A Study of Salinity in the Lower South Platte Basin

Annual Summary - Fiscal Year 2005
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Conducted by:
Northern Colorado Water Conservancy District

In Cooperation with:
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1. Project Overview

In 2005 the Northern Colorado Water Conservancy District (District), in cooperation with the United States Bureau of Reclamation (Reclamation), completed its fifth year of the seven-year assessment project entitled, “A Study of Salinity in the Lower South Platte Basin,” agreement number 00FC601426. In continuing the precedent set in previous years, the District collected and compiled salinity data from a network of automated and manual surface water monitoring stations, groundwater observation wells, and agricultural soils.

The 2005 growing season was favorable to many growers throughout the Lower South Platte Basin. Good spring moisture and timely rains provided for an average to above-average irrigation season. Furthermore, many irrigation canals and reservoir companies reported a return to normal deliveries for the year, compared to lower than usual deliveries in several previous years due to drought. These favorable conditions allowed many growers to reestablish their planting acres that were rotated into fallow during recent years. Additionally, groundwater well users became more content with augmentation policies, as sufficient streamflows were maintained during the summer months. Lastly, while most municipalities have suspended watering restrictions enforced over the last few years, those that remain in place limiting outdoor watering have been greatly relaxed when compared to restrictions in previous years. District constituents have reason to be hopeful that Northern Colorado may be slowly emerging from drought conditions experienced in 2000 and 2001.

Surface water data presented in Section 2 were collected from 26 automated and 76 manual electrical conductivity monitoring stations in 2005. The only change in this sampling scheme from 2004 was a slight reduction in the number of sites monitored along two irrigation drainage canals. In addition to the electrical conductivity monitoring, 10 grab samples were collected twice during 2005 and sent to an outside laboratory for a complete total dissolved solids analysis. Overall, surface water sampling was successful and resulted in significantly increasing the District’s ever-expanding database.

Furthermore, during the 2005 sampling season the District monitored 42 groundwater wells. This network of wells spanning District boundaries was measured for electrical conductivity and depth. The complied data are presented in Section 3. While data from 75 additional groundwater wells have been requested from cooperating entities, they have not yet been made available and are therefore not presented at this time.

The soil assessment facet of this study encountered mixed productivity in 2005. The District was encouraged by the sheer number of fields it was able to survey. Thirty fields, totaling approximating 1,800 acres, were surveyed. Thirteen of these fields were surveyed in the spring via a Geonics Incorporated Electromagnetic Induction Meter Dual-Dipole (EM38-DD). Upon analysis in the laboratory and through a Sampling, Assessment and Prediction Model (ESAP) the District became aware of problems; correlations that should have been present between the laboratory and field data were lacking in quite a few instances. After unsuccessfully attempting to find and correct the root causes of these problems, the District switched its surveying technique in the fall. A grid sampling method was employed to survey and collect data. In the second half of the 2005 soil sampling year, 17 fields were surveyed using this grid sampling technique. The data from these latter fields has yet to be analyzed; it will be included in the 2006 annual report. Section 4 further outlines the surveying problems the District encountered and the associated solutions, as wells as the soil data gathered and analyzed in 2005.

As with any study, it is imperative to implement and adhere to rigid sampling and analyzing quality assurance and quality control guidelines. Such guidelines help guarantee data and valid and meaningful. These procedural checks employed by the District are thoroughly discussed in Section 5. Lastly, Section 6 presents in tabular form a summary of the budget and expenses for the 2005 fiscal year.

With several years of data collected so far, the District has begun the process of compiling it in order to enter it into the Environmental Protection Agency's national STORET (short for STOrage and RETrieval) database. The amount of data, in conjunction with the intricacies of the STORET program, has hindered the progress of this process. However, the District foresees completing this task during the first half of 2006.

The District continues to be appreciative of Reclamation's ongoing support. Moreover, the District would like to thank all cooperating entities that provided, or have allowed for, the collection of salinity-based data. If there are any questions regarding this report please contact the District at (970) 532-7700.

2. Surface Water Electrical Conductivity Sampling

2.1 Introduction and Overview

Electrical Conductivity Monitoring

Surface water sampling conducted for the 2005 study include data gathered from both automated and manual sampling sites located on stream and canal systems throughout the Lower South Platte Basin. Since the study began in 2000, the District has worked on refining the number and location of sampling sites in order to provide an optimal overview of the spatial and temporal variability of the surface water electrical conductivity throughout the basin. The automated sites are primarily co-located with state and federal stream gauging stations, thus allowing for total salt loading calculations to be made at these locations. The manual sampling locations were selected both to fill in the gaps between the automated sites, and to measure the electrical conductivity of the water (EC_w) along several canal systems. In addition to the year-round testing at these manual and automated stations, the District has implemented bi-yearly sampling events aimed at identifying the concentration and composition of several commonly occurring cations and anions that contribute to the EC_w of our rivers. The sum of these ions result in an approximation of overall total dissolved solid (TDS) concentrations for a variety of stream sites within the basin. In addition, their relative concentrations allow for predictions to be made as to the contributing salt compounds.

Automated Electrical Conductivity Sampling

The network of automated electrical conductivity monitoring sites consists of 26 stations. Each station is equipped with a Campbell Scientific CS547A (CS547A) located within the streamflow. The CS547A measures electrical conductivity (normalized to 25^oC) from 0.005 to 7.0 dS/m and water temperature from 0^o to 50^o C. In addition to the electrical conductivity/temperature sensor, each site is equipped with an air temperature sensor and a tipping bucket to measure rainfall (Figure 2.1).

These sensors are used in conjunction with Campbell Scientific CR-10X data loggers (CR-10Xs). The CR-10Xs continuously record EC_w and average the readings over 15-minute intervals. For purposes of this report, the 15-minute data have been condensed to weekly averages in order to smooth short-term variability and highlight general patterns.

In previous years the District utilized Kyocera 2335 cell phones (digital signals) and Motorola brick phones (analog signals) to transfer data from the automated stations to its headquarters. However, not being satisfied with the cost, transfer speed or reliability, in 2005 the District upgraded the telemetry process by installing Code Division Multiple Access (CDMA) modems for remote data access. This has reduced associated costs by half, resulted in a five-fold increase in the data transfer rate and significantly improved the overall telemetry reliability.

Figure 2.1 Automated Electrical Conductivity Sampling Station

The majority of automated sites are co-located with streamflow gauging stations. Where possible, flow data have been compiled in order to calculate salt loading values via the following equation (2.1):

$$Q_{EC_i} = \overline{C}_i \overline{Q}_i t_i k \ ,$$

Equation 2.1 Salt Loading

where Q_{EC_i} = salt load discharge in time interval *i* (English or metric tons),

$\overline{C}_i$ = mean salt concentration for time interval *i* (mg/L),

$\overline{Q}_i$ = mean water discharge for time interval *i* (ft^3/sec or m^3/sec),

t_i = duration of time interval *i* and

k = appropriate conversion factor for units used.

To convert EC_w from deciseimens per meter (dS/m) (which is how this data is recorded) to a salt concentration in milligrams per liter (mg/L), a multiplying factor of 640 has been used in all calculations. It should be noted that this conversion only yields an approximate dissolved solids/salt concentration. The true conversion is complicated by the type of salts present, their relative concentrations and the temperature of the water sample. While all of the sensors used by the District are able to compensate for temperature, they do not have the ability to compensate for different ionic salts (ion chromatography is necessary for such distinctions to be made). Since not all salts conduct an electric current equally, any umbrella conversion from an EC_w reading to a concentration will result in some degree of error. The method used to then extrapolate the calculated salt load to a total annual salt load per sampling site (Q_{EC}) is explained via Equation 2.2:

$$Q_{EC} = \sum_{i=1}^{n} Q_{EC_i} \ ,$$

Equation 2.2 Annual Salt Load

where the sample year has been divided into *n* time intervals.

The flow data used for these calculations are only provisional in most cases. The Colorado Department of Water Resources (DWR) and the United States Geological Survey (USGS), the entities responsible for the gauging stations, review and frequently revise flow data at the end of each water year.

Obtaining accurate data from the automated sites has proven a challenge at some stations. The four major obstacles involved telemetry, siltation, algae and freezing water. The District is hopeful the switch to CDMA modems will continue to reduce telemetry problems encountered in previous years. Siltation and algal interferences are major problems the District continues to grapple with. To address both issues, the automated sites are visited and cleaned at regular intervals and, when necessitated by changing bed and flow configurations, the stations are relocated. The District's experience so far has been that when sensors are located in higher flow areas siltation is reduced. However, this reduced siltation tends to be accompanied by an increased occurrence of algal growth. The District is currently working on methods to find a balance between these two hindrances to accurate data collection. Finally, the issue of freezing water/freezing sensors is one that cannot be avoided at the canyon monitoring locations during the winter months. Yet, in order to maintain accurate data records the District must recognize freezing events and adjust incoming data accordingly. The District has implemented additional quality assurance/quality control measures in 2005 to address the above issues. These procedures have improved the confidence in the accuracy of the automated data and are further discussed in Section 5.

Manual Electrical Conductivity Sampling

Weekly manual sampling was conducted at several sites located between automated stations and along various canal systems. This sampling was accomplished primarily via In-Situ Multi-Parameter Troll 9000s (In-Situs) while Hydrolab Multi-Probe Quantas (Hydrolabs) were used as back-ups. Both instruments measure electrical conductivity (normalized to 25^{o}C), pH, temperature and dissolved oxygen.

All of the manual sampling takes place from bridges or other structures that cross over the given stream, river or canal (Figure 2.2). Sampling protocol requires a minimum of three samples to be taken along the transect of the stream at each location. These data are then averaged to yield a representative value for each of the measured parameters. To be consistent with the automated data, these values are presented as weekly averages.


Figure 2.2 Manual Electrical Conductivity Sampling

In 2004 the District initially began using the In-Situ instruments. In 2005 the In-Situs became the District's primary manual data collection instruments. While the District had experienced great success with the performance and accuracy of the Hydrolab probes, we were anxious to move away from the process of hand recording and entering data. (Hydrolab does offer an upgrade from their Quanta model that allows for the electronic transfer of data. However, the associated software was incompatible with the District's needs.) The In-Situ probes work in conjunction with a RuggedReader, a hand-held display that allows data to be uploaded and downloaded via 9-pin serial RS-232 and USB ports. These RuggedReaders significantly simplify field collections and data transfer. However, it should be noted that the included software, Win-Situ, automatically puts each sampling event or day into its own separate folder. When compiling data collected on a yearly basis with samples taken several times a week, this software feature leads to the creation of data files so numerous that compiling them is incredibly time consuming. To more efficiently deal with these files, the District's computer department wrote a program that extracts relevant data files from their individual daily log folders and compiles them into a single Access database.

While data transfer was simplified by this instrument switch, new problems attributed to the In-Situs arose. It was discovered that if the pH probe was not stored, both in transit and while in the laboratory, at a downward angle, air bubbles could migrate to the tip and interfere with accurate data collection. Moreover, sensor shock, which is the tendency for the probes to require long periods of time to stabilize when deployed due to a rapid change in environment, was encountered when the instruments were carried site-to-site in the cabs of the sampling trucks. To address both of these problems, the District constructed PVC sleeves to house the instruments while in transit (Figure 2.3). These sleeves are mounted in the beds of the District's sampling trucks in an effort to maintain a temperature close to that of the sampling water body. Moreover, they guard against allowing air bubbles to migrate to the tip of the pH probes while ensuring the probes remain hydrated at all times. The District also experienced difficulties with the In-Situs maintaining their calibrations. While the technical support staff at In–Situ, Inc., was very willing to assist in tackling this calibration problem, it continues to be an issue. Calibration procedures are dealt with in greater detail in Section 5.

Figure 2.3 PVC Sleeve for Housing In-Situ Instruments while in Transit

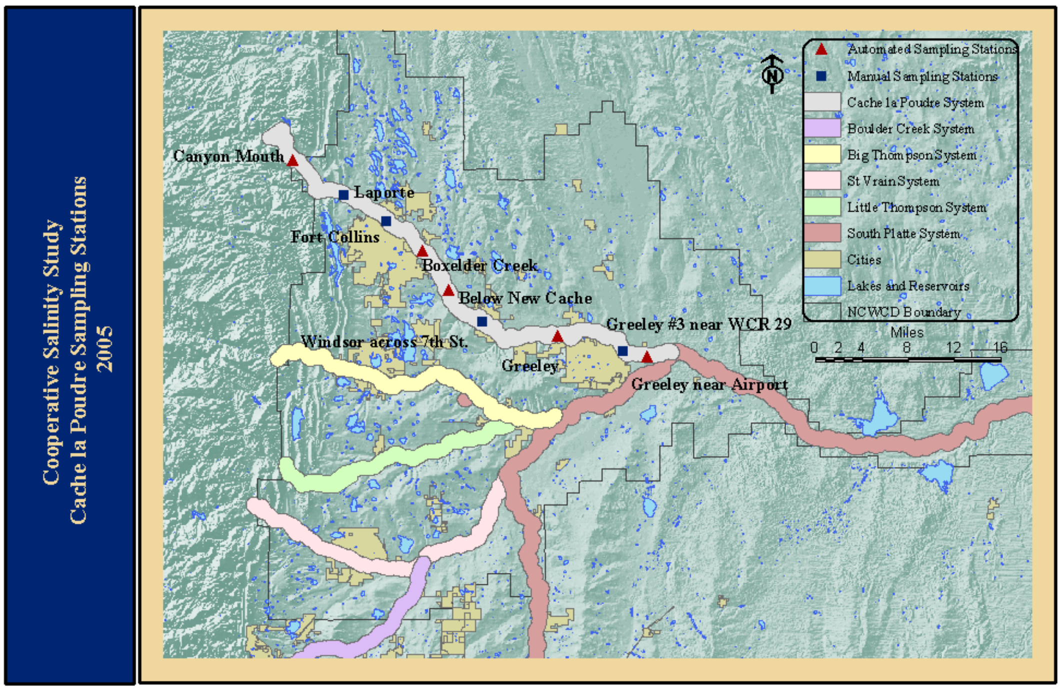
Total Dissolved Solids Sampling

Twice during 2005, once immediately following spring runoff in late May and a second time towards the end of August, grab samples were taken at 10 locations throughout the basin. These grab samples were tested for a wide variety of commonly-occurring salt species. The parameters measured are as follows: sodium, potassium, magnesium, nitrate, sulfate, chloride, carbonate, bicarbonate, total alkalinity and total hardness. The individual sums of these salts yield approximations of the TDS at given locations. Moreover, a comparison of the highest concentrations of both anions and cations from individual samples enable one to speculate as to the original source of the dominant salts in the system.

2.2 Stream and River Systems

Cache la Poudre System

The Cache la Poudre System was monitored for EC_w at nine locations, ranging from the mouth of the Poudre Canyon to just above its confluence with the South Platte River east of Greeley (Map 2.1). Overall EC_w values, streamflow and salt loading statistics are compiled in Table 2.1. Additionally, Figures 2.4 - 2.17 graphically illustrate the annual EC_w and salt loading values as they change with time, space, and streamflow.



Map 2.1 Automated and Manual Sampling Stations - Cache la Poudre System

Site Information			Annual Statistics							Monthly Statistics	
Site Description	Site Abbreviation	Type of Site	Average EC_w (dS/m)	Maximum EC_w (dS/m) / week #	Minimum EC_w (dS/m) / week #	Standard Deviation of EC_w (dS/m)	Average Flow (cfs)	Standard Deviation of Flow (cfs)	Salt Loading (10^3 tons)	Maximum Salt Loading (10^3 tons) /month	Minimum Salt Loading (10^3 tons) /month
Canyon Mouth	CLAFTCCO	automated	0.10	0.18 / 5	0.05 / 30	0.04	275 [1,2]	471	11.1	3.81 / June	0.139 / Jan.
Near Laporte	CLALAPCO	manual	0.25	0.54 / 15	0.05 / 25	0.17	NA[3]	NA	NA	NA	NA
Fort Collins	CLAFORCO	manual	0.36	0.67 / 2	0.06 / 25	0.22	NA[3]	NA	NA	NA	NA
Boxelder Creek	CLABOXCO	automated	0.97	1.80 / 49	0.14 / 21	0.54	71 [4]	162	12.2	4.05 / June	0.212 / Dec.
Below New Cache	CLARIVCO	automated	0.84	1.40 / 14	0.02 / 49	0.40	85 [1]	173	29.9	6.43 /June	1.12 / Nov.
Windsor across 7th St.	CLAWIN7ST	manual	1.06	1.75 / 50	0.31/ 23	0.36	NA[3]	NA	NA	NA	NA
Greeley #3 near WCR 29	CLAGRLCO	automated	1.25	1.80 / 49	0.14 / 21	0.35	NA[3]	NA	NA	NA	NA
Greeley	CLPGREELEY	manual	1.40	1.89 / 16	0.39 / 23	0.33	NA[3]	NA	NA	NA	NA
Greeley near Airport	CLAGRECO	automated	1.24	1.75 / 1	0.44 / 44	0.33	114 [1]	180	70.3	11.9 / June	2.28 / Sept.

Table 2.1 Annual and Monthly Statistics - Cache la Poudre System

[1] Provisional DWR flow data
[2] No flow data for December
[3] Flow data not available for this location
[4] Provisional USGS flow data

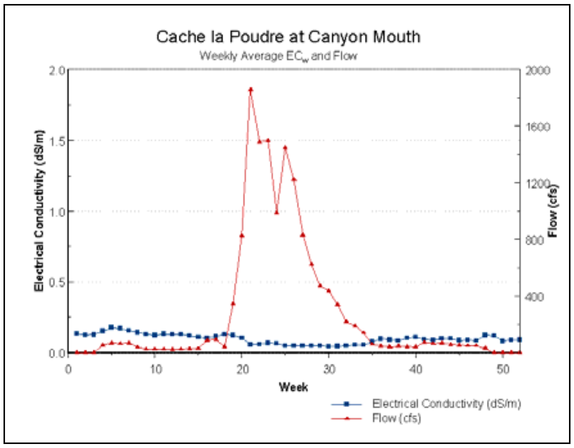


Figure 2.4 Weekly Average EC_w and Flow
Cache la Poudre at Canyon Mouth

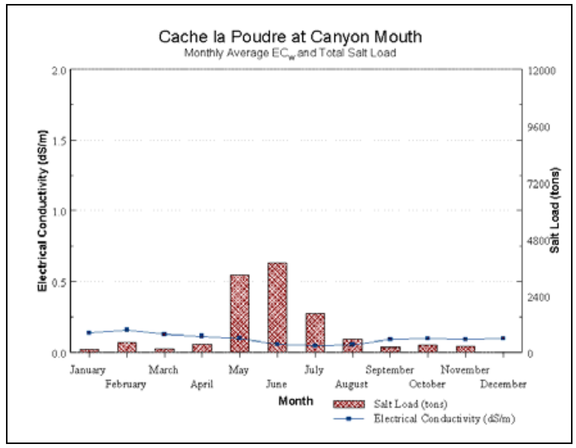


Figure 2.5 Monthly Average EC_w and
Total Salt Load
Cache la Poudre at Canyon Mouth

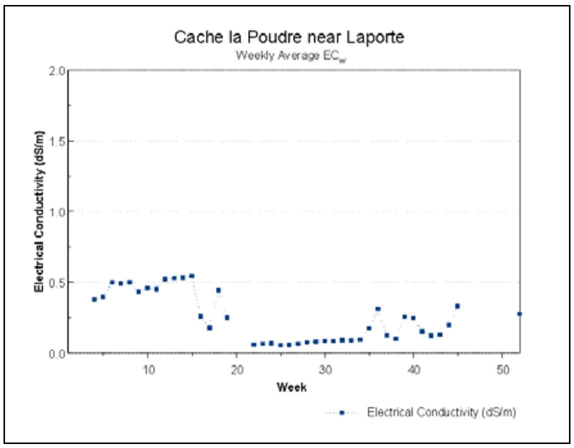


Figure 2.6 Weekly Average EC_w
Cache la Poudre near Laporte

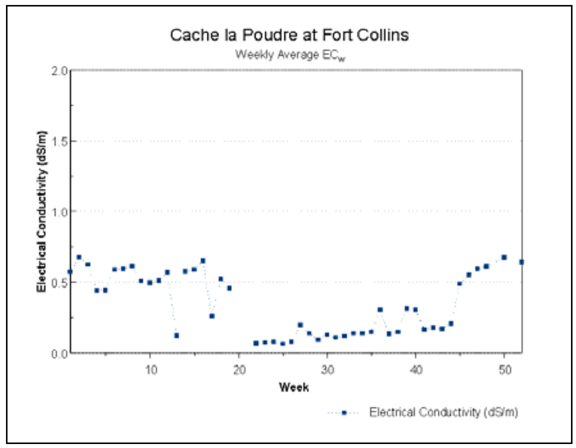


Figure 2.7 Weekly Average EC_w
Cache la Poudre at Fort Collins

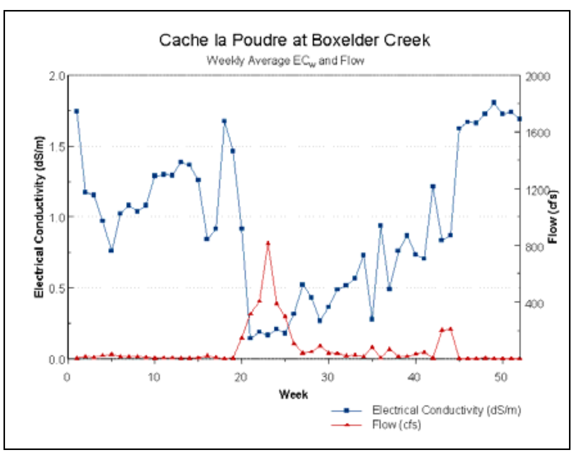


Figure 2.8 Weekly Average EC_w and Flow
Cache la Poudre at Boxelder Creek

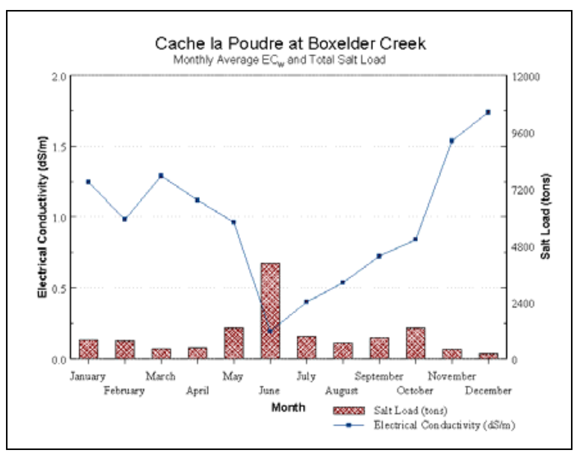


Figure 2.9 Monthly Average EC_w and
Total Salt Load
Cache la Poudre at Boxelder Creek

