hansen (1981), Chadwick et al. (1983), and Sturm (1986) confirmed the bi-directional flow and made some of the first attempts to measure and gauge this outflow from Farmington Bay. All publications identified the importance of accurate flow measurement at the bridge to completing a water balance model for Farmington Bay. Many recommended the installation of a gage capable of continuous flow measurement. The USGS installed and began operation of a gage capable of measuring the bi-directional water flow on October 1, 2003. This gage continues in operation to this day.

Note that no measurements or analysis of flow through the causeway embankment was found. Hansen (1981) assumed this flow was negligible.

## 2.3 Farmington Bay Wetlands

Section 3.0 provides a detailed discussion of the various areas contributing surface water inflows to Farmington Bay. A common trait of all of these areas is the significant role that management of the available water has on the timing, quantity, and source of the water entering Farmington Bay in any given area. CH2M HILL (2005) completed a detailed water balance of the Jordan River system to better understand the role these management actions (i.e., trans-basin and intra-basin diversions, consumptive use, water conservation, and population growth) have on return flows in the Jordan River, including the amount of water available for the downstream wetlands, duck

clubs, preserves, and other water users along Farmington Bay. While the wetlands receive this water, they are also subject to complex water management practices. Flow through these wetlands, primarily composed of duck clubs and conservation areas, presents a significant challenge in defining the hydrology of Farmington Bay.

Hansen (1981) describes the significant challenge of attempting to measure all inflows to the Farmington Bay Wildlife Management Area and measure the various diversions within the preserve. His effort to create a detailed water balance model within the preserve, and the challenges experienced at the preserve, resulted in the simplification of the analysis and reallocation of flow monitoring resources to other areas of Farmington Bay to better understand those areas. The Farmington Bay Wildlife Management Area currently uses a detailed Water Management Plan (Utah Division of Wildlife Resources, 2008) that clearly defines management objectives and management practices.

The South Shore Duck Club Study (National Audobon Society, 1995) identified 14 duck clubs that own water rights along the south shore; of these, 11 remained active in managing water on their properties. The Newstate Duck Club has over 29 miles of internal canals and 17 different management units with which they can independently control water resources. Each club has its own strategy for attracting waterfowl during the hunting season and each strategy often hinges on water management throughout the year. Each club's strategy depends on the physical area of the club's property, the wetlands characteristics of the property, the different preferences for hunting and aquatic/wetland habitat, the amount and timing of the water allocation, the infrastructure for conveying and controlling water, available water in any given year, and human and economic resources. Each duck club's and preserve's management goals influence the timing, quantity, and quality of water moving through its wetlands and often affect the same for water moving into Farmington Bay.

Christiansen and Low (1970) summarize research begun in 1959 to better understand the water requirements of managed waterfowl marshlands in northern Utah. While their research focused on the Howard Slough Waterfowl Management Area in the Weber River drainage, much of the work is directly applicable to Farmington Bay wetlands as well. The work focused on estimating accurate monthly evapotranspiration rates, determining the salinity tolerance of vegetation in these wetlands and how that affects the water quality and quantity requirements for these wetlands, and developing management practices for water circulation and timing, depth control, and desirable vegetation. In general, the recommended flow per 100 acres of wetlands was 1 cubic foot per second (cfs).

Dev (2008) and Dicataldo (2008) completed a detailed water balance model for the Ambassador Duck Club as part of an evaluation of selenium dynamics in Farmington Bay wetlands. Nine ponds with multiple inflows, diversions, and outflows were modeled by Dev using GoldSim (GoldSim Technology Group). Evaporation was estimated using climatic data from the Salt Lake City International Airport and evaporation pan data from Brigham Young University. Groundwater contributions were not considered significant, and infiltration rates were assumed to be 2 to 10 mm per day. Average monthly flows at points between ponds are reported for 2006. Monthly average losses to evaporation, infiltration, and outflow to Farmington Bay are also reported for the same period. Data was used to calibrate the GoldSim water balance model.

The studies described above provide a significant foundation for understanding the areas that contribute water to Farmington Bay and how that water is managed. This understanding is critical to understanding each facet of the bay's ecosystem and making management decisions that balance the various interests.

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# 3.0 Contributing Areas

Farmington Bay's watershed is likely the most complex, dynamic, and e most populous and fastest growing area of Great Salt Lake's watershed (see Figure 1-1).. While the natural hydrologic cycle dominates delivery of water to Farmington Bay, the watershed's water resources are heavily managed, and flows to Farmington Bay are heavily regulated. This section provides a summary of Farmington Bay's sources of water, water delivery considerations, and available data. For ease of discussion, the watershed was divided into three drainage areas and an additional six basins. These areas are illustrated in Figure 3-1 and described in detail in the sections that follow:

- Antelope Island Drainage
- Davis County Drainage
  - North Davis Basin
  - Central Davis Basin
  - South Davis Basin
- Jordan River Drainage
  - Lower Jordan River Basin
  - Surplus Canal Basin
  - Sewage Canal Basin

## 3.1 Antelope Island Drainage

Antelope Island is a prominent feature on the western shore of Farmington Bay, extending approximately 15 miles from the Davis County Causeway on the north side of Farmington Bay to the Antelope Island causeway on the south side of the island (see Figure 1-1). The island is largely unpopulated, owned by the State of Utah, and designated as a State Park and conservation area. Antelope Island's contribution of surface water to Farmington Bay is limited to runoff from precipitation and snowmelt and flow from various groundwater springs on the eastern slope of the island. A review of the literature did not identify any estimates of surface runoff to Farmington Bay; however, Mayo and Klauk (1991) estimated that the combined dry season discharge of springs on Antelope Island is approximately 100 gallons per minute (gpm). While these springs are a critical source of water for habitat and wildlife on the island, they do not represent a significant source of direct surface water input to Farmington Bay.

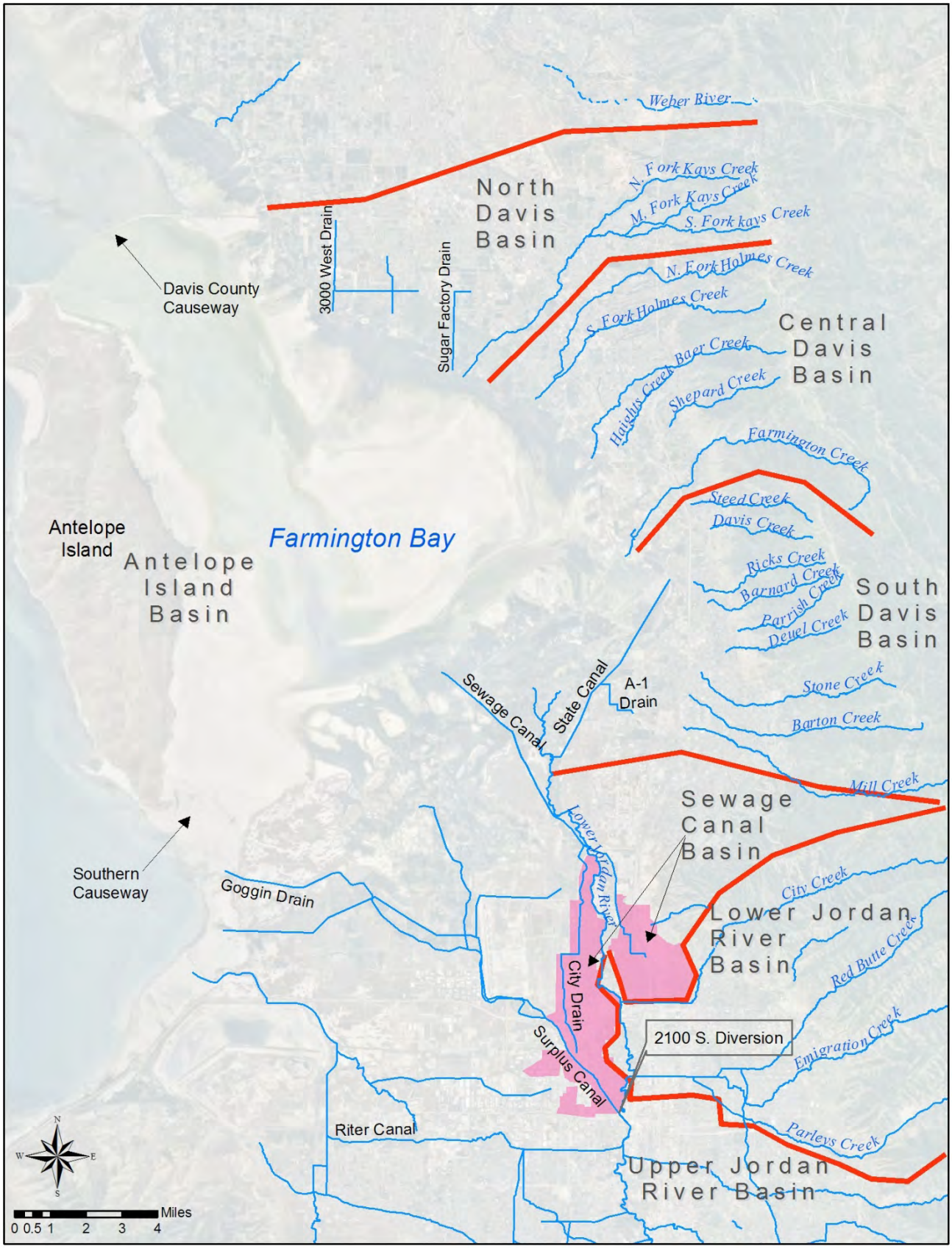
## 3.2 Davis County Drainage

Much of Farmington Bay and its entire eastern shore is located within Davis County. Numerous streams drain the Wasatch Mountains to Farmington Bay from the east; however, minimal flow gage data, diversions for irrigation use, and sparse mapping of storm drain and irrigation facilities make estimating surface water contributions from this large drainage area difficult. Imported flows of approximately 140,000 acre-feet per year from the Weber River watershed to this drainage (UDWR, 2009) and an unquantified amount of irrigation return flows are exported to the north to the Weber River. All of these factors further complicate estimates of the actual runoff contributed to Farmington Bay.

Figure 3-1 illustrates three basins within Davis County that contribute to Farmington Bay and correspond closely to the contributing areas for three municipal sewer districts within Davis County: North Davis, Central Davis, and South Davis. A description of each basin and its available data is provided below.

Although there are no recent studies evaluating surface runoff contributing to Farmington Bay from the Davis County Drainage (personal communication, Adam Wright, 2011), Waddell and Fields (1977) estimated a total monthly flow contribution for the period 1931-1973 for the following streams in Davis County: Holmes Creek, Farmington Creek, Ricks Creek, Parrish Creek, Centerville Creek (i.e., Deuel Creek), Stone Creek, and Mill Creek. These flows were estimated using a correlation to the flow record at City Creek in Salt Lake County.

FIGURE 3-1
**Drainage Basins**



### 3.2.1 North Davis Basin

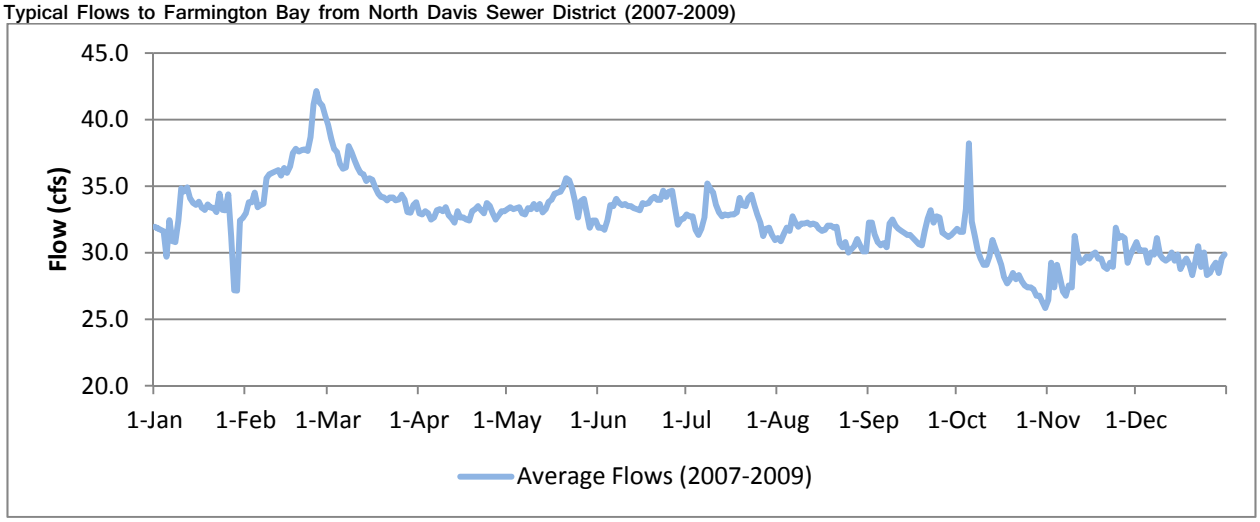
The North Davis Basin includes the area contributing surface runoff to the shoreline between the Davis County Causeway and just south of Kays Creek. Much of the Farmington Bay shoreline is contained within the Great Salt Lake Shorelands Preserve established by the Utah Reclamation Mitigation & Conservation Commission and Nature Conservancy to preserve this wetlands and shoreline habitat. Kays Creek and two storm drains, the 300 West Drain and Sugar Factor Drain, convey the majority of surface runoff and irrigation return flows to Farmington Bay from this sub-basin. Kays Creek has three channels in its upper watershed: North Fork Kays Creek, Middle Fork Kays Creek, and South Fork Kays Creek. The North Davis Sewer District contributes its treated effluent to Farmington Bay at its Utah Pollutant Discharge Elimination System (UPDES) permitted outfall located just south of the Davis County Causeway.

