Utah Lake Tributary Flow Analysis

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A project submitted to the faculty of
Brigham Young University
in partial fulfillment of the requirements for the degree of

Master of Science

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April 2012

ABSTRACT

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Water flows from the Wasatch Mountains down into Utah Valley and mingles with water from Valley precipitation to feed the many tributaries and springs flowing into Utah Lake. For many years the LKSIM model, initially developed at Brigham Young University nearly 40 years ago, has been used to model Utah Lake dissolved conservative ions (soluble salts) and water balance (hydrology) and help predict changes associated with various climatic cycle and water use scenarios. Due to the number of tributaries and the large expense of continuous measuring and sampling, estimates for tributary quality and quantity depend on hydrologic correlations with the few tributaries that are continuously monitored and climatological data such as measured precipitation.

Since Utah Lake is a key part of water storage, water development and water use in Utah, it is crucial that the hydrologic data be accurate. Since past quality and quantity correlations used in LKSIM are based largely on measured data collected before about 1980, there was concern that data might be somewhat outdated due to changes in upstream water development and land use.

Over the past three years, the Central Utah Water Conservancy District (CUWCD) funded a study, conducted by faculty and students in the Civil and Environmental Engineering Department at Brigham Young University, to collect field data and samples from some 15 major Utah Lake tributaries. The main goal was to determine whether significant changes have occurred in tributary flows and quality (old measured data and correlations). This report addresses the tributary flow issue—the hydrologic correlations and resulting tributary flowrates that are used to generate sequential monthly tributary flows for Utah Lake simulations in the LKSIM model

New tributary flow correlations have been developed using the best of several annual precipitation indices. Equations and graphs are presented showing these correlations. It is felt that this report will be a key resource in the ongoing assessment of temporal changes in Utah Lake water quantity and quality, as well as provide improved and updated flow data for use in the LKSIM Model and other water management work.

Keywords: Justin Dye, LKSIM, flow correlation, Utah Lake tributaries, precipitation

ACKNOWLEDGMENTS

First and foremost, a special thanks to my loving wife who has supported me through these long years of schooling. Without her I wouldn't be where I am today.

Also a special thanks to my advisor A. Woodruff Miller, and my graduate committee members M. Brett Borup, and E. James Nelson for their numerous contributions in my education. I also thank the Central Utah Water Conservancy District for the opportunity to work on this interesting, real-life project. Both the professional development and the financial support are sincerely appreciated.

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1 INTRODUCTION

The objective of this project report is to update flowrate correlations for the Utah Lake Water Quality Salinity Model (LKSIM). The LKSIM model has been used since the mid 1970's to simulate soluble salt concentrations, with emphasis on total dissolved solids (TDS), to within +/- 50 mg/L of historical and simulated future concentrations (Blankenstein, 1992). The most frequent use of the LKSIM model is to monitor trends in the lake and project response to future water resource developments, particularly features associated with the Central Utah Project Completion Act (CUPCA).

Utah Lake serves many purposes. It is a major natural lake system, invaluable to large numbers of wildlife; it is also used for many other beneficial uses, including significant recreational uses. One major water resource use is as a source for irrigation and other water uses in the Salt Lake Valley and parts of Utah Valley. Water quality affects all of these uses; the tracking of water quantities and quality is very important in professional management of these waters. For example, a report prepared for the Utah State Division of Water Quality reports that in the past, cyclic high TDS concentrations in Utah Lake water have at times resulted in 0.5-2.5% yield reduction in crops (Psomas / SWCA Environmental Consultants, 2007). Water Quality also affects Utah Lake plants and fish, e.g., the endangered June Sucker, found only in Utah Lake.

1.1 Purpose

The purpose of this report is to re-evaluate the hydrologic parameters that are used establish the tributary flowrate estimates for LKSIM. To date, The LKSIM model, uses correlations developed largely from measured flowrate and quality values from the 1930 to 1979 time period. Over the past 30 years many changes have occurred in the Utah Lake watershed. The issue at hand is whether there have been substantial changes in tributary flows and salts as changes have occurred in the drainage basin and its water use patterns.

LKSIM uses flowrate and quality values generated from correlations between measured flowrates and qualities for each of the 50 + “tributary” inputs to the lake. Some tributaries have actual continuous or regular periods of flow measurements and quality sampling, but most rely on correlations with measured tributaries or with measured precipitation to generate their “synthetic” flow and quality values, month by month during for a LKSIM simulation of the lake on a computer.

Precipitation indices are used to estimate discharges which are based on correlations between the indices and discharges. If the hydrology in the area has changed significantly, then a new correlation might be needed to estimate the flows.

Because of funding and personnel factors, CUWCD and BYU personnel decided to limit this study to some 15 “major” tributaries. The criterion used to select them was primarily the magnitude of their volume contributions to Utah Lake with the largest being the most important, down to the 15th largest inflow volume. The approach used was to use the limited funds available to assess the most important tributaries with the goal of using those results to help determine whether additional years of additional data collection and additional tributaries should be undertaken as soon as possible, or might be deferred for a few years.

This study is based on additional data collection for about three years, from March, 2008 to June, 2011. The data collected includes the precipitation indices and discharges. The functional purpose of this report is to establish and present the old, the updated, and new 3-yr correlations for each of the 15 tributaries.

1.2 Background

The LKSIM model was conceived and developed by Dr. LaVere B. Merritt, BYU Professor Emeritus, in the 1970's. The LKSIM model needs data for monthly flowrate and quality for over 50 inflows and outflows. It also needs monthly precipitation and evaporation values for the lake. The flowrates are based on either actual data or correlations that are used to generate the flowrate values. Flowrates are used internally in the LKSIM model to generate monthly quality values from correlations embedded in the Model.

The original correlations were generated from regression analyses based on all available data for the 1930-1980 period – about 50 years of data. Actually most of the "small" surface and all groundwater tributaries relied primarily on 3 yrs of intensive field measurements and sampling in the early 1970s. A few of the larger surface tributaries, and the waste water treatment plants had more data, even continuous in a few cases. Over the years, flowrate correlation updates have been made or were necessary to replace precipitation and weather stations that were dropped from service or relocated.

1.2.1 History of Previous Studies

Ian Van Blankenstein completed a LKSIM flowrate correlation update in April of 1992. Blankenstein adjusted the precipitation values to represent the re-location of the Provo precipitation station by using a double mass analysis on the Provo station with the Spanish Fork, Lehi and Elberta stations. Blankenstein then re-developed correlations for all of the sites and reported the results (Blankenstein, 1992).

David W. Rice did another LKSIM update in April of 1999. Rice collected data to update precipitation indices for the Elberta station which went out of service in 1991. The Elberta station was replaced by the Santaquin station in the Average Valley Precipitation index. The Lehi groundwater well was also completely removed from the correlations. The Lakeshore gaging station on the Spanish Fork River was also removed (Rice, 1999).

2 PRECIPITATION INDICES

About 70% of lake inflows are surface flows. This water comes from snow-melt runoff, groundwater, or precipitation. Most of the tributary flow correlations developed in this study use precipitation indices. The annual index is an accumulation of the monthly rainfall recorded at a particular weather station. When adding up the annual index, 2 inches is used for any monthly value over 2 inches. This was done to ensure that an unusually wet month (high precipitation value) would not over-bias the correlations. Two inches maximum of rain is a monthly value that already represents a high precipitation to correlate with a high flow.

The discharges of some tributaries do not correlate well with the current year's index but correlate better with the previous year's index. This is because of the groundwater influence in the area. In these areas a larger percentage of the precipitation from the previous year enters the groundwater. This water eventually shows up in the stream. The more precipitation that enters the groundwater, the higher the flow in the tributary, only delayed due to the travel time in the groundwater. Thus where it improves the correlation, tributary flow is correlated with the previous year's precipitation index.

An effort was made to be consistent with previous reports by using the same indices as before. This was not possible for all of the tributaries since many of the original weather and gaging stations have been discontinued or no longer offer the necessary data. Among the discontinued indices are the Lehi precipitation index, American Fork above power plant (used for Apr-Jul runoff), and the old Average Valley Precipitation Index (Lehi, Provo, Santaquin). During this study the Orem WWTP precipitation station was also discontinued. The following are previous and new indices that were used in this report:

- Provo Precipitation Index
- Santaquin Precipitation Index
- Spanish Fork Precipitation Index
- Alpine Precipitation Index
- Average Valley Precipitation Index

The first three indices listed are the only stand-alone indices (Provo, Santaquin and Spanish Fork). The Average Valley Index is different from previous reports because the Lehi Index is no longer available. The new Average Valley Index consists of the following:

- Alpine Precipitation Index
- Provo Precipitation Index
- Santaquin Precipitation Index

Another Average Valley Index was also calculated using the Pleasant Grove Precipitation Index instead of Alpine but was not used as the Alpine-Average Valley Index correlated better. A complete table of all precipitation indices and their values can be seen in APPENDIX A. PRECIPITATION DATA of this report. A South Valley Average Index was also computed using Provo, Santaquin, and Spanish Fork but did not correlate well with any of the tributary flows in the southern region of Utah Valley and was not included in this report.

3 TRIBUTARIES

3.1 Site Descriptions and Locations

In this report only 15 of the original 50-plus tributaries were used. These 15 tributaries represent the major surface-flow contributors and outflows to Utah Lake. Table 3-1 is a list of all the tributaries historically used in LKSIM. Those with asterisks are the 15 tributaries that were studied. Figure 3-1 and Figure 3-2 are maps of Utah Lake tributaries and the sampling stations, respectively.

Table 3-1: Tributary Locations

Station No.	Description
UT 1	Drain, 6900 N. Saratoga Road
UT 3	Dry Creek (Lehi) near 7350 N. and 9550 W.
UT 4	Drain, 0.7 mi. east of 9550 W. and 7350 N.
UT 5	Drain, near 8730 W. and 7350 N.
UT 6	Drain, near 8350 W. and 7350 N.
UT 7	Drain, near 8000 W. and 7350 N.
UT 8	Minnie Creek, near 7500 N. 7800 W.
UT 9*	Mill Pond (Spring Creek) near 7550 N. and 7400 W.
UT 10	Drain, 1.25 mi. south of 6500 W. and 7550 N.
UT 11	American Fork WWTP effluent
UT 12	Drain, on 6150 W. and 1.1 mi. South of 7750 N.
UT 13*	American Fork River about 0.25 mi. North of Boat Harbor
UT 14	Drain, 0.1 mi. west of 6400 N. and 5750 W.
UT 15	Drain, 0.1 mi east of 6400 N. and 5750 W.
UT 16	Drain, near 6400 N. and 5300 W.
UT 17	Drain, near 6400 N. and 4850 W. (Olefson's Slough)
UT 18*	Lindon Cannery Drain (Geneva Cannery Drain) 4250 W. and 5600 N.
UT 19	Drain 0.15 mi. north of Geneva Channel on U114

Table 3.1: Continued

Station No.	Description
UT 20*	Geneva Steel outflow at Parshall flume
UT 21	Drain, 0.2 mi. south of Geneva Channel on W. Geneva Rd
UT 22	Drain, 0.5 mi. south of Geneva Channel on W. Geneva Rd
UT 23	Drain, 0.9 mi. south of Geneva Channel on W. Geneva Rd
UT 24	Drain, 1.3 mi. south of Geneva Channel on W. Geneva Rd
UT 25	Drain, 4000 N. and W. Geneva Road
UT 26	Orem City WWTP effluent
UT 27*	Powell Slough, west of Orem
UT 28	Drain, on north Boat Harbor Drive
UT 29*	Provo River at USGS Gaging Station
UT 31	Little Dry Creek, near 1150 S. and 1160 W.
UT 32	Drain, near 1150 S. and 1600 W. (Provo)
UT 33	Flowing well near 1150 S. and 1600 W. (Provo)
UT 34	Big Dry Creek, near 1150 S. and 1600 W. (Provo)
UT 35	11th West Ditch, near 1560 S. and 1600 W. (Provo)
UT 36	5th West Ditch, near 1560 S. and 500 W.
UT 37	University Ditch, near 1420 S. and University Ave. (Provo)
UT 38*	Mill Race, 1500 S. and 350 E. (Provo)
UT 39	Provo WWTP effluent
UT 40	Drain, 0.4 mi. SE. of Provo WWTP
UT 41	Rat Farm Drain, 0.5 mi. SE. of Provo WWTP
UT 42*	Steel Mill Drain, on Kuhni Boulevard
UT 43*	Spring Creek, on Kuhni Boulevard
UT 44*	Hobble Creek at USGS 1650 W. Gaging Station
UT 45	Packard Drain, Frontage Road near 3900 S.
UT 46	Drain, 0.35 mi. W. of I15 on 3900 S.
UT 47*	Dry Creek, near 3200 N. and Spanish Fork Main Street
UT 48*	Spanish Fork River at Huff Diversion Dam
UT 49	Drain, 0.8 mi. N. of 5200 S. and 3200 W.
UT 50	Drain, 5200 S. 6400 W.
UT 51*	Benjamin Slough, near 6400 S. and 6000 W.
UT 52	White Lake overflow to Goshen Bay
UT 53*	Jordan River outflow from Lake
UT 70	Lehi WWTP
UT 71*	Timpanogos WWTP from ponds
UT 72	Pleasant Grove WWTP
UT 73	Springville WWTP
UT 74	Spanish Fork WWTP
UT 75	Salem WWTP
UT 76	Payson WWTP