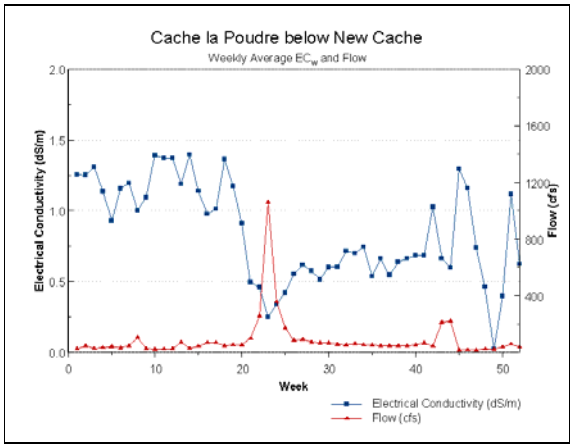


Figure 2.10 Weekly Average EC$_w$ and Flow
Cache la Poudre below New Cache[5]

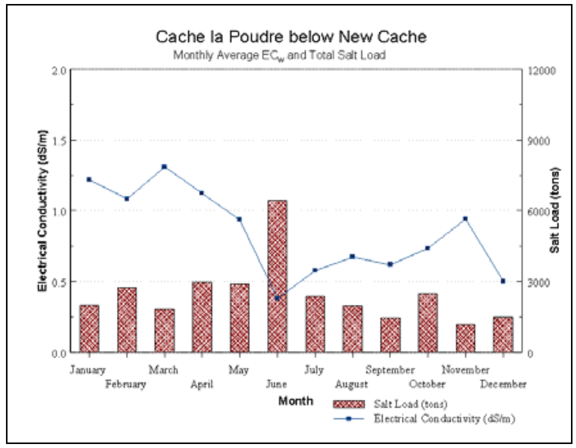


Figure 2.11 Monthly Average EC$_w$ and Total Salt Load
Cache la Poudre below New Cache

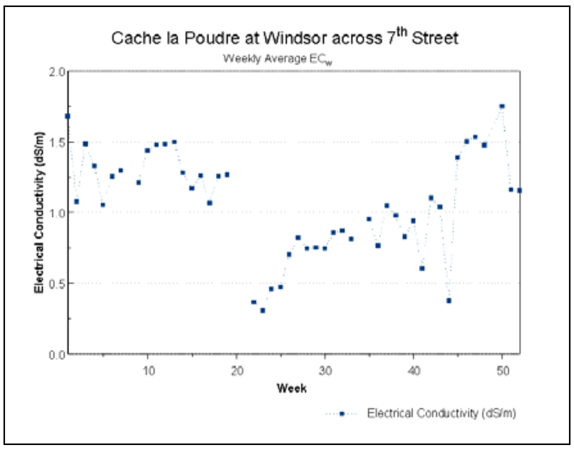


Figure 2.12 Weekly Average EC$_w$
Cache la Poudre at Windsor across
across 7th Street

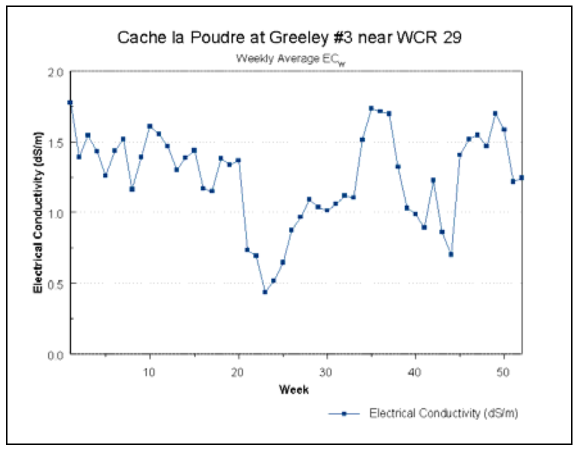


Figure 2.13 Weekly Average EC$_w$
Cache la Poudre at
Greeley #3 near WCR 29

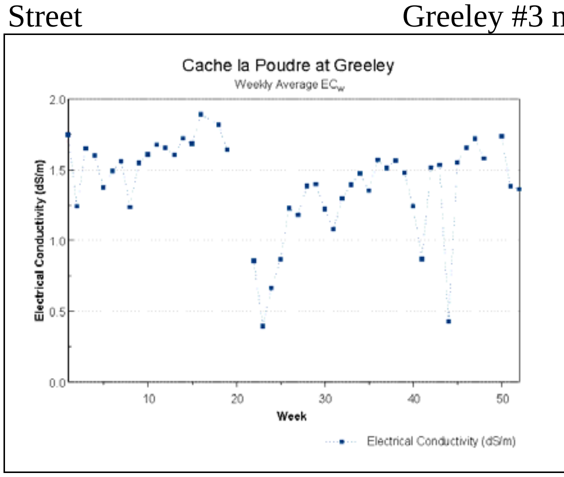


Figure 2.14 Weekly Average EC$_w$
Cache la Poudre at Greeley

[5]Beginnig in October, reduced flows caused the sensor at this site to repeatedly be out of the water. The conduit housing the sensor has been relocated several times in attempts to remedy this problem.

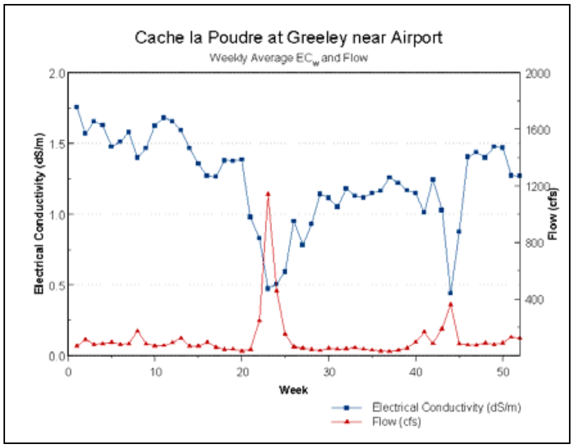


Figure 2.15 Weekly Average EC$_w$ and Flow Cache la Poudre at Greeley near Airport

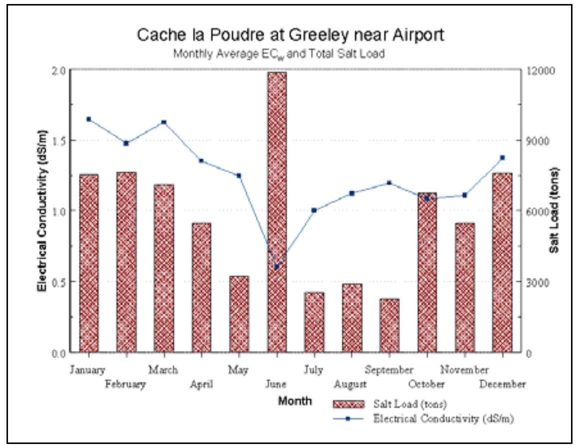


Figure 2.16 Monthly Average EC$_w$ and Total Salt Load Cache la Poudre at Greeley near Airport

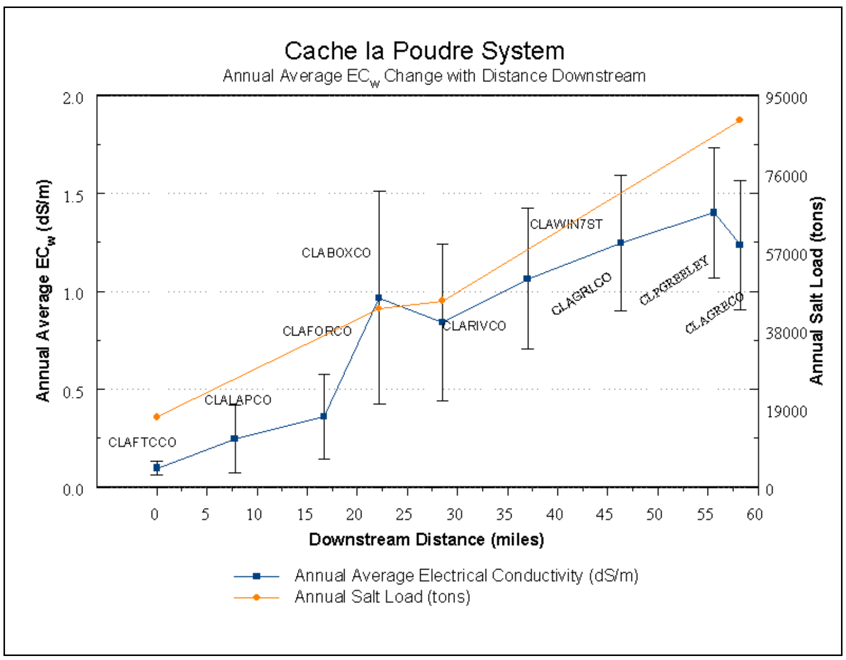
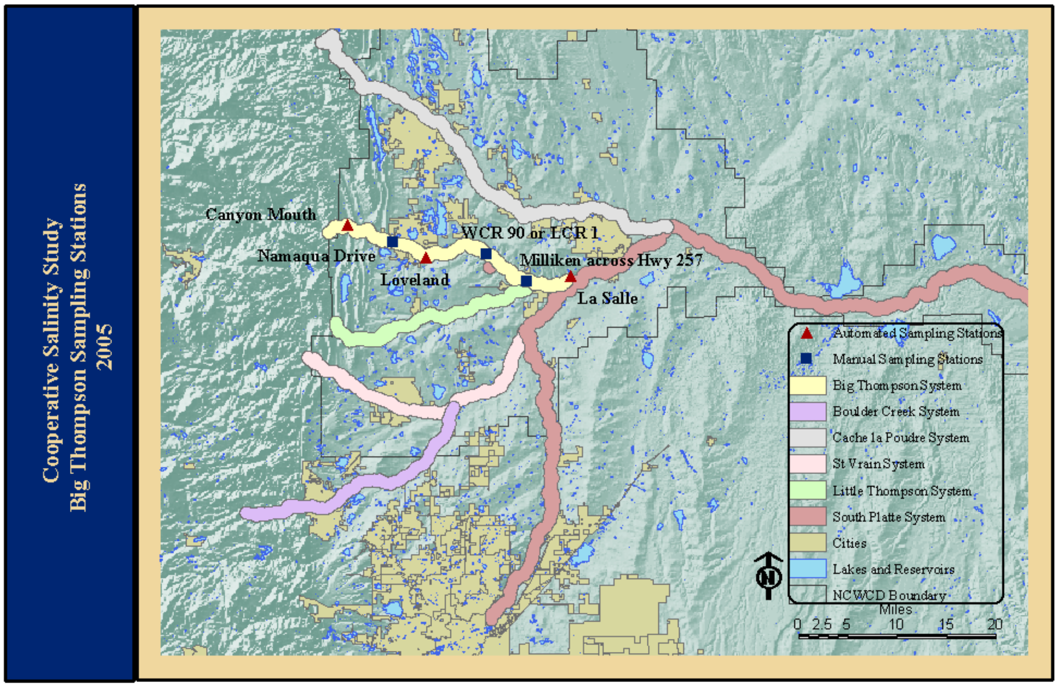


Figure 2.17 Annual Average EC$_w$ and Salt Load with Distance Downstream - Cache la Poudre System

Big Thompson System

The Big Thompson System was sampled at six locations from the mouth of the Big Thompson Canyon near Loveland to directly upstream of its convergence with the South Platte River in La Salle (Map 2.2). Table 2.2 contains average and monthly statistics for this system. Graphs of EC_w and salt loading values as they change with time, space and streamflow are presented in Figures 2.18 – 2.27.



Map 2.2 Automated and Manual Sampling Stations - Big Thompson System

Site Information			Annual Statistics							Monthly Statistics	
Site Description	**Site Abbreviation**	**Type of Site**	**Average EC_w (dS/m)**	**Maximum EC_w (dS/m) / week #**	**Minimum EC_w (dS/m) / week #**	**Standard Deviation of EC_w (dS/m)**	**Average Flow (cfs)**	**Standard Deviation of Flow (cfs)**	**Salt Loading (10^3 tons)**	**Maximum Salt Loading (10^3 tons) /month**	**Minimum Salt Loading (10^3 tons) /month**
Canyon Mouth	BTCANYCO	automated	0.06	0.15 / 14	0.03 / 29	0.03	80 [6,7]	59	1.89	0.428 / May	0.122 / Sept.
Namaqua Drive	BTCACRNAMQ	manual	0.45	1.12 / 7	0.06 / 26	0.35	NA[8]	NA	NA	NA	NA
Loveland	BIGLOVCO	automated	0.73	1.73 / 7	0.18 / 26	0.46	64 [9]	84	1.61	0.276 / June	0.473 / Feb.
Across WCR 90 or LCR 1	BTACRLCWC	manual	0.85	1.3 / 5	0.12 / 26	0.31	NA[8]	NA	NA	NA	NA
Miliken at Hwy 257	BTMILH257	manual	1.02	1.44 / 8	0.17 / 26	0.35	NA[8]	NA	NA	NA	NA
Near La Salle	BIGLASCO	automated	1.21	1.64 / 16	0.32 / 26	0.27	79 [6]	80	51.9	8.25 / June	2.38 / Sept.

Table 2.2 Annual and Monthly Statistics - Big Thompson System

[6] Provisional DWR flow data
[7] No flow data for January, February or December
[8] Flow data not available for this location
[9] Provisional USGS flow data

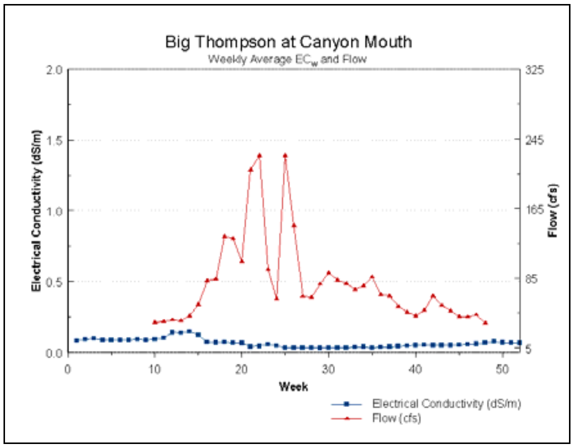


Figure 2.18 Weekly Average EC_w and Flow
Big Thompson at Canyon Mouth

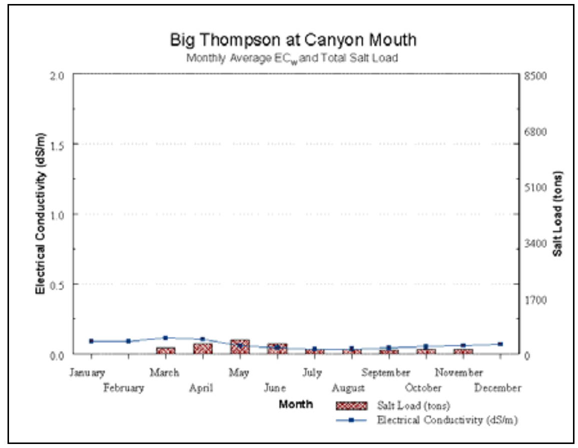


Figure 2.19 Monthly Average EC_w and
Total Salt Load
Big Thompson at Canyon Mouth