#### Historical Record

No continuous flow record was located for the drains and creeks in this basin. The lower 1 mile of the Kays Creek channel was restored by the Nature Conservancy and Ducks Unlimited in 2004-2006. While flow data used for the design of this restoration project was not located as part of this effort, there is a possibility it exists and should be further investigated. Hansen (1981) includes flow measurements for October 1980 to March 1981 for Kays Creek (4.1 to 15.9 cubic feet per second [cfs]). Additional effort to locate available storm drain and irrigation system mapping and master plans should be undertaken in order to better define the contributing area and potentially estimate stormwater contributions.

Figure 3-2 illustrates typical flows from the North Davis Sewer District based on data available from its annual Discharge Monitoring Reports from 2007 through 2009.

FIGURE 3-2
Typical Flows to Farmington Bay from North Davis Sewer District (2007-2009)




### 3.2.2 Central Davis Basin

The Central Davis Basin includes the area contributing surface runoff to the shoreline between, and including, Holmes Creek and Farmington Creek (see Figure 3-1). Holmes Creek has two channels in its upper watershed: North Fork Holmes Creek and South Fork Holmes Creek. Other creeks in this basin include Baer Creek, Haights Creek, Shepard Creek, and Rudd Creek. Rudd Creek combines with Farmington Creek near Interstate 15. Holmes Creek flows into part of the Great Salt Lake Shorelands Preserve, and Farmington Creek can be diverted into the Farmington Bay Wildlife Management Area or directly to Farmington Bay. All seven creek systems have diversions at the foot of the Wasatch Mountains; thus, while snowmelt contributes flow during the spring, flow is dominated by stormwater, groundwater inflow, and irrigation return flows the remainder of the year (personal communication, Adam Wright, 2011). The Central Davis Sewer District also contributes treated effluent to Farmington Bay at its UPDES permitted outfall located just west of the Baer Creek discharge location.

## Historical Record

Of the seven creeks named above, only South Fork Holmes Creek and Farmington Creek are known to have had flow gages in operation at the mouth of their respective canyons (see Figures 2-1 and 2-2). The U.S. Geological Survey (USGS) currently maintains the flow gage at Farmington Creek. Figures 3-3 and 3-4 illustrate annual flow patterns for these creeks for average, wet, and dry years at their respective USGS gage location. See Section 2.0 for a description of how wet and dry year flows were identified. Figure 3-5 illustrates typical flows from the Central Davis Sewer District from data available from its annual Discharge Monitoring Reports for 1998 through 2008.

Loving, et al. (2000) estimated average monthly flow volumes for Holmes Creek and Farmington Creek at 226 acre-feet per month and 808 acre feet per month, respectively, from the available historical record. Wold, et al., (1997) estimated average monthly flow volumes for Farmington Creek at 800 acre feet per month. These estimates corresponds closely to the average monthly volumes computed from the average of available flow data shown in Figures 3-3 and 3-4 of 223 acre feet per month for Holmes Creek (1950-1966) and 843 acre feet per month for Farmington Creek (1949-1971, 1975-1980, 2008-2011). Both Wold, et al. (1997) and Loving, et al. (2000) developed a regression for these streams based on flows at City Creek.

Hansen (1981) includes flow measurements for October 1980 to March 1981 for Farmington Creek (0.5 to 4.5 cfs). A hydrologic study for the streams and canals in this basin was completed CH2M HILL (1997) in 1997 to determine peak flood flows for South Fork Holmes Creek, Shepard Creek, and the combined Rudd and Farmington Creek channel where they cross Interstate 15. Table 3-1 summarizes estimated flood frequency discharges for the Central Davis Streams at Interstate 15.

FIGURE 3-3
Typical Flows for Available Flow Data for South Fork Holmes Creek (1950-1966)

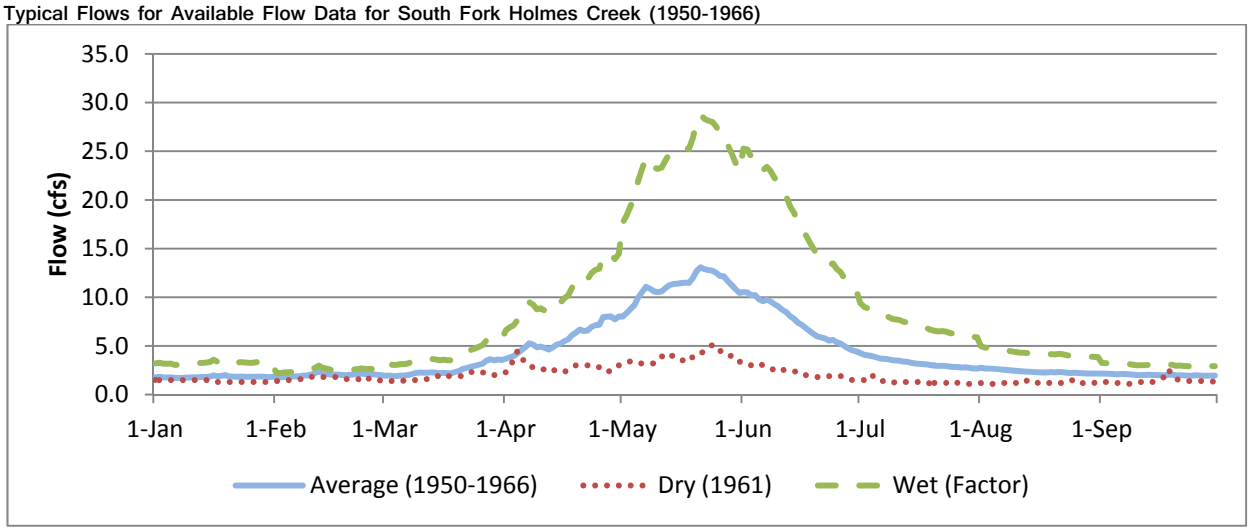


FIGURE 3-4
Typical Flows for Available Flow Data for Farmington Creek (1949 - current)

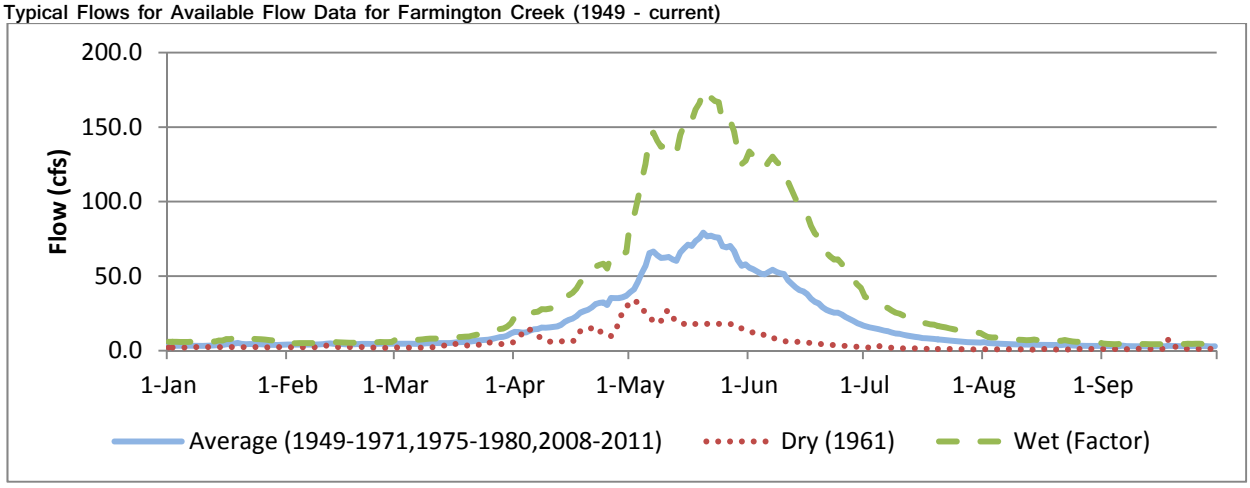



FIGURE 3-5
Typical Flows to Farmington Bay from Central Davis Sewer District (1998-2008)

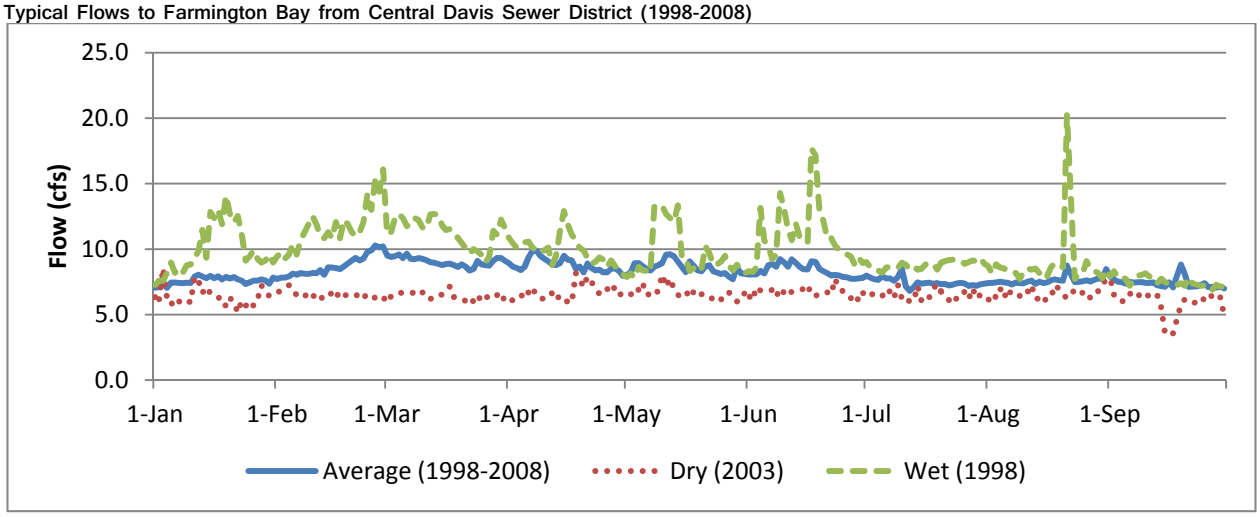



TABLE 3-1
Estimated Flood Frequency Discharges for Central Davis Streams at Interstate 15

| Natural Channel | 10-year Summer Cloudburst (cfs) | 25-year Summer Cloudburst (cfs) | 100-year Clear Sky Snowmelt (cfs) |
|---|---|---|---|
| South Fork Holmes Creek | 209 | 432 | 226 |
| Shepard Creek | 469 | 989 | 190 |
| Combined Rudd and Farmington Creeks | 209 | 441 | 876 |

Source: CH2M HILL, 1997.

Note that these flows include a larger watershed than the flow data included in Figures 3-3 and 3-4.

### 3.2.3 South Davis Basin

The South Davis Basin includes the creeks and drainages in Davis County south of Farmington Creek that discharge to the State Canal and/or the Farmington Bay Wildlife Management Area (see Figure 3-1). This includes Steed Creek, Davis Creek, Ricks Creek, Barnard Creek, Parrish Creek, Deuel Creek (also known as Centerville Creek), Stone Creek, Barton Creek, Mill Creek, and the A-1 Drain. Steed Creek and Davis Creek combine into one channel

near Interstate 15. Deuel Creek, Stone Creek, and Barton Creek also combine into one channel near Interstate 15. With the exception of the A-1 Drain, all creeks have headwaters in the Wasatch Mountains and have diversions at the mouth of their respective canyons. Snowmelt typically dominates flow in these creeks during the spring; in the remainder of the year, flow is dominated by stormwater, groundwater inflow, and irrigation return flows (personal communication, Adam Wright, 2011). The North Plant of the South Davis Sewer District also contributes treated effluent to the State Canal at its UPDES permitted outfall.

## Historical Record

Of the nine creeks named above, only five are known to have had flow gages in operation at the mouth of their respective canyon (see Figures 2-1 and 2-2): Ricks Creek, Parrish Creek, Deuel Creek, Stone Creek, and Mill Creek. The USGS currently maintains the flow gage at Deuel Creek. Figures 3-6 through 3-10 illustrate annual flow patterns for these creeks for average, wet, and dry years at their respective USGS gage locations. See Section 2.0 for a description of how wet and dry year flows were identified. Figure 3-11 illustrates typical flows from the South Davis Sewer District's North Plant based on data available from its annual Discharge Monitoring Reports from 2007 through 2008.

Loving, et al. (2000) and Wold, et al. (1997) estimated average monthly flow volumes for Ricks Creek, Parrish Creek, Deuel Creek, Stone Creek, and Mill Creek. Table 3-2 provides a comparison of these values with the average flow time series shown in Figures 3-6 through 3-10. Hansen (1981) includes flow measurements for October 1980 to March 1981 for Stone Creek (1.8 to 3.0 cfs).

A hydrologic study for the streams and canals in this basin was completed by Davis County Flood Control in 1997 to determine peak flood flows for Steed Creek, Davis Creek, Ricks Creek, Barnard Creek, Parrish Creek, Deuel Creek, Stone Creek, and Barton Creek (and combined Deuel, Stone, and Barton creeks) where they cross Interstate 15. Table 3-3 summarizes estimated flood frequency discharges for the South Davis Streams at Interstate 15.