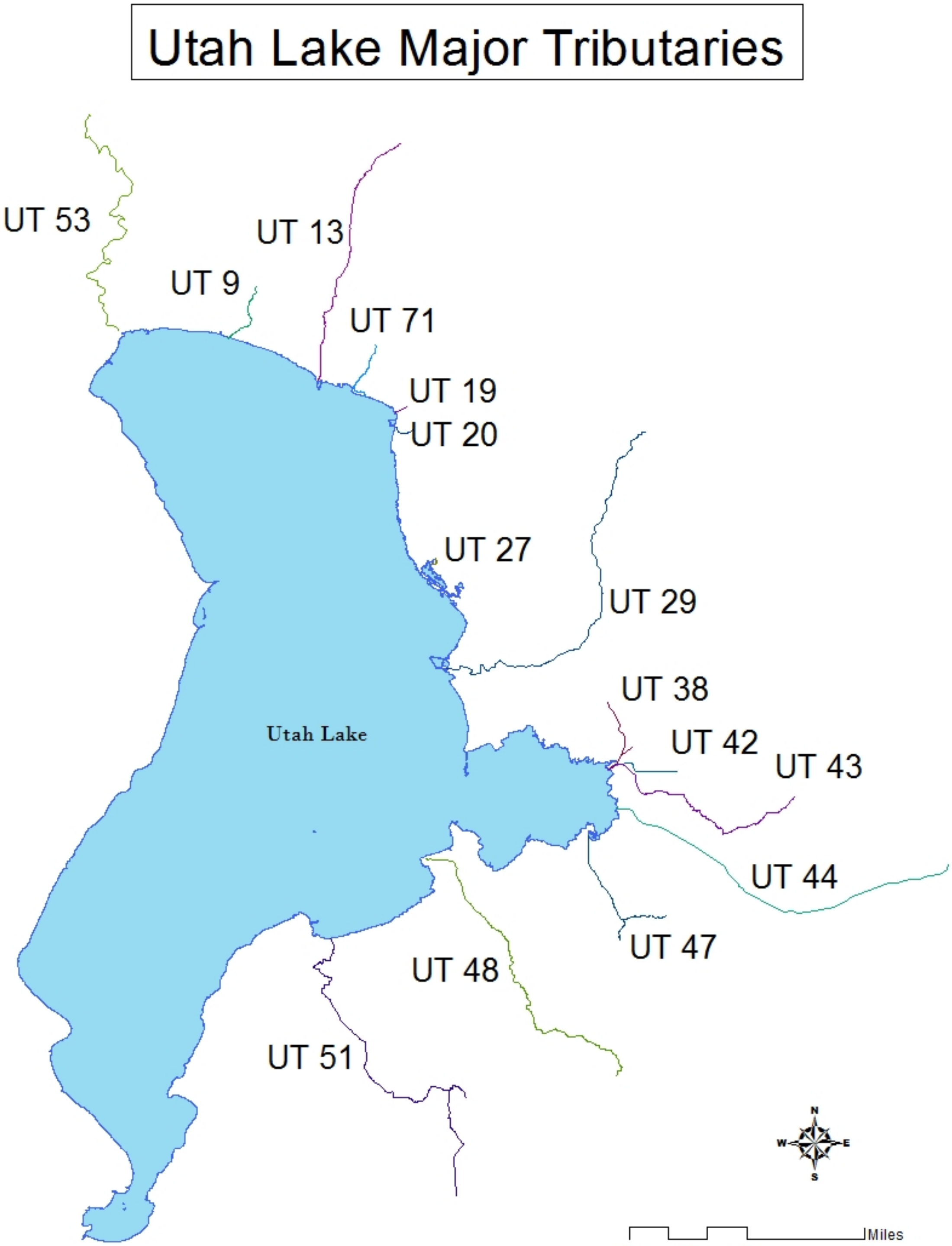

Figure 3-1: Utah Lake Major Tributary Map

3.1.1 Tributary Gaging Locations

Table 3-2 contains a list of each of the sampling locations that were used and their respective GPS coordinates. The GPS coordinates allow for pinpointing the exact locations of sampling and gaging stations as used in this report. UT 71 and all other stations labeled with "A" are wastewater treatment plants and their GPS coordinates were approximated using Google Earth. The other coordinates were found using a handheld Trimble device.

Table 3-2: GPS Coordinates of Gaging Stations

Station	N	E
UT 9	40.37281	-111.8340
UT 13	40.34487	-111.8017
UT 18	40.33177	-111.7619
UT 20	40.32363	-111.7620
UT 27	40.27705	-111.7446
UT 27A	40.27705	-111.7446
UT 29	40.23809	-111.6952
UT 38	40.21647	-111.6549
UT 38A	40.21317	-111.6526
UT 38B	40.20860	-111.6523
UT 42	40.19932	-111.6399
UT 43	40.19167	-111.6385
UT 43A	40.17811	-111.6001
UT 43B	40.74097	-111.6268
UT 44	40.18418	-111.6472
UT 47	40.15045	-111.6572
UT 47A	40.13764	-111.6519
UT 47B	40.14576	-111.6474
UT 48	40.15462	-111.7296
UT 51	40.11427	-111.7933
UT 51A	40.08213	-111.7312
UT 51B	40.05495	-111.7322
UT 53	40.35728	-111.8986
UT 71	40.33700	-111.7770

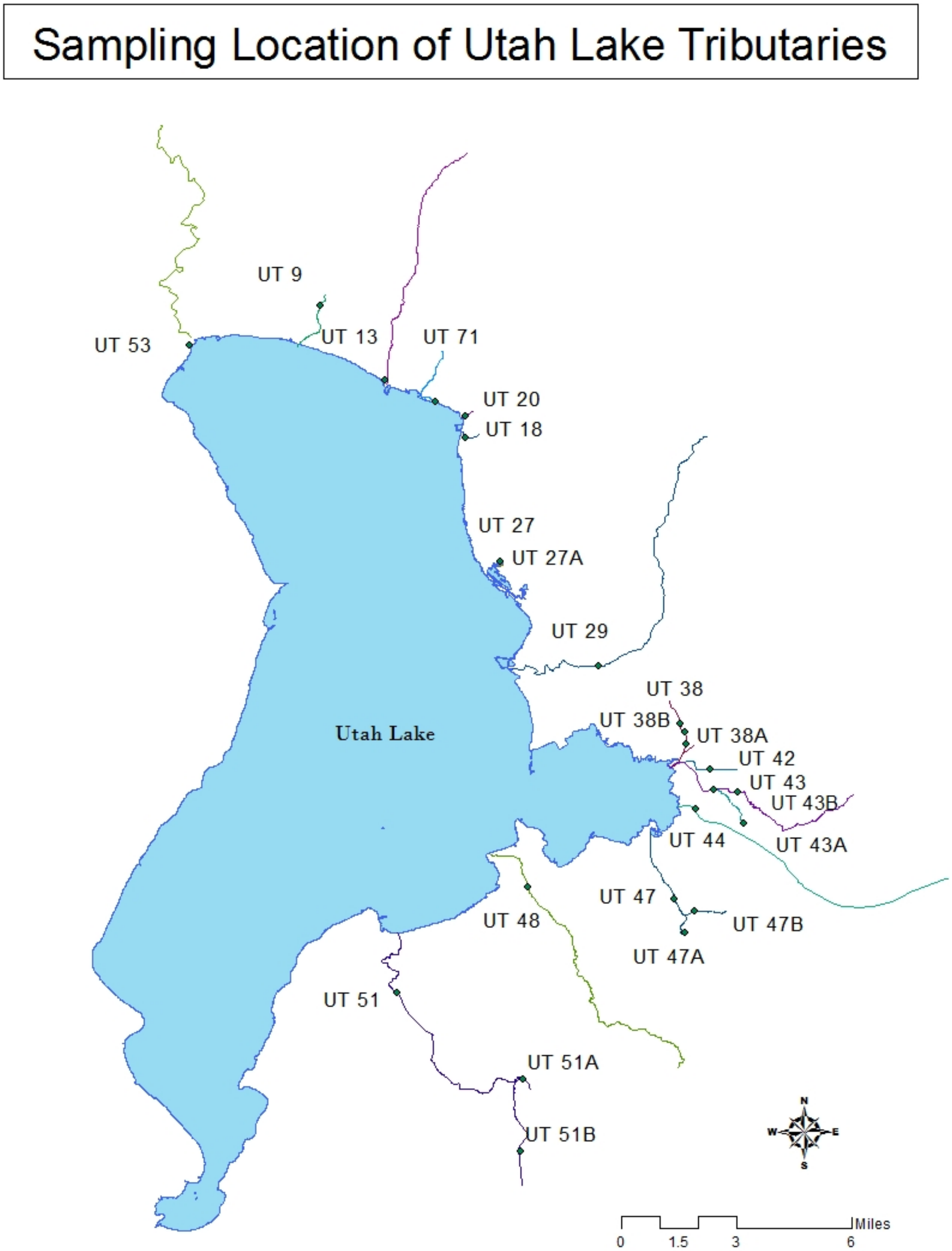

Figure 3-2: Sampling Locations of Utah Lake Tributaries

Note: Identified are the " major" tributaries included in this study—another 35, or so, smaller tributaries and "lumped" flows exist in the LKSIM tributary list. Those existing as a single actual flow at the measuring point are given in Table 3.1 above.

3.1.2 Flow Measurements

Most flow measurements were made using the Velocity-Area method. Usually the flows were calculated by measuring the depth and velocity of the tributaries at 2 to 4 sub sections within the total cross section. The velocity was measured using a Flo-Mate Model 2000 Portable Flow Meter, manufactured by Marsh-McBinney, Inc. The velocity sensor was set to 0.4 (measured from the bottom) of the surface depth to obtain the average of the velocity profile at each subsection. Multiplying the area of the sub cross section by the average velocity gives the incremental flowrate for each subsection. The total tributary flow is the sum of the subsection flows.

4 RESULTS

In following pages a compilation is given for all the tributary stations monitored in the study. Each correlation presented a unique set of challenges and obstacles as various analytical methods and correlation indices were used. For some stations new indices were needed while others only required addition of new data. The "new data" are data collected during the field phase of this study. All of the correlations reported below have been updated using this new data. The "old data" are data collected before 2009.

A linear regression analysis was used in past correlation studies and was continued in this report after finding high R^2 values in the new data correlations. Often referred to as "goodness of fit," R-squared measures statistically how well the regression line approximates the real data points. An R^2 of 1.0 indicates that the regression line perfectly fits the data. An R^2 value of 0.7 was considered to be a "good" correlation for the purposes of this report. The "old data" had R^2 values ranging from 0.14 to 0.91; the "all-data" correlations ranged from 0.14 to 0.83; and the "new data" had R^2 values ranging from 0.63 to 1.0.

4.1 Analysis of Tributary Flows

4.1.1 UT 9 – Mill Pond (Spring Creek)

This tributary is the outflow from Mill Pond in Lehi. It is also known as Spring Creek. Its drainage area is generally the area between Lehi and American Fork. Flow measurements were made at the downstream side of the 6-ft box culvert crossing under 7750 N in Lehi. Flowrates ranged from 5 to 25 cfs during this study.

The past correlation was with the previous year's Provo precipitation index (Blankenstein, 1992). The same year Provo precipitation index was found to be an improvement. See Table 4-2 and Table 4-3 and Figure 4-1, Figure 4-2, and Figure 4-3 for results. The old data give a R^2 of 0.47. When including all the data the R^2 drops to 0.29.

When considering just the new data, the flow correlated better with the same year-Provo index than with the previous year index. The R-squared value is nearly perfect for this new data at 0.98 but with a steeper slope than before.

4.1.2 UT 13 – American Fork River

Most of the water in the American Fork River is diverted during the irrigation season. For this reason, previously the American Fork River discharge correlation was divided into the April-July runoff and August-March runoff. An exponential relationship was used in developing correlations for this river for April-July using the American Fork Powerhouse flow readings. The rest of the year was correlated linearly with the Lehi Precipitation Index (Blankenstein, 1992).

The gaging station upstream at the American Fork Powerhouse was discontinued in 1989 and is no longer a valid index. The flows at this site have also been dramatically changed, suggesting the need for a new correlation. During the irrigation season, some of the American Fork water is held in detention ponds at the base of the canyon. American Fork City also plans on using the detention ponds for secondary water use and is in a transition phase. The flow is difficult to estimate because of the cities involvement and the diverted irrigation use.

It has been suggested that additional new data be collected for this location for the further development of new correlations. Three new data points were collected during this study and the analysis and data are found in Table 4-4 and Figure 4-4. The R-squared value of the distribution was 0.67 with an extremely steep slope. A new correlation with time of year may be appropriate when there are more data. The tributary discharge has ranged from 2 to 370 cfs during this study.

4.1.3 UT 18 – Geneva Cannery Drain (Lindon Drain)

This channel drains the area both south and west of Pleasant Grove. The previous year's Provo precipitation index was used to develop the correlation (Blankenstein, 1992). This was changed to the Average Valley Index in our report. See Table 4-5 and Figure 4-5, Figure 4-6, and Figure 4-7 for data and analysis. The R-squared of the distribution was 0.9 with the old data, but drops to 0.63 when the new data is added. The new data alone has an R-squared value of 0.99 with a slightly steeper slope.

The sampling location for this site is by the rear entrance to the North Utah County Transfer Station and just east of the railroad track. The cross section at the gaging site was downstream of the culverts under the road. This used to be a double barrel culvert with 4.5-foot diameter corrugated metal pipes. During this study a new single box concrete culvert was constructed. The water now backs up behind the new culvert and moves very slowly through it. The last few measurements were taken from an 8-foot barrel culvert on the west side of the railroad tracks, just downstream of the original location. The tributary discharge has ranged from 13 to 50 cfs during this study.

4.1.4 UT 20 – Geneva Steel

The flow in this tributary comes from the former Geneva Steel plant. The flows have been historically reported by the Geneva Works office (Rice, 1999). Since the dismantling of Geneva Steel, the flow has been reported by the Geneva Land Company. The Land Company should continue to provide the flow. The tributary discharge has ranged from 5 to 32 cfs during this study.