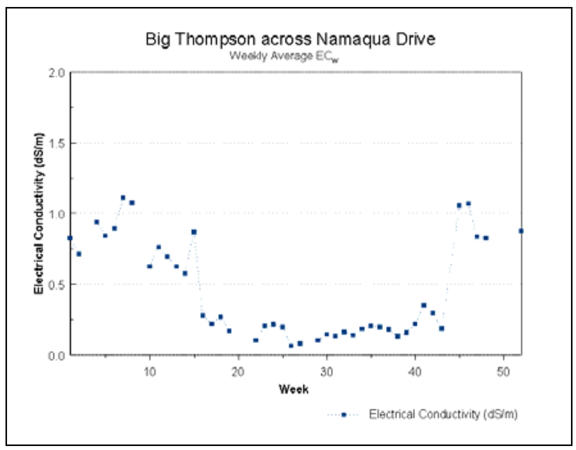


Figure 2.20 Weekly Average EC_w
Big Thompson across Namaqua Drive

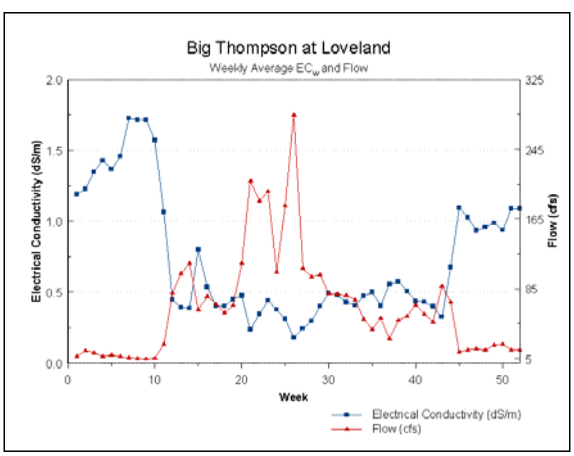


Figure 2.21 Weekly Average EC_w and Flow
Big Thompson at Loveland

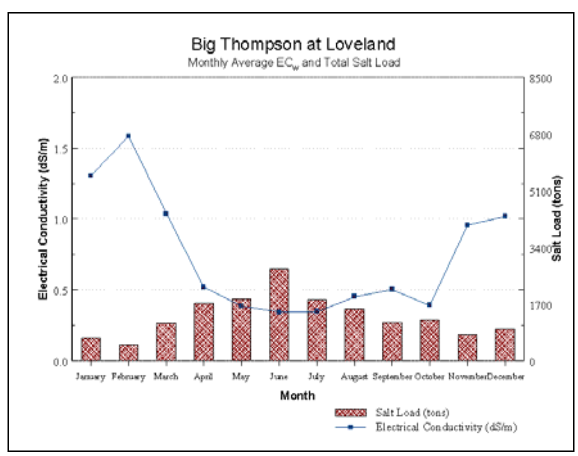


Figure 2.22 Monthly Average EC_w and
Total Salt Load
Big Thompson at Loveland

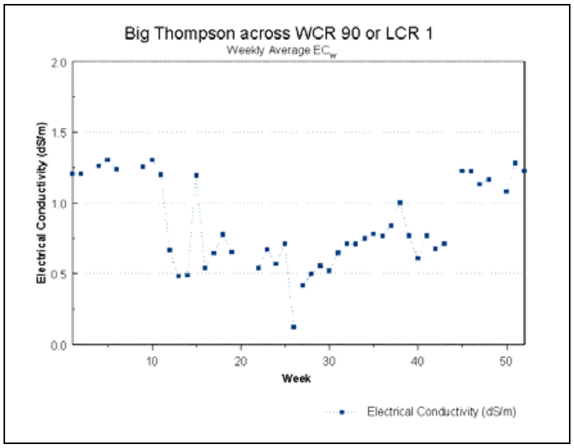


Figure 2.23 Weekly Average EC_w
Big Thompson across WCR 90 or LCR 1

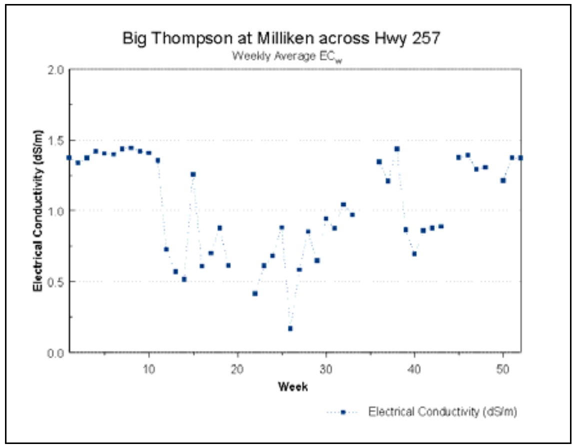


Figure 2.24 Weekly Average EC_w
Big Thompson at Milliken across Hwy 257

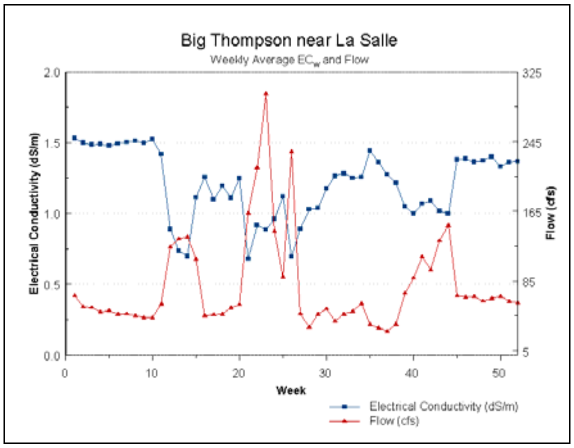


Figure 2.25 Weekly Average EC_w and Flow
Big Thompson near La Salle

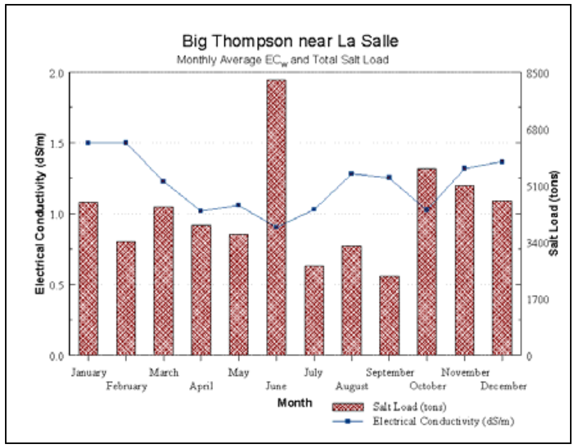


Figure 2.26 Monthly Average EC_w and
Total Salt Load
Big Thompson near La Salle

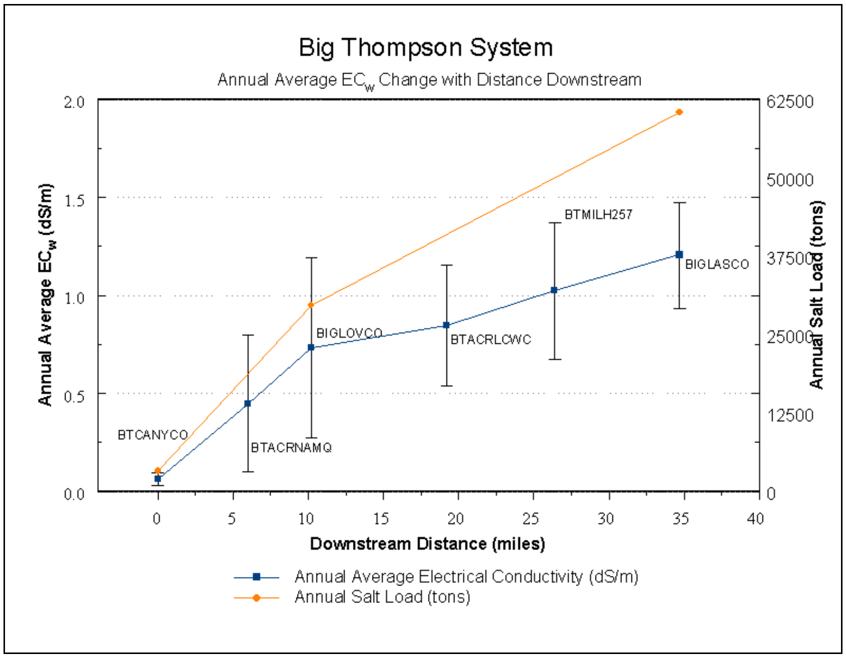
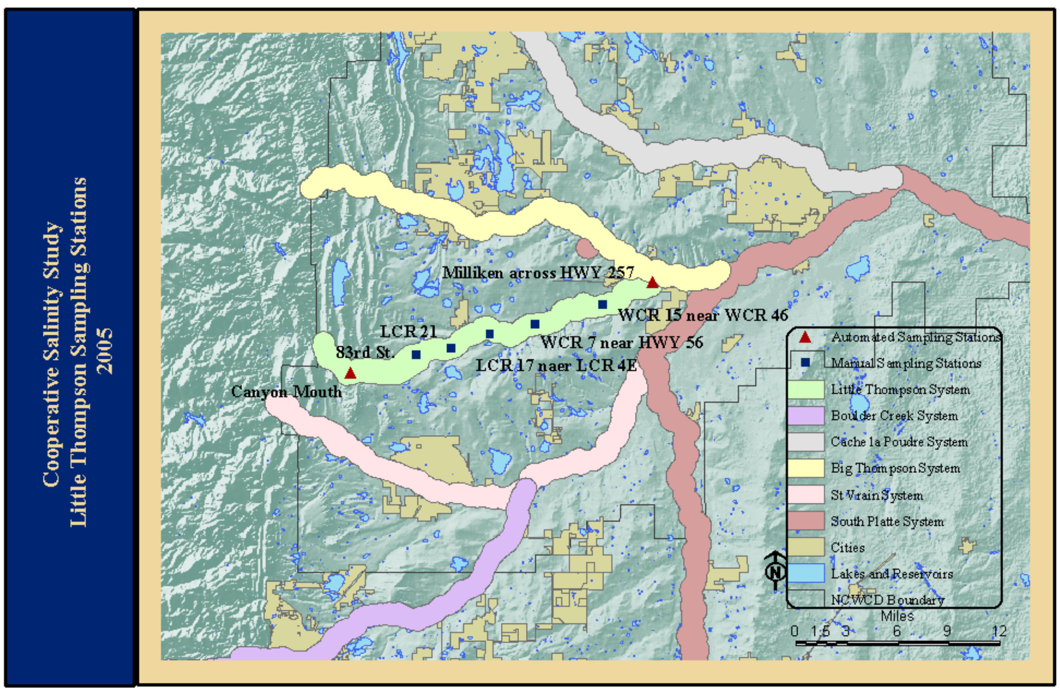


Figure 2.27 Annual Average EC_w and Salt Load with Distance Downstream - Big Thompson System

Little Thompson System

The Little Thompson System was sampled at seven locations ranging from the canyon mouth north of Rabbit Mountain to just above the river's convergence with the Big Thompson River near Milliken (Map 2.3). The majority of the EC_w monitoring along this tributary is accomplished via manual sampling. Only two of the seven monitoring stations are automated and there exists only a single gauging station that measures streamflow. A compilation of annual and monthly statistics for this system is located in Table 2.3. Moreover, Figures 2.28 - 2.36 graphically depict the annual, temporal and spatial changes in EC_w and salt loading values.



Map 2.3 Automated and Manual Sampling Stations - Little Thompson System

Site Information			Annual Statistics							Monthly Statistics	
Site Description	**Site Abbreviation**	**Type of Site**	**Average EC_w (dS/m)**	**Maximum EC_w (dS/m) / week #**	**Minimum EC_w (dS/m) / week #**	**Standard Deviation of EC_w (dS/m)**	**Average Flow (cfs)**	**Standard Deviation of Flow (cfs)**	**Salt Loading (10^3 tons)**	**Maximum Salt Loading (10^3 tons) /month**	**Minimum Salt Loading (10^3 tons) /month**
Canyon Mouth	LTCANYCO	automated	0.47	0.97 / 50	0.11 / 19	0.25	9 [10,11]	21	1.89	0.483 / June	0.018 / Sept.
83rd Street near Boulder & Weld County Line	LTACR83ST	manual	0.62	0.81 / 30	0.04 / 24	0.17	NA[12]	NA	NA	NA	NA
LCR 21 near Boulder & Weld County Line	LTACRLC21	manual	1.20	1.68 / 51	0.56 / 33	0.28	NA[12]	NA	NA	NA	NA
LCR 17 near 4E	LTACRLC17	manual	1.61	2.28 / 52	0.76 / 29	0.33	NA[12]	NA	NA	NA	NA
WCR 7 near Hwy 56	LTACRWC7	manual	2.26	2.93 / 41	0.91 / 2	0.36	NA[12]	NA	NA	NA	NA
WCR 15 near 46 Rd	LTACRWC15	manual	2.14	2.64 / 15	1.23 / 30	0.33	NA[12]	NA	NA	NA	NA
Near Platteville	LTMIL257	automated	1.97	2.35 / 20	1.47 / 28	0.21	NA[12]	NA	NA	NA	NA

Table 2.3 Annual and Monthly Statistics - Little Thompson System

[10] Provisional DWR flow data
[11] No flow data for January, February or December
[12] Flow data not available for this location

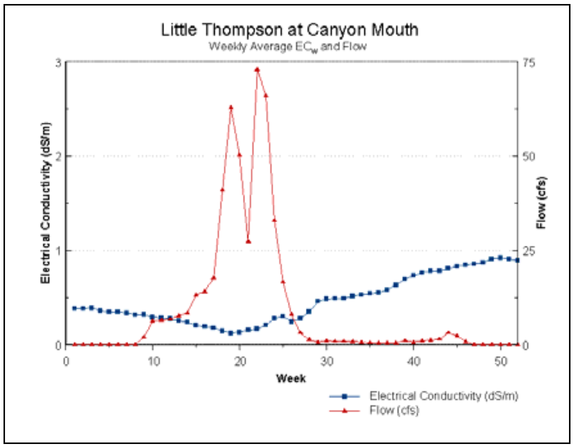


Figure 2.28 Weekly Average EC_w and Flow
Little Thompson at Canyon Mouth

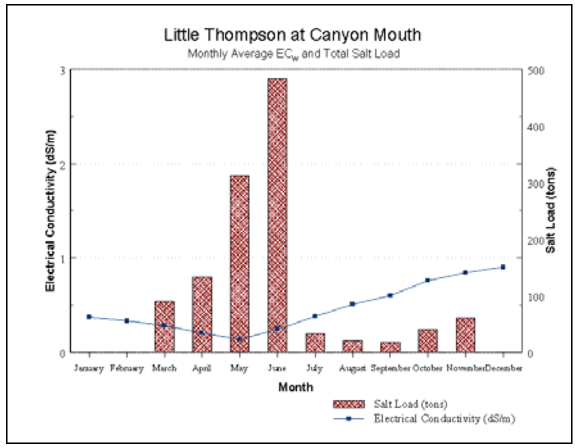


Figure 2.29 Monthly Average EC_w and
Total Salt Load
Little Thompson at Canyon Mouth

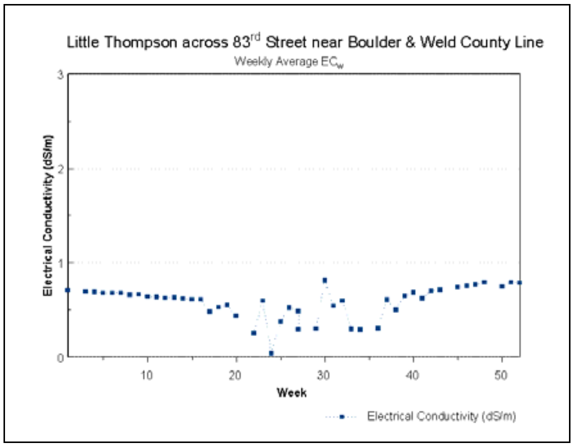


Figure 2.30 Weekly Average EC_w
Little Thompson across 83rd Street near
Boulder and Weld County Line

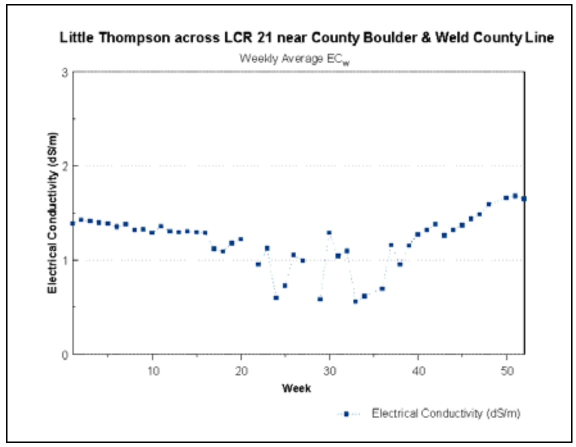


Figure 2.31 Weekly Average EC_w
Little Thompson across LCR 21 near
Boulder and Weld County Line

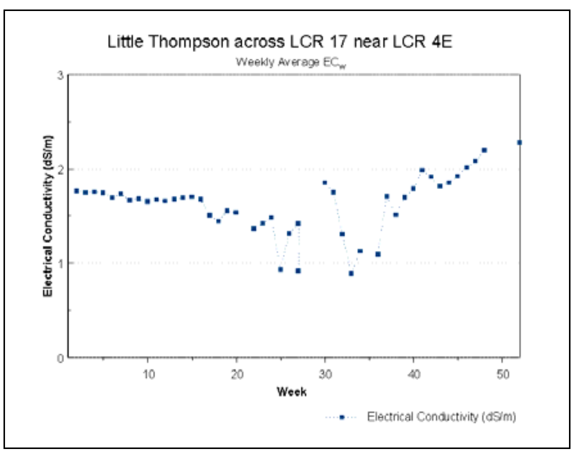


Figure 2.32 Weekly Average EC_w
Little Thompson across LCR 17
near LCR 4E

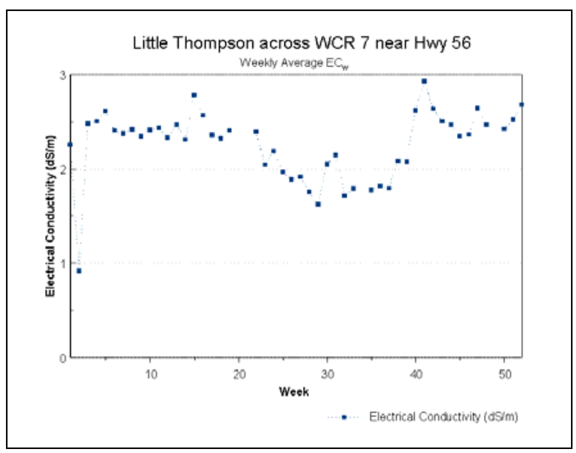


Figure 2.33 Weekly Average EC_w
Little Thompson across WCR 7
near Hwy 56

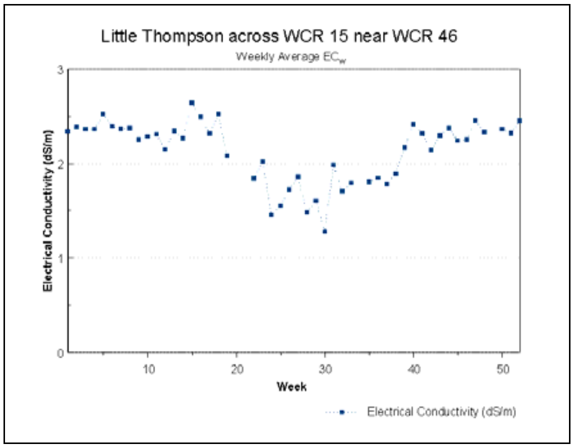


Figure 2.34 Weekly Average EC_w
Little Thompson across WCR 15
near WCR 46

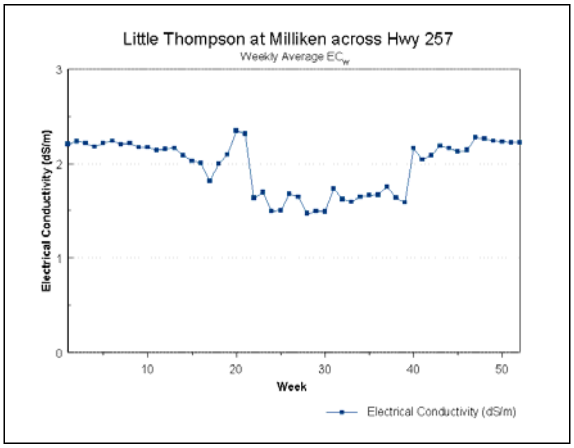


Figure 2.35 Weekly Average EC_w
Little Thompson at Milliken
across Hwy 257

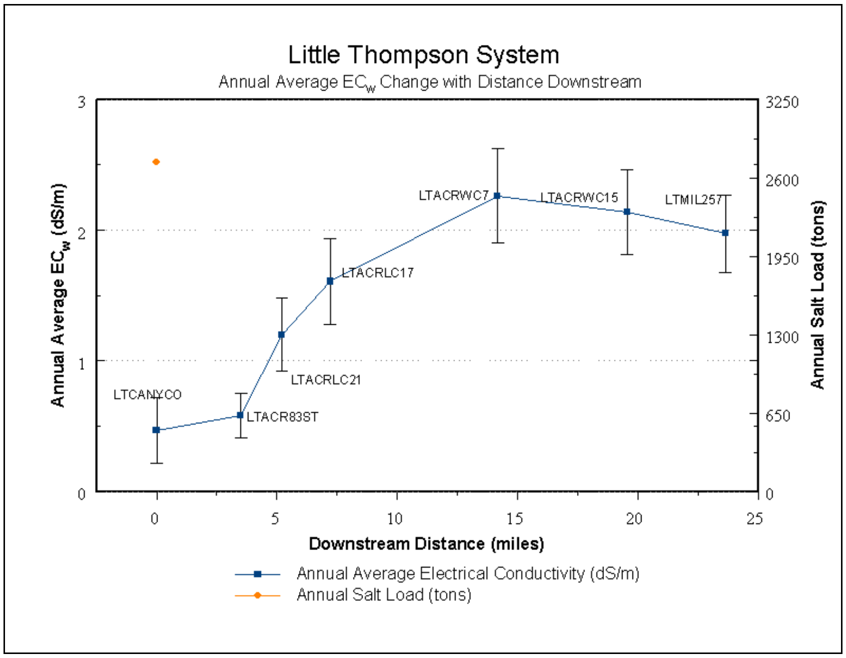
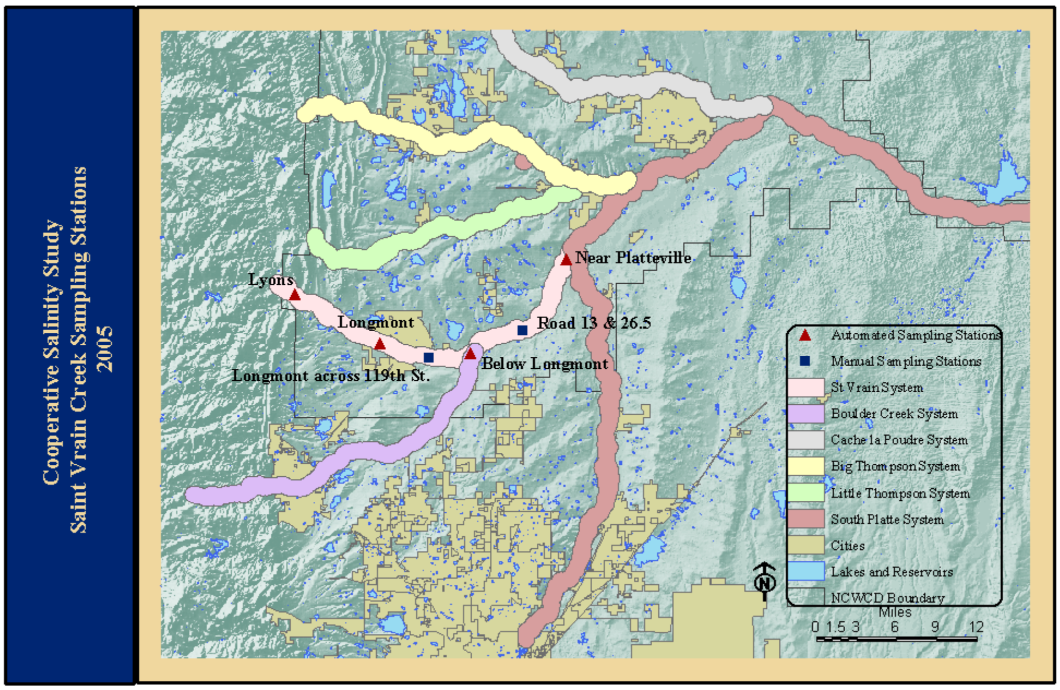


Figure 2.36 Annual Average EC_w and Salt Load with Distance
Downstream - Little Thompson System

Saint Vrain Creek System

The District monitored EC_w levels at four automated and two manual sampling stations along the Saint Vrain Creek System. These six locations range from the canyon mouth in Lyons where the North and South Saint Vrain Creeks join, to its confluence with the South Platte River near Platteville (Map 2.4). Averages of EC_w values, streamflow and salt loading, along with their associated standard deviations, maximums and minimums, are compiled in Table 2.4. Additionally, Figures 2.37 - 2.47 graphically illustrate the annual EC_w and salt loading values as they change with time, space and streamflow.