FIGURE 3-6
Typical Flows for Available Flow Data for Ricks Creek (1950 – 1966)

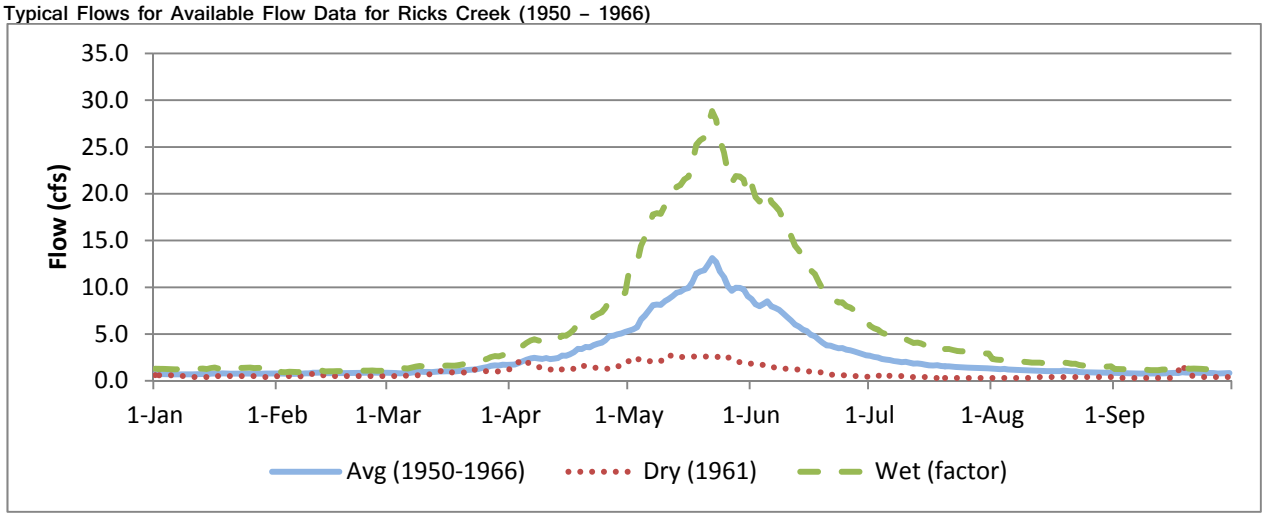


FIGURE 3-7
Typical Flows for Available Flow Data for Parrish Creek (1949 – 1968)

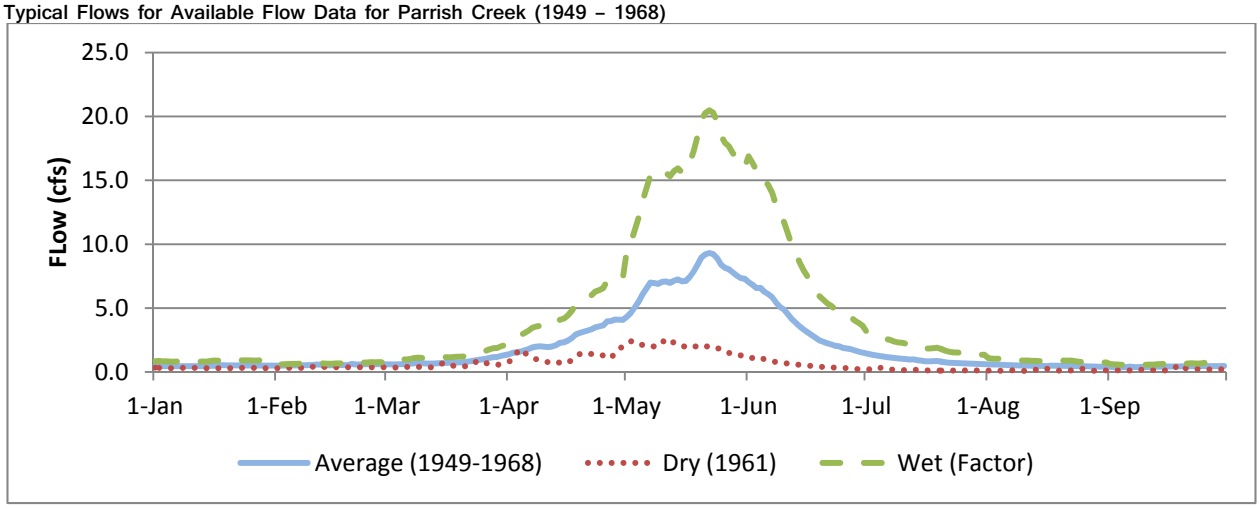



FIGURE 3-8
Typical Flows for Available Flow Data for Deuel Creek (1949 – current)

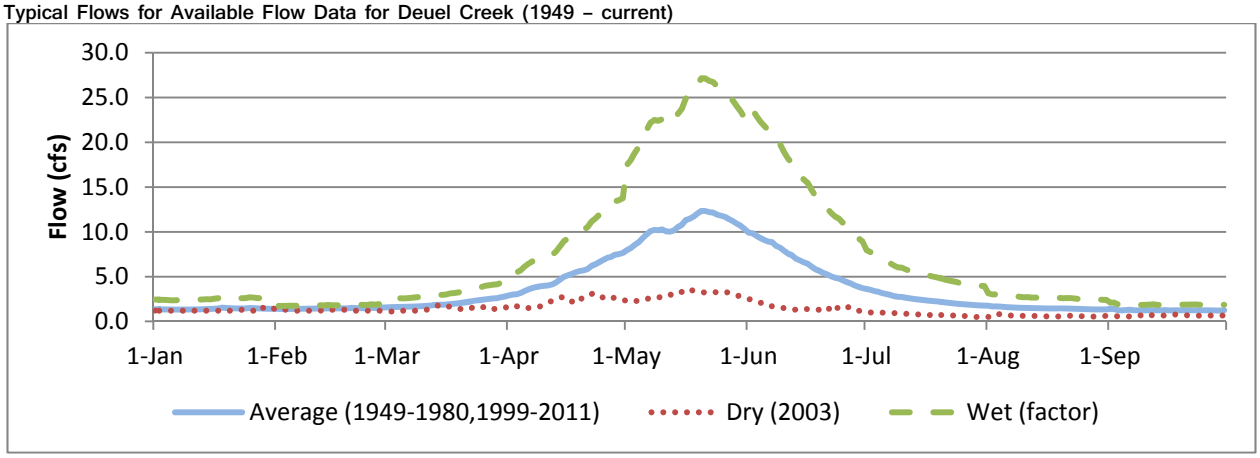



FIGURE 3-9
Typical Flows for Available Flow Data for Stone Creek (1950 – 1966)

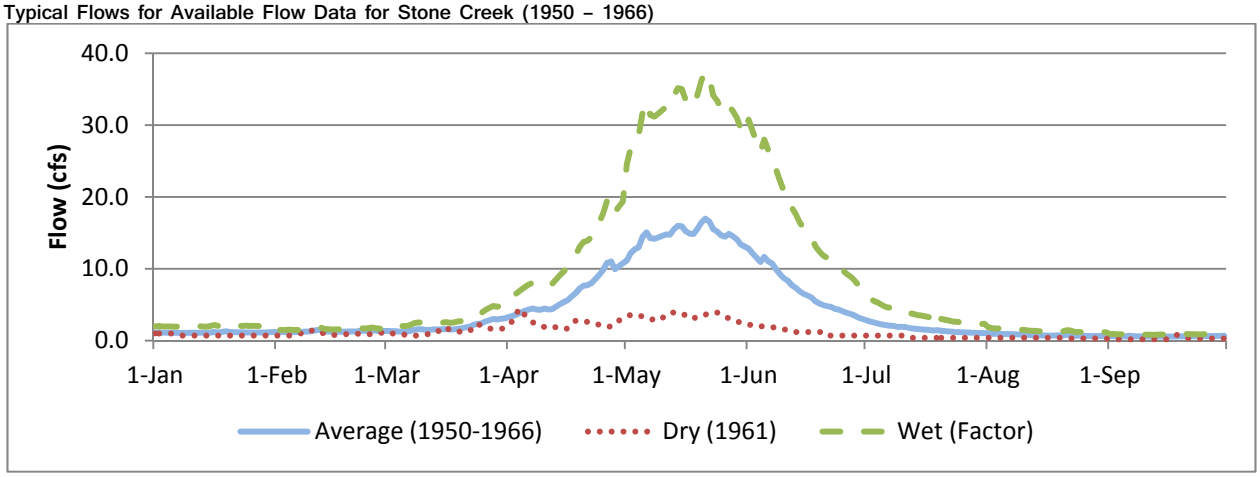


FIGURE 3-10
Typical Flows for Available Flow Data for Mill Creek (1950 – 1968)

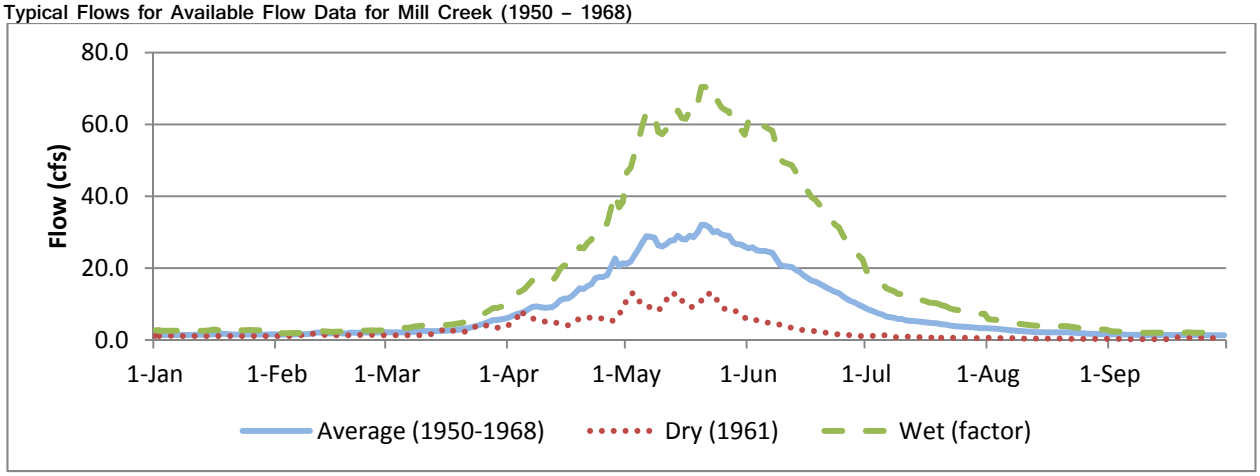



FIGURE 3-11
Typical Flows to Farmington Bay from South Davis Sewer District (2007-2008)

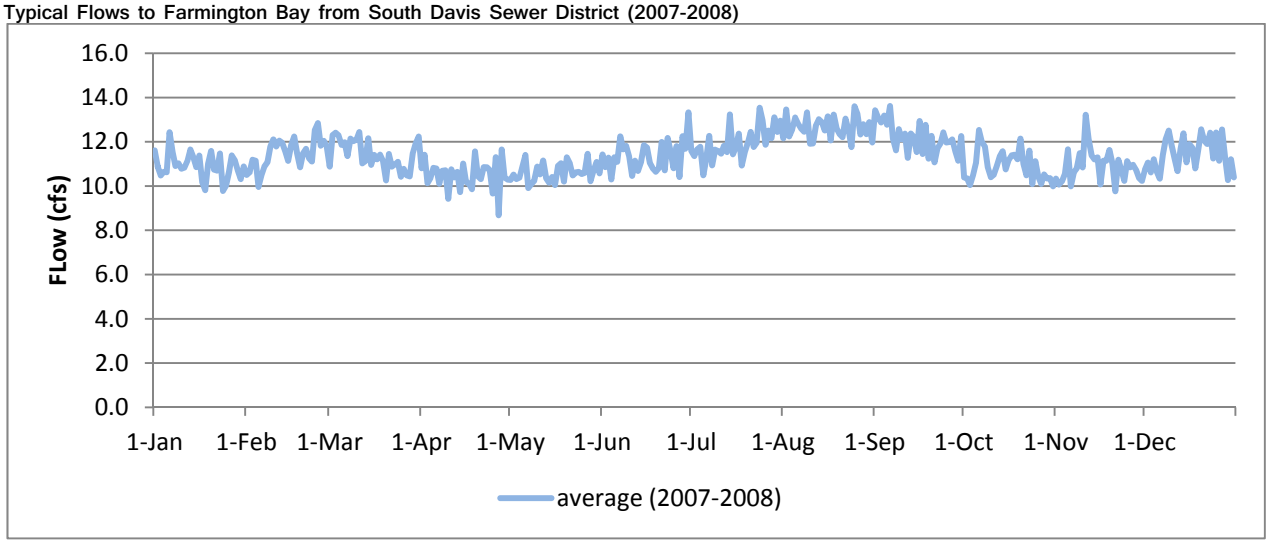



TABLE 3-2
Comparison of Estimated Average Monthly Flow from South Davis Streams

| Natural Channel | Average Flow from Loving, et al., 2000 Acre-feet/month (years) | Average Flow from Wold, et al., 1997 Acre-feet/month (years) | Average Flow from Time Series in Figures 3-6 through 3-10 Acre-feet/month (years) |
|---|---|---|---|
| Ricks Creek | 137 (1987-1998) | 134 (1980-1986) | 135 (1950-1966) |
| Parrish Creek | 96 (1987-1998) | 95 (1980-1986) | 95 (1949-1968) |
| Deuel Creek | 183 (1987-1998) | 183 (1980-1986) | 184 (1949-1980, 1999-2011) |
| Stone Creek | 198 (1987-1998) | 190 (1980-1986) | 195 (1950-1966) |
| Mill Creek | 401 (1987-1998) | 388 (1980-1986) | 395 (1950-1968) |

Note that both Wold, et al. (1997) and Loving, et al. (2000) developed a regression for these streams based on the available flow record and flows at City Creek.

TABLE 3-3
Estimated Flood Frequency Discharges for South Davis Streams at Interstate 15

| Natural Channel | 10-year Summer Cloudburst (cfs) | 25-year Summer Cloudburst (cfs) | 100-year Clear Sky Snowmelt (cfs) |
|---|---|---|---|
| Steed Creek | 95 | 196 | 211 |
| Davis Creek | 21 | 80 | 127 |
| Ricks Creek | 289 | 533 | 194 |
| Barnard Creek | 212 | 407 | 113 |
| Parrish Creek | 184 | 312 | 167 |
| Deuel Creek | 210 | 410 | 259 |
| Stone Creek | 656 | 1308 | 361 |
| Barton Creek | 455 | 855 | 373 |
| Combined Deuel, Stone, and Barton Creeks | 1080 | 2015 | 993 |

Source: CH2M HILL, 1997.
Note that these flows include a larger watershed than the flow data included in Figures 3-6 through 3-10.