4.1.5 UT 27 – Powell's Slough

Powell's Slough is not very well defined, and it is very difficult to identify a single outlet point to Utah Lake. This has made it difficult to measure accurately. The Orem Wastewater Treatment Plant effluent and site drainage both empty into Powell Slough. There are several other drains that empty into Powell Slough. This station's runoff was historically correlated with the Average Valley index (Blankenstein, 1992). It was continued with the new Average Valley index in this report. Using just the old data the R-squared value is 0.75. Adding the new data to the set changes the R-squared value 0.74. The new data alone has an R-squared value of 0.61 and the slope of 680 is about the same as with all the data.

This sampling location is the outlet of Clegg's Pond (north flow), just north (downstream) of the Orem WWTP. The flow was gaged at the downstream side of the 5-foot culvert. The tributary discharge ranged from 3 to 10 cfs during this study.

The total flow of Powell's Slough consists of the north flow, the south flow and the WWTP discharge. The south flow is 1.3 times the Clegg's Pond (north flow), so the total flow is

2.3 times the Clegg's Pond measurement, plus the WWTP discharge. See Table 4-6 and Figure 4-8, Figure 4-9, and Figure 4-10 for data and analysis.

4.1.6 UT 27A – Orem WWTP

This is the effluent of the Orem WWTP. The State conducted a study that coincided with the study done for this report. The data collected from this site came from the State's study. No correlation graph for discharge is needed for this site as the WWTP continuously measures outflow. The tributary discharge has ranged from 11 to 15 cfs during this study.

4.1.7 UT 29 – Provo River

The flow in the Provo River is recorded by the USGS. This station is located on the west side of Provo downstream of the Geneva Road bridge. This river represents a large part of the inflow to Utah Lake (Blankenstein, 1992). The station used is USGS 10163000 Provo River at Provo. The tributary discharge has ranged from 44 to 1470 cfs during this study.

4.1.8 UT 38 – Millrace

This tributary carries small flows diverted from Provo River and other small flows from the area adjacent to the Provo WWTP. This correlation is based on the previous year's Provo index. No change was made to the precipitation index for this station. The flow was measured at a small Parshall Flume located at the GPS coordinates given in this report. The 2009-2011 flows at UT 38 have been significantly lower than historical flows and the new R-squared value reflects this change. The R-squared value changes from 0.3 for the old data to 0.16 for all data and to 0.63 with only the new data and clearly shows the drastic change. The tributary discharge has ranged from 1.5 to 12 cfs during this study. See Table 4-7 and Table 4-8 and Figure 4-11, Figure 4-12, and Figure 4-13 for data and analysis.

4.1.9 UT 38A – Provo WWTP

This is the effluent of the Provo WWTP between UT 38B and UT 38. The State conducted a study that coincided with the study done for this report. The data collected from this site came from the State's study. No correlation graph for discharge is needed for this site as the WWTP continuously measures outflow. The tributary discharge has ranged from 17 to 33 cfs during this study.

4.1.10 UT 38B – Mill Race below WWTP

This site is located below UT 38 and downstream from the Provo WWTP outfall. The purpose of the two locations on the same tributary is to check the effects of the treatment plant on the downstream water quality. The issue of water quality is discussed in the accompanying report. The tributary discharge has ranged from 18 to 50 cfs during this study. No correlations are needed as the flow can be determined by adding the flows from UT 38 and UT 38A. A slight variance could occur between this sum and the measured flow due to inflows of other small tributaries in the area.

4.1.11 UT 42 – Steel Mill Drain

This tributary drains part of some industrial properties. This includes the Ironton property and the Pacific Cast Iron Pipe property (Blankenstein, 1992). The correlation is based on the previous year's Provo Precipitation index and was not changed. See Table 4-9, and Figure 4-14, Figure 4-15, and Figure 4-16 for analysis and data. The R-squared for the distribution changed from 0.31 for old data to 0.14 with all the data. The R-squared value for the distribution of only the new data is 0.88 but the slope is nearly flat. This could signify that this tributary's flow is now controlled more by industry and groundwater than precipitation.

The cross section used for gaging is located at the downstream side of the 5.5-foot circular culvert running under Kuhni Boulevard. The tributary discharge has ranged from 7 to 15 cfs during this study.

4.1.12 UT 43 – Spring Creek Springville

Spring Creek is located west of Springville and represents the flow with the Springville Wastewater Treatment Plant effluent subtracted from the flow. This sampling location is on the west side of Kuhni Boulevard and is identified by 3 circular culverts (Rice, 1999). This station was previously correlated with the Average Valley index and was continued in this study.

The cross section consists of a three 3-foot diameter culverts on the downstream side of Kuhni Boulevard. See Table 4-10 and Figure 4-17, Figure 4-18, and Figure 4-19 for analysis and data. The R-squared for the distribution of all the data is 0.47, a significant increase from the old data with R-squared equal to 0.14. The new data has an R-squared value of 0.80 and the slope is about the same as with all the data. The tributary discharge has ranged from 14 to 43 cfs during this study.

4.1.13 UT 43A – Springville WWTP

This is the effluent of the Springville WWTP between UT 43B and UT 43. The State conducted a study that coincided with the study done for this report. The data collected from this site came from the State's study. No correlation graph for discharge is needed for this site as the wastewater treatment plant continuously measures outflow. The tributary discharge has ranged from 5 to 8 cfs during this study.

4.1.14 UT 43B – Spring Creek above Springville WWTP

This tributary is located upstream of UT 43 and upstream of the Springville WWTP (UT 43A). It is located on North Technology Drive and consists of three 3-foot diameter culverts. The purpose of the two locations on the same tributary was to examine the effects of the treatment plant on the downstream water quality which will not be discussed in this report. No correlation graph is given for this site because the discharge is the difference between the measured flows at UT 43 and UT 43A (plus other small tributaries). Flows have ranged from 8 to 22 cfs during this study.

4.1.15 UT 44 – Hobble Creek

Hobble Creek drains a large area in the mountains and Hobble Creek canyon. It is largely influenced by snow–melt runoff (Rice, 1999). A USGS gaging station is used to measure discharge at the time of the sample retrieval. The flow data are available on the USGS website. The station used is USGS 10153100 Hobble Creek at 1650 W in Springville. The tributary discharge has ranged from 0.02 to 507 cfs during this study.

4.1.16 UT 47 – Dry Creek

The Spanish Fork WWTP generates a portion of the flow in this tributary along with the area around the southern end of Springville and northern Spanish Fork. The WWTP effluent was subtracted from the flow before the correlations were made (Rice, 1999). The new correlation was made with the Spanish Fork Precipitation Index. See Table 4-11 and Figure 4-20, Figure 4-21, and Figure 4-22 for data and analysis. The R-squared value of the distribution improved with the new data from 0.33 for old the data to 0.57 for all the data. Using just the new data, the R-squared value of the distribution is 0.99 and the slope is slightly less steep than with all the data. The sampling location is near the Utah County Jail. The cross section used is a 10-foot wide rectangular culvert on the downstream side of 3200 N., just off Spanish Fork Main Street. The tributary discharge has ranged from 11 to 32 cfs during this study.

4.1.17 UT 47A – Spanish Fork WWTP

This is the effluent of the Spanish Fork WWTP between UT 47B and UT 47. The State conducted a study that coincided with the study done for this report. The data collected from this site came from the State's study. No correlation graph for discharge is needed for this site as the treatment plant continuously monitors the flow. The flow has ranged from 6 to 8 cfs during this study.

4.1.18 UT 47B – Dry Creek above Spanish Fork WWTP

This tributary sampling site is located above the Spanish Fork Wastewater Treatment Plant on the west freeway frontage road in Springville. The cross section used is a 16-foot wide rectangular box culvert. No correlation graph is given for this site because the discharge is the difference between the measured flows at UT 47 and UT 47A (plus other small tributaries). The tributary discharge has ranged from 3 to 21 cfs during this study.

4.1.19 UT 48 – Spanish Fork at Lakeshore

The Spanish Fork River is a major inflow to Utah Lake and drains a large area in the Wasatch Mountain Range and Spanish Fork Canyon. Historically, the flow was gaged by the USGS at the Lakeshore gaging station. The gaging station has been discontinued and cannot be used for this report. Diversion dams are on the Spanish Fork River for irrigation which makes it difficult to correlate the flow to any type of index. The sampling location is at Huff Diversion Dam which is used for withdrawing water for irrigation. This dam occasionally bypasses water from upstream of the dam to the downstream side when the gate is closed.

Historically, the flows have been estimated based on the Castilla gaging station in Spanish Fork Canyon. The method used estimated these flows depending on the time of year. The method was developed as part of the 1991 update. During the months of June-September, when irrigation use is heavy, a complex method was used and during the rest of the year a different and simpler approach was taken.

"The historical ratio of the flow in the Provo River below Deer Creek Dam to the flow in the Provo River at Provo, or ratio A, was determined for each month of record since 1930. The historical ratio of the flow in the Spanish Fork River at Castilla to the flow in the Spanish Fork at Lakeshore, or ratio B, was also determined for each month. Linear equations were then developed to correlate the historical ratio of the flows in the Provo River with the historical ratio of the flows in the Spanish Fork River for each month in the form B=f(A). These correlations were used to determine the ratio of the flows in the Spanish Fork River, or B, during each of the summer months after the Lakeshore station was discontinued. Continuously measured monthly flows at Castilla were then divided by B to find the flow at Lakeshore." (Rice, 1999)

In the months of October – December and January – May, a correlation equation was developed relating the flow at Lakeshore to the flow at Castilla for each month. These methods are still being used to estimate the Spanish Fork flow that contributes to Utah Lake. The tributary discharge at the Huff Diversion Dam has ranged from 5 to 1180 cfs during this study.

4.1.20 UT 51 – Benjamin Slough

Benjamin Slough drains a large part of the Payson area. It also receives influent from the Payson WWTP. The effluent flow from the wastewater treatment plant was subtracted before the correlation was developed. This location is correlated with the Santaquin Precipitation index and was not changed (Blankenstein, 1991). With the addition of the new flow data, the R-squared coefficient changes from 0.91 for old data to 0.83 for all data. The new data has an R-squared value of 0.99 with a much steeper slope than all data. See Table 4-12 and Figure 4-23, Figure 4-24, and Figure 4-25 for data and analysis.

The sampling location for Benjamin Slough was the stream crossing on the downstream side of Highway 147. The culvert was split into two 12-foot wide rectangular sections which were used for gaging. The west section of the bridge normally carried the majority of flow. The tributary discharge ranged from 13 to 150 cfs during this study.

4.1.21 UT 51A – Payson WWTP

This is the effluent of the Payson WWTP between UT 51B and UT 51. The State conducted a study that coincided with the study done for this report. The data collected from this site were taken from the State's study. No correlation graph for discharge is needed for this site.

4.1.22 UT 51B – Beer Creek above the Payson WWTP

This location is above the Payson WWTP and is used only for water quality analysis. It can be found at the crossing of Beer Creek and Highway 115. The downstream side of the culvert under the highway was used as a sampling location. It is a circular culvert with a diameter of 5.5 feet. No correlation graph is given for this site because the discharge is the difference between the measured flows at UT 51 and UT 51A (plus other tributaries). Measured flows for this tributary have ranged from 5 to 58 cfs.

4.1.23 UT 53 – Jordan River at the outlet dam

Jordan River is the outflow from Utah Lake. The flow is reported by the Jordan River Commissioner. The flow is the combined flow of the Jordan River measured at The Narrows, and two canals which are diverted upstream of the measurement. The outflow from Utah Lake is called the "Jordan River Combined Flow" in the "Utah Lake/Jordan River" section of the

"Distribution System List" of the Utah Water Rights webpage. The outlet structure consists of three 20-foot gates. Low flows are typically experienced in the winter months when the gates are closed. The outlet discharge ranged from 0 to 1350 cfs during this study.

4.1.24 UT 71 – Timpanogos WWTP Holding Ponds

This is the outflow of the Timpanogos Wastewater Treatment Facility Pond. We measured the flow at a 4-foot diameter culvert below the ponds. The State conducted a study on the WWTP effluent that coincided with the study done for this report. We are assuming that over the long term, the WWTP effluent is approximately the same as the outflow from the ponds. We compared the flows from the 2 locations and developed the equation $Q_{pond} = - 0.041 * Q_{effluent} + 25.614$. The equation gives the flow at the pond outlet from the WWTP effluent flow, which can be used in the future. The loss in flow from the pond is due to evaporation. No correlation graph for discharge is used for this site because the wastewater treatment plant continuously measures effluent.

4.2 Correlation Graphs and Tables

Table 4-1 contains abbreviations used in the correlation graphs and tables.