Map 2.4 Automated and Manual Sampling Stations - Saint Vrain Creek System

Site Information			Annual Statistics							Monthly Statistics	
Site Description	Site Abbreviation	Type of Site	Average EC_w (dS/m)	Maximum EC_w (dS/m) / week #	Minimum EC_w (dS/m) / week #	Standard Deviation of EC_w (dS/m)	Average Flow (cfs)	Standard Deviation of Flow (cfs)	Salt Loading (10^3 tons)	Maximum Salt Loading (10^3 tons) /month	Minimum Salt Loading (10^3 tons) /month
Lyons	SVCLYOCO	automated	0.06	0.11 / 13	0.03 / 28	0.02	112 [13,14]	157	2.95	0.914 / June	0.003 / Feb.
Longmont	SVLONGCO	automated	0.32	0.52 / 49	0.13 / 19	0.09	68 [13,14]	122	5.96	3.34 / June	0.054 / Feb.
Longmont across 119 St.	SVLONGMONT	manual	0.94	1.41 / 1	0.15 / 25	0.29	NA[15]	NA	NA	NA	NA
Below Longmont	SVCBLOCO	automated	1.05	1.61 / 47	0.25 / 25	0.31	111 [16]	139	52.3	92.4 / June	2.25 / Dec.
13 and 26.5 Rd.	SVCACRWC13	manual	0.99	1.23 / 47	0.28 / 25	0.24	NA[15]	NA	NA	NA	NA
Near Platteville	SVCPLACO	automated	1.12	0.11 / 13	0.03 / 28	0.28	233 [13]	246	135	24.6 / June	6.73 / July

Table 2.4 Annual and Monthly Statistics - Saint Vrain System

[13] Provisional DWR flow data
[14] No flow data for January or December
[15] Flow data not available for this location
[16] Provisional USGS flow data

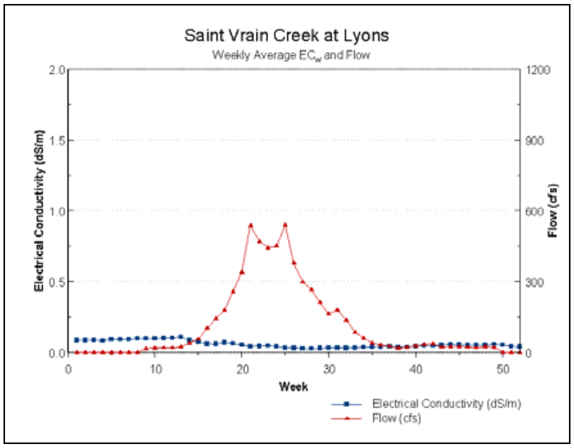


Figure 2.37 Weekly Average EC_w and Flow Saint Vrain Creek at Lyons

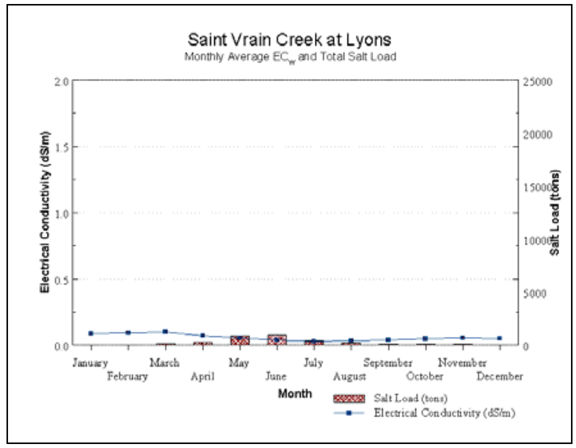


Figure 2.38 Monthly Average EC_w and Total Salt Load Saint Vrain Creek at Lyons

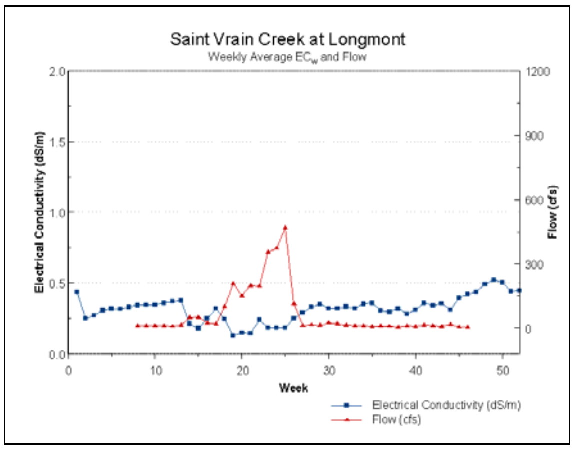


Figure 2.39 Weekly Average EC_w and Flow Saint Vrain Creek at Longmont[17]

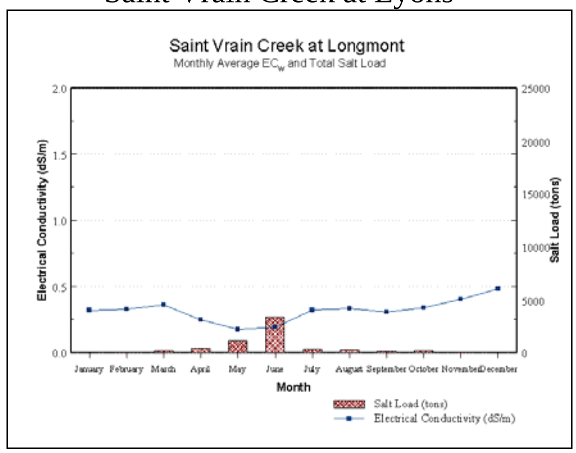


Figure 2.40 Monthly Average EC_w and Total Salt Load Saint Vrain Creek at Longmont

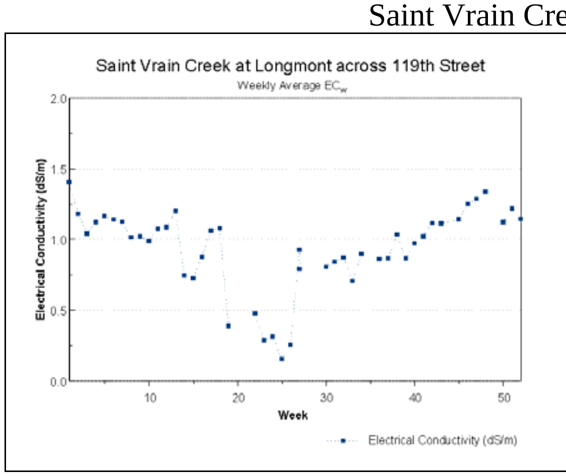


Figure 2.41 Weekly Average EC_w Saint Vrain Creek at Longmont across 119th Street

[17] This site regularly encountered problems associated with siltation; it was frequently buried in sediment throughout the 2005 sampling year.

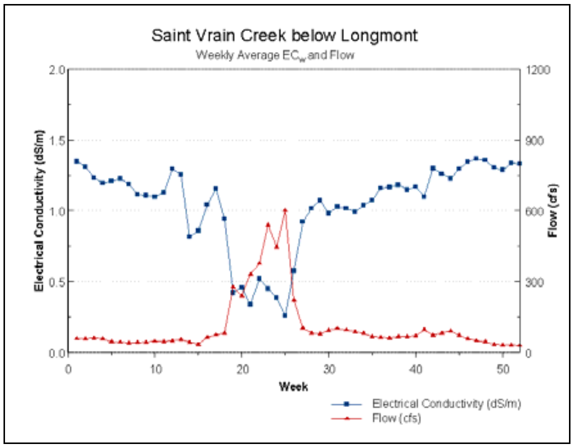


Figure 2.42 Weekly Average EC_w and Flow
Saint Vrain Creek below Longmont

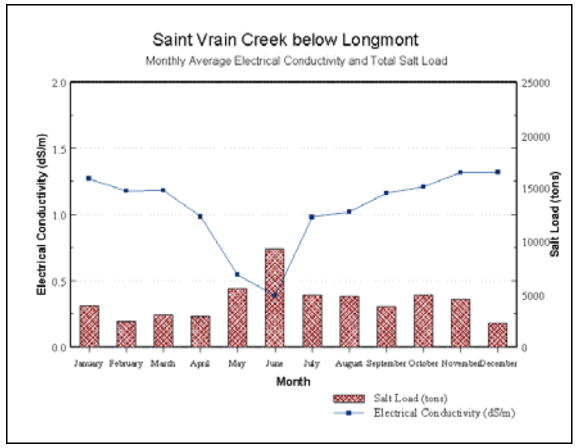


Figure 2.43 Monthly Average EC_w and Total Salt Load
Saint Vrain Creek below Longmont

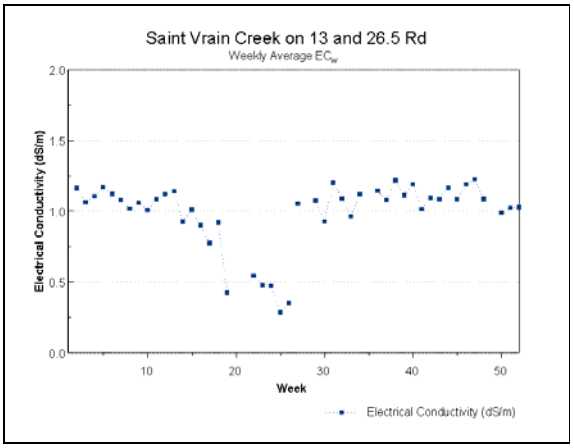


Figure 2.44 Weekly Average EC_w
Saint Vrain Creek on 13 and 26.5 Road

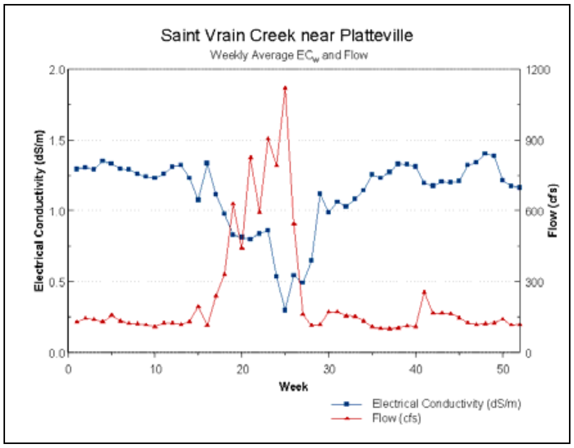


Figure 2.45 Weekly Average EC_w and Flow
Saint Vrain Creek near Platteville[18]

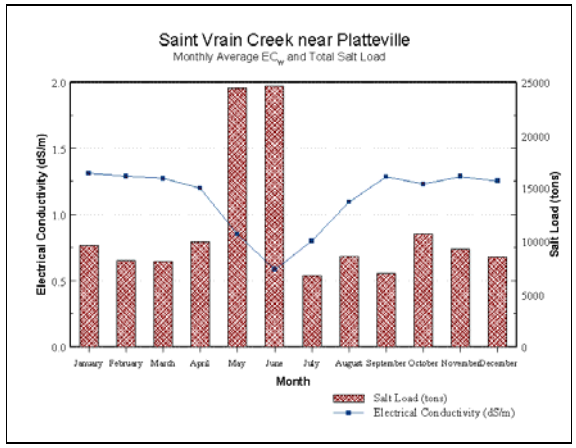


Figure 2.46 Monthly Average EC_w and Total Salt Load
Saint Vrain Creek near Platteville

[18] This site regularly encountered problems associated with siltation; it was frequently buried in sediment throughout the 2005 sampling year. The District has moved the EC_w sensor several times in attempts to remedy this problem, but has yet to recognize and implement a satisfactory solution.

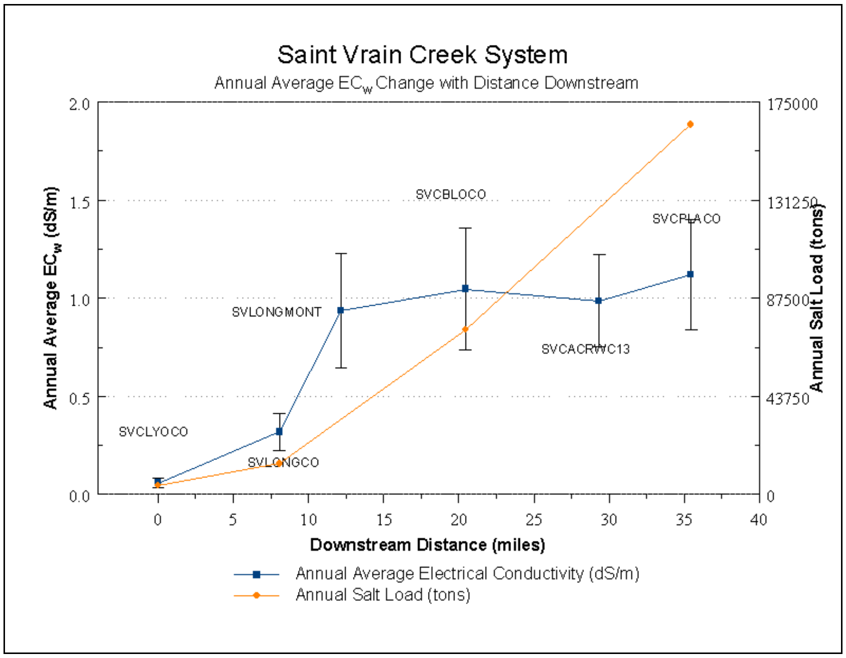
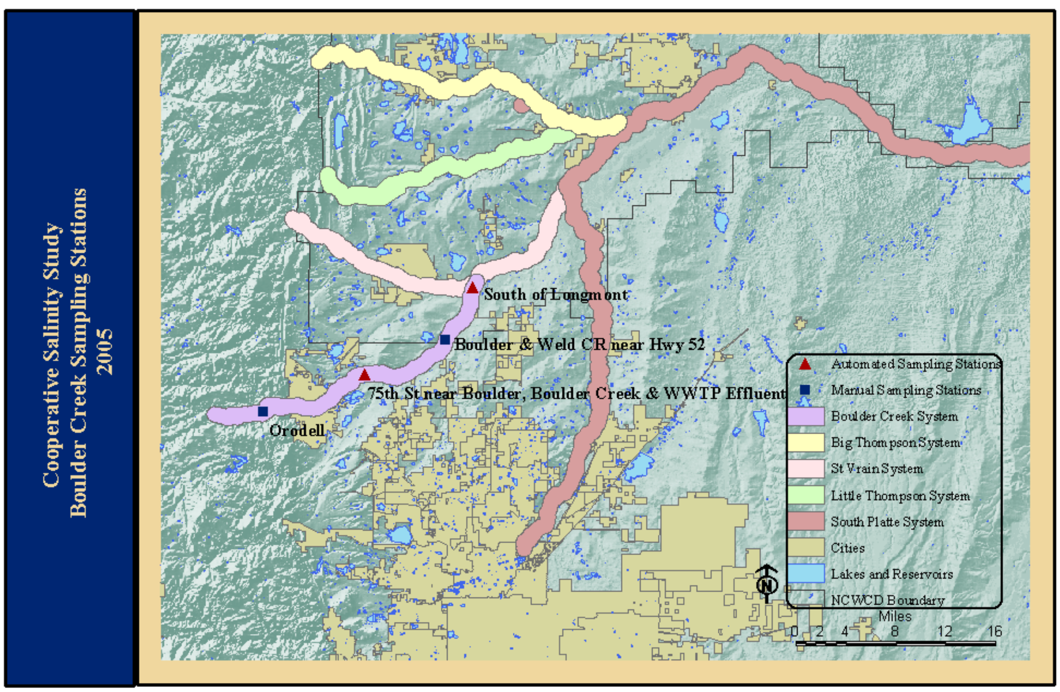


Figure 2.47 Annual Average EC_w and Salt Load with Distance Downstream - Saint Vrain Creek System

Boulder Creek System

The Boulder Creek System was sampled from the mouth of the Boulder Canyon to directly above the tributary's confluence with the Saint Vrain Creek east of Longmont (Map 2.5). There are a total of four sampling stations along this system, two automated and two manual. However, the automated station located across 75th Street near Boulder (directly downstream of the Boulder wastewater treatment plant) is equipped with two sensors; one is placed in the creek streamflow, and the other in the treatment plant effluent flow. Therefore, while there are only four individual monitoring stations, there are a total of five data sets collected from this tributary. Table 2.5 contains average, standard deviation, maximum and minimum values for EC_w, streamflow and salt loading. Additionally, graphs of EC_w and salt loading values as they change with time, space and streamflow are complied in Figures 2.48 - 2.54.



Map 2.5 Automated and Manual Sampling Stations - Boulder Creek System

Site Information			Annual Statistics							Monthly Statistics	
Site Description	**Site Abbreviation**	**Type of Site**	**Average EC_w (dS/m)**	**Maximum EC_w (dS/m) / week #**	**Minimum EC_w (dS/m) / week #**	**Standard Deviation of EC_w (dS/m)**	**Average Flow (cfs)**	**Standard Deviation of Flow (cfs)**	**Salt Loading (10^3 tons)**	**Maximum Salt Loading (10^3 tons) /month**	**Minimum Salt Loading (10^3 tons) /month**
Orodell	BOCOROCO	manual	0.17	0.46 / 5	0.05 / 28	0.17	91 [19,20]	126	NA[23]	NA	NA
75th St. near Boulder	BOCNORCO	automated	0.37	0.72 / 2	0.06 / 25	0.17	81 [21]	124	10.0	3.02 / May	0.197 / Dec.
75th St. near Boulder, WWTP Effluent	BOCNORCO	automated	0.67	0.80 / 13	0.43 / 6	0.07	NA[22]	NA	NA	NA	NA
Boulder & Weld County Road near Hwy 52	BOACBCWC	manual	0.66	1.00 / 5	0.19 / 25	0.19	NA[22]	NA	NA	NA	NA
South of Longmont	BOLONGCO	automated	0.95	1.48 / 3	0.24 / 21	0.36	NA[22]	NA	NA	NA	NA

Table 2.5 Annual and Monthly Statistics - Boulder Creek System

[19] Provisional DWR flow data
[20] No flow data for January or February
[21] Provisional USGS flow data
[22] Flow data not available for this location
[23] Salt load calculations not included due to insufficient EC_w data associated with manual sampling site

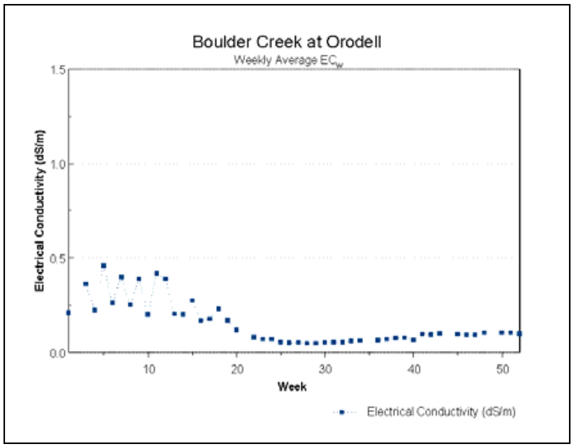


Figure 2.48 Weekly Average EC_w
Boulder Creek at Orodell

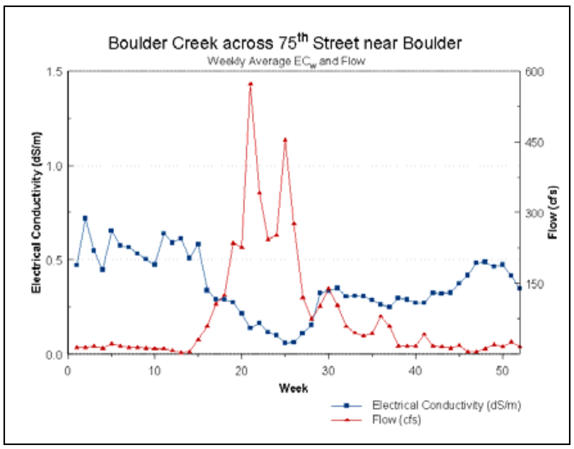


Figure 2.49 Weekly Average EC_w and Flow
Boulder Creek across 75th Street near Boulder

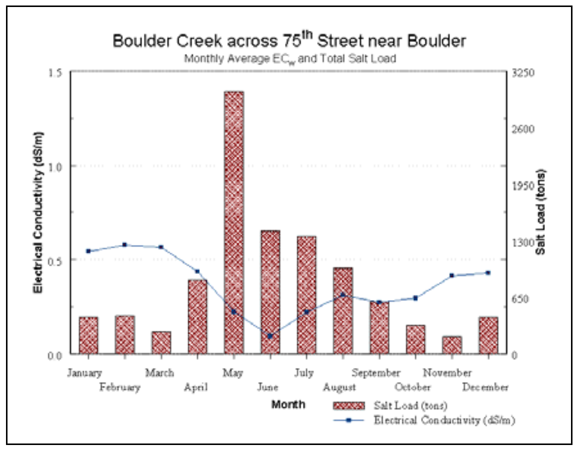


Figure 2.50 Monthly Average EC_w and Total Salt Loading
Boulder Creek across 75th Street near Boulder

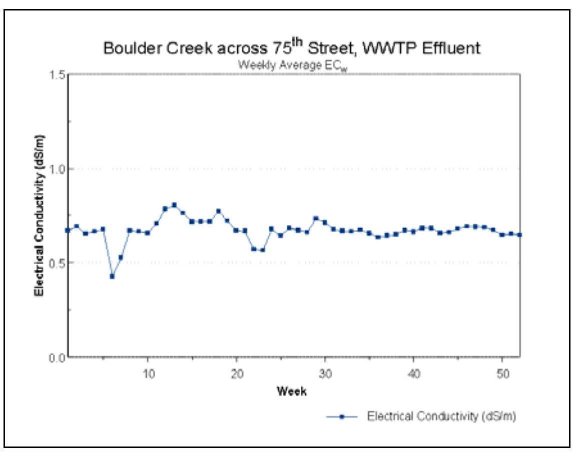


Figure 2.51 Weekly Average EC_w
Boulder Creek across 75th Street,
Wastewater Treatment Plant Effluent

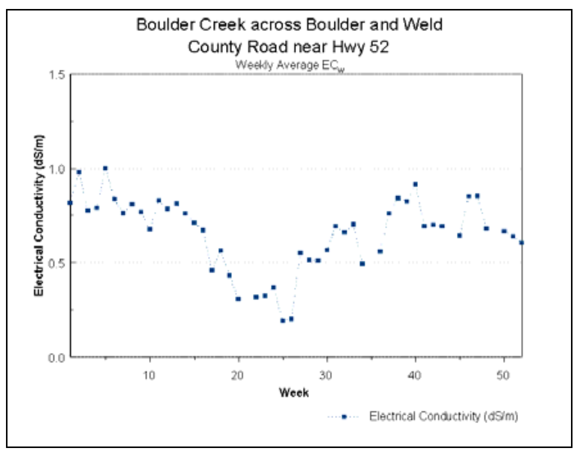


Figure 2.52 Weekly Average EC_w
Boulder Creek across Boulder and Weld
County Road near Hwy 52