## 3.3 Jordan River Drainage

One of the most complex and significant components of Farmington Bay's watershed is the Upper Jordan River Watershed, with an average yield of 418,000 acre-feet per year flowing past the 21st South bridge (CH2M HILL, 2005). Of this amount, approximately 308,000 acre-feet per year originate from the Utah Lake system (UDWR, 1997). Understanding and accounting for how this water is managed is a critical component to understanding the management and distribution of water around Farmington Bay.

Flow patterns in the Jordan River are complex. It is a thoroughly managed system that begins with the Upper Provo watershed, Weber-Provo watershed, and Duchesne Tunnel, which drain into the Jordanelle Reservoir. The Provo River carries water from this reservoir, picking up flows within the Middle Provo watershed where it then drains to Deer Creek Reservoir. From this point, additional runoff is collected in the Provo River from the Lower Provo watershed before entering Utah Valley, where the river passes through Orem and Provo and enters Utah Lake. Some diversions take water from the Provo River, bypassing Utah Lake to metropolitan areas along the Wasatch Front for municipal use. A significant amount of water is also supplied to Utah Lake by the Strawberry Reservoir and Spanish Fork River (UDWR, 1997). During dry to average water yield years, releases from Utah Lake to the Jordan River are managed closely to supply water mostly for irrigation and wildlife management/duck clubs. During wet years, excess water is released down the Jordan River (Hooten, 1999).

While Utah Lake operations have a significant role in the timing and quantity of flow in the Jordan River, snow melt, irrigation, stormwater, and groundwater interaction also play a significant role in the water yield of the Upper Jordan River Watershed (Bear West Consulting, 1999). The Jordan River Return Flow Study was completed in 2005 to better understand the complex interactions of inflows and outflows in the Jordan River system and how water management decisions could affect flow rates in the Jordan River (CH2M HILL, 2005). This evaluation accounted for imported waters, snowmelt, irrigation diversions and return flows, stormwater runoff, groundwater interactions, consumptive uses, population increases, agricultural practices, water conservation, and industrial and municipal discharges. The water balance model that was developed is an important tool that can be used to understand flow contributions to Farmington Bay.

The majority of flow from the Jordan River is diverted down the Surplus Canal, with some flows remaining in the Lower Jordan River. This section provides a summary of the operation of this diversion and the flows received by Farmington Bay wetlands from the Surplus Canal and Lower Jordan River.

### 3.3.1 Surplus Canal Basin

The Surplus Canal was constructed in 1885 to divert flood flows from the Jordan River away from the more populated areas of Salt Lake City and convey them directly to Great Salt Lake. A diversion structure located just north of 2100 South allows the Lower Jordan River Commissioner to regulate the quantity of flow entering the Lower Jordan River with the remaining Jordan River flow continuing down the Surplus Canal to two primary points of diversion (see Figure 3-12): the North Point Canal Diversion and the Goggin Diversion Dam. These two diversions turn water toward the wetlands along the south shore and then into Farmington Bay; however, a majority of the water typically continues west in the Goggin Drain to Great Salt Lake.

It is important to note that it is the responsibility of the Lower Jordan River Commissioner to deliver the flow required to meet the water rights of the downstream users, including duck clubs, conservation areas, and agricultural users. The Commissioner works with these water users to deliver their water and uses discretion in managing excess or higher available flows. The objective is to put the available water to use in the fields, duck clubs, and conservation areas along the south shore of Farmington Bay and Great Salt Lake and minimize the loss of water directly to Great Salt Lake. Our understanding of some of the key operational mechanisms used to manage the water in the Surplus Canal (personal conversations, Layne Jensen, 2010 and 2011) is presented below.

#### North Point Consolidated Canal

The North Point Canal Diversion is the first diversion structure along the Surplus Canal and is located just south of the Salt Lake City International Airport. The diversion typically turns a minimum of 90 cfs but up to 114 cfs from the Surplus Canal into the North Point Consolidated Canal. Summer flows can be up to 120 cfs. Diverted flows are typically decreased to 90 cfs after the irrigation season is finished. Rather than change the configuration at the North Point Canal Diversion, the Commissioner uses the Jensen Flume, where the North Point Consolidated Canal crosses the Surplus Canal, to turn excess flows (typically up to 40 cfs) into the Surplus Canal during the irrigation off-season. The primary objective for water management on the North Point Consolidated Canal is to use the water and not let excess water flow directly to Great Salt Lake.

The first diversion downstream of the North Point Canal Diversion along the North Point Consolidated Canal is the North Point Y diversion. A minimum flow of 21 cfs is diverted down the East Branch to the North Point East complex shown in Figure 3-12. Water is conveyed through ditches through this complex and used either for agricultural uses or conveyed to the Rudy complex, as shown in Figure 3-12. Excess water eventually flows through the Rudy complex and into Farmington Bay.

Flow remaining in the North Point Consolidated Canal continues to the west. There are various turnouts along this canal, including the Blackhawk ditch, an unnamed ditch, the Harrison ditch, the airport mitigation ponds ditch, and Sheep ditch. Each of these turnouts conveys water to the north into wetlands along the south shore and then into Farmington Bay. The Blackhawk (8 cfs), unnamed, and Harrison (10 cfs) ditches convey water to the north and eventually into the Ambassador complex (see Figure 3-12). Tailwaters from the airport mitigation ponds (5 cfs) and Sheep ditch combine and flow north and west to the Great Salt Lake South Shore Ecological Preserve/Gilmore Wildlife Sanctuary (see North Point West complex in Figure 3-12).

Remaining flows in the North Point Consolidated Canal continue to the west for agricultural use and to Kennecott's Inland Sea Shore Preserve (10 cfs). The canal also receives irrigation return flows from various canals from the south. Excess water flows into the South Arm of Great Salt Lake.

#### Historical Record

The only available flow record identified for the North Point Consolidated Canal system is the North Point Diversion Dam. This data is archived by the UDWR and USGS and there are many significant gaps in the record. Figure 3-13 illustrates the available record. Waddell and Fields (1977) estimated total monthly flow contributions for the period 1931-1973 for the combined Goggin Drain, North Point Consolidated Canal, and Surplus Canal at Cohen Flume using correlations with flow gauges at the Surplus Canal near 2100 South.

FIGURE 3-12
**Surplus Canal**

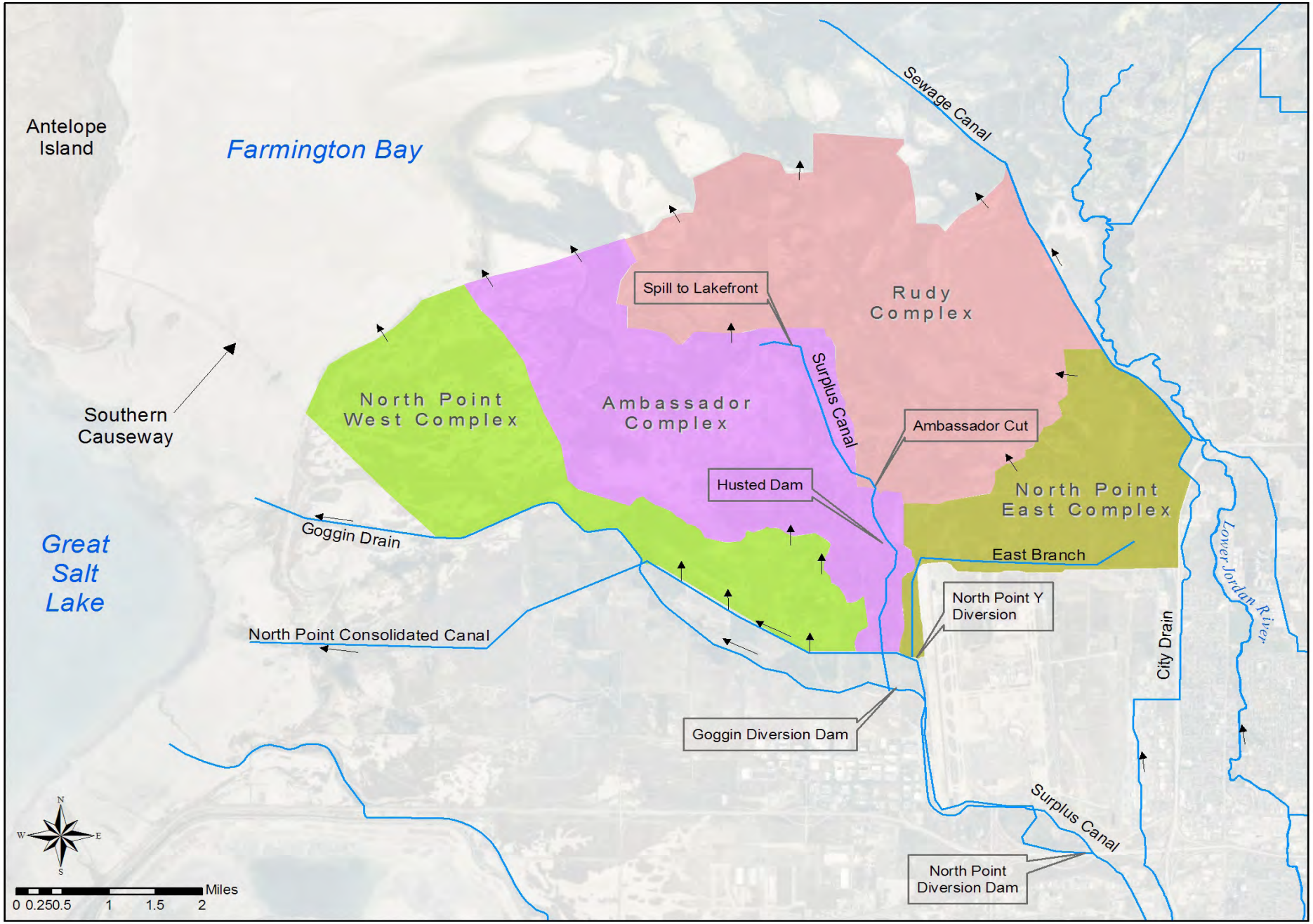
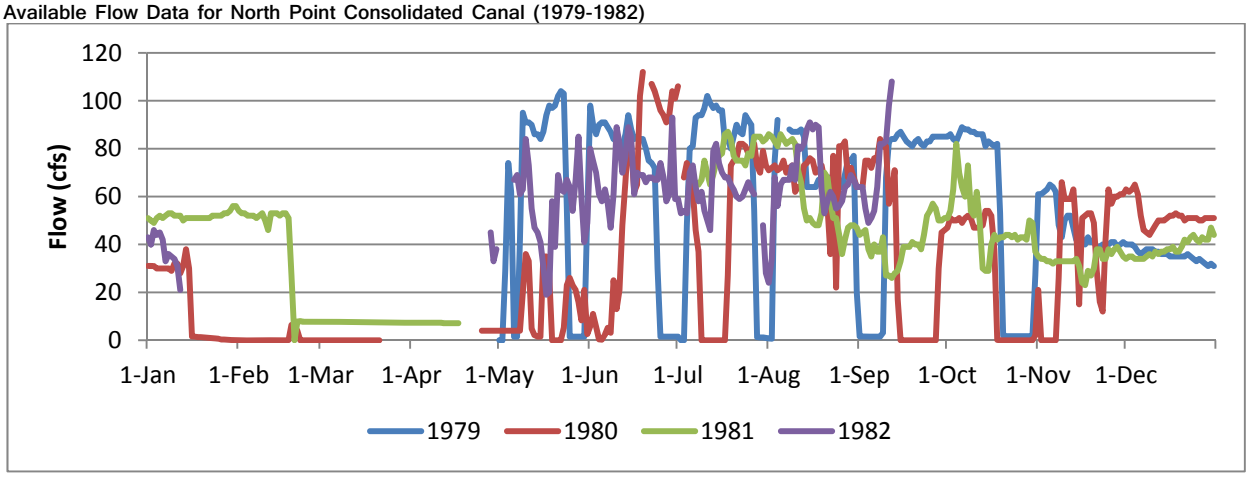


FIGURE 3-13
Available Flow Data for North Point Consolidated Canal (1979-1982)




## Surplus Canal

The Goggin Diversion Dam represents the beginning of the Goggin Drain, carrying excess flow to Great Salt Lake, and where the Surplus Canal turns to the north toward Farmington Bay. The flow from the Surplus Canal – which can be up to 700 cfs but is typically 120 to 150 cfs from April to October and 60 cfs from October to April – is distributed to various duck clubs along the south shore of Farmington Bay via three diversions. There is generally enough water in the Surplus Canal to provide 120 to 150 cfs to the duck clubs if Utah Lake is spilling. Once Utah Lake reaches compromise and no longer spills, the Goggin Diversion Dam is usually closed to divert all water north via the Surplus Canal. The primary objective for water management on the Surplus Canal is to use the water and not let excess water flow directly to Great Salt Lake via the Goggin Drain.

The first diversion along the Surplus Canal north of the Goggin Diversion Dam is the Husted Dam. This dam raises the water surface level in the canal to allow delivery of water to the west toward the Harrison Duck Club in the Ambassador complex (water right of 10 cfs) (see Figure 3-12). The next diversion along the Surplus Canal is the Ambassador Cut. Generally, 50 percent of flow is diverted to the east to the Rudy Duck Club and Northpoint Duck Club in the Rudy complex (water right of 26 cfs), and 50 percent of the flow continues north to the Utah Duck Club and Ambassador Duck Club in the Ambassador complex (water right of 35 cfs) (see Figure 3-12). One last diversion at the Ambassador Duck Club diverts 50 percent of the flow into Ambassador Duck Club to the west in the Ambassador complex (water right of 12 cfs) and 50 percent of the flow into the Lakefront Duck Club in the Rudy complex (water right of 11.7 cfs) (see Figure 3-12). Excess water flows through the duck clubs and into Farmington Bay.