Table 4-1: Correlation Abbreviations

AV	Average Valley (Alpine, Provo, Santaquin)
PI	Precipitation Index
PY	Previous Year
SF	Spanish Fork
SQ	Santaquin

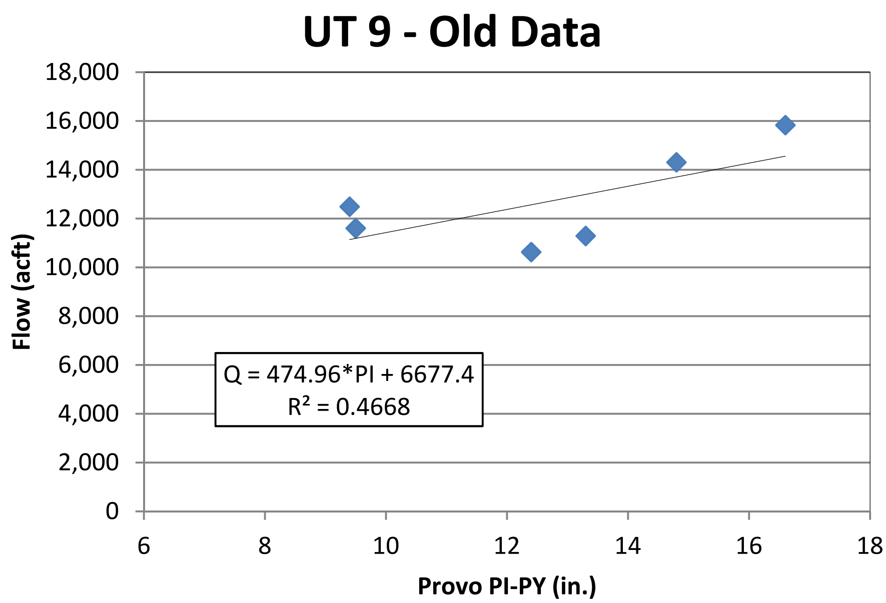

Figure 4-1: UT 9 - Mill Pond (Old Data)

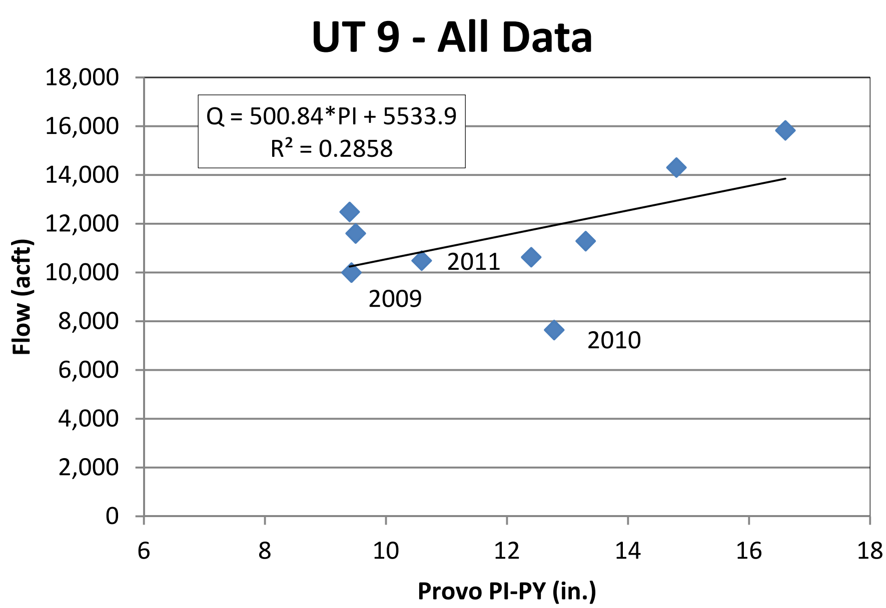

Figure 4-2: UT 9 – Mill Pond (All Data)

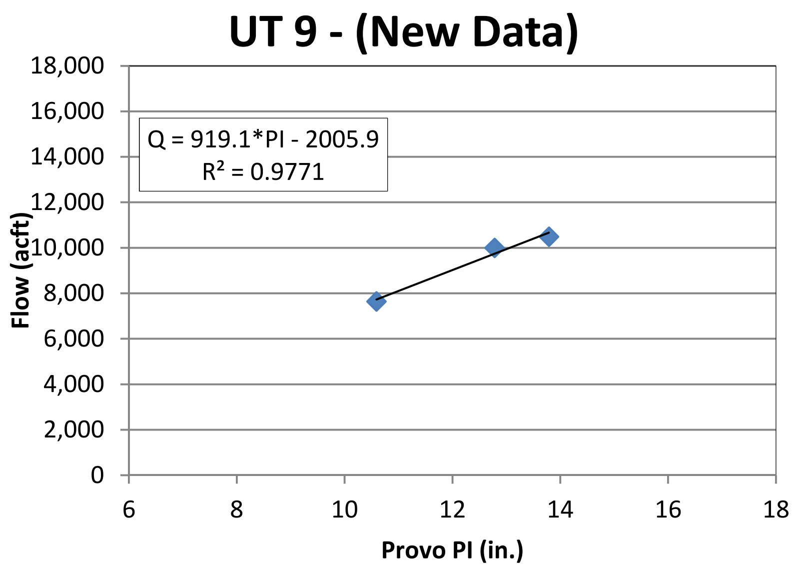

Figure 4-3: UT 9 - Mill Pond (New Data)

Table 4-2: UT 9 - Correlation Table (Previous Year Precipitation)

Year	Flow (acft)	Provo PI-PY
1943	10,632	12.40
1944	11,606	9.50
1945	11,291	13.30
1971	15,833	16.60
1972	14,309	14.80
1978	12,490	9.40
2009	10,000	9.43
2010	7,645	12.78
2011	10,491	10.59

Table 4-3: UT 9 - Correlation Table (Same Year Precipitation)

Year	Flow (acft)	Provo PI
2009	10,000	12.78
2010	7,645	10.59
2011	10,491	13.79

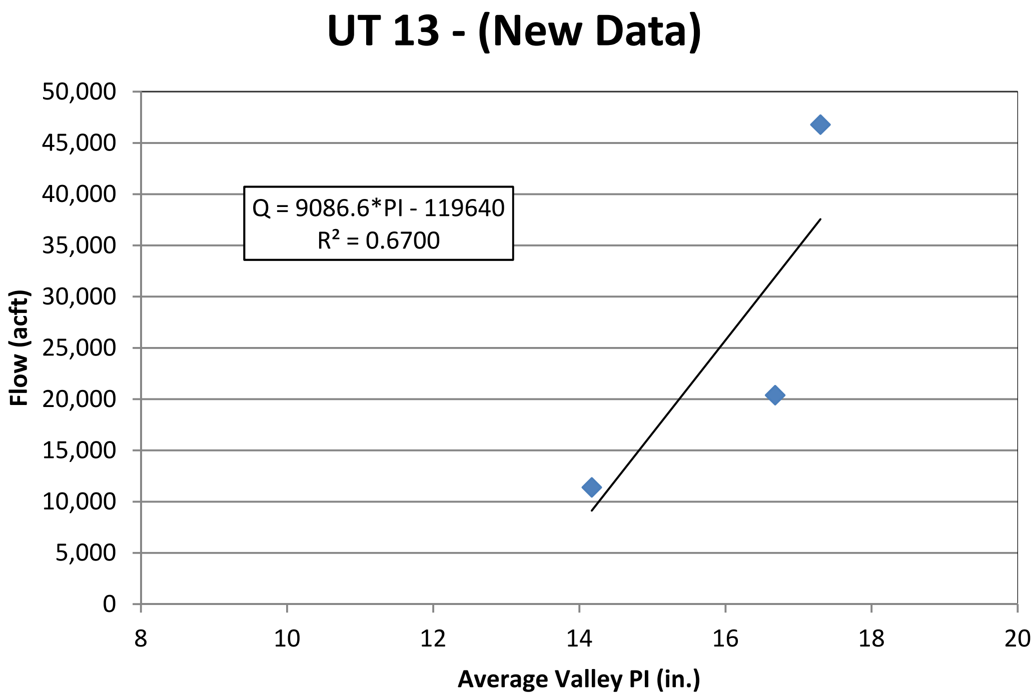

Figure 4-4: UT 13 – American Fork River (New Data)

Table 4-4: UT 13 - Correlation Table

Year	Flow (acft)	AV PI
2009	20,400	16.68
2010	11,400	14.17
2011	46,800	17.30

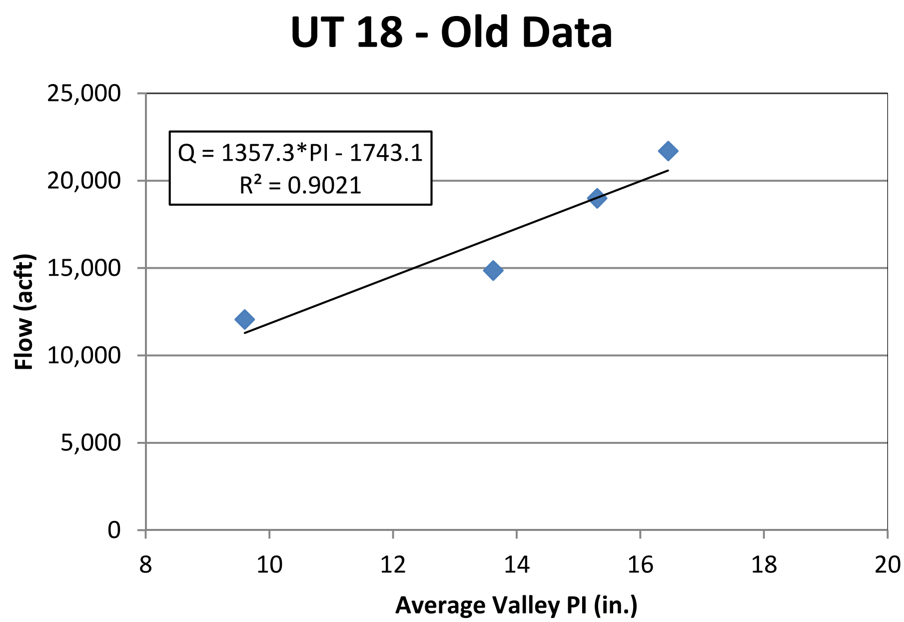

Figure 4-5: UT 18 - Lindon Cannery Drain (Old Data)

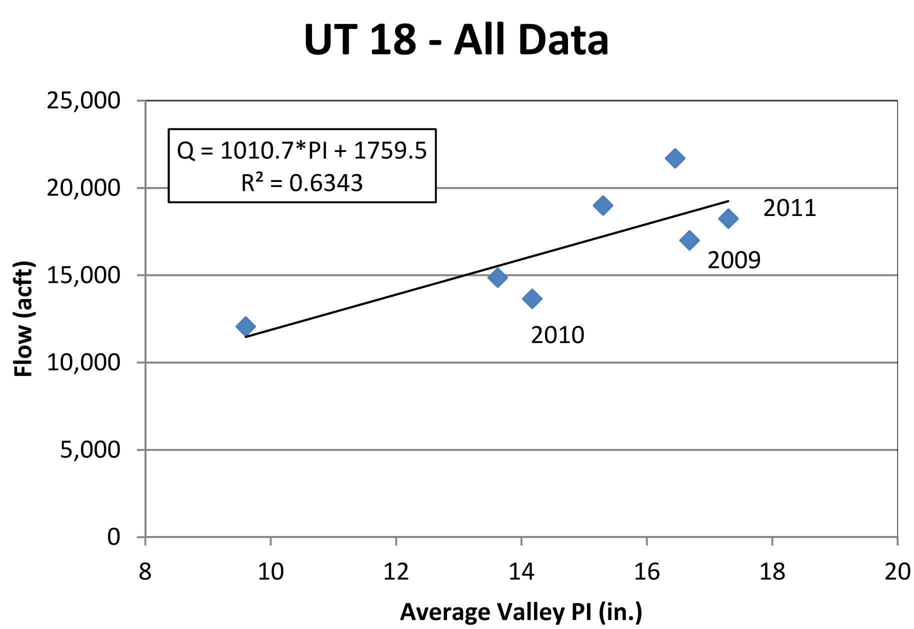

Figure 4-6: UT 18 - Lindon Cannery Drain (All Data)

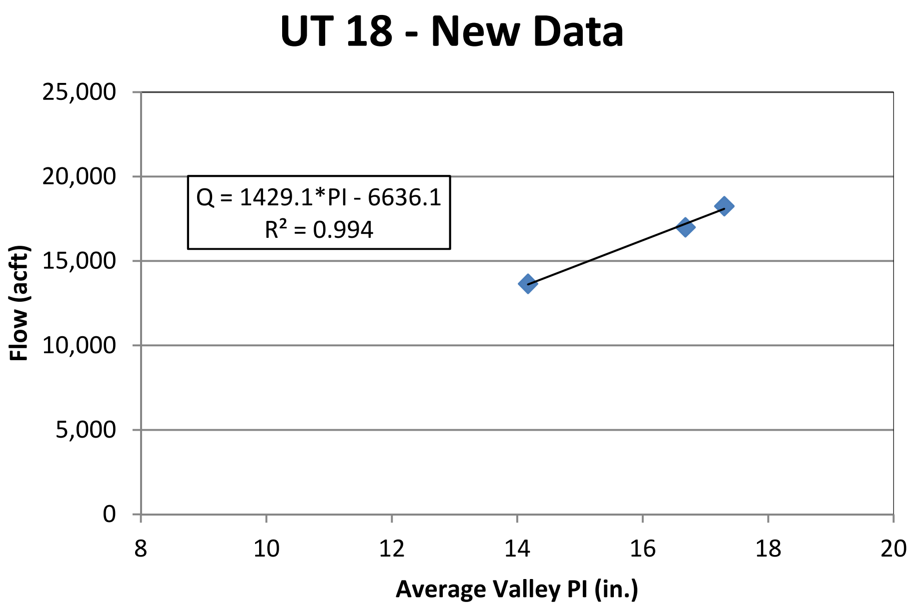

Figure 4-7: UT 18 - Lindon Cannery Drain (New Data)

Table 4-5: UT 18 - Correlation Table

Year	Flow (acft/yr)	AV PI
1971	21,705	16.45
1972	19,000	15.30
1978	12,066	9.60
1979	14,867	13.62
2009	17,000	16.68
2010	13,654	14.17
2011	18,249	17.30