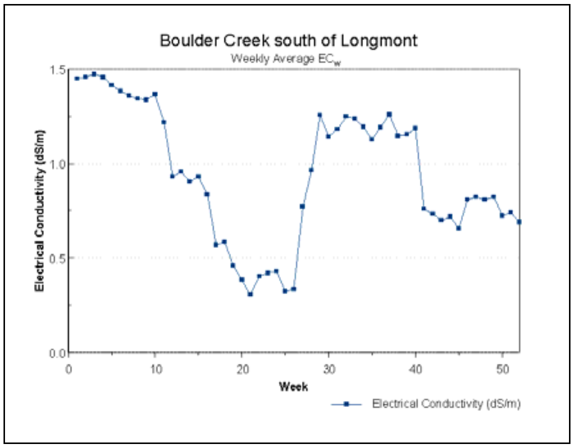


Figure 2.53 Weekly Average EC_w and Flow
Boulder Creek south of Longmont

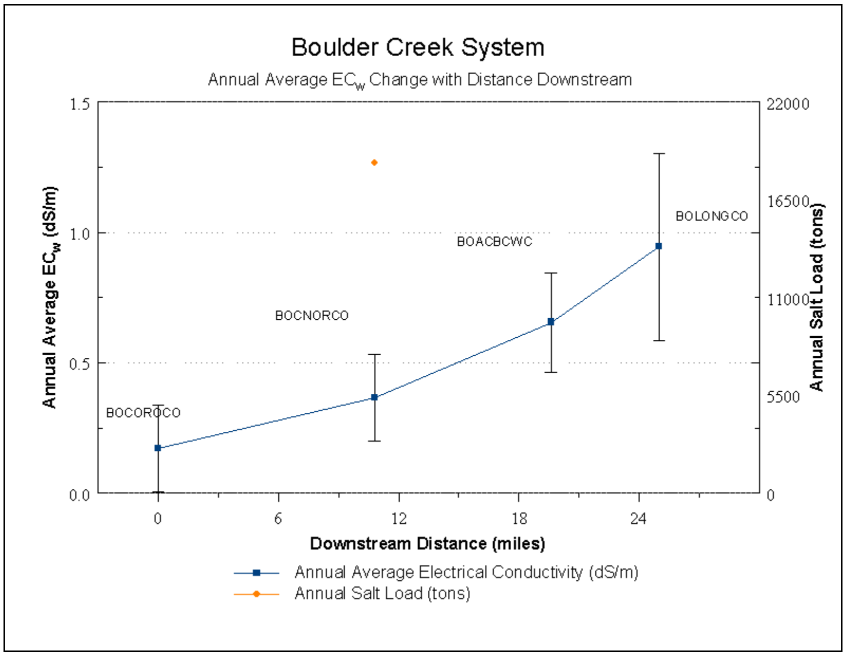
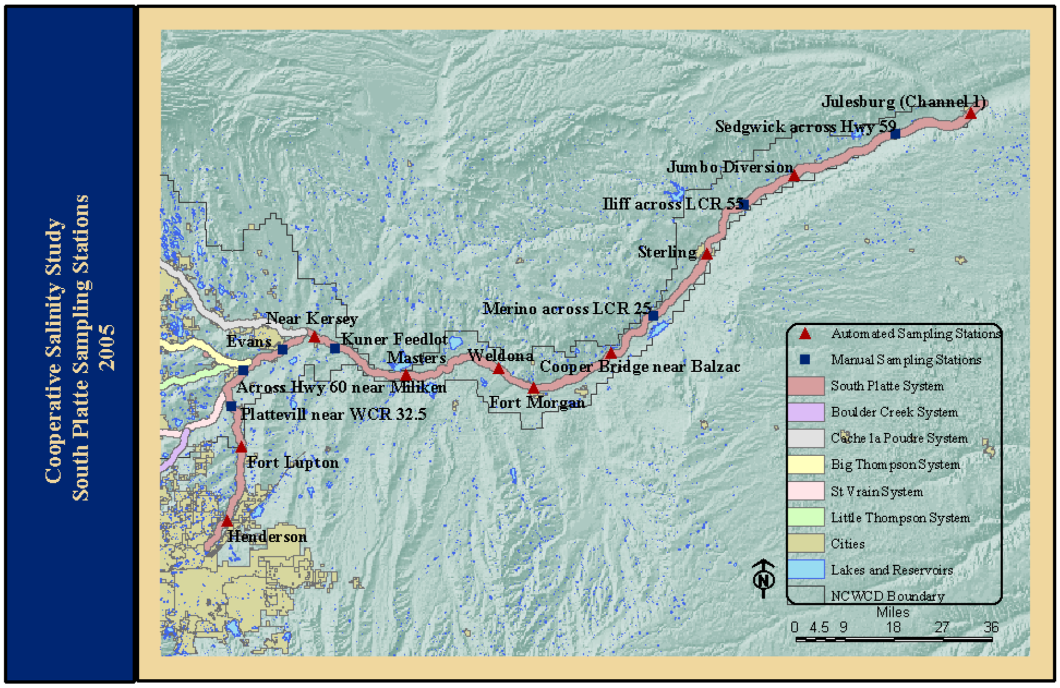


Figure 2.54 Annual Average EC_w and Salt Load with Distance
Downstream - Boulder Creek System

South Platte System

The most heavily sampled system was that of the South Platte. It was monitored at 17 locations beginning just north of Denver at Henderson and following the system all the way to Julesburg (Map 2.6). A list of the monitoring stations and annual/monthly statistics for each site can be found in Table 2.6. Moreover, Figures 2.55 - 2.79 highlight the annual EC_w and salt loading values as they change with time, space and streamflow.



Map 2.6 Automated and Manual Sampling Stations - South Platte System

Site Information			Annual Statistics							Monthly Statistics	
Site Description	Site Abbreviation	Type of Site	Average EC_w (dS/m)	Maximum EC_w (dS/m) / week #	Minimum EC_w (dS/m) / week #	Standard Deviation of EC_w (dS/m)	Average Flow (cfs)	Standard Deviation of Flow (cfs)	Salt Loading (10^3 tons)	Maximum Salt Loading (10^3 tons) /month	Minimum Salt Loading (10^3 tons) /month
Henderson	PLAHENCO	automated	0.83	1.38 / 2	0.22 / 25	0.26	439 [24]	451	186	30.2 / Apr.	9.70 / Nov.
Fort Lupton	PLALUPCO	automated	0.91	1.20 / 2	0.52 / 25	0.13	392 [25]	476	180	92.3 / June	3.78 / Mar.
Platteville near WCR 32.5	PLAPLACO	manual	1.03	1.24 / 2	0.59 / 23	0.18	NA[26]	NA	NA	NA	NA
Hwy 60 near Miliken	PLAACRH60	manual	1.07	1.25 / 2	0.43 / 25	0.21	NA[26]	NA	NA	NA	NA
Evans	PLAEVACO	manual	1.14	1.39 / 35	0.51 / 25	0.24	NA[26]	NA	NA	NA	NA
Near Kersey	PLAKERCO	automated	0.96	1.46 / 49	0.32 / 23	0.32	824 [24]	905	401	64.1 / June	16.7 / Sept.
Kuner Feedlot	PLAKUNCO	manual	1.24	1.47 / 1	0.61 / 23	0.24	NA[26]	NA	NA	NA	NA
Masters near Jackson Reservoir	PLAMASCO	automated	1.23	1.51 / 1	0.64 / 23	0.25	NA[26]	NA	NA	NA	NA
Weldona	PLAWELCO	automated	1.43	1.79 / 47	0.71 / 23	0.28	448 [24]	567	330	71.9 / June	12.9 / Nov.
Fort Morgan	PLAMORCO	automated	1.20	1.88 / 4	0.23 / 50	0.43	574 [25]	861	396	43.4 / June	8.60 / Dec.
Cooper Bridge near Balzac	PLABALCO	automated	1.40	1.80 / 49	0.43 / 36	0.39	266 [24]	462	190	51.3 / June	3.37 / Apr.
Merino across LCR 55	PLAMERCO	manual	1.72	1.90 / 19	1.05 / 24	0.15	NA[26]	NA	NA	NA	NA
Sterling	PLASTLCO	automated	1.86	2.15 / 7	0.98 / 24	0.24	NA[26]	NA	NA	NA	NA
Iliff across LCR 55	PLALIFCO	manual	2.03	2.42 / 5	0.97 / 23	0.29	NA[26]	NA	NA	NA	NA
Jumbo Diversion	PLAJUMCO	automated	2.03	2.48 / 8	1.06 / 24	0.34	NA[26]	NA	NA	NA	NA
Sedgwick across Hwy 59	PLASEDCO	manual	2.20	2.43 / 19	2.00 / 27	0.09	NA[26]	NA	NA	NA	NA
Julesburg (Channel 1)	ONEJURCO	automated	2.08	2.34 / 10	1.13 / 24	0.23	168 [24]	267	190	356 / June	2.56 / Mar.

Table 2.6 Annual and Monthly Statistics - South Platte System

[24] Provisional DWR flow data
[25] Provisional USGS flow data
[26] Flow data not available for this location

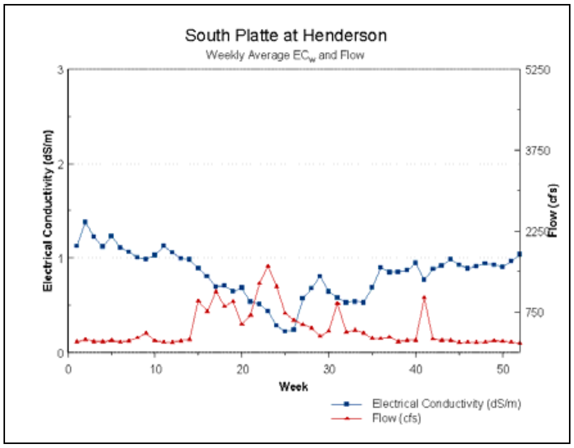


Figure 2.55 Weekly Average EC_w and Flow South Platte at Henderson[27]

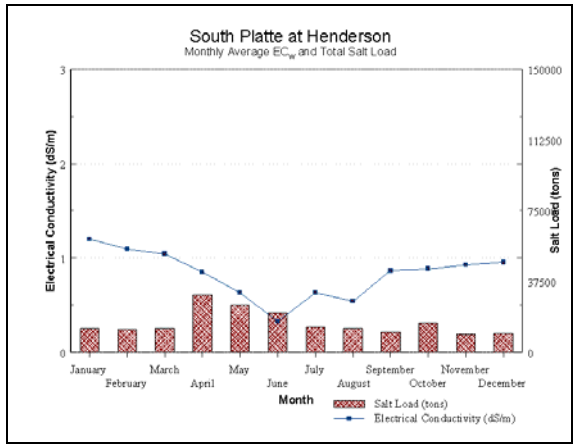


Figure 2.56 Monthly Average EC_w and Total Salt Load South Platte at Henderson

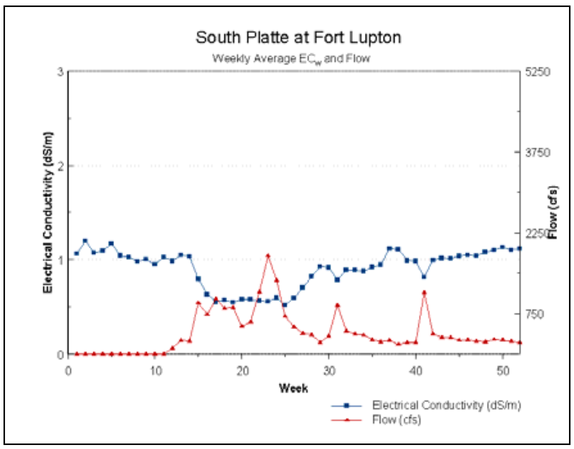


Figure 2.57 Weekly Average EC_w and Flow South Platte at Fort Lupton

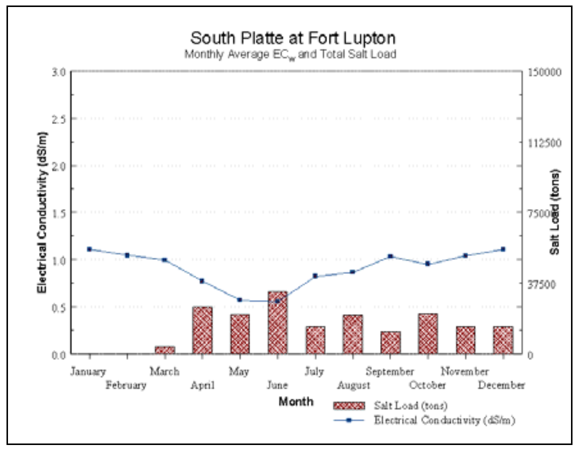


Figure 2.58 Monthly Average EC_w and Total Salt Load South Platte at Fort Lupton

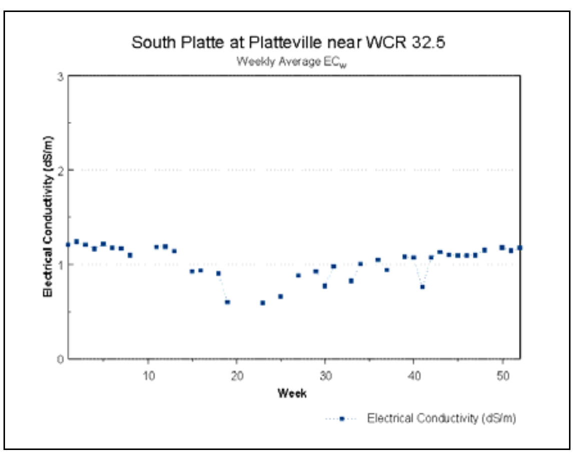


Figure 2.59 Weekly Average EC_w South Platte at Platteville near WCR 32.5

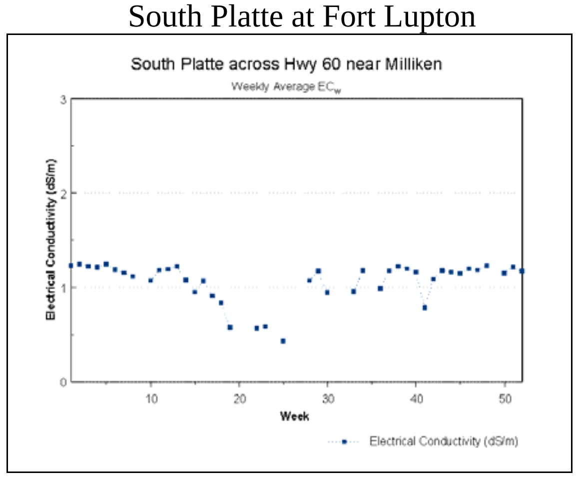


Figure 2.60 Weekly Average EC_w South Platte across Hwy 60 near Milliken

[27]Due to construction in the Henderson area, the sediment load and streamflows at this site during the 2005 sampling year were very dynamic. The sensor, therefore, was frequently either out of the water or buried in sediment. The District does not possess confidence in the accuracy of the data gathered from this site.

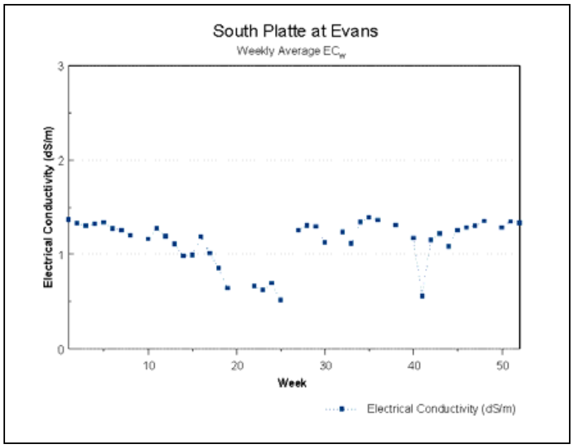


Figure 2.61 Weekly Average EC_w
South Platte at Evans

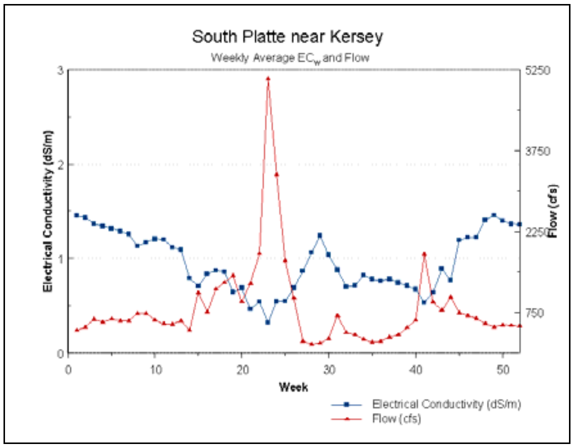


Figure 2.62 Weekly Average EC_w and Flow
South Platte near Kersey[28]

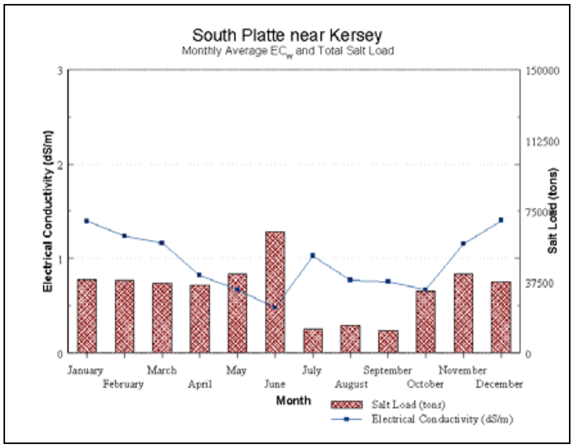


Figure 2.63 Monthly Average EC_w and
Total Salt Load
South Platte near Kersey

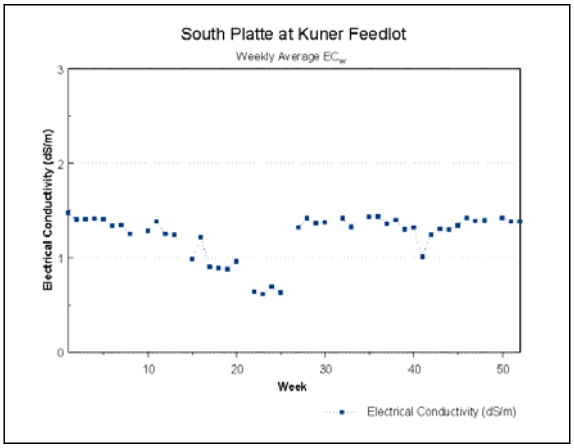


Figure 2.64 Weekly Average EC_w
South Platte at Kuner Feedlot

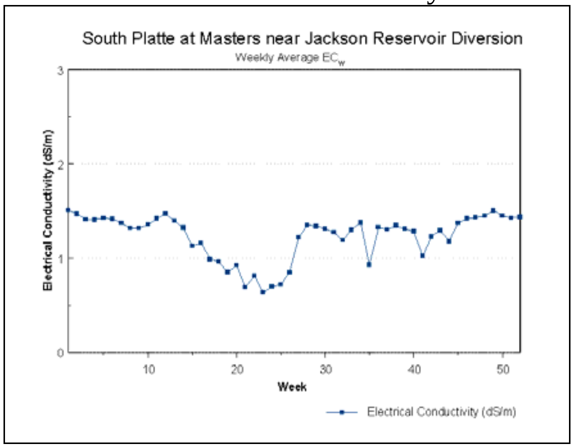


Figure 2.65 Weekly Average EC_w
South Platte at Masters
near Jackson Reservoir Diversion

[28]From January to October the sensor at this site was repeatedly buried. In October the sensor was moved to an area with higher flows and the accuracy of our readings has since improved.