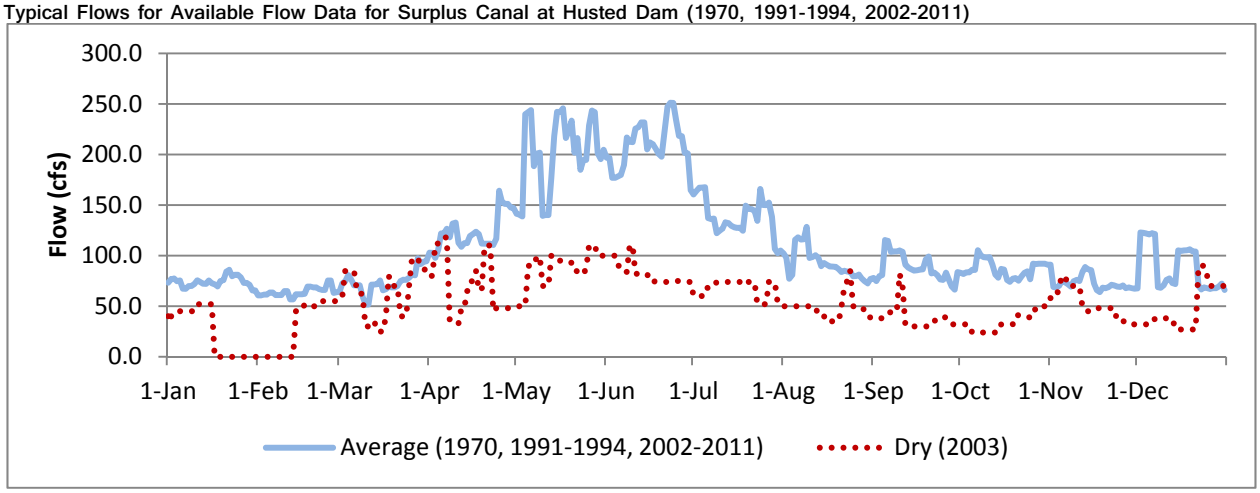
Diversions along the Surplus Canal are regulated by the seniority of the water rights held by the duck clubs. The duck clubs' priority is as follows: Rudy Duck Club, Northpoint and Lakepoint duck clubs, Ambassador Duck Club, and Harrison Duck Club. When water is scarce (typically during October to April), it is distributed according to the duck club priority.

### Historical Record

The Lower Jordan River Commissioner and water users monitor flows in the Surplus Canal and downstream diversions on a daily basis, with the UDWR serving as the depository of the available historical record. As shown in Figure 2-1, the UDWR archives include a daily record of a staff gauge located at Husted Dam (portions of 1970, 1991-1994, and 2002-current), just below Husted Dam (portion of 2004), the Ambassador Cut (portion of 1993), and at the Utah Duck Club (portion of 2002). Figure 3-14 illustrates annual flow patterns at Husted Dam for average and dry years at the gage location. See Section 2.0 for a description of how the dry year flows were identified. Waddell and Fields (1977) estimated a total monthly flow contribution for the period 1931-1973 for the Surplus Canal at the Cohen Flume (upstream of the Husted Dam).

Wadell and Fields (1977) measured discrete flow events during the period 1973-1975 at the outlets of North Point Duck Club (48 to 201 cfs), Lake Front Duck Club (20 to 125 cfs), and the West Ambassador Duck Club (7 to 54 cfs) to estimate their total contribution to Farmington Bay.

FIGURE 3-14
Typical Flows for Available Flow Data for Surplus Canal at Husted Dam (1970, 1991-1994, 2002-2011)




## Goggin Drain

The Goggin Drain is a large ditch that conveys excess flows from the Surplus Canal directly to the South Arm of Great Salt Lake. While there are no known diversions along its length, the drain collects irrigation return flows from the south and conveys them to Great Salt Lake.

### Historical Record

The USGS gauge on the Goggin Drain is a critical element to our understanding of waters that flow into Farmington Bay (see Table 3-4). With the exception of flows in the North Point Consolidated Canal, all flows in the Jordan River that are not conveyed down the Goggin Drain enter Farmington Bay. Thus, the historical flow record at Goggin Drain is critical to understanding the water balance for Farmington Bay. Waddell and Fields (1977) estimated total monthly flow contributions for the period 1931-1973 for the Goggin Drain using correlations with flow gauges at the Surplus Canal near 2100 South.

TABLE 3-4
Estimate of Flow Contribution from Upper Jordan River to Farmington Bay Using Goggin Drain Data[1]

| | Total Annual Jordan River Flow (acre-feet) | Estimated Jordan River to Farmington Bay (acre-feet) | Percent of Jordan River Flow to Farmington Bay |
|---|---|---|---|
| 1975 | 388,128 | 240,590 | 62% |
| 1976 | 495,646 | 316,606 | 64% |
| 1977 | 218,600 | 197,522 | 90% |
| 1978 | 282,137 | 213,421 | 76% |
| 1979 | 323,403 | 221,841 | 69% |
| 1980 | 373,065 | 231,313 | 62% |
| 1981 | 427,995 | 274,716 | 64% |
| 1982 | 506,565 | 292,033 | 58% |
| 1983 | 1,230,599 | 515,758 | 42% |
| 1984 | 1,558,717 | 777,181 | 50% |

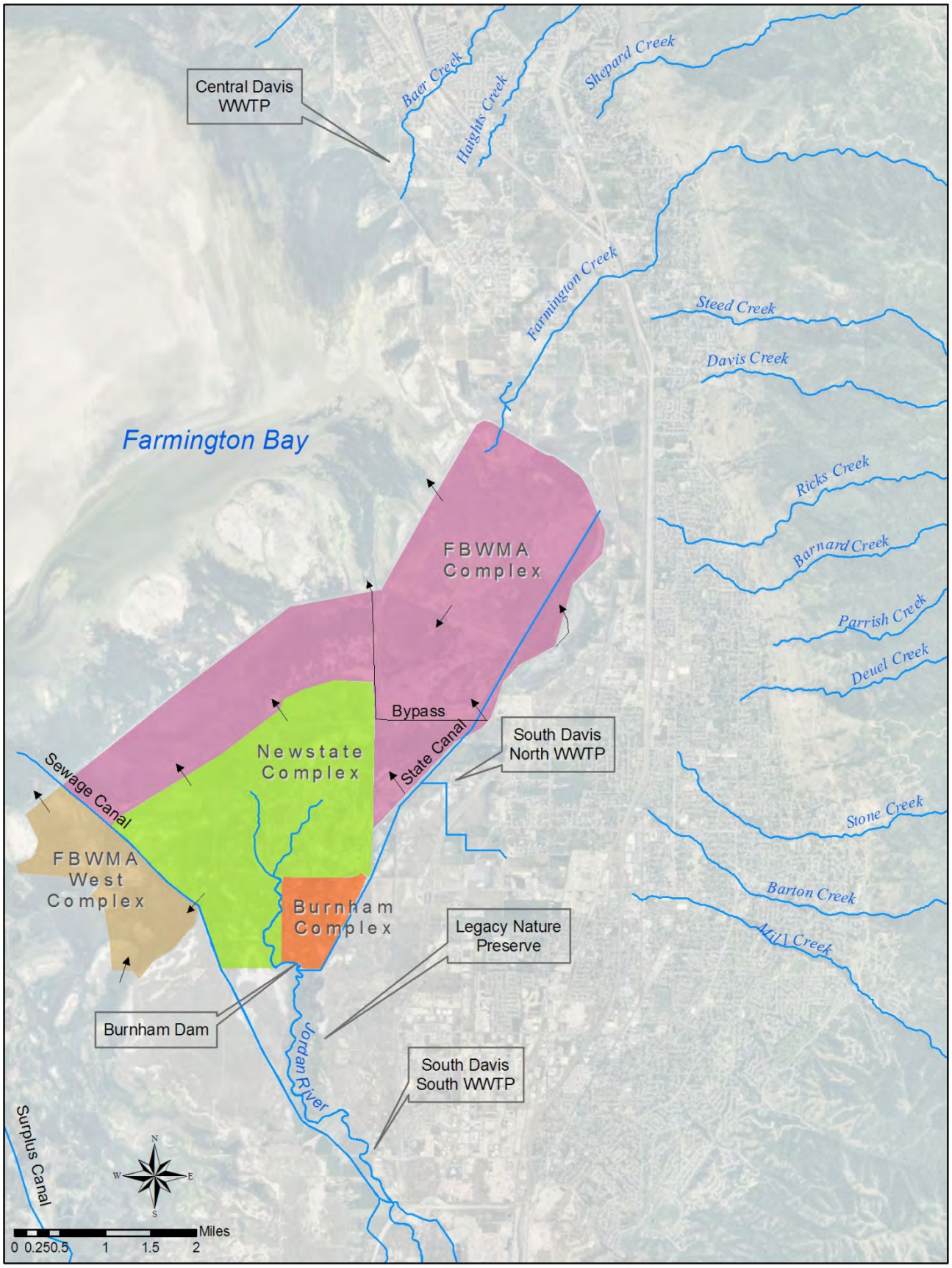
[1] Total Jordan River Flow is the Jordan River at 1700 South plus the Surplus Canal.

### 3.3.2 Lower Jordan River Basin

Flows in the Lower Jordan River are managed to achieve two objectives: 1) minimize flooding through Salt Lake City, and 2) deliver the required water rights to downstream users. To that end, flows into the lower Jordan River from the main stem of the Jordan River are controlled at the Surplus Canal Diversion just north of 2100 South. Several creeks and major storm drain outfalls contribute snowmelt from the Wasatch Mountains, as well as stormwater and irrigation return flows into the lower Jordan River. Parley's Creek, Red Butte Creek, and Emigration Creek enter the 1300 South storm drain system and discharge to the Lower Jordan River at 1300 South. Other major storm drain outfalls at 2100 South, 900 South, 800 South, 500 South, and 400 South convey stormwater to the river from Salt Lake City. City Creek enters the Lower Jordan River via the North Temple Drive storm drain outfall. Local stormwater runoff also contributes to the channel as the river meanders through Salt Lake City. Water is eventually distributed to various water users via the river channel to the north and the State Canal to the northeast at the Burnham Dam. (See Figure 3-1 and Figure 3-15.)

It is important to note that it is the responsibility of the Lower Jordan River Commissioner to deliver the flow required to meet the water rights of the downstream users (including duck clubs, conservation areas, and agricultural users). The Commissioner works with these water users to deliver their water and uses discretion in managing excess or higher available flows. The description below is our understanding of some of the key operational mechanisms used to manage the water in the Lower Jordan River (personal conversations, Layne Jensen, 2010 and 2011).

FIGURE 3-15
**Lower Jordan Canal**



## Surplus Canal Diversion at 2100 South

The Lower Jordan River Commissioner operates the Surplus Canal diversion at 2100 South in coordination with Salt Lake County Flood Control and Salt Lake City Department of Public Utilities. To that end, the Commissioner will equally split flows in the Jordan River between the Surplus Canal and Lower Jordan River for flows up to 300 cfs in the Jordan River. The typical target flow diverted into the Lower Jordan River is 150 cfs (a typical maximum of 200 cfs) to meet water rights (personal communication, Layne Jensen, 2010 and 2011). The maximum capacity of the diversion in its current configuration is approximately 500 cfs (Salt Lake County, 2010). Excess flows from the Jordan River are conveyed down the Surplus Canal. The Commissioner will often significantly reduce diversions to the Lower Jordan River, or even close the gates completely for a few months, during spring runoff to preserve the capacity of the Lower Jordan River to convey water from its tributaries (see Figure 3-16) (personal conversation, Layne Jensen, 2010 and 2011). Figure 3-17 illustrates how diversions into the Lower Jordan River are managed to account for anticipated flooding from Lower Jordan River tributary flows.