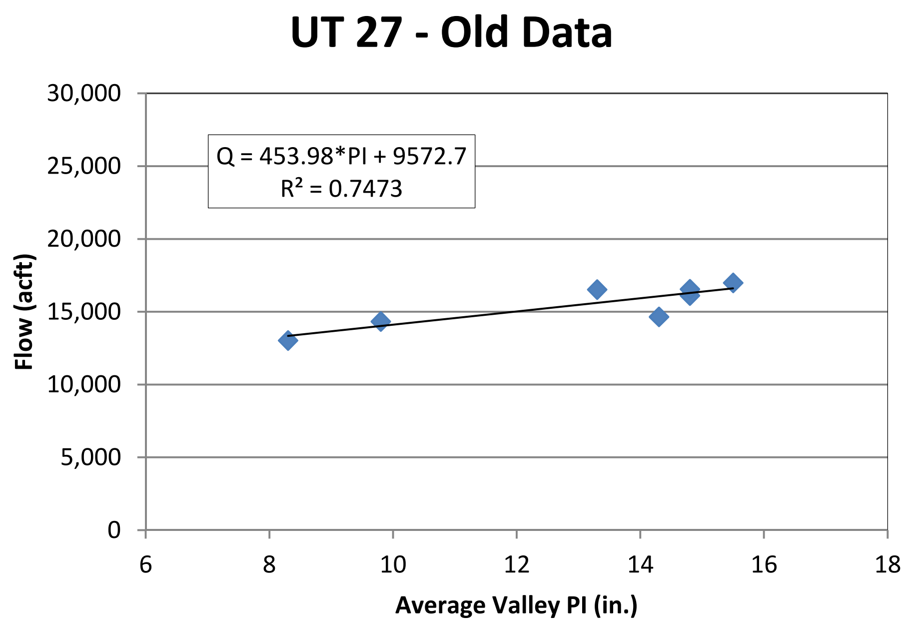

Figure 4-8: UT 27 - Powell's Slough (Old Data)

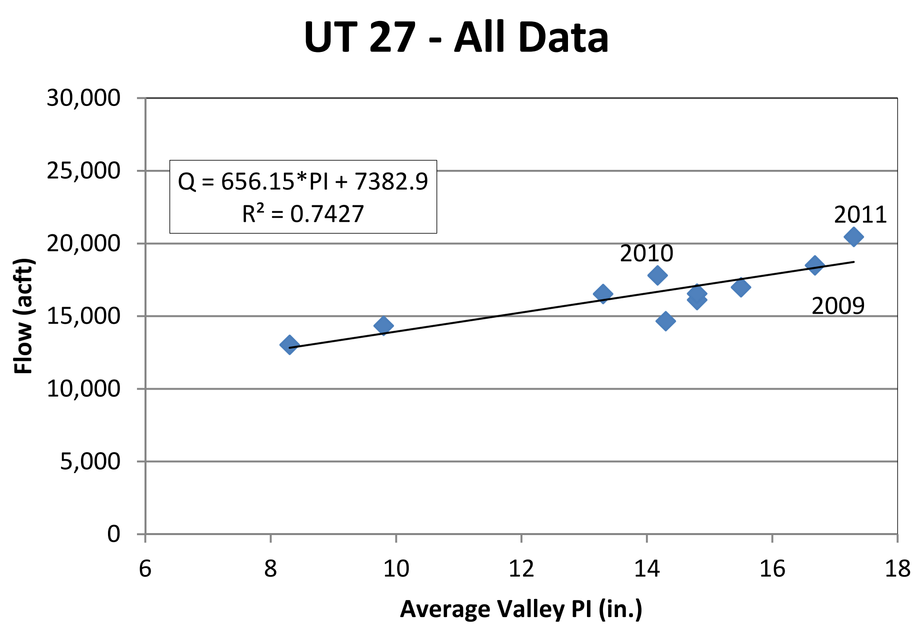

Figure 4-9: UT 27 - Powell's Slough (All Data)

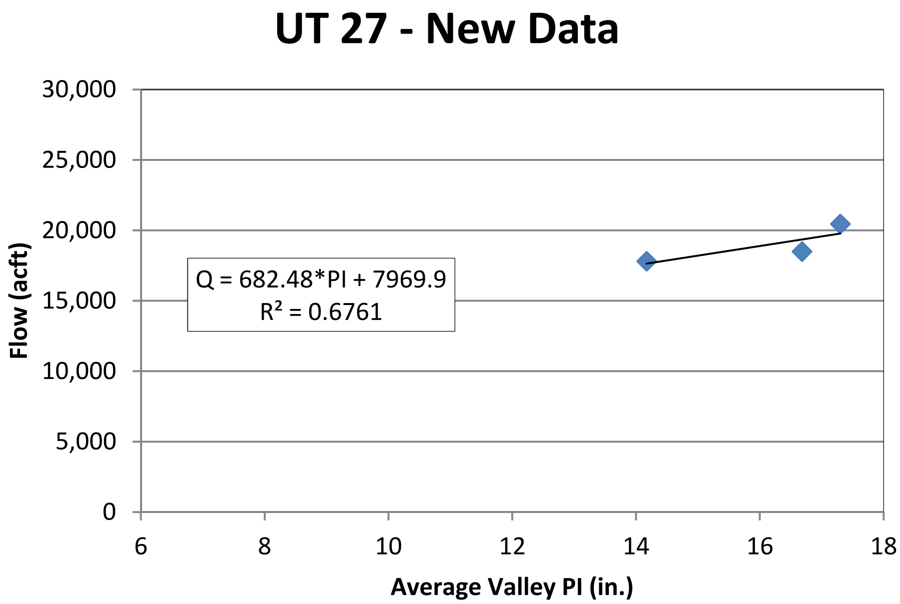

Figure 4-10: UT 27 - Powell's Slough (New Data)

Table 4-6: UT 27 – Correlation Table

Year	Total Flow (acft/yr)	AV PI
1967	16,119	14.8
1968	16,992	15.5
1969	16,530	13.3
1970	16,557	14.8
1971	14,659	14.3
1972	14,340	9.80
1974	13,033	8.30
2009	18,500	16.68
2010	17,810	14.17
2011	20,461	17.3

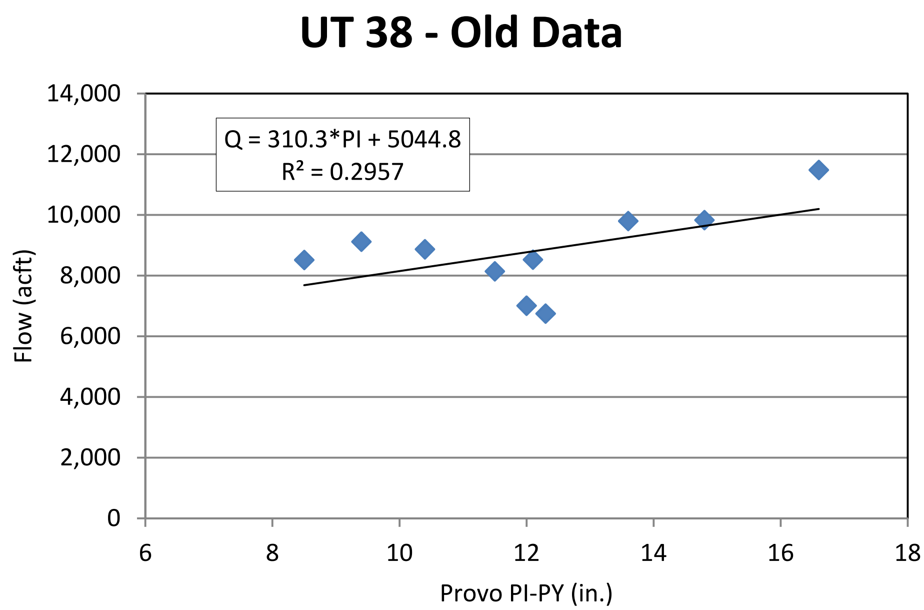

Figure 4-11: UT 38 - Millrace (Old Data)

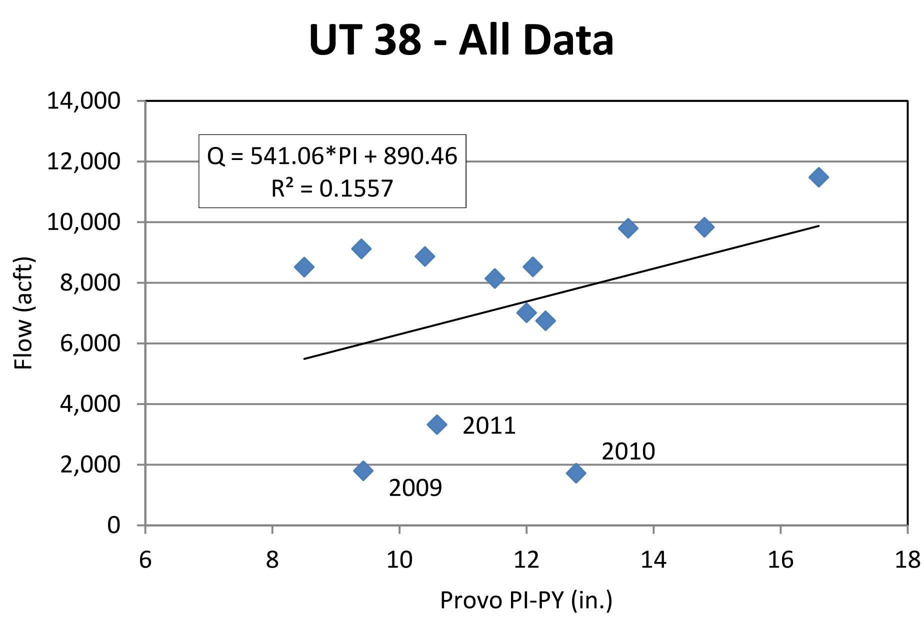

Figure 4-12: UT 38 - Millrace (All Data)

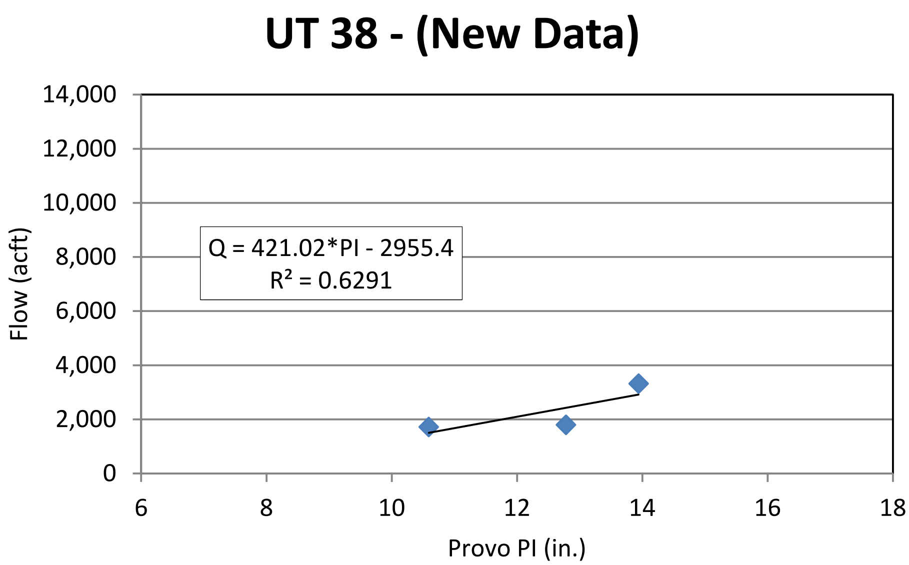

Figure 4-13: UT 38 - Millrace (New Data)

Table 4-7: UT 38 - Correlation Table (Previous Year Precipitation)

Year	Flow (acft/yr)	Provo PI-PY
1958	6,749	12.30
1959	8,143	11.50
1961	8,519	8.50
1964	8,870	10.40
1965	7,011	12.00
1966	8,528	12.10
1971	11,483	16.60
1972	9,833	14.80
1978	9,121	9.40
1979	9,800	13.60
2009	1,800	9.43
2010	1,720	12.78
2011	3,322	10.59

Table 4-8: UT 38 - Correlation Table (Same Year Precipitation)

Year	Flow (acft/yr)	PPI-PY
2009	1,800	12.78
2010	1,720	10.59
2011	3,322	13.94

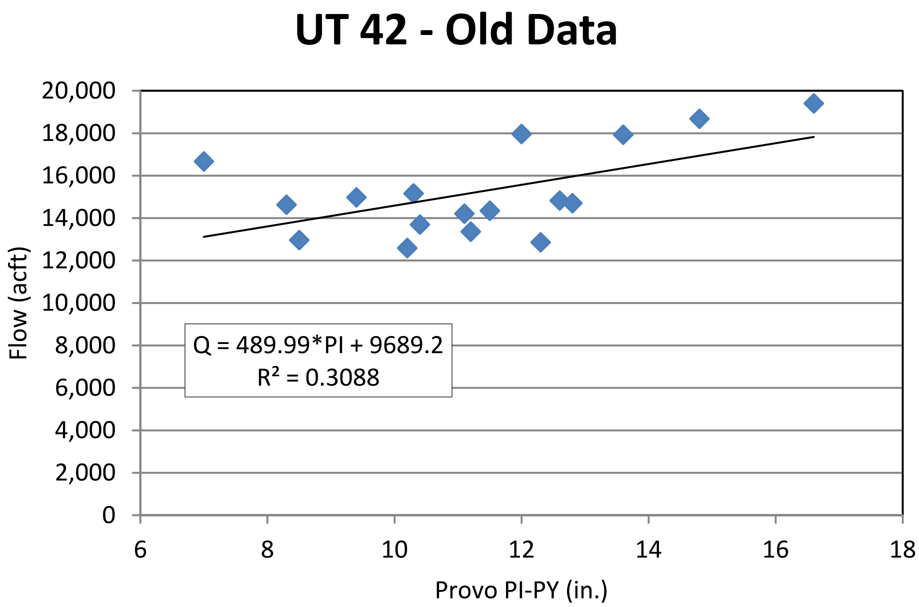

Figure 4-14: UT 42 - Steel Mill Drain (Old Data)