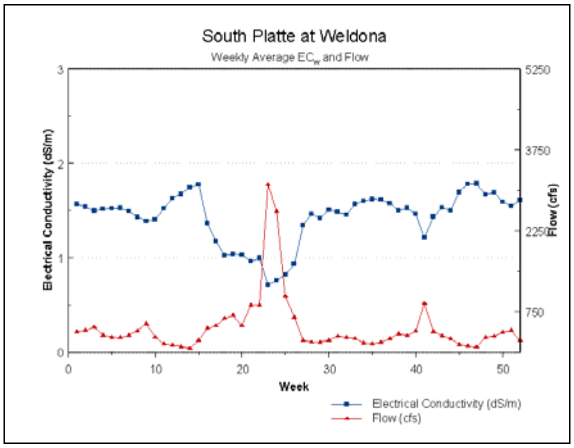


Figure 2.66 Weekly Average EC_w and Flow
South Platte at Weldona

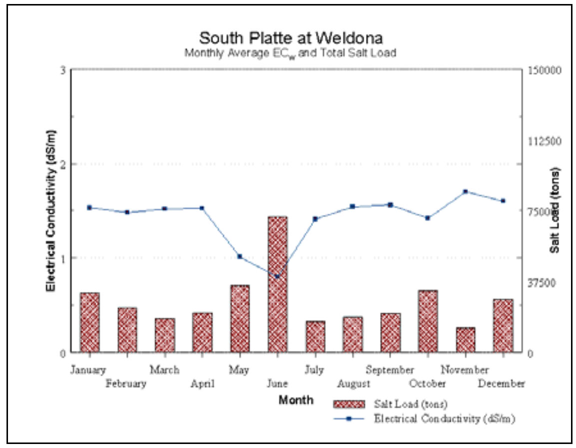


Figure 2.67 Monthly Average EC_w and
Total Salt Load
South Platte at Weldona

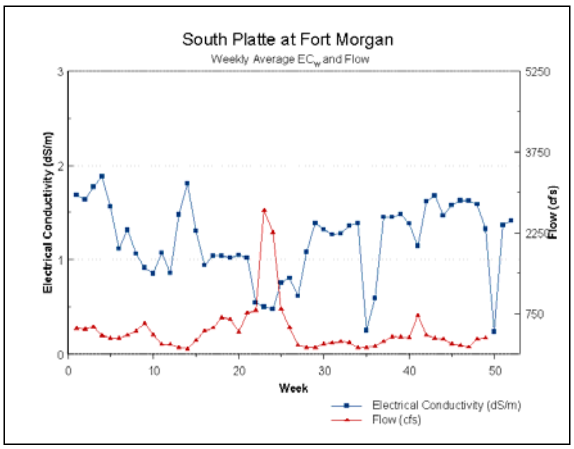


Figure 2.68 Weekly Average EC_w and Flow
South Platte at Fort Morgan[29]

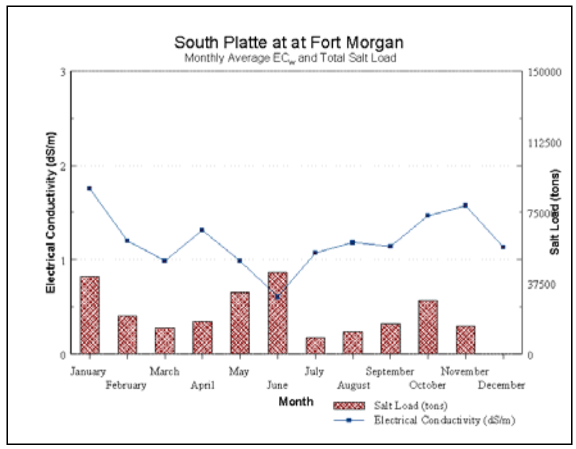


Figure 2.69 Monthly Average EC_w and
Total Salt Load
South Platte at Fort Morgan

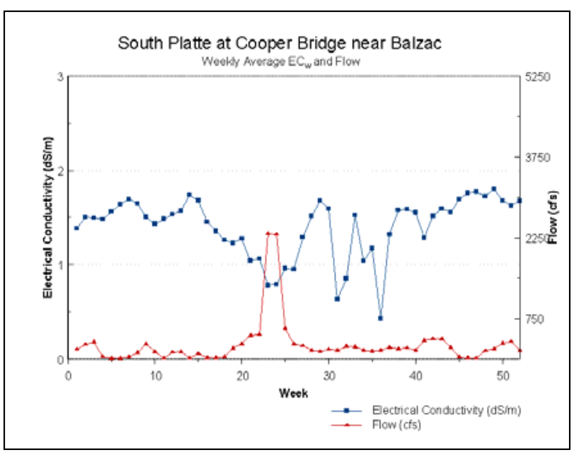


Figure 2.70 Weekly Average EC_w and Flow
South Platte at Cooper Bridge near Balzac

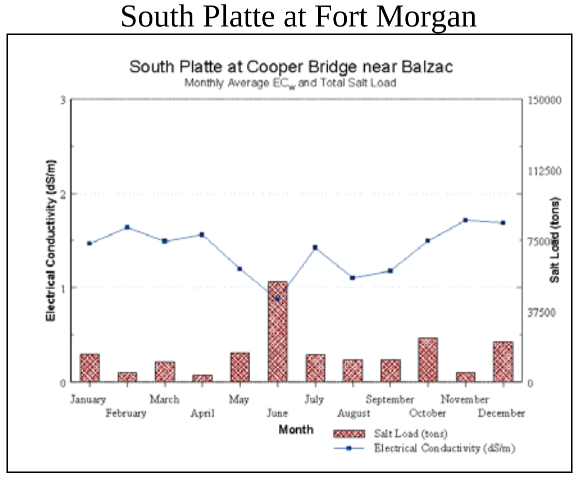


Figure 2.71 Monthly Average EC_w and
Total Salt Load
South Platte at Cooper Bridge near Balzac

[29] This site has experienced several problems attributed to dynamic flows and siltation. The District has tried, to date without success, moving the sensor housing conduit and frequent cleaning in attempts to improve data accuracy from this site.

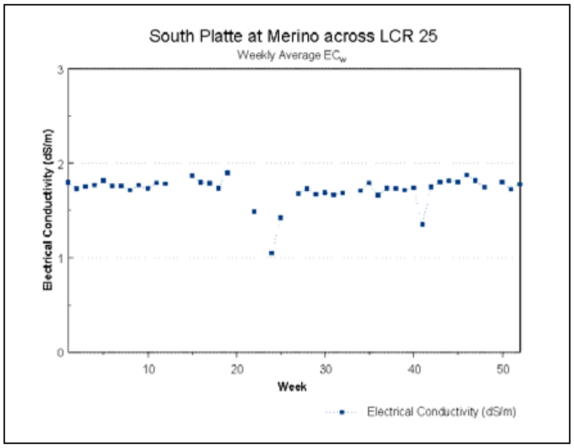


Figure 2.72 Weekly Average EC_w
South Platte at Merino across LCR 25

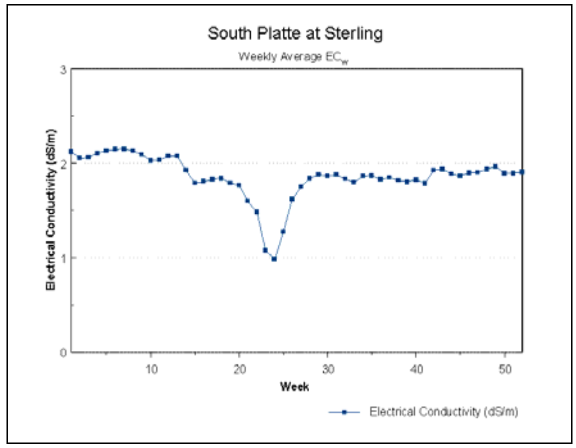


Figure 2.73 Weekly Average EC_w
South Platte at Sterling

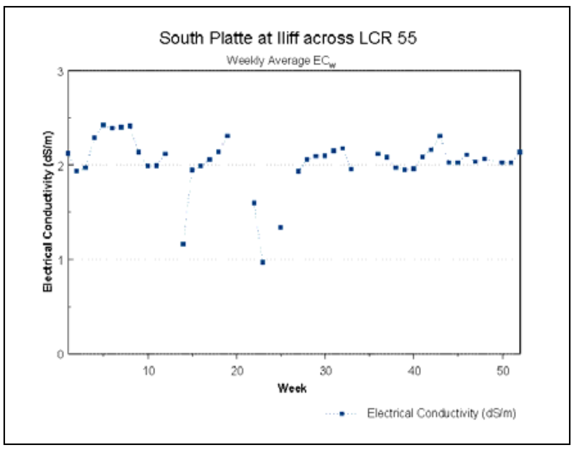


Figure 2.74 Weekly Average EC_w
South Platte at Iliff across LCR 55

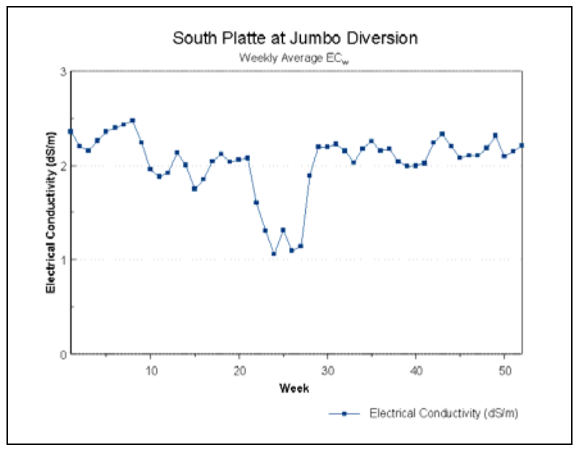


Figure 2.75 Weekly Average EC_w
South Platte at Jumbo Diversion

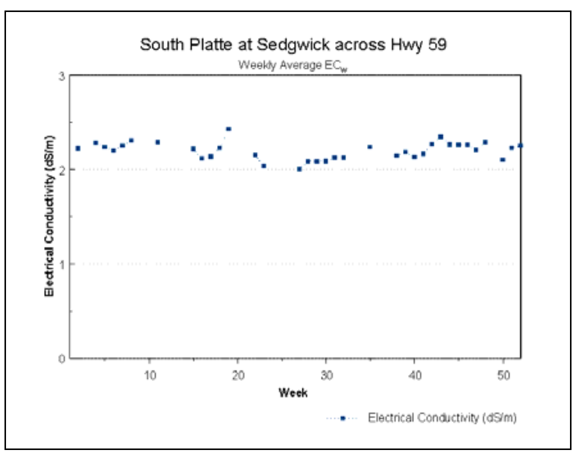


Figure 2.76 Weekly Average EC_w
South Platte at Sedgwick across Hwy 59

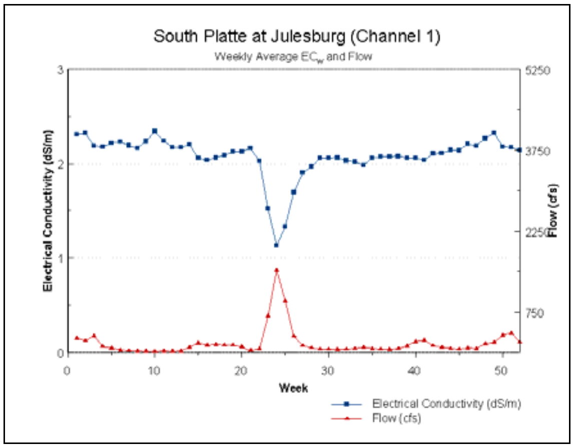


Figure 2.77 Weekly Average EC_w and Flow South Platte at Julesburg (Channel 1)

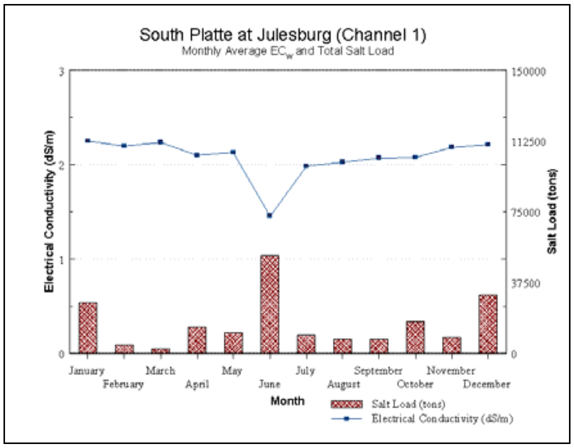


Figure 2.78 Monthly Average EC_w and Total Salt Load South Platte at Julesburg (Channel 1)

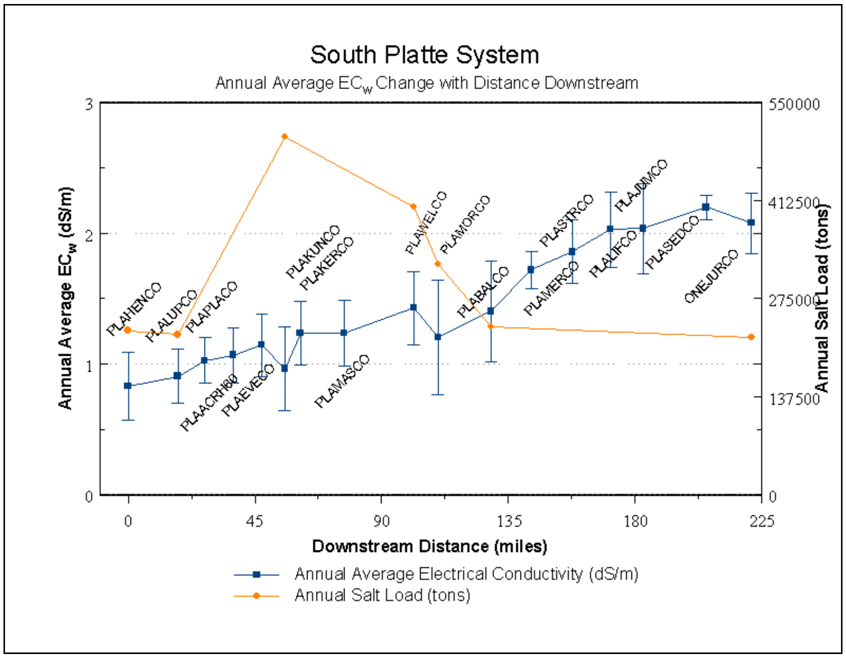


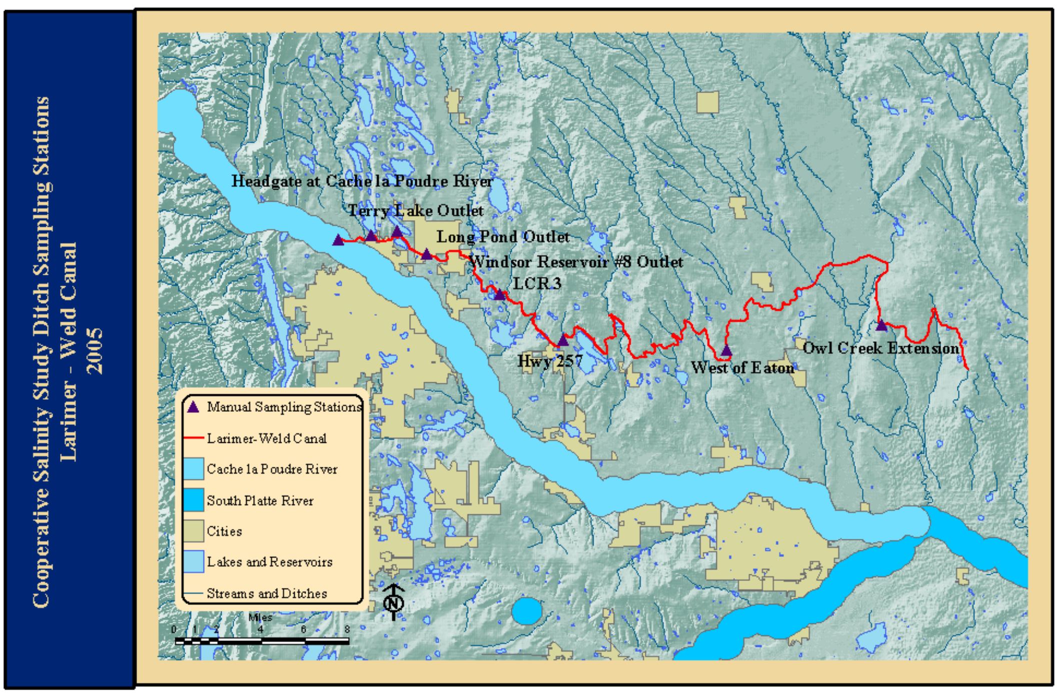
Figure 2.79 Annual Average EC_w and Salt Load with Distance Downstream - South Platte System

2.3 Canal Irrigation and Drainage Systems

A total of nine irrigation and drainage systems were monitored in 2005. The systems sampled are as follows: Larimer-Weld Canal, New Cache/Greeley #2 Canal, Boxelder Creek, Lone Tree Creek, Riverside Canal, Empire and Bijou Canal, Jackson and Fort Morgan Canal, Prewitt and North Sterling Canal and Julesburg Canal.

Larimer-Weld Canal

The Larimer-Weld irrigation system was monitored at eight locations from the headgate at the Cache la Poudre River to the Owl Creek Extension east of Eaton (Map 2.7). Table 2.7 lists the average, standard deviation, maximum and minimum EC_w values for the system. Moreover, Figures 2.80 - 2.88 provide graphical representations of temporal and spatial changes in EC_w levels.



Map 2.7 Manual Sampling Stations – Larimer-Weld Canal

Site Description	Average EC_w (dS/m)	Average EC_w Standard Deviation (dS/m)	Maximum EC_w (dS/m) /week #	Minimum EC_w (dS/m) /week #
Headgate at Cache la Poudre River	0.10	0.05	0.28 / 36	0.06 / 25
Terry Lake Outlet	0.25	0.23	0.70 / 35	0.07 / 22
Long Pond Outlet	0.73	0.10	0.79 / 23	0.53 / 34
Windsor Reservoir #8 Outlet	0.97	1.06	3.14 / 27	0.28 / 33
Canal at 3 Rd	0.40	0.20	0.70 / 35	0.11 / 38
Canal at 257	0.03	0.17	0.70 / 35	0.12 / 38
Canal West of Eaton	0.33	0.20	0.85 / 36	0.14 / 25
Owl Creek Extension	0.28	0.12	0.57 / 29	0.13 / 26

Table 2.7 Electrical Conductivity Statistics - Larimer -Weld Canal

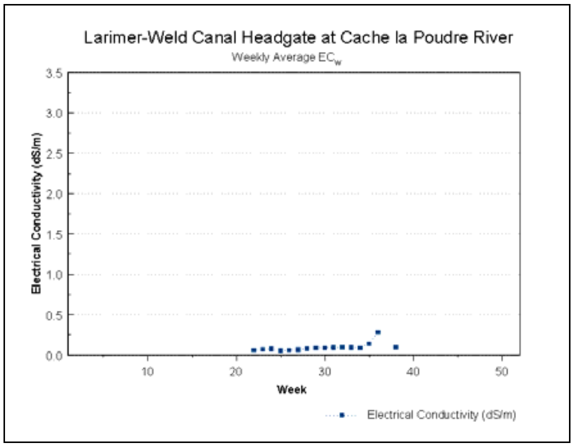


Figure 2.80 Weekly Average EC_w Larimer-Weld Canal Headgate at Cache la Poudre River