FIGURE 3-16
Average Daily Flows in Lower Jordan River at 1700 South Illustrating Typical Diversions from Jordan River (USGS, 2008-2011)

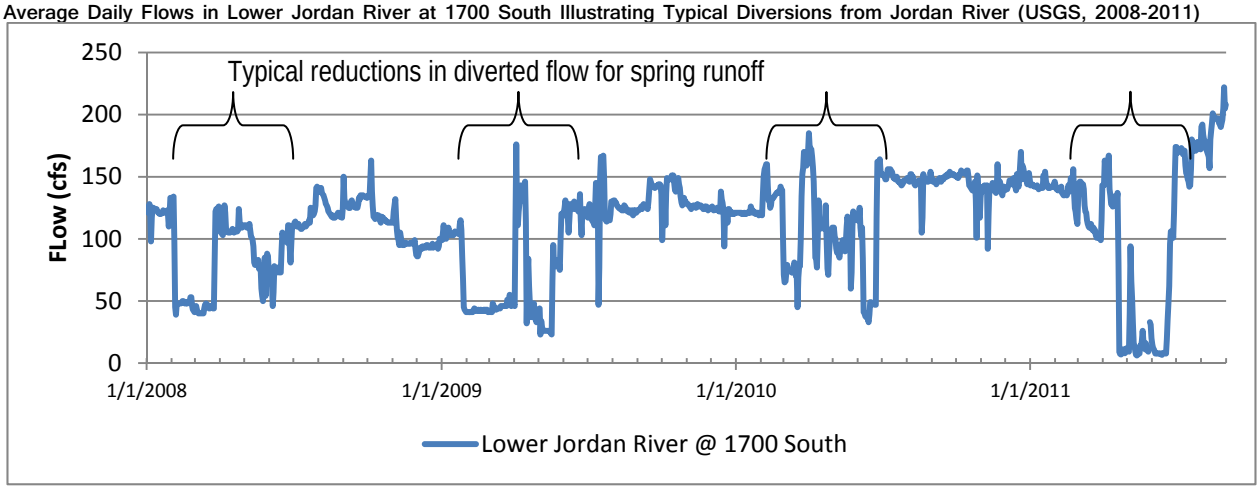
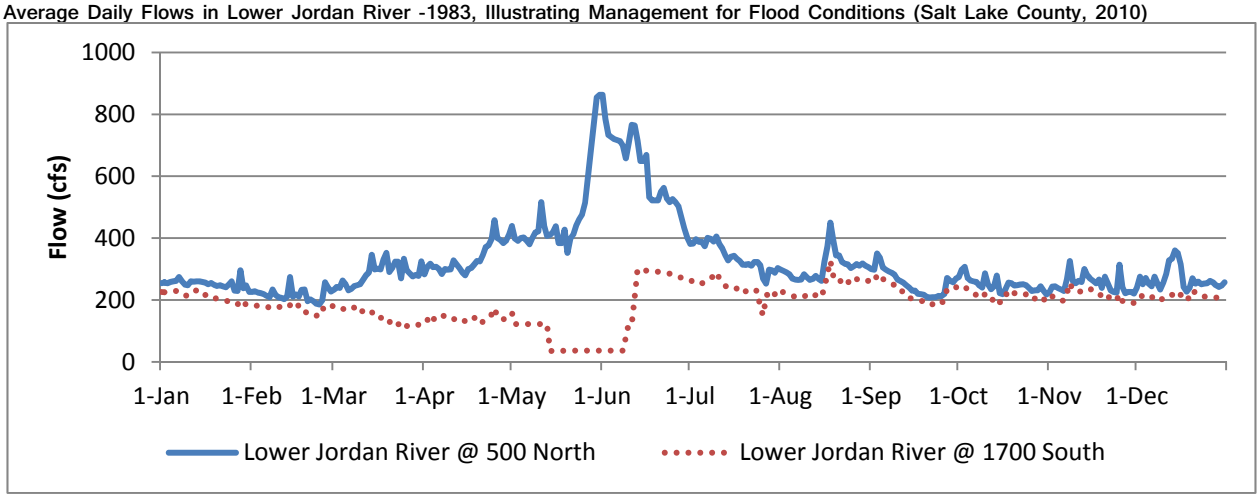



FIGURE 3-17
Average Daily Flows in Lower Jordan River -1983, Illustrating Management for Flood Conditions (Salt Lake County, 2010)




## Lower Jordan River Tributaries

The Lower Jordan River has several significant, natural tributaries, including Parley's Creek, Emigration Creek, Red Butte Creek, and City Creek (see Figure 3-1). These are perennial streams reaching the Lower Jordan River from their headwaters in the Wasatch Mountains. As such, snowmelt in the spring can provide significant flows to the Lower Jordan River. Each of these streams travels through Salt Lake City and diverted into underground storm drain pipelines (Parley's Creek, Emigration Creek, and Red Butte Creek into 1300 South and City Creek into North Temple Drive). Storm drain outfalls at 2100 South, 1300 South, 900 South, 800 South, 500 South, 400 South, and

North Temple Drive also convey significant stormwater flows to the river in Salt Lake County. The South Plant of the South Davis Sewer District also contributes its treated effluent to the Lower Jordan River at its UPDES permitted outfall near Cudahy Lane.

As the river moves into North Salt Lake City and Davis County, additional storm drains and creeks contribute to the Lower Jordan River. The North Salt Lake Drain collects significant stormwater flows from this area. North Canyon Creek and Hooper Draw also bring snowmelt and runoff from the foothills above North Salt Lake City.

### Historical Record

Each of the four creeks in Salt Lake County has had several flow gauges along its length maintained for various management objectives (see Figures 2-1 and 2-2). Salt Lake County currently maintains important flow gauges for each creek prior to the flow being diverted into the storm drain systems. Flow gauges on the 1300 South and 800 South storm drain outfalls in the 1980s provide an important glimpse into how stormwater runoff contributes to these stream flows.

The flow contribution from these tributaries is most easily understood by looking at flow data in the Lower Jordan River at 500 North and Cudahy Lane in combination with the flows entering the Lower Jordan River (from the gauge at 1700 South). As shown in Figure 2-1, the flow gauge at 1700 South has been maintained since 1942, the flow gauge at 500 North since 1975, and the flow gauge at Cudahy Lane since 2002. Figure 3-17 (above) provides a comparison of diverted flows into the Lower Jordan River (at 1700 South) versus flow at 500 North that includes contributions from tributaries. Figure 3-18 illustrates annual flow patterns for the Lower Jordan River at Cudahy Lane for average and dry years at the UDWR gage location. See Section 2.0 for a description of how the dry and wet year flows were identified.

Salt Lake County (2010) recently completed the Lower Jordan River Hydrology Study with the objective of updating estimates of peak flood flows to account for the available historical flow record. Table 3-5 provides a summary of these peak flood flows.

Waddell and Fields (1977) estimated total monthly flow contributions for the period 1931-1973 for the Jordan River at Cudahy Lane using correlations with flow gauges at Jordan River at 1700 South, City Creek and Parleys Creek.

FIGURE 3-18
Typical Flows for Available Flow Data for Jordan River @ Cudahy Lane (1963-1968, 1991-1994, 2002-2011)

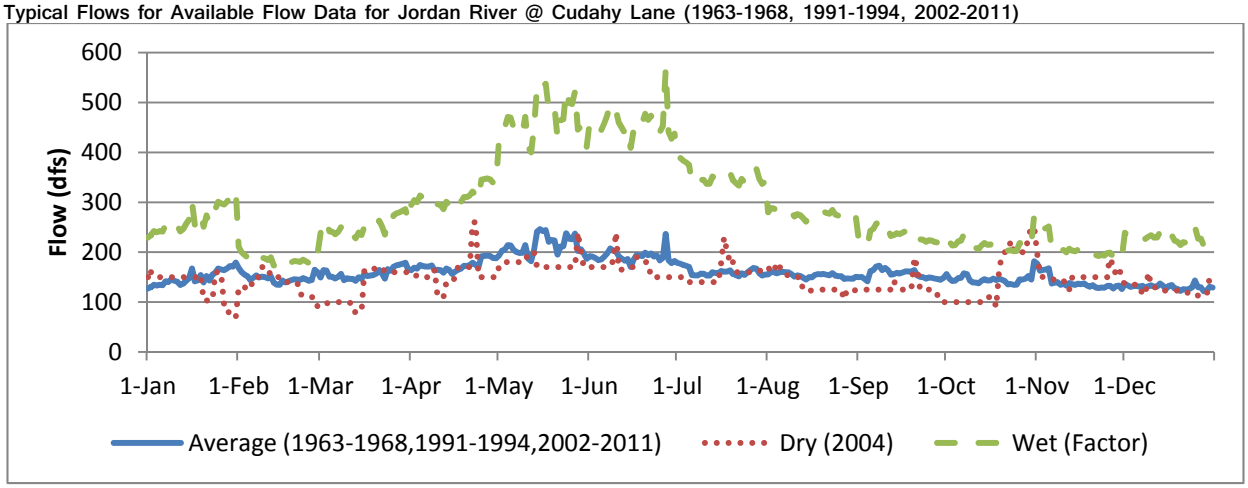



TABLE 3-5
Estimated Peak Flood Flows for Lower Jordan River at 500 North

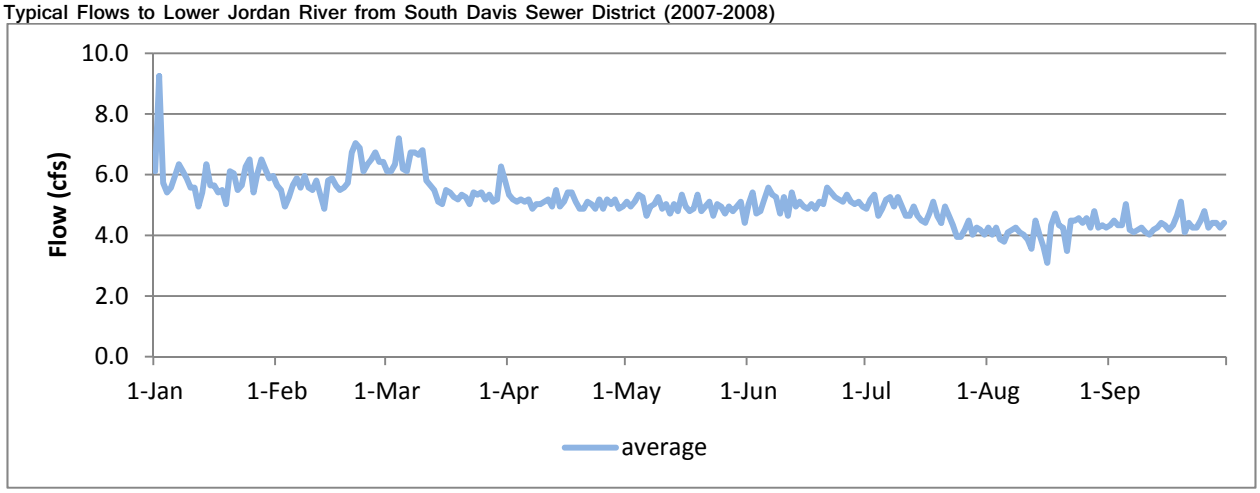
| Return Interval | Estimated Peak Flow (cfs) |
|---|---|
| 2-year | 607 |
| 5-year | 727 |
| 10-year | 798 |
| 50-year | 938 |
| 100-year | 992 |

Source: Salt Lake County, 2010.

Information on flow contributions to the Lower Jordan River from North Salt Lake City and Davis County were not identified. The Legacy Nature Preserve has installed a staff gauge on the North Canyon channel and has been monitoring flows since 2009. Base flows in the channel typically range from 1 to 2 cfs, with peaks resulting from snowmelt and storm events ranging from 5 to 12 cfs (personal communication, Eric McCaulley, October 11, 2011).

Figure 3-19 illustrates typical flows from South Davis Sewer District's South Plant from data available from its annual Discharge Monitoring Reports from 2007 through 2008.

FIGURE 3-19
Typical Flows to Lower Jordan River from South Davis Sewer District (2007-2008)



## Burnham Dam

The Burnham Dam is located near the end of the Lower Jordan River (see Figure 3-19. River flows are generally split at the dam, with 50 percent of the flow typically continuing down the historic river channel to the north and 50 percent diverted to the State Canal flowing to the northeast. The description below is our understanding of some of the key operational mechanisms used to manage the water in the Lower Jordan River from this point (personal conversations, Rich Hansen, 2011).

Flows continuing down the historic channel to the north flow first into the Newstate Duck Club, then through the Turpin Unit of the Farmington Bay Wildlife Management Area, with excess water flowing into Farmington Bay. Excess water from the Newstate Duck Club can also spill into the Sewage Canal if river flows are high. Approximately 10 cfs of flow is diverted from the historic channel and crosses over the Sewage Canal into the western portion of the Farmington Bay Wildlife Management Area. This water mingles with flow contributed by the North Point Consolidated Canal, with excess water flowing into Farmington Bay.

Approximately 14 cfs of water is diverted from the State Canal to the Burnham Duck Club just to the east of the Burnham Dam. Excess water from the Burnham Duck Club flows into the Newstate Duck Club and continues as described above. Various streams, storm drains, and effluent from the North Plant of South Davis Sewer District flow into the State Canal downstream of the diversion to the Burnham Duck Club. All flow in the State Canal flows into the Farmington Bay Wildlife Management Area. Approximately 30 to 40 percent of available flow is typically diverted through a bypass canal at the Farmington Bay Wildlife Management Area, with the remainder of the flow distributed to the area via the State Canal.

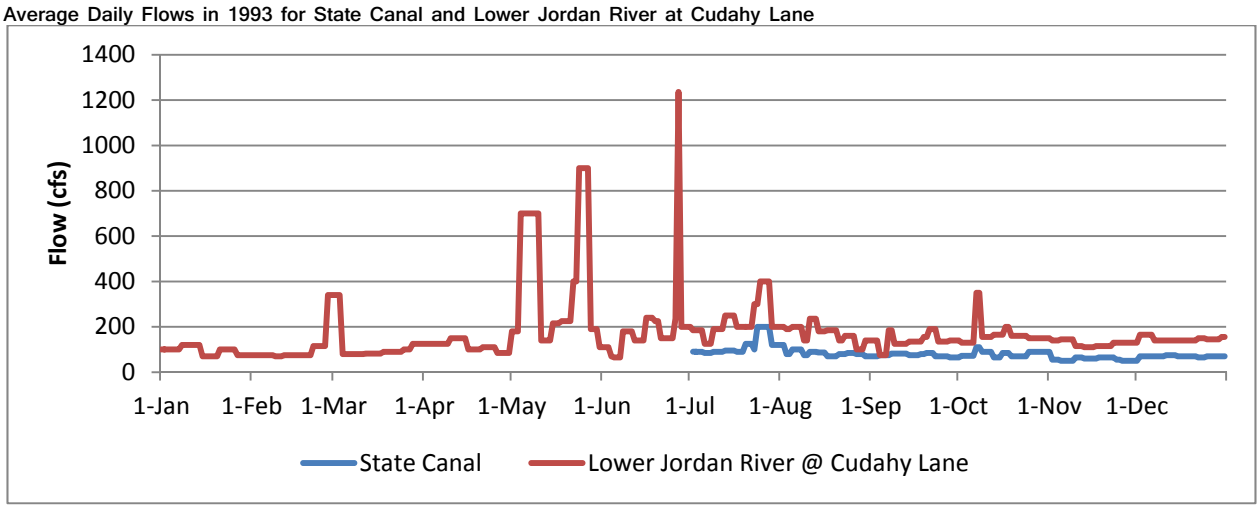
### Historical Record

The UDWR has an average daily flow record for the State Canal for 6 months in 1993. The Utah Division of Water Quality is known to sample water quality in the State Canal on a regular basis; however, it is not known whether this agency also monitored flows. Hansen (1981) includes flow measurements for October 1980 to March 1981 for the State Canal (21 to 64 cfs) and for two storm drains into the State Canal (each less than 3.0 cfs). Flow contributions from the South Davis Drainage to the State Canal are described above. Hansen (1981) also includes flow measurements for October 1980 to March 1981 for the State Canal bypass channel to the Turpin Unit in the Farmington Bay Wildlife Management Area (21.7 to 28.4 cfs).