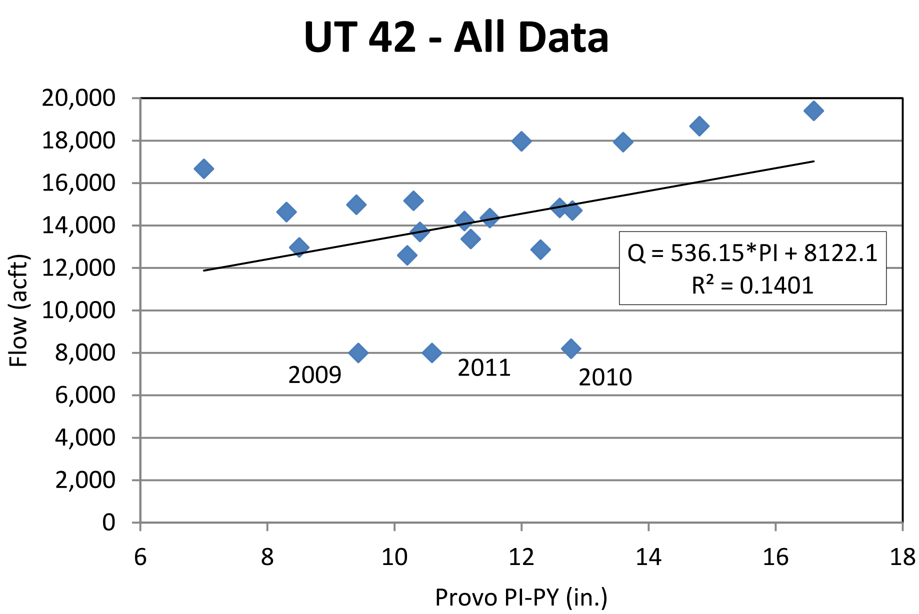

Figure 4-15: UT 42 - Steel Mill Drain (All Data)

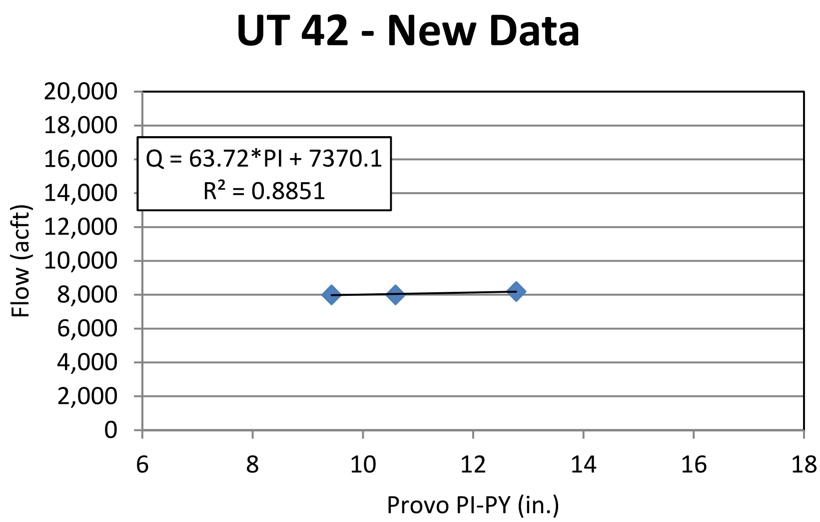

Figure 4-16: UT 42 - Steel Mill Drain (New Data)

Table 4-9: UT 42 - Correlation Table

Year	Flow (acft/yr)	Provo PI-PY
1938	14,835	12.60
1939	13,368	11.20
1940	12,597	10.20
1954	14,639	8.30
1955	15,168	10.30
1956	14,216	11.10
1957	16,677	7.00
1958	12,867	12.30
1959	14,354	11.50
1960	14,710	12.80
1961	12,970	8.50
1964	13,704	10.40
1965	17,971	12.00
1971	19,409	16.60
1972	18,687	14.80
1978	14,984	9.40
1979	17,934	13.60
2009	8,000	9.43
2010	8,200	12.78
2011	8,000	10.59

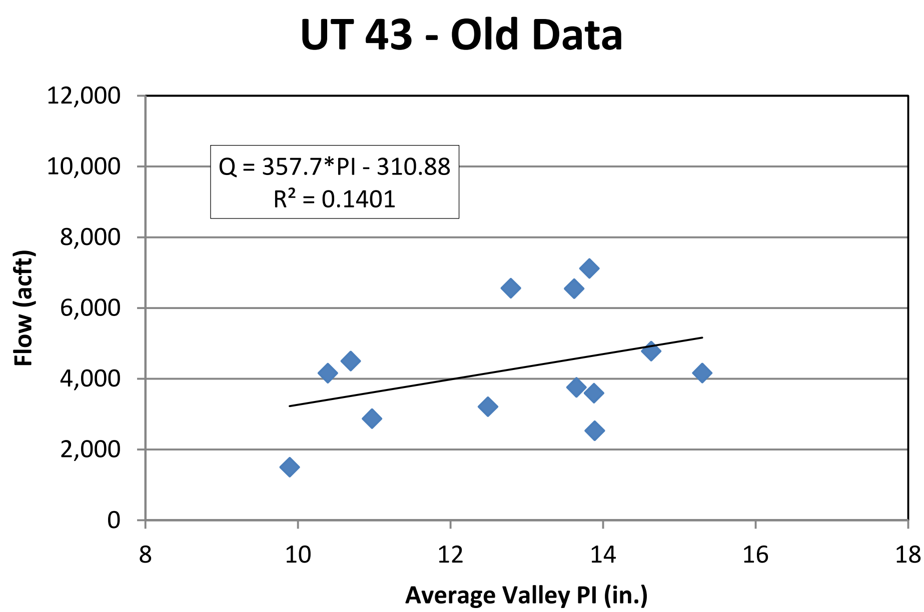

Figure 4-17: UT 43 - Spring Creek Springville (Old Data)

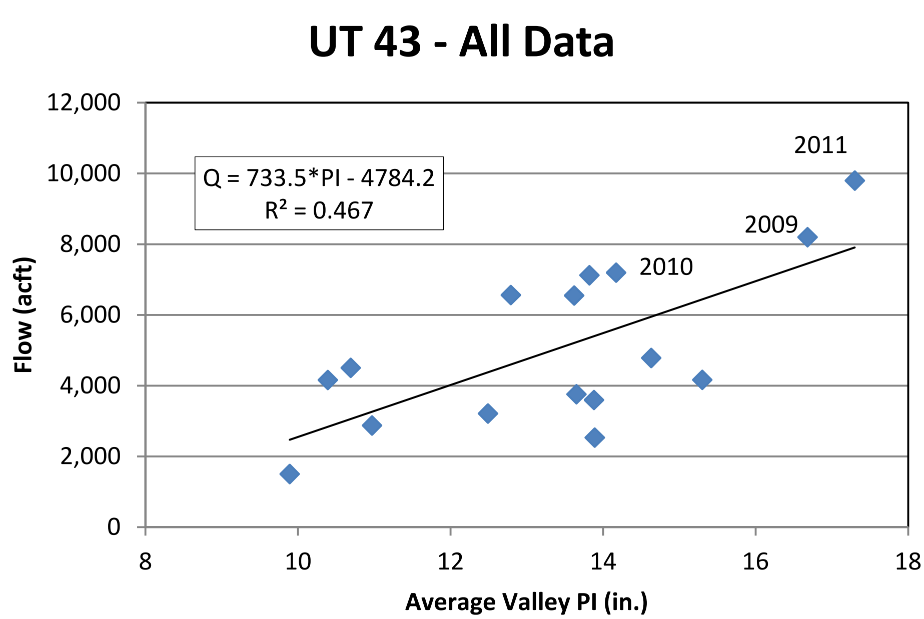

Figure 4-18: UT 43 - Spring Creek Springville (All Data)

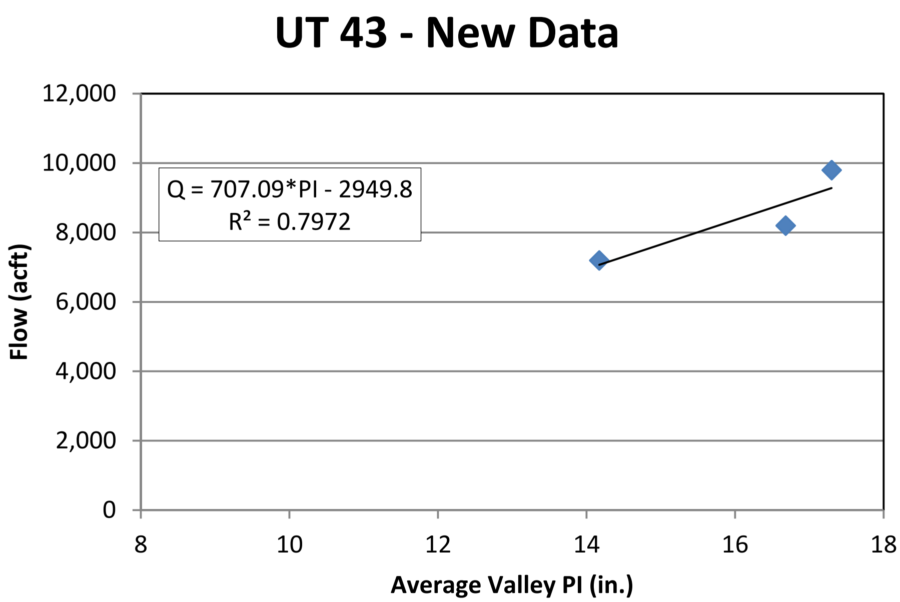

Figure 4-19: UT 43 - Spring Creek Springville (New Data)

Table 4-10: UT 43 - Correlation Table

Year	Flow (acft/yr)	AV PI
1954	6,564	12.79
1955	2,534	13.89
1956	1,504	9.89
1957	3,597	13.88
1958	7,123	13.82
1959	4,785	14.63
1960	4,505	10.69
1961	3,214	12.49
1964	3,760	13.65
1971	4,166	15.30
1972	4,162	10.39
1978	6,551	13.62
1979	2,876	10.97
2009	8,200	16.68
2010	7,197	14.17
2011	9,800	17.30

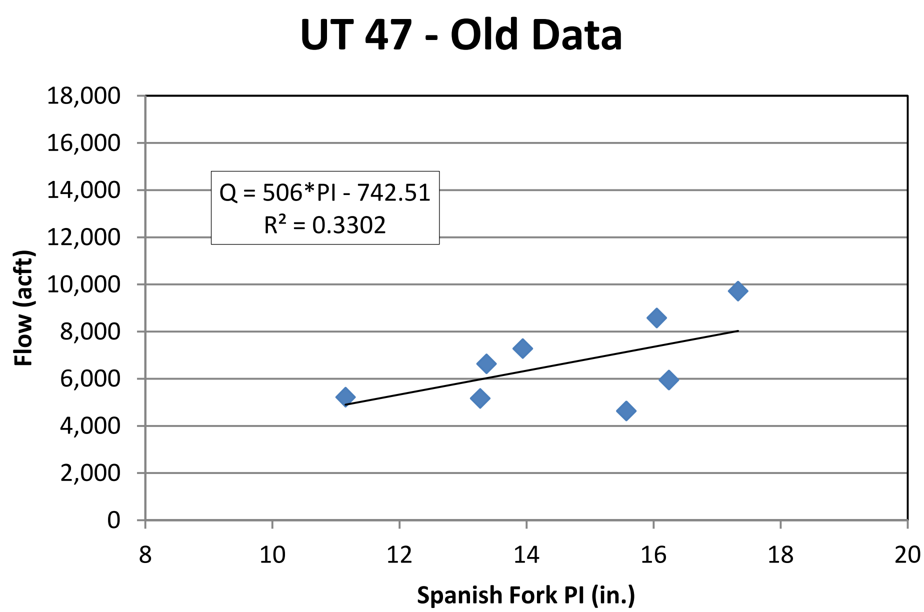

Figure 4-20: UT 47 - Dry Creek Spanish Fork (Old Data)

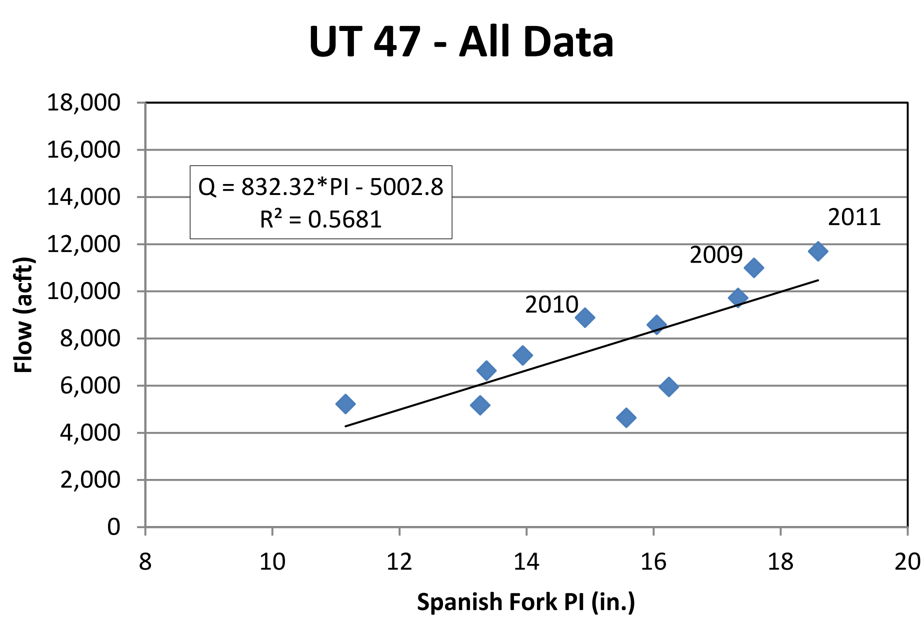

Figure 4-21: UT 47 - Dry Creek Spanish Fork (All Data)