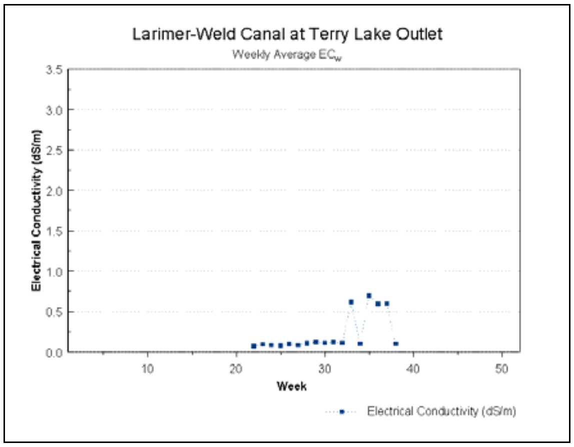


Figure 2.81 Weekly Average EC_w Larimer-Weld Canal at Terry Lake Outlet

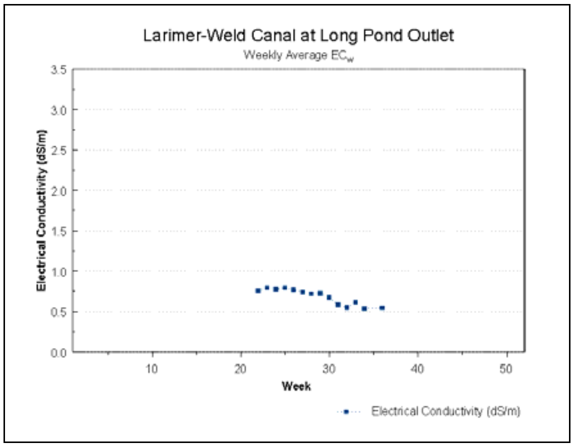


Figure 2.82 Weekly Average EC_w Larimer-Weld Canal at Long Pond Outlet

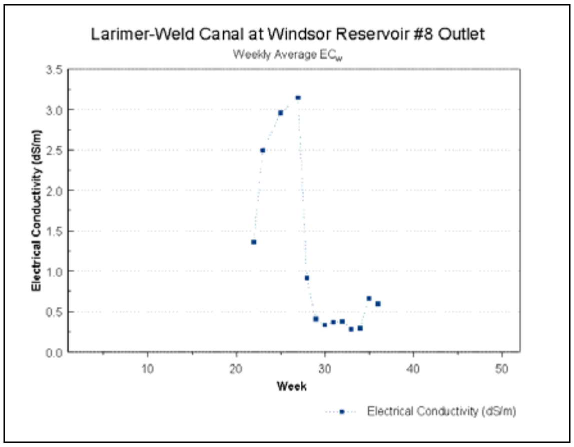


Figure 2.83 Weekly Average ECw Larimer-Weld Canal at Windsor Reservoir #8

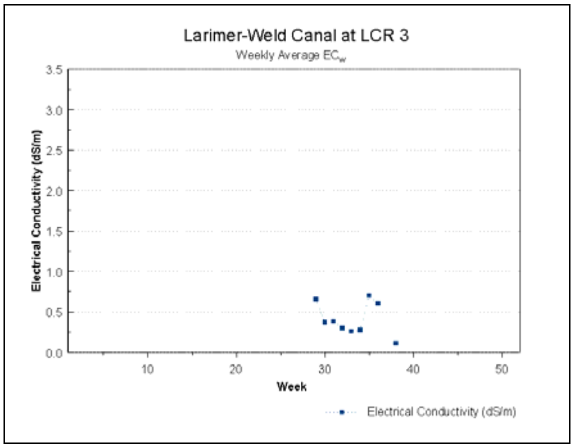


Figure 2.84 Weekly Average EC_w
Larimer-Weld Canal at LCR 3

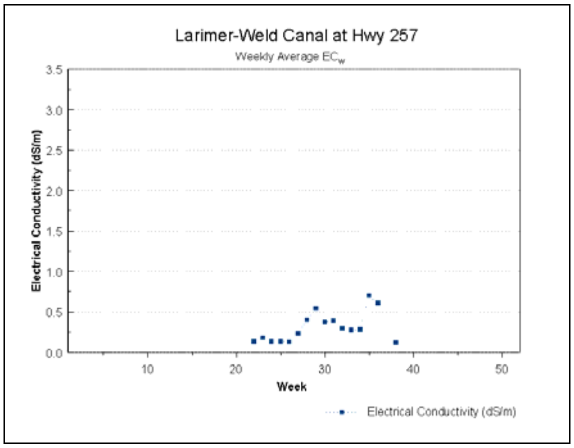


Figure 2.85 Weekly Average EC_w
Larimer-Weld Canal at Hwy 257

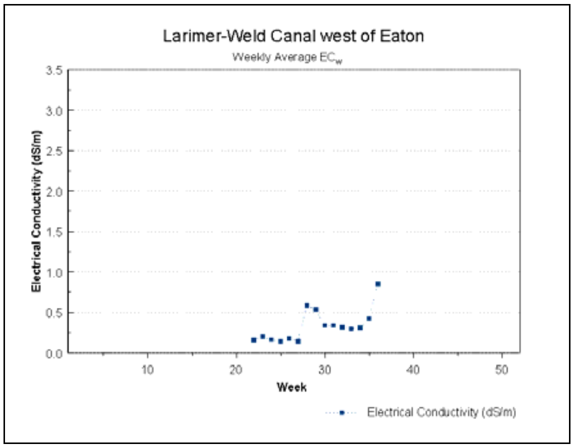


Figure 2.86 Weekly Average EC_w
Larimer-Weld Canal west of Eaton

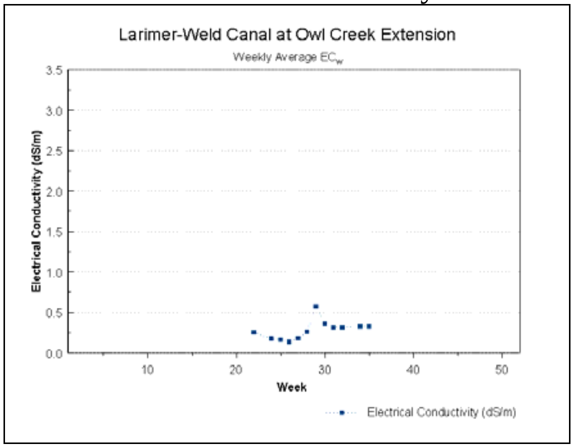


Figure 2.87 Weekly Average EC_w
Larimer-Weld Canal at
Owl Creek Extension

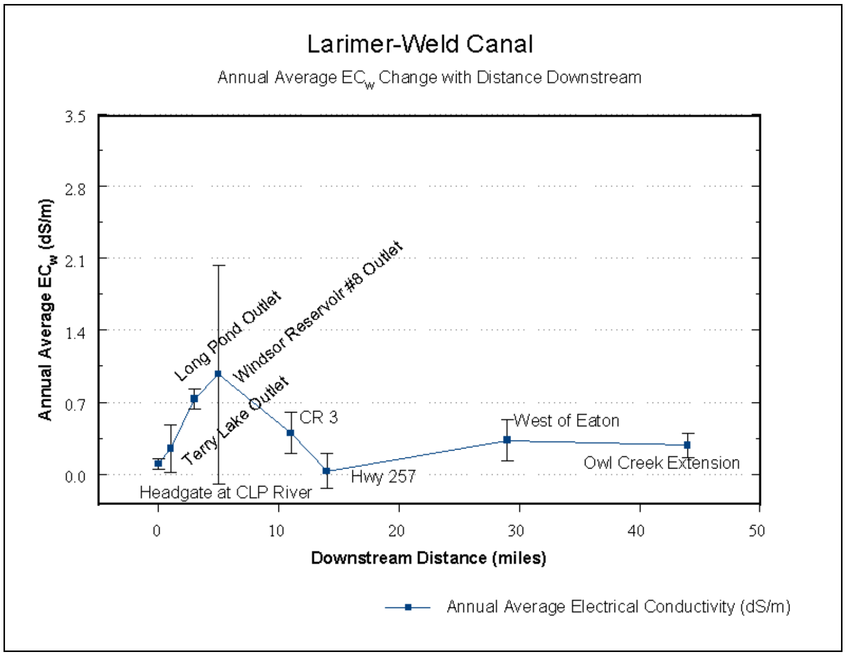
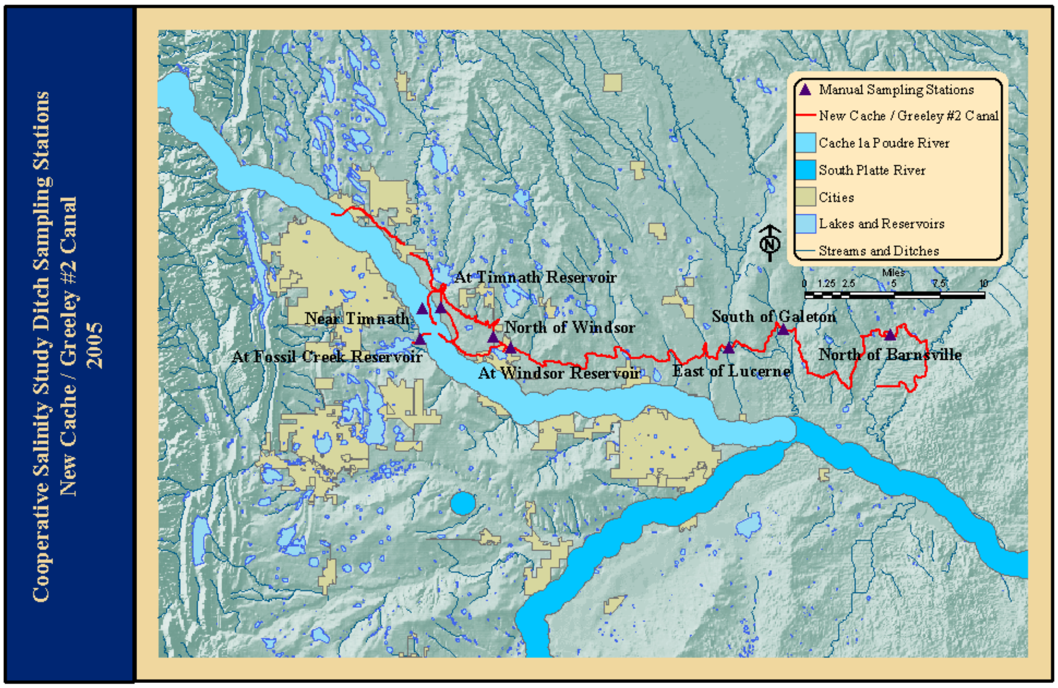


Figure 2.88 Annual Average EC_w with Distance Downstream – Larimer-Weld Canal

New Cache/Greeley #2 Canal

Map 2.8 illustrates the eight locations where the New Cache/Greeley #2 Canal was monitored. Additionally, Table 2.8 presents a compilation of the average, standard deviation, maximum and minimum EC_w levels for the individual monitoring stations along the canal. Lastly, Figures 2.89 - 2.97 graphically depict the changes in EC_w with time and space.



Map 2.8 Manual Sampling Stations – New Cache/Greeley #2 Canal

Site Description	Average EC_w (dS/m)	Average EC_w Standard Deviation (dS/m)	Maximum EC_w (dS/m) /week #	Minimum EC_w (dS/m) /week #
Near Timnath	0.71	0.46	1.54 / 36	0.14 / 23
Fossil Creek Reservoir Outlet	0.64	0.05	0.75 / 23	0.58 / 31
Timnath Reservoir Outlet	1.12	0.53	1.85 / 36	0.59 / 34
Windsor Reservoir Outlet	0.62	0.22	1.33 / 23	0.36 / 26
North of Windsor	0.62	0.08	0.70 / 37	0.44 / 25
East of Lucerne	0.65	0.09	0.77 / 39	0.46 / 25
South of Galeton	0.63	0.08	0.72 / 29	0.47 / 25
North of Barnsville	0.65	0.11	0.92 / 36	0.47 / 24

Table 2.8 Electrical Conductivity Statistics - New Cache/Greeley #2 Canal

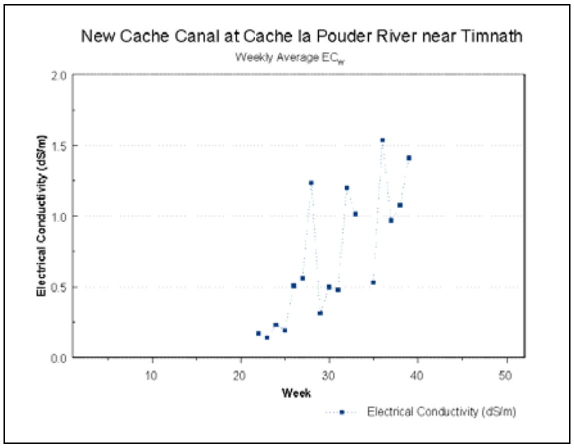


Figure 2.89 Weekly Average EC_w
New Cache Canal at Cache la Poudre
River near Timnath

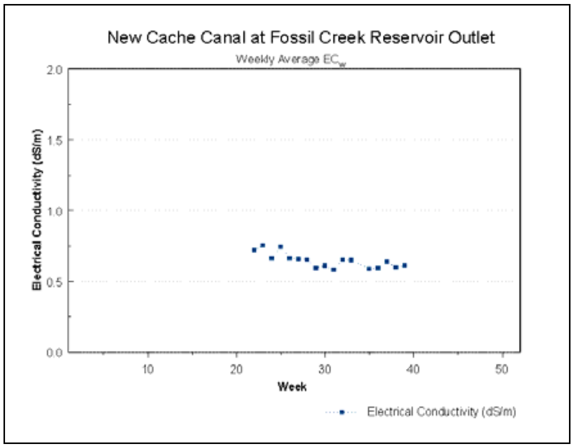


Figure 2.90 Weekly Average EC_w
New Cache Canal at Fossil Creek
Reservoir Outlet

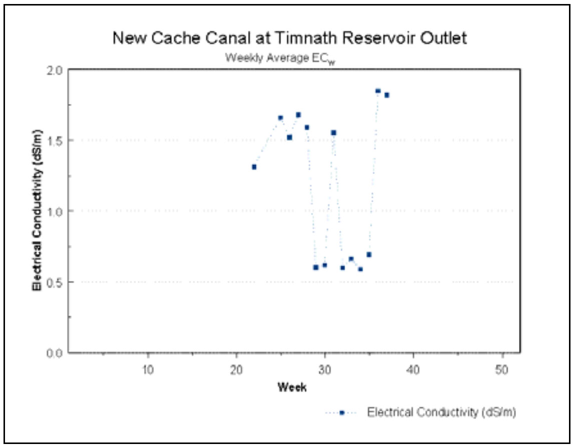


Figure 2.91 Weekly Average EC_w
New Cache Canal at
Timnath Reservoir Outlet

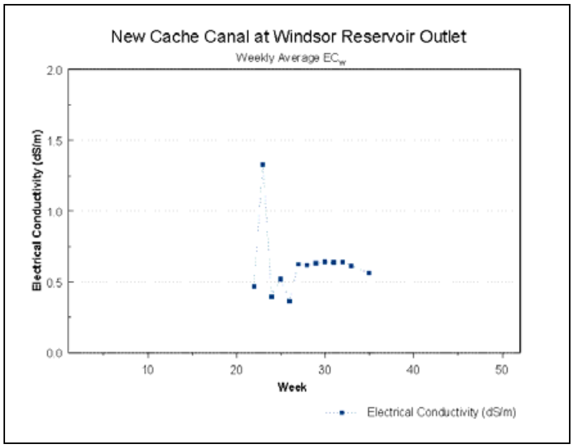


Figure 2.92 Weekly Average EC_w
New Cache Canal at
Windsor Reservoir Outlet

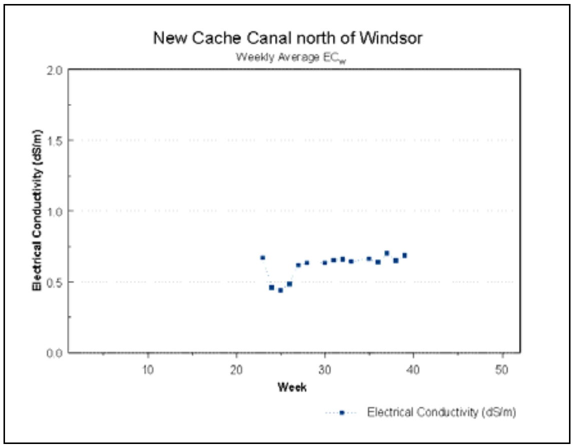


Figure 2.93 Weekly Average EC_w
New Cache Canal north of Windsor

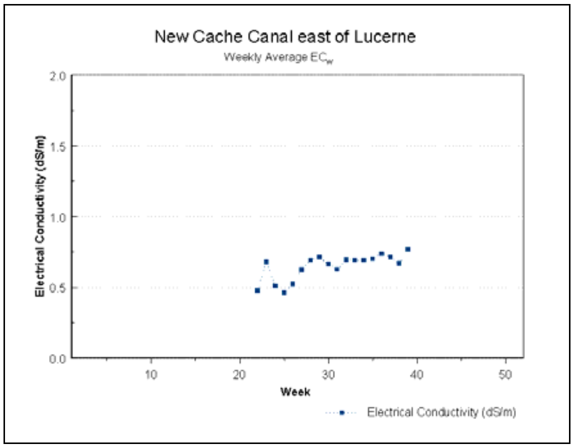


Figure 2.94 Weekly Average EC_w
New Cache Canal east of Lucerne

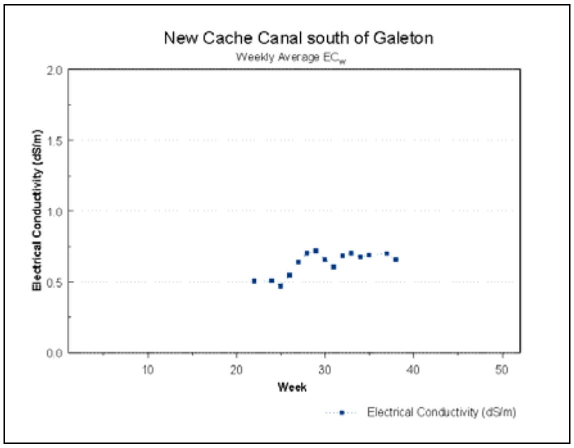


Figure 2.95 Weekly Average EC_w
New Cache Canal south of Galeton

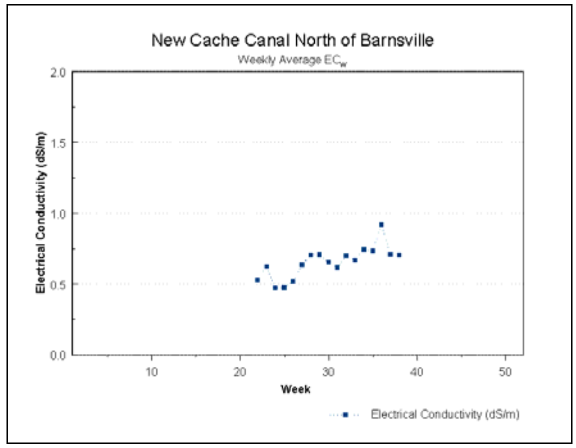


Figure 2.96 Weekly Average EC_w
New Cache Canal north of Barnsville

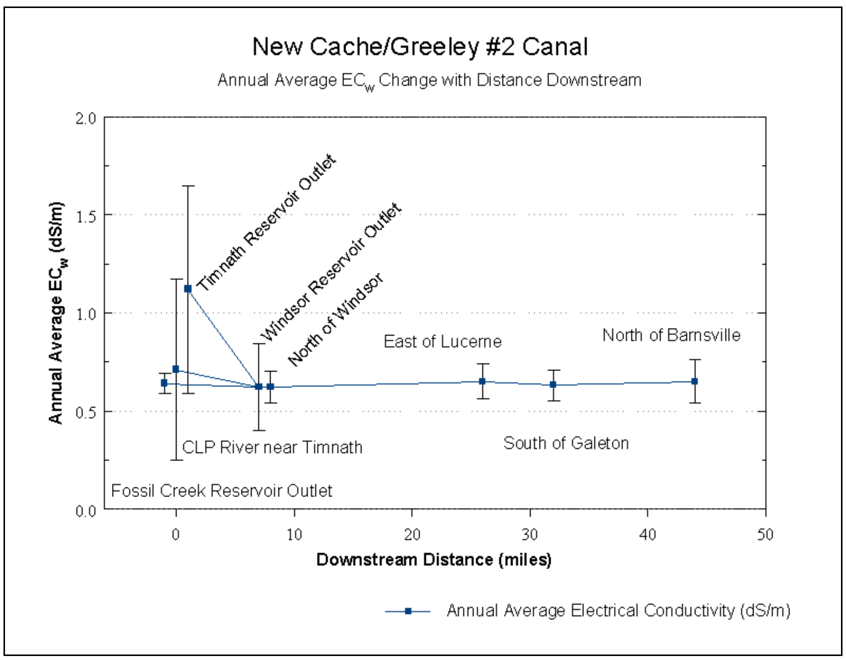
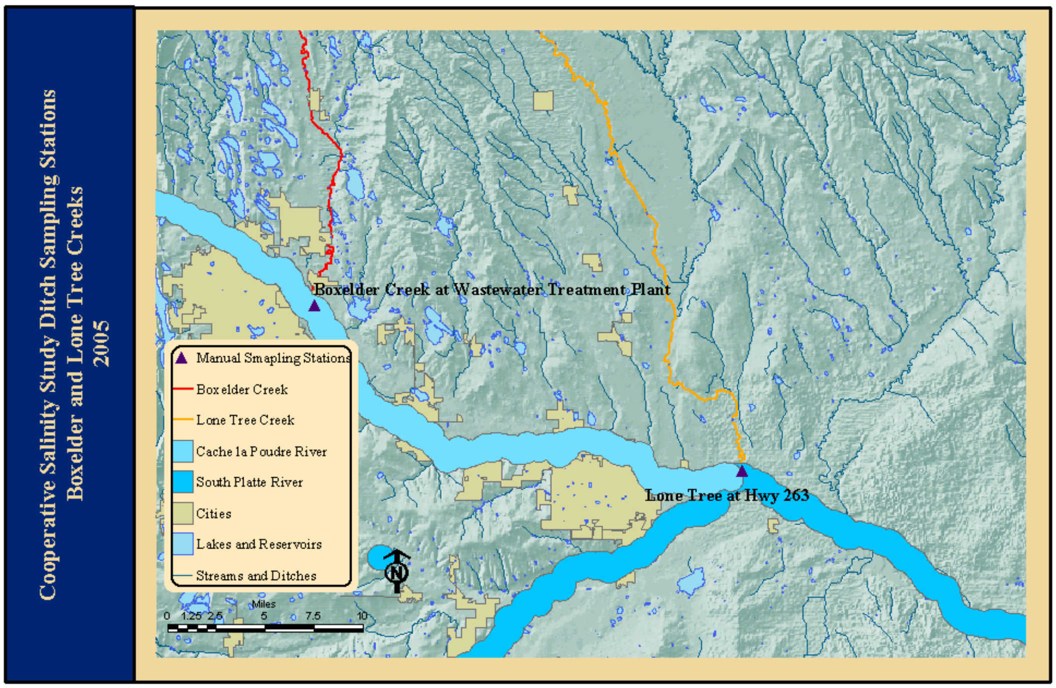


Figure 2.97 Annual Average EC_w with Distance Downstream
New Cache/Greeley #2 Canal

Boxelder and Lone Tree Creeks

In 2004 Boxelder Creek was monitored at four locations, while Lone Tree Creek was monitored at six. Due to redundancy, and in order to free up recourses for use elsewhere, this sampling scheme was reduced in 2005. Both systems were only sampled at their confluences with the South Platte River, as illustrated by the manual sampling stations depicted in Map 2.9. While Table 2.9 list the overall statistics for these two sites, Figures 2.98 and 2.99 graphically display the monitored EC_w data.