Figure 3-20 illustrates the available 1993 flow data for State Canal in conjunction with available flow data for the Lower Jordan River at Cudahy Lane. Note that flows in the State Canal are approximately 50 percent of those in the Lower Jordan River.

Waddell and Fields (1977) measured discrete flow events during a period 1973-1975 at the outlets of Farmington Bay Wildlife Management Area to estimate the total contribution to Farmington Bay. Flows ranged from 121 to 523 cfs. While Hansen (1981) did not measure outflows from the Farmington Bay Wildlife Management Area, he does include a detailed water balance for the wildlife management area for a period in 1980-1981.

FIGURE 3-20
Average Daily Flows in 1993 for State Canal and Lower Jordan River at Cudahy Lane



### 3.3.3 Sewage Canal Basin

The present-day Sewage Canal is an agglomeration of canals built beginning in 1922 as a means to convey municipal and industrial waste flows and stormwater from areas of Salt Lake City and Davis County to Farmington Bay (see Figure 3-1 and Figure 3-19). The existing canal extends over 10 miles, bypassing the impounded wetlands of Farmington Bay, before discharging its flow directly to Farmington Bay. The Sewage Canal is often referred to as the Northwest Oil Drain or just Oil Drain upstream of its siphon under the Jordan River and the Sewage Canal downstream of the siphon.

The Oil Drain still receives much of its flow from municipal and industrial waste flows and stormwater. Approximately 2,780 acres of the Rose Park and Capitol Hill area contributes stormwater to the start of the canal through 60-inch and 36-inch-diameter culverts. These culverts and the beginning of the canal are located approximately 0.5 mile south of the Salt Lake City Water Reclamation Facility (SLCWRF).

Estimated peak stormwater runoff flows at the beginning of the canal are summarized in Table 3-6. A base flow of 1.2 cfs from these culverts was measured on January 25, 2011 (EarthFax Engineering, 2011). The canal then collects local drainage and inflows from the Beck area hot springs (estimated at 3 to 5 cfs [personal communication, Jeff Niermeyer, March 29, 2010], measured as 0.8 on January 25, 2011 [EarthFax Engineering, 2011]), before reaching a flood control weir adjacent to the SLCWRF. The capacity of the canal was estimated to be approximately 230 cfs in this first reach (EarthFax Engineering, 2011).

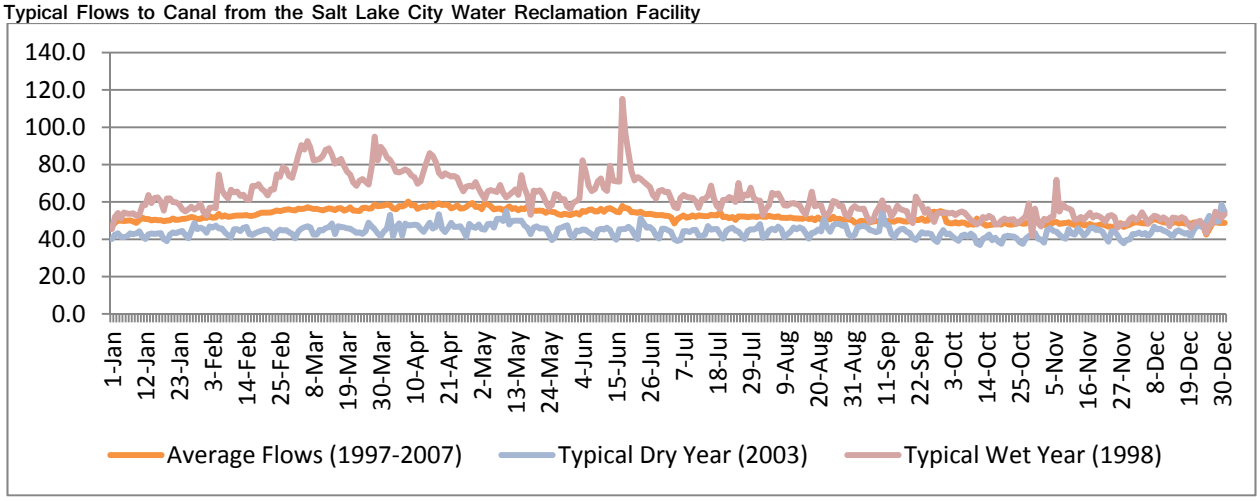
TABLE 3-6
**Estimated Peak Stormwater Flows Contributed by Rose Park and Capitol Hill Drainage at Beginning of Northwest Oil Drain**

| Storm Return Interval | Estimated Peak Flow (cfs) |
|---|---|
| 2-year, 3-hour | 104 |
| 10-year, 3 hour | 228 |
| 25-year, 3-hour | 392 |
| 50-year, 3-hour | 683 |
| 100-year, 3-hour | 835 |

Source: EarthFax Engineering, 2011.

The SLCWRF normally contributes a flow of around 51 cfs to the canal downstream of the flood control weir, but flows from the plant can range up to 70 cfs during typical storm events (EarthFax Engineering, 2011). Figure 3-21 illustrates average flows from SLCWRF for 1997 to 2007, flows for a dry year (using year 2003), and for a wet year (using year 1998); flows werer obtained from annual Discharge Monitoring Reports from Salt Lake City Department of Public Utilities. Dry-year flows typically represent primarily wastewater effluent flows. Wet-year flows often include more groundwater and stormwater infiltration in the effluent. The average flow is useful as it encompasses all of these conditions; however, it does not illustrate typical daily fluctuations as shown in the dry- and wet-year data, i.e., the average flow time series is represented by a “smoother” line.

FIGURE 3-21
Typical Flows to Canal from the Salt Lake City Water Reclamation Facility




A 36-inch culvert at 2300 North seasonally contributes up to 10 cfs from wetlands located adjacent to Interstate 15 (personal communication, Jeff Niermeyer, 2011). The Chevron refinery contributes up to 15 cfs the canal from its wastewater treatment facility during storm events (EarthFax Engineering, 2011). Flow contributions to the canal from a large Davis County storm drain at the canal's crossing of Interstate 215 are unknown.

The City Drain discharges to the Sewage Canal downstream of its siphon under the Jordan River, approximately 2.8 miles from the start of the Oil Drain. This drainage system serves the 1700 South and CWA drainage areas in Salt Lake City with a combined area of approximately 9 square miles (RB&G, 1993). The CWA1 drainage area typically contributes all stormwater runoff directly to the Jordan River so is not included in the area total. Estimated peak stormwater runoff flows at the beginning of the canal are summarized in Table 3-7.

TABLE 3-7
Estimated Peak Stormwater Flows Contributed by the 1700 South/CWA Drainage at Confluence with Sewage Canal

| Storm Return Interval | Estimated Peak Flow (cfs) |
|---|---|
| 5-year, 3-hour | 139 |
| 10-year, 3 hour | 153 |
| 100-year, 3-hour | 164 |

Source: RB&G, 1993.

Aside from an overflow to the canal from the Newstate Duck Club, there are no significant inflows to the canal other than precipitation, groundwater inflows, or minor irrigation return flows after the canal's confluence with the City Drain. The overflow from the Newstate Duck Club typically only operates during spring runoff on very wet years (personal communication, Richard Hansen, 2011).

### Historical Record

There is currently no means of measuring flow discharged to Farmington Bay from the Northwest Oil Drain/Sewage Canal, and no continuous flow records were located as part of this effort. Waddell and Fields (1977) measured flow in the canal on 11 occasions from 1973 to 1975 and reported flows varying from 57 to 207 cfs. Hansen (1981) measured flows for the Sewage Canal from October 1980 to March 1981, with flow rates ranging from 64 to 163 cfs.

## 3.4 Water Balance Model Development

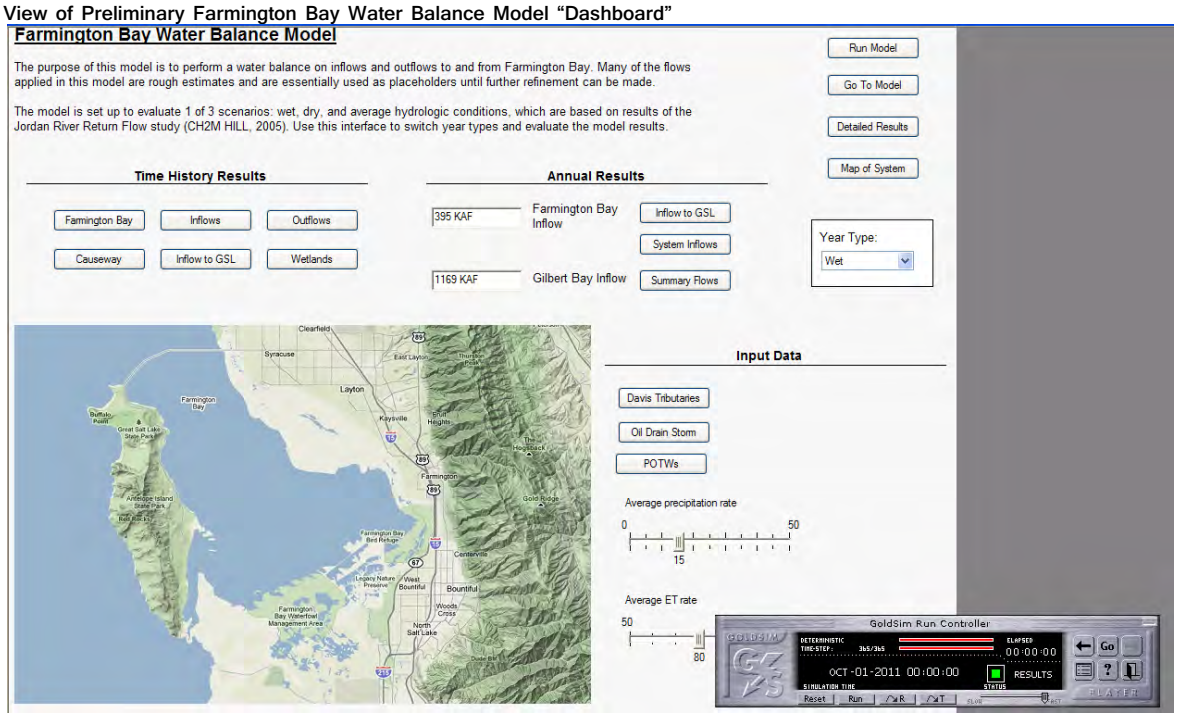
CH2M HILL developed a comprehensive water balance model for the Jordan River Return Flow Study with the objective of evaluating future reuse projects in Salt Lake County and how they might impacts flows in the Jordan River (CH2M HILL, 2005). The water balance model was created on a monthly time step using CH2M HILL's

VOYAGE™ water balance simulation tool and allows the user significant flexibility in modifying numerous variables in the water management system to evaluate river flows for dry, average, and wet periods. See CH2M HILL (2005) for additional information about development of the model.

The simulation capability of the model makes this a very useful tool in evaluating water management scenarios that affect Farmington Bay's hydrology. Another useful characteristic of the model is that it can track the source of flow as it moves through the system. This feature is particularly useful when evaluating water quality conditions in the wetlands along Farmington Bay's shoreline. The user can look at flows in the Jordan River at 2100 South and readily understand how variables may impact the percentage of surface runoff, return flows, or wastewater effluent.

While not included in the scope of this study, CH2M HILL began work to develop a water balance model for Farmington Bay using the Jordan River model as a starting place. The VOYAGE™ model was transposed into a GoldSim model to take advantage of numerous features this platform provides, and the monthly time step was converted into a daily time step using average daily flows as the basis (see Figure 3-22 for view of the model's "dashboard"). While much work remains in its development, our initial work was instrumental in helping house available flow data and identify data gaps for this project. These gaps were useful in developing the recommendations included in Section 4.0.

FIGURE 3-22
View of Preliminary Farmington Bay Water Balance Model "Dashboard"




Figures 3-23 and 3-24 illustrate one capability of the Farmington Bay model for dry, average, and wet periods. Figure 3-23 illustrates the relative contribution of flow from various sources in the Jordan River at 2100 South before it is split into the Surplus Canal and Lower Jordan River. The relative contribution at this location is consistent with flows lower in the Surplus Canal system with the exception that return flows begin to become a larger percentage of the flow. Figure 3-24 illustrates the relative contribution of flow from various sources in the Lower Jordan River near the Burnham Dam. Similar relationships could be developed elsewhere in the system, e.g., State Canal prior to entering the Farmington Bay Wildlife Management Area, to help evaluate how different sources of water may be influencing water quality in the duck clubs and preserves.

Similarly, more detailed information regarding water allocation and water management practices for the Surplus Canal and Lower Jordan River systems, or even for individual duck clubs, could be added to create an operational model that allows the user to evaluate the impact of different water management practices for a host of

scenarios. While very preliminary, the current Farmington Bay water balance model shows much promise as a valuable water management tool for the Farmington Bay watershed.