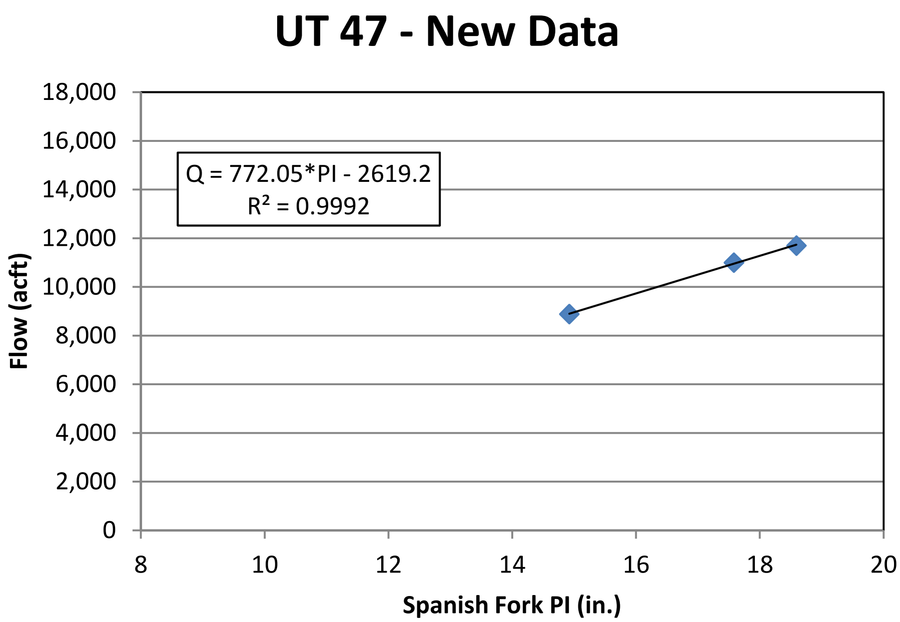

Figure 4-22: UT 47 - Dry Creek Spanish Fork (New Data)

Table 4-11: UT 47 - Correlation Table

Year	Flow (acft/yr)	SF PI
1960	5,225	11.15
1961	5,171	13.27
1964	4,640	15.57
1965	8,584	16.05
1971	9,723	17.33
1972	7,286	13.94
1978	5,952	16.24
1979	6,640	13.37
2009	11,000	17.58
2010	8,887	14.92
2011	11,699	18.59

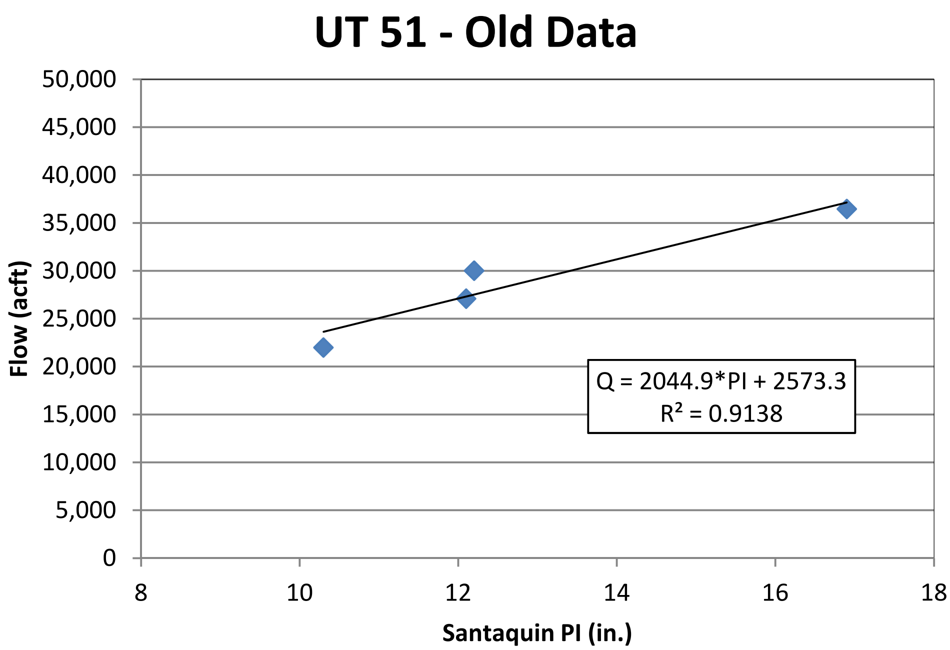

Figure 4-23: UT 51 - Benjamin Slough (Old Data)

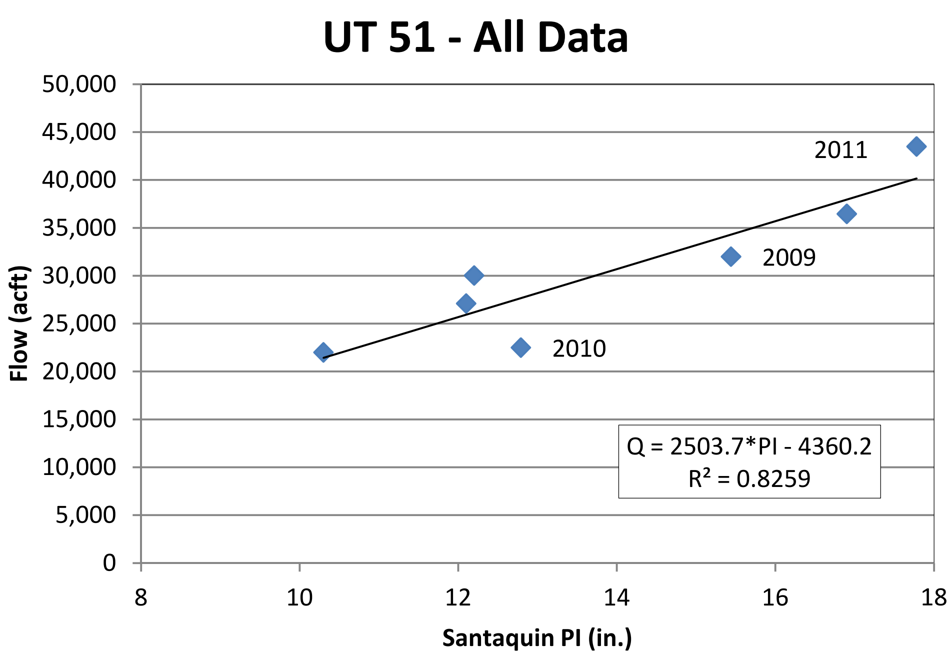

Figure 4-24: UT 51 - Benjamin Slough (All Data)

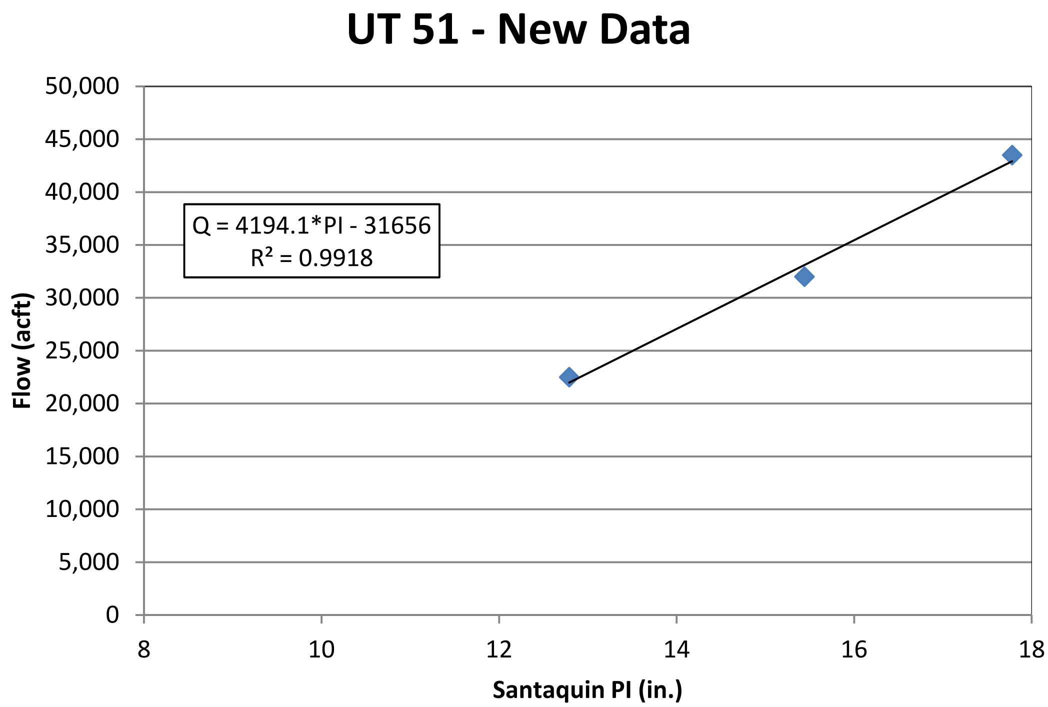

Figure 4-25: UT 51 - Benjamin Slough (New Data)

Table 4-12: UT 51 - Correlation Table

Year	Flow (acft/yr)	SQ PI
1971	36,469	16.90
1972	30,027	12.20
1978	27,107	12.10
1979	22,005	10.30
2009	32,000	15.44
2010	22,504	12.79
2011	43,501	17.78

5 CONCLUSIONS

R^2 values decreased for 5 of 8 correlations when new data was added to the data. These are stations UT 9, UT 18, UT 38, UT 42, and UT 51. UT 27 (Powell's Slough) remained the same while UT 43 (Spring Creek) and UT 47 (Dry Creek) increased.

One reason that so many of the correlations decreased could be that the land and water uses have changed significantly in the time between studies. For example, the average flow for 2009-2011 at UT 38 (Millrace) was only a quarter of the average for the old data and UT 42 (Steel Mill Drain) was about half the old data. This suggests that these flows have changed significantly since the last data point was collected in 1979. The R-squared values for new data correlations for these two sites are much higher than either the old data or all data. The slope in the new equations are not nearly as steep as the old correlations and signifies that while the flow is still dependent on precipitation, the volume of flow is not as large as it was previously. The old equations no longer represent the current flow so the new equations should be utilized in the LKSIM model for these two sites.

UT 27's (Powell's Slough) R-squared value slightly decreased from 0.74 to 0.67 in both cases. The R-squared value is about the same between the old data and all the data, but the slope of the trend line is steeper with all the data. The change in slope suggests that the equation from the old data should no longer be used. A significant portion of the Powell's Slough flow comes from the Orem WWTP and the treatment plant processes much more water than before. The change in correlation between all the data and the new data isn't very big and the slope remains about the same, so either equation can be used in the LKSIM model.

The R-squared values of 7 of the 8 correlations increased when comparing both the old data to the new data, and all the data to the new data. Table 5-1 summarizes the R^2 values for these seven stations, and for UT 13. Values decreased slightly for UT 27.

Table 5-1: Stations with Increase in R^2 Values

Station	R^2 Values		
	Old Data	**All Data**	**New Data**
UT 9	0.47	0.29	0.98
UT 13	-	-	0.67
UT 18	0.90	0.63	0.99
UT 38	0.30	0.16	0.63
UT 42	0.31	0.14	0.89
UT 43	0.14	0.47	0.80
UT 47	0.33	0.57	1.00
UT 51	0.91	0.83	0.99

Three tributaries of the eight have significant increases in R-squared values from all the data to the new data, while two others (UT 18 & UT 51) only slightly increased. UT 9 (Mill Pond), UT 43 (Spring Creek), and UT 47 (Dry Creek) had significant increases in correlation. The R^2 values are summarized below in Table 5-2.

Table 5-2: Stations with Significant Increases in R2 Values

Station	R2 Values	
	All Data	**New Data**
UT 9	0.29	0.98
UT 43	0.47	0.80
UT 47	0.57	1.00

These areas have seen substantial residential growth and land use changes since the late 1970s. The new equations presented in this report reflect the current correlations between precipitation and tributary flows and should be used in the LKSIM model. The R-squared values for UT 18 (Lindon Cannery Drain) and UT 51 (Benjamin Slough) slightly increased from all the data to the new data. These values are found in Table 5-3.

.

Table 5-3: Stations with Slight Increase in R^2 Values

	R2 Values		
Station	**Old Data**	**All Data**	**New Data**
UT 18	0.90	0.63	0.99
UT 51	0.91	0.83	0.99

These areas have not seen as much growth and land use changes as the others whose correlations significantly increased. The slope for UT 18 is about same as the old data and slightly steeper than all the data. The equation from the new data should be used in the LKSIM model.

The slope for the UT 51 equation is much steeper than either the old or all data equations (4200 compared to about 2500). This new equation should be used cautiously until more data are collected because a data point from a drier year could decrease the slope somewhat closer to the slope from the all data equation.

Table 5-4 summarizes the R-squared values for the old data, all data, and new data for each of the 8 correlations, in addition to the new data correlation for UT 13.