Map 2.9 Manual Sampling Stations – Boxelder and Lone Tree Creeks

Site Description	Average EC_w (dS/m)	Average EC_w Standard Deviation (dS/m)	Maximum EC_w (dS/m) /week #	Minimum EC_w (dS/m) /week #
Boxelder Creek at Wastewater Treatment Plant	2.08	0.22	2.37 / 37	1.54 / 24
Lone Tree Creek at Hwy 263	1.98	0.96	3.15 / 39	0.39 / 23

Table 2.9 Electrical Conductivity Statistics - Boxelder and Lone Tree Creeks

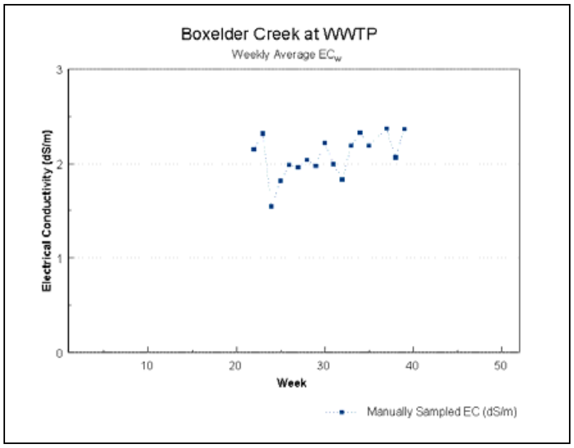


Figure 2.98 Weekly Average EC_w
Boxelder Creek at
Wastewater Treatment Plant

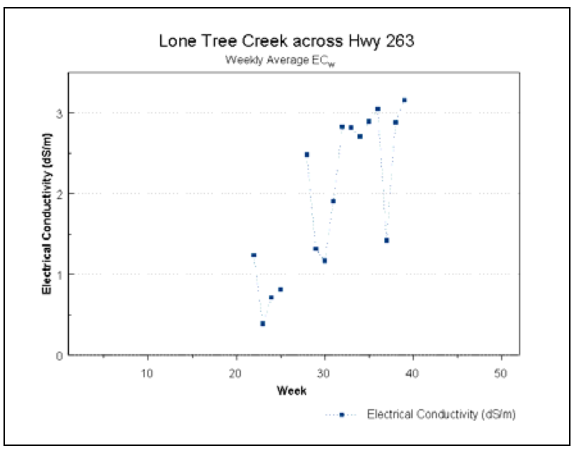
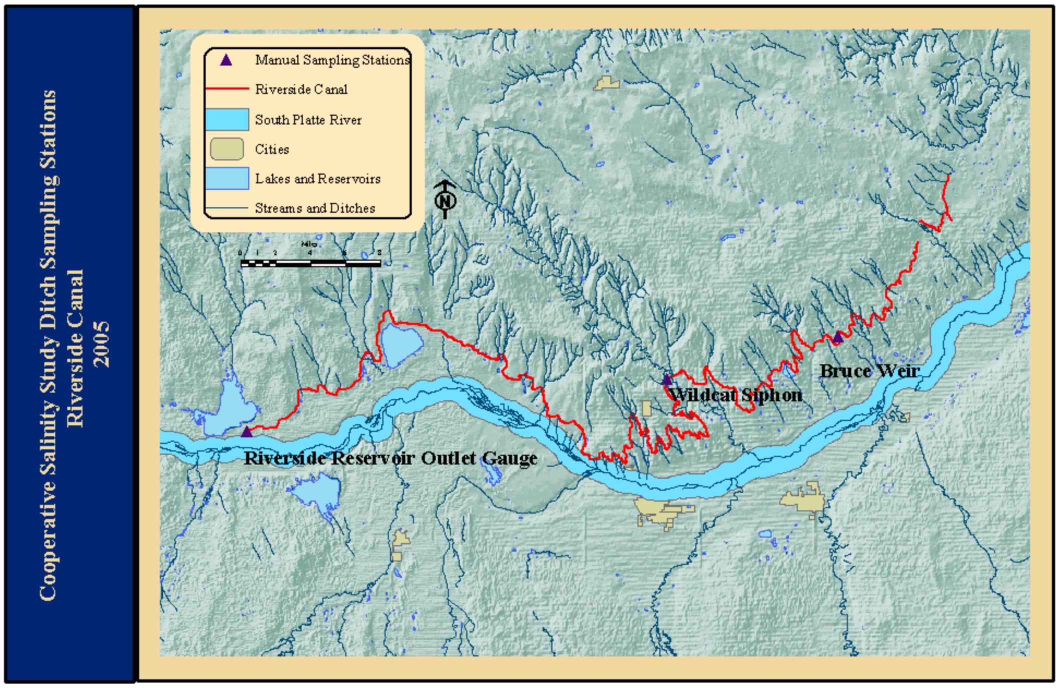


Figure 2.99 Weekly Average EC_w
Lone Tree Creek across Hwy 263

Riverside Canal

The Riverside Canal was monitored from its origin at the Riverside Reservoir to the end of the canal at the Bruce Weir north of Snyder (Map 2.10). The statistics for this irrigation system are compiled in Table 2.10, while the graphical representations are displayed in Figures 2.100 - 2.103.



Map 2.10 Manual Sampling Stations – Riverside Canal

Site Description	Average EC_w (dS/m)	Average EC_w Standard Deviation (dS/m)	Maximum EC_w (dS/m) /week #	Minimum EC_w (dS/m) /week #
Riverside Reservoir Outlet Gauge	1.04	0.05	1.20 / 39	0.99 / 32
Wildcat Siphon	1.05	0.05	1.14 / 22	1.04 / 33
Bruce Weir	1.12	0.03	1.14 / 22	1.07 / 33

Table 2.10 Electrical Conductivity Statistics - Riverside Canal

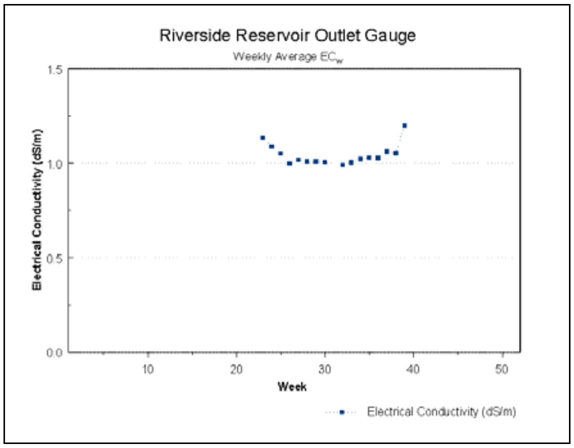


Figure 2.100 Weekly Average EC_w
Riverside Reservoir Outlet Gauge

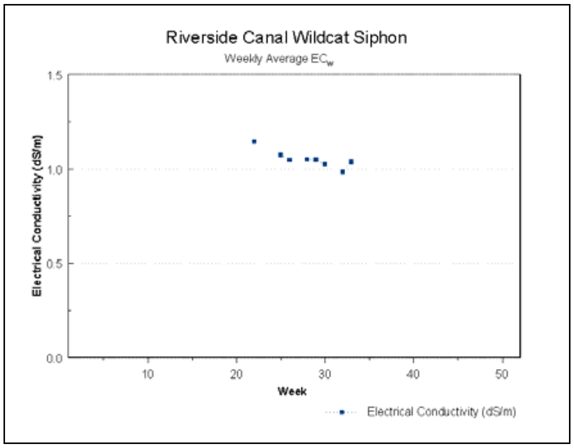


Figure 2.101 Weekly Average EC_w
Riverside Canal Wildcat Siphon

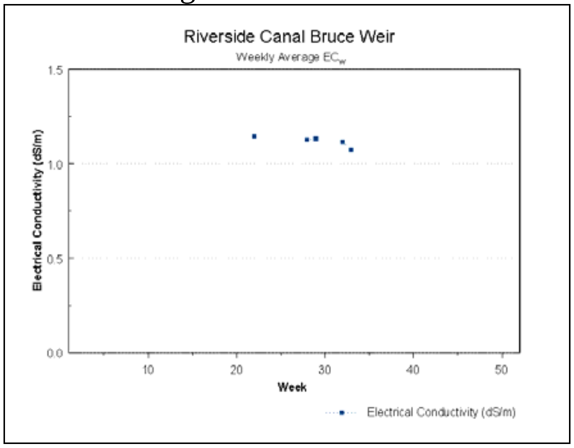


Figure 2.102 Weekly Average EC_w
Riverside Canal Bruce Weir

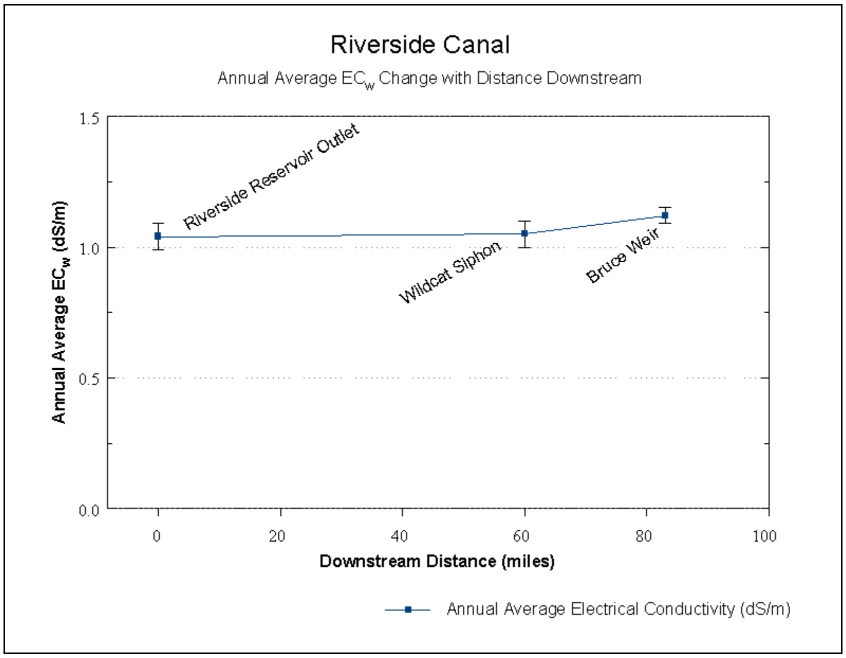
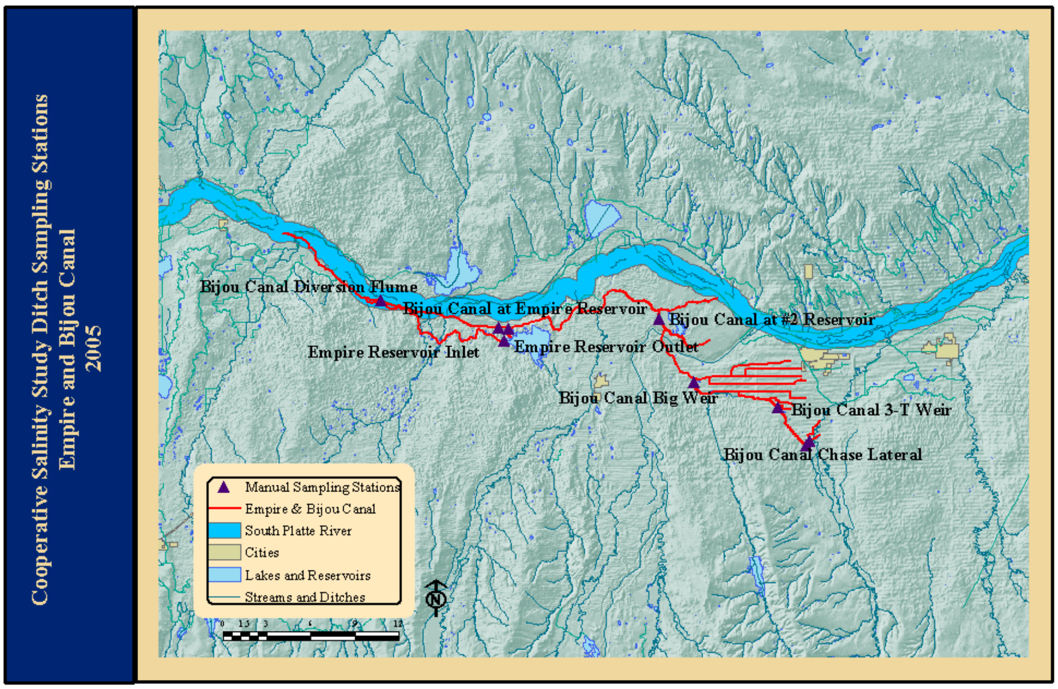


Figure 2.103 Annual Average EC_w with Distance Downstream
Riverside Canal

Empire and Bijou Canal

The Empire and Bijou Irrigation System was sampled from the Empire Reservoir inlet and outlet to the end of the canal system at the Bijou Canal Chase Lateral (Map 2.11). The EC_w statistics for this system are listed in Table 2.11 and the graphical representations are presented in Figures 2.104 - 2.112.



Map 2.11 Manual Sampling Stations – Empire and Bijou Canal

Site Description	Average EC_w (dS/m)	Average EC_w Standard Deviation (dS/m)	Maximum EC_w (dS/m) /week #	Minimum EC_w (dS/m) /week #
Empire Reservoir Inlet	1.15	0.23	1.53 / 1	0.70 / 25
Empire Reservoir Outlet	1.17	0.15	1.32 / 32	0.73 / 24
Bijou Canal Diversion Flume/Gauge	1.26	0.32	1.51 / 35	0.65 / 23
Bijou Canal at Empire	1.25	0.34	1.51 / 35	0.65 / 23
Bijou Canal at #2 Reservoir	1.16	0.24	1.43 / 39	0.66 / 23
Bijou Canal Big Weir	1.17	0.24	1.45 / 37	0.66 / 23
Bijou Canal 3-T Weir	1.21	0.18	1.45 / 37	0.70 / 25
Bijou Canal Chase Lateral or Pond	1.22	0.19	1.47 / 37	0.68 / 25

Table 2.11 Electrical Conductivity Statistics - Empire and Bijou Canal

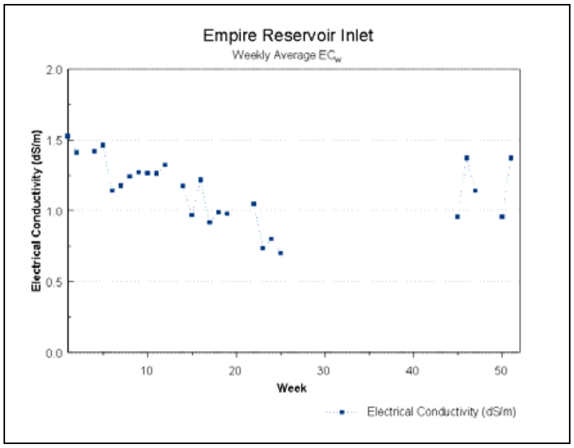


Figure 2.104 Weekly Average EC_w
Empire Reservoir Inlet

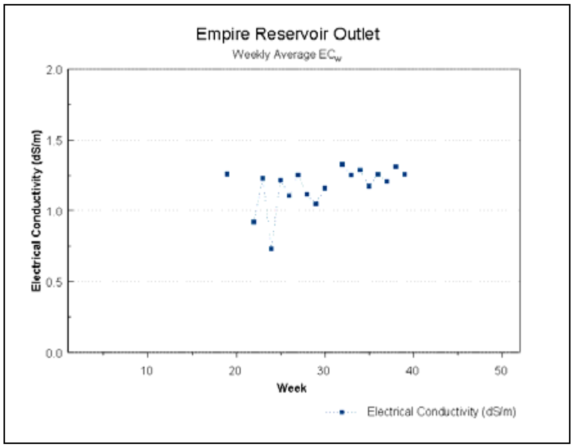


Figure 2.105 Weekly Average EC_w
Empire Reservoir Outlet

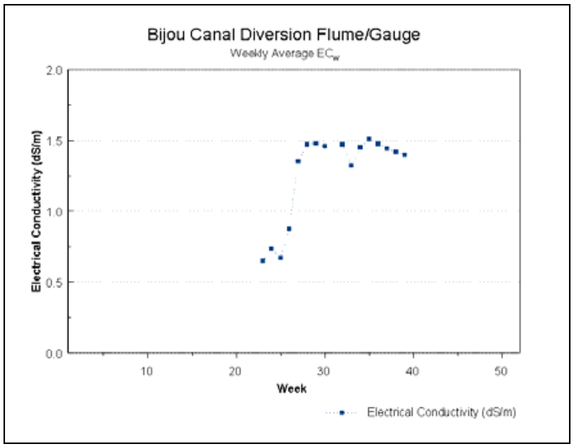


Figure 2.106 Weekly Average EC_w
Bijou Canal Diversion Flume/Gauge

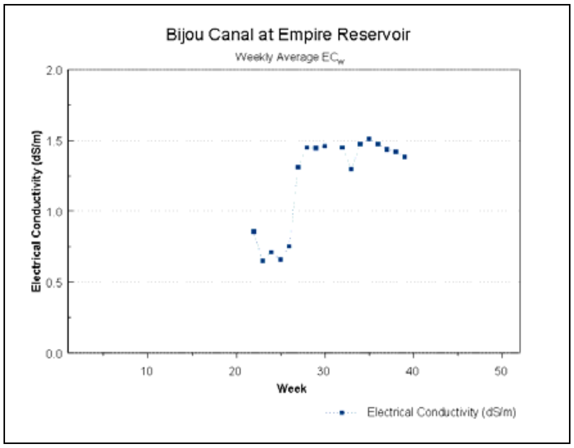


Figure 2.107 Weekly Average EC_w
Bijou Canal at Empire Reservoir

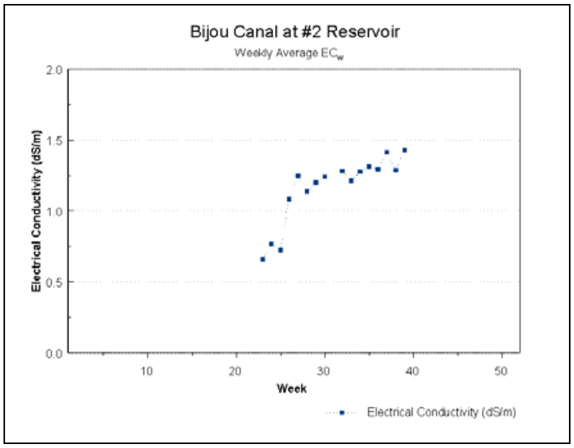


Figure 2.108 Weekly Average EC_w
Bijou Canal at #2 Reservoir

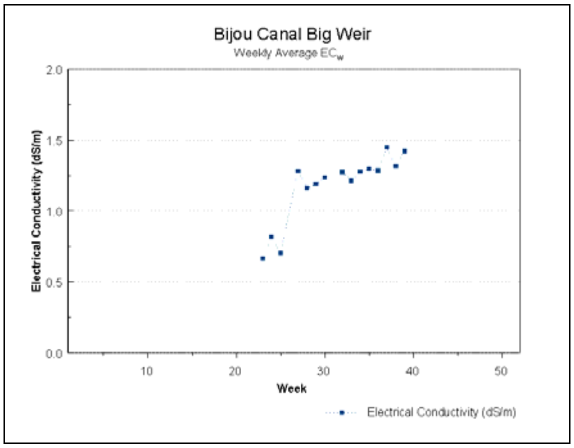


Figure 2.109 Weekly Average EC_w
Bijou Canal Big Weir

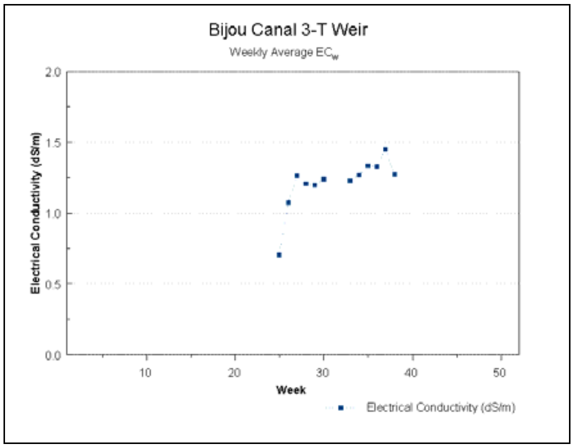


Figure 2.110 Weekly Average EC_w
Bijou Canal 3-T Weir

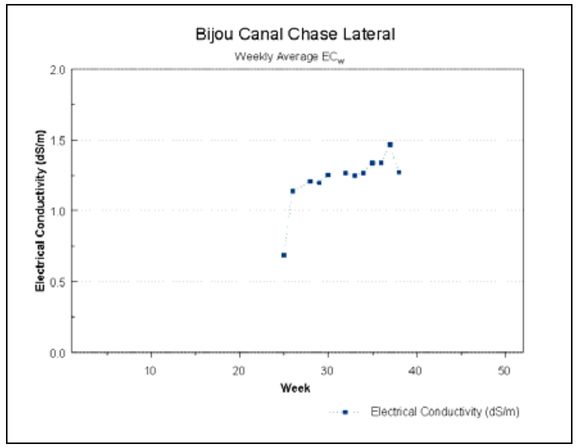


Figure 2.111 Weekly Average EC_w
Bijou Canal Chase Lateral

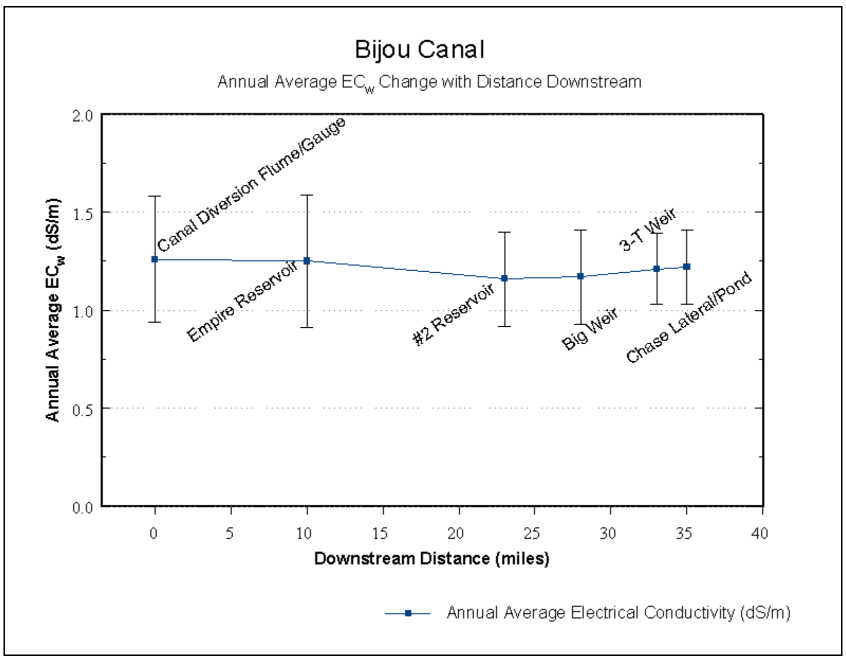