FIGURE 3-23

**Contributions of Various Water Sources in Jordan River at 2100 South**

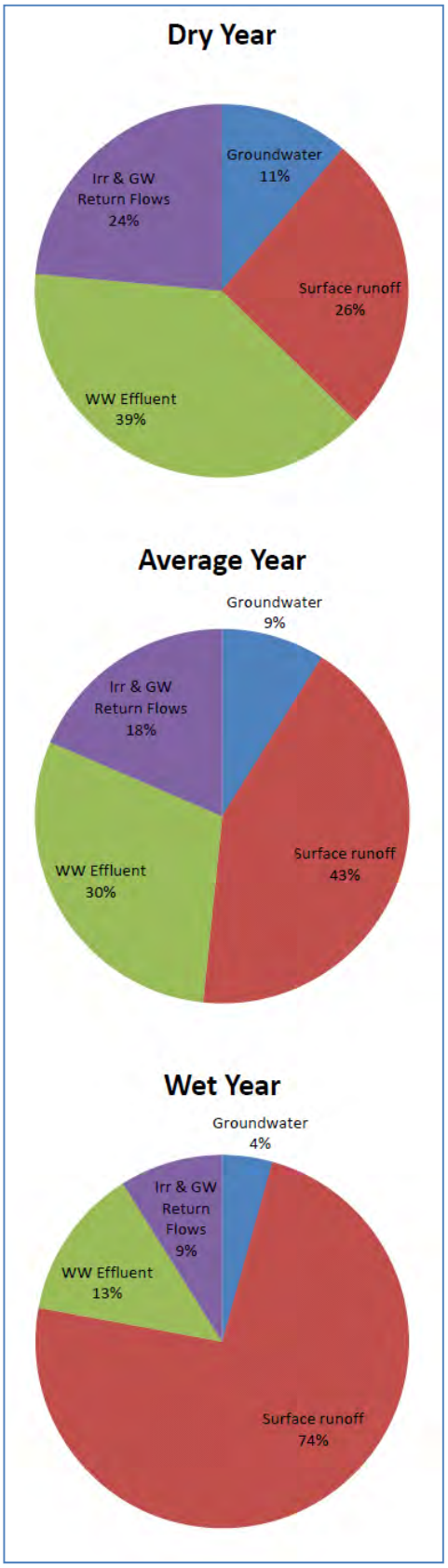
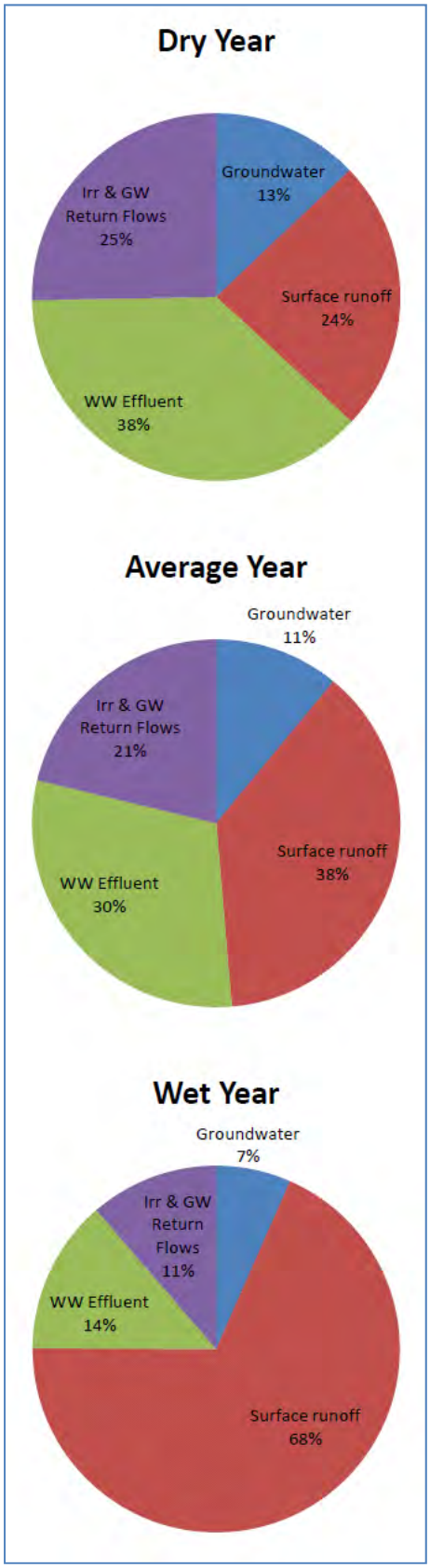



FIGURE 3-24

**Contributions of Various Water Sources in Jordan River near Burnham Dam**



# 4.0 Recommendations

Significant work has already been completed to understand the hydrologic dynamics of Farmington Bay, its shoreline, and its watershed. Each study conducted and article or report written addressed specific objectives or answered specific questions that were raised in the course of managing this resource. Each study advanced the historical record and increased our understanding of Farmington Bay's idiosyncrasies. Taken as a whole, as documented in this report, we now have a more complete picture of the dynamics and drivers that can help in making management decisions and focusing future research efforts.

We recognize that future research efforts also will be guided by specific objectives identified by planners, managers, and stakeholders of Farmington Bay. This section provides recommendations intended to guide ongoing and future monitoring and research efforts that seek to address two issues at the forefront today: water management and water quality. (It is recognized that this report likely did not uncover all available information and some recommendations may have already been completed). Recommendations are organized into three areas: 1) flow monitoring, 2) management practices, and 3) water balance.

## 4.1 Flow Monitoring

The USGS, UDWR, Salt Lake County Public Works, and municipal wastewater treatment plants already have an extensive network of flow gages that have been and are currently used to monitor surface water inflows to Farmington Bay. Following are recommendations to augment this network and historical record.

### 4.1.1 Davis County Tributaries

Very little information was found that documents actual flows reaching Farmington Bay from Davis County tributaries. At 5 percent of the inflow to Great Salt Lake (Arnow and Stephens, 1987), these tributaries are not an insignificant source of inflow to Great Salt Lake and represent a significant source to Farmington Bay. Several flow gages have been and are currently located at the foot of the Wasatch Mountains and are useful for determining the available supply of water from these watersheds that can be used for water resource planning as well as flood control decisions. As indicated herein, flow patterns in the valley have been significantly altered through irrigation diversions, urban development, and altered stormwater runoff. Following are recommendations to better understand these changes:

1. Identify existing irrigation diversions and facilities with the aim of understanding the location, timing, and quantity of water diverted from Davis County streams. Identify water allocations and the location where return flows are conveyed.
2. Evaluate urban stormwater runoff, locations where storm drains discharge to streams and or Farmington Bay, and this runoff's contribution to stream flows. It is recognized that much of this work may already have been completed but was not identified as part of this study. Peak flood flows should be identified not only where streams enter the valley or where they cross Interstate 15, but also where they enter Farmington Bay. Understanding these peak flows will help the properties and preserves located along the streams and downstream to better prepare.
3. Using the information above, flow gages should be installed along key streams where they discharge to Farmington Bay. This information will help to better understand mountain and urban runoff as well as inflows to Farmington Bay. Gages should preferentially be placed at the largest flow contributors and where they could be used to correlate to flow measurements at the foot of the mountains and the historical record already provided. As completed by previous studies, base flows could then be measured at all other inflow locations at discrete intervals and correlated to available flow gages with continuous measurement.
4. While the Newstate Duck Club, Burnham Duck Club, and Farmington Bay Wildlife Management Area receive a similar "mix" of water from the Jordan River, flows to the Farmington Bay Wildlife Management Area are augmented by flows from the South Davis Sewer District North Plant and significant inflows from other

streams and drains. An effort should be made to better understand the sources, timing, and quantity of flow entering the Farmington Bay Wildlife Management Area in order to improve upon water management and water quality in the Farmington Bay Wildlife Management Area.

### 4.1.2 Jordan River System

The Jordan River system already includes the most extensive network of flow gages. Flow gages should be installed at the following locations to better understand the timing and quantity of flow that is distributed to the various downstream users. Data from these gages can then be used in conjunction with gages with a longer flow record to better understand long-term dynamics.

1. The long-term flow record for the Surplus Canal at 2100 South is an invaluable resource. The flow gage at Goggin Drain is also invaluable in understanding how much of the Surplus Canal flow reaches Farmington Bay or Gilbert Bay. However, numerous diversions from the Surplus Canal, including the North Point Consolidated Canal, complicate the determination of actual flows reaching the wetlands and ultimately Farmington Bay. Flow measurement along the Surplus Canal at Husted Dam should continue in order to better understand these dynamics.
2. Duck clubs and preserves should monitor and record flows entering and leaving their properties. This information would not only make onsite water management more efficient but also serve to develop management practices to improve habitat and water quality.
3. Flow measurement along the Lower Jordan River at 500 North and Cudahy Lane would also be invaluable in understanding the contribution of the Jordan River and tributaries along the Lower Jordan River. Adjustments to diversions made at the Burnham Dam should be recorded in conjunction with flows measured at the historic gage location on State Canal (see UDWR record). This information would be helpful in better understanding the sources, timing, and quantity of water delivered to the users downstream.

### 4.1.3 Sewage Canal

1. A flow gage should be installed on the Sewage Canal to allow for continuous measurement of flows to allow for characterization of the urban runoff contribution. Past efforts have typically assumed that the effluent from the SLCWRF represents the total of this flow. A flow gage, in combination with flow information from the SLCWRF, would help in better understanding the sources, timing, and quantity of flow from this facility.

### 4.1.4 Farmington Bay Outflows

1. The USGS currently monitors flows through the bridge at Davis County Causeway in partnership with the Utah Division of Water Quality. This flow gage should be continued as it is an invaluable resource in understanding the water balance of Farmington Bay.
2. The water surface elevation differential across the Davis County Causeway is unknown. In conjunction with flow measurement at the bridge, water surface elevations should be monitored from time to time to develop and better understand the relationship between flow through the bridge, wind events, and water levels in Great Salt Lake. Previous estimates of 6 inches (Hansen, 1981) and 9 inches (Chadwick, et al., 1986) should be refined with actual data.
3. Little is known about the structure of and infiltration through the Davis County Causeway embankment. As part of a more comprehensive effort to develop a water balance for Farmington Bay, an effort should be made to better understand the characteristics of flow through this embankment.
4. Little is known about the structure of and flow through the culvert on the east end of the Davis County Causeway. This structure should be surveyed to allow for better estimates of flow through this culvert and correlation to flows through and water surface elevations at the bridge.
5. Little is known about the southern causeway of Antelope Island. At a minimum, this causeway should be surveyed and any culverts or breaks identified to better understand if and when flow may go through this area.

## 4.2 Management Practices

As documented by National Audobon Society (1995), most duck clubs and preserves actively manage their water supplies to address different objectives. In most cases, these management practices are implemented independently and in some cases without much coordination or interaction with other facilities. Efficiencies and improvements could be realized if there was a forum to share current practices and lessons learned.

1. The 1995 survey should be updated and expanded to reach current duck clubs and preserves to identify water management objectives and drivers, available flow information, existing water management facilities, best management practices, problems and issues, and lessons learned at these facilities. Much has been learned in the recent past in terms of water quality and invasive species (e.g., phragmites) that could be implemented across Farmington Bay's shoreline.
2. Duck clubs and preserves should document their management practices in individual, written water management plans. The simple act of preparing such a document can be instrumental in formulating objectives and making significant improvements in habitat, water quality, and water efficiency. Sharing of these documents can further promote better water management practice.
3. An attempt was made in this report to identify the most significant points of active water management and general decision rules used at locations in the Jordan River system. Further work should be completed to interview water managers and further document how water is managed in various scenarios to address existing water allocations and other drivers (e.g., flood control).
4. Water management practices implemented in the Davis County drainage should be further investigated and documented to identify factors and data that can help describe inflows to Farmington Bay.

## 4.3 Water Balance

The following recommendations are made to develop a water balance for Farmington Bay:

1. Some efforts have been made to map the existing topography and bathymetry of Farmington Bay (Waddell and Fields 1977). The bathymetry of Farmington Bay should be updated to provide a better elevation-area-volume relationship. This information would be fundamental to developing an accurate water balance for Farmington Bay.
2. Data collected from the efforts described above should be consolidated into one database and/or report. Coordination of these efforts by one agency would facilitate and improve the efficiency of execution.
3. A water balance model for the Davis County watershed to Farmington Bay, similar to that for the Jordan River system (CH2M HILL, 2005), could be a valuable tool for coordinating and identifying trans-basin and intra-basin diversions, consumptive use, water needs, and contributions to Farmington Bay.
4. The existing Jordan River water balance model (CH2M HILL, 2005) should be updated to include Farmington Bay. The following series of improvements should be made to accomplish this:
    a. It should be first extended beyond the Surplus Canal diversion at 2100 South and Cudahy Lane on the Lower Jordan River to include deliveries to Surplus Canal, North Point Consolidated Canal, Goggin Drain, and Burnham Dam (State Canal).
    b. The current model should be reviewed and updated to better account for and track water sources in the Jordan River system. The upper Jordan River water balance model should be reviewed in detail by key water managers to ensure that it appropriately and accurately represents current and anticipated practice.
    c. The conversion to daily time steps should be reviewed and a mechanism to convert to monthly or annual flow volumes incorporated.

d. The model should be updated to include distribution of flow to and through the various duck clubs and preserves along Farmington Bay. Existing water allocations should be documented and incorporated into the model.

e. The model should be updated using additional information describing inflows from precipitation, groundwater, wastewater treatment plants, and Davis County tributaries; outflows through the Davis County Causeway and via evaporation; and to account for storage and flow in Farmington Bay.

5. The water balance model could be further developed to include additional details regarding management practices at the drainage system or even the duck club level to allow for an evaluation of management practices during various scenarios. Such a tool would be instrumental for evaluating the impact water management has upon water quality in the open water and wetlands of Farmington Bay and evaluating scenarios for improvement.

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