Table 5-4: R-squared Summary

	R^2 Values		
Station	**Old Data**	**All Data**	**New Data**
UT 9	0.47	0.29	0.98
UT 13	-	-	0.67
UT 18	0.90	0.63	0.99
UT 27	0.75	0.74	0.68
UT 38	0.30	0.16	0.63
UT 42	0.31	0.14	0.89
UT 43	0.14	0.47	0.80
UT 47	0.33	0.57	1.00
UT 51	0.91	0.83	0.99

Considerable uncertainty remains as to the magnitude and nature of significant flowrate correlation changes. The results were weakened by the fact that only three years of data (three correlation point) were obtained and all were well above average water years. Obviously, a longer monitoring period and a wider range of climatological conditions are desirable. And at this juncture we conclude that some additional years of sampling are highly desirable, a bonus would be drier years. For this reason it is suggested that sampling continue through the 2012 water year and preferably longer; again, a bonus would be some drier years. This would provide valuable data points for each correlation to strengthen the conclusions.

The three years during which this study was conducted were especially wet years. Precipitation in the valley was much higher than the 30 year average. For example, the Provo weather station records the 2009-2011 average as 23.14 inches while the 30 year average is 20.13 inches. The 2009-2011 average in Spanish Fork is 25.74 inches while the 30 year average is only 21.55 inches. The 47-year average flow for the Provo River at Woodland is 211 cfs, and the 2009-2011 average was 257 cfs. The Woodland site was considered instead of the gaging station near Provo's Geneva Road because the flow below Deer Creek dam is regulated. The flow in the Spanish Fork River was also much higher than the long term average. Measured flows at the USGS gaging site at Castilla for the past three years average 287 cfs while the 83-year average is only 237 cfs. Flow and precipitation data are needed from dry years to ensure the correlations represent all precipitation trends and not just the wet ones.

UT 13 (American Fork River) and UT 48 (Spanish Fork River) must also be considered for additional work. Because of inconclusive data and the discontinuation of the gaging stations on these tributaries, it is suggested that flow measurements on the American Fork River and Spanish Fork River be continued. Correlations may be stronger using a time of year relationship or a diversion pattern relationship where the flow is based on the season or month. Obtaining more data for these sites will help determine whether or not a time of year or diversion pattern correlation would be better. It is hoped that continuing research on Utah Lake will improve the correlations and ultimately the LKSIM water quality model of Utah Lake.

A main objective of this study was to generate information to help decide if there is a need for a similar study for the balance of the tributary flows to Utah Lake. In favor of new studies is the fact that rather large flow and correlation differences were found for several of the tributaries evaluated in this study. However, as in the past, the relatively small contributions of the remaining tributaries hints that differences in these smaller flows may not result in appreciable differences in the overall water and salt balances for Utah Lake. The continuing key component needed to answer this question is the effect on the overall water and salinity balances for Utah Lake.

Therefore, we recommend that the results of this study be incorporated into the LKSIM model and simulation studies done to determine the effect of the new inflow and quality data on Utah Lake simulation results.

REFERENCES

Blankenstein, I. V. (1992). Utah Lake Tributary Correlations and Precipitation Determinations for the Utah Lake Water Quality Salinity Model. Provo: Brigham Young University.

Psomas / SWCA Environmental Consultants. (2007). Utah Lake TMDL: Pollutant Loading Assessment and Designated Beneficial Use Impairment Assessment. Salt Lake City.

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APPENDIX A. PRECIPITATION DATA

Data tables are found on the following pages.

Table A-1: Original Precipitation Indices

Water Year	Lehi	Provo	Average Valley (Lehi, Provo, Santaquin)	Santaquin
1930	12.1	9.8	12.7	16.1
1931	6.6	7.5	8.3	10.9
1932	11.2	10.7	13	17.2
1933	6.9	6.9	8.9	12.8
1934	7.1	5.9	7.3	8.8
1935	9.4	10.9	11.4	13.9
1936	10.3	11.4	12.5	15.7
1937	11.3	12.6	13.4	16.4
1938	9.9	11.2	12.3	15.9
1939	8.8	10.2	12.1	17.2
1940	9.4	11.2	11.4	13.5
1941	14.7	15.6	17.3	21.5
1942	10.5	12.4	13.1	16.3
1943	8.8	9.5	10.9	14.3
1944	11	13.3	12.7	13.9
1945	12.8	15.1	15.3	18.1
1946	8.3	11.5	11.1	13.5
1947	13.3	13.9	14.8	17.1
1948	8.9	9.9	11.1	14.5
1949	10	12.1	12.7	16
1950	7.8	11.8	11.7	15.4
1951	12.7	12.6	13.4	14.8
1952	12.6	15.7	15.5	18.1
1953	7.8	8.3	9.6	12.8
1954	6.6	10.3	11.1	16.4
1955	9.2	11.1	12.5	17.1
1956	6.4	7	8.9	13.2
1957	10	12.3	12.6	15.6
1958	8.5	11.5	12.1	16.2
1959	8.9	12.8	12.7	16.4
1960	6.7	8.5	9.2	12.5
1961	9.2	11.2	12	
1962	12.3	14.7	14.8	17.5
1963	10.3	10.4	11.5	13.7
1964	13.3	12	13.7	15.7
1965	13.2	12.1	14.8	19
1966	8.5	8.5	10.5	14.4
1967	13.7	12.2	14.8	18.6
1968	12.9	15.1	15.5	18.4
1969	10.3	12.6	13.3	16.9
1970	10.1	16.6	14.8	17.8
1971	11.3	14.8	14.3	16.9
1972	7.7	9.5	9.8	12.25
1973	14	16.9	16.3	18.1
1974	5.4	8.2	8.3	11.3
1975	13	13.8	13.5	13.8
1976	10.2	11.6	11.6	13
1977	8.5	9.4	9	9.1
1978	14.1	13.6	13.3	12.1
1979	8.4	10.5	9.7	10.3
1980	10.7	12.5	12.8	15.1
1981	9.9	12	12.2	14.8
1982	12.6	14.4	13.9	14.8
1983	16.9	19.9	19.3	21.1
1984	15.3	18	17.1	18.1
1985	12.7	15.2	15.2	17.8
1986	13.6	19	16.3	16.4
1987	9.2	10.9	10.5	11.3
1988	10.1	9.3	11.4	14.9
1989	8.9	12.8	11.2	11.8
1990	7.6	10.7	10.8	14.2
1991	13.7	14	14.8	16.6
1992	10.7	11.5	11.4	11.9
1993	15.6	17.3	17.4	19.3
1994	11.1	10.6	11.8	13.8
1995	16.1	16.5	17	18.5
1996	9.4	13.2	12	13.4
1997	15.1	15	16.6	19.8
1998	17.1	16	17.2	18.6
2008	-	9.43	-	17.97
2009	-	12.78	-	15.44
2010		10.59		12.79
2011	-	13.79	-	17.78

Table A-2: New Precipitation Indices

Water Year	Alpine	Spanish Fork	Average Valley (Alpine, Provo, Santaquin)
2008	14.47	14.81	14.91
2009	18.90	17.58	16.68
2010	17.27	14.92	14.17
2011	18.84	18.59	17.30

APPENDIX B. DISCHARGE DATA

Table B-1: Measured Discharge Data

Sampling Date	Measured Flow (cfs)											
	UT 9	**UT 13**	**UT 18**	**UT 20**	**UT 27**	**UT 27A**	**UT 29**	**UT 38**	**UT 38A**	**UT 38B**	**UT 42**	**UT 43**
5-Mar-09	14	10	16.5	7.8	5.5	-	106	1.5	-	-	12	18
11-Apr-09	12	13	18.1	8	5	-	218	1.8	-	-	15	16
30-Apr-09	16.5	40	35	11	5.7	-	839	1.7	-	-	13	18
12-May-09	7	100	36	13	4	-	710	12?	-	-	12	19
2-Jun-09	16	190	30	16	6.5	-	1010	2.3	-	-	12	20
23-Jun-09	16	110	32	32	5.5	14.1	764	2.3	23.7	-	17	20
21-Jul-09	11	10	23	11	10	13.6	180	1.8	25.8	-	15	19
25-Aug-09	7	5	25	16	3	14.8	95	1.5	21.2	-	10	20
28-Sep-09	13	5	32	14	3	11.8	46	2.0	20.7	-	8	16
26-Oct-09	17	3	19	6	4	11.5	149	1.5	20.3	24	10	15
16-Nov-09	14	3	13	-	4.5	11.0	160	1.5	21.4	28	12.5	14
16-Dec-09	14	3	15	5	5	12.0	-	1.5	22.3	28	15	14
26-Jan-10	14	3	19	-	6	12.4	190	1.5	19.0	28	13	14
16-Feb-10	13	2	17	6	6	12.6	141	1.5	17.5	25	11	18
17-Mar-10	10	4	18	-	4	12.0	104	2.0	18.7	22	12	17
14-Apr-10	7	4	18	-	6	12.7	198	2.5	20.4	26	12	16
11-May-10	11	2	20	-	6	12.2	516	3.0	20.9	29	11	21
27-May-10	13	5	40	-	6	13.2	230	4.0	23.4	29	13	20
8-Jun-10	7.5	200	22	-	7.5	13.0	117	5.0	21.7	26	11	17
30-Jun-10	8	10	14	-	8	13.2	65	5.0	21.2	28	10	20
20-Jul-10	5	2	16	-	4	13.3	44	3.0	21.2	20	10.5	16
17-Aug-10	6	6	21	-	4	15.4	64	2.0	21.5	28	10	13
14-Sep-10	7	5	22	-	5	13.2	55	3.0	21.4	25	7	10
19-Oct-10	8	13	17	-	9	12.4	83	4.0	21.0	27	7	12
16-Nov-10	11	2	19	-	4	12.1	95	3.0	21.2	18	9	17
28-Dec-10	16	5	24	6	6	12.7	210	3.0	23.4	29	12	19
18-Jan-11	17	7	25	-	8	13.6	408	3.0	23.4	30	12	17
21-Feb-11	15	7	24	-	6	11.2	490	3.0	22.6	23	11	20
22-Mar-11	13	8	15	-	6	12.5	455	3.0	23.2	26	8	20
19-Apr-11	14	100	24	-	7	15.5	1240	4.0	26.6	40	10	19
10-May-11	15	130	35	-	8	13.5	1150	7.0	26.9	35	9	20
30-May-11	25	370	50	-	8	12.5	1470	15.0	33.6	50	10	30
21-Jun-11	20	300	32	-	8	-	564	11.0	-	34	12	30

Table B-1 Continued.

Sampling Date	Measured Flow (cfs)											
	UT 43A	**UT 43B**	**UT 44**	**UT 47**	**UT 47A**	**UT 47B**	**UT 48**	**UT 51**	**UT 51A**	**UT 51B**	**UT 53**	**UT 71**
5-Mar-09	-	-	30	19	-	-	150	60	-	-	19	20
11-Apr-09	-	-	98	24	-	-	250	60	-	-	163	19.4
30-Apr-09	-	-	177	29	-	-	350	100	-	-	1035	24
12-May-09	-	-	201	30	-	-	450	105	-	-	1066	22
2-Jun-09	-	-	82	37	-	-	80	52	-	-	1105	23
23-Jun-09	6.4		41	39	7.7	-	90	60	2.6	-	1057	24
21-Jul-09	5.4		1.4	17	6.7	-	80	13	2.4	-	397	25
25-Aug-09	6.5		4	14	7.4	-	10	15	2.4	-	371	27
28-Sep-09	6.1		4.4	34	6.8	-	180	36	2.3	-	320	25
26-Oct-09	5.3	10	32	25	6.7	12	160	35	2.3	15	13	25
16-Nov-09	5.26	10	31	22	6.96	15	140	35	2.2	-	5	-
16-Dec-09	6.65	10	30	19	7.06	17	120	36	2.2	12	-	-
26-Jan-10	5.73	11	28	19	7.12	13	125	40	1.9	14	6	-
16-Feb-10	5.07	11	29	19	6.65	15	135	48	2.1	15	884	-
17-Mar-10	5.39	11	30	20	6.04	14	145	48	2.29	15	849	-
14-Apr-10	5.21	12	44	16	6.19	11	140	42	2.72	16	400	-
11-May-10	6.09	14	65	13	7.12	7	150	35	2.28	15	466	-
27-May-10	5.9	14	56	25	7.74	17	140	70	2.37	14	361	-
8-Jun-10	5.87	14	53	30	6.81	3	120	32	2.37	12	537	-
30-Jun-10	5.96	16	0.02	11	7.27	3	45	17	2.38	5	460	-
20-Jul-10	6.76	13	1.3	12	6.96	15	30	16	2.32	7	459	-
17-Aug-10	6.74	11	0.83	21	7.27	18	5	14	2.45	5	451	-
14-Sep-10	6.15	8	4.4	20	6.81	18	85	7	2.46	4	436	-
19-Oct-10	6.09	9	17	20	6.5	16	135	24	2.34	12	164	25
16-Nov-10	6.11	12	30	23	6.96	15	150	28	2.35	18	38.8	22
28-Dec-10	6.73	15	43	25	7.58	21	120	55	2.24	34	33.7	24
18-Jan-11	6	13	41	31	6.5	18	180	58	2.12	22	22	25
21-Feb-11	6.05	14	31.5	25	7.12	16	160	120	2.24	58	29	24
22-Mar-11	6.3	13	65	22	7.12	20	260	65	2.26	25	1223	27
19-Apr-11	7.05	15	507	30	8.2	15	800	120	3.44	33	1039	25
10-May-11	7.44	15	503	23	8.2	21	1150	130	2.48	34	1309	26
30-May-11	6.88	22	356	32	8.36	14	1180	150	2.63	35	1280	27
21-Jun-11	-	22	195	17	-	-	350	75	-	30	-	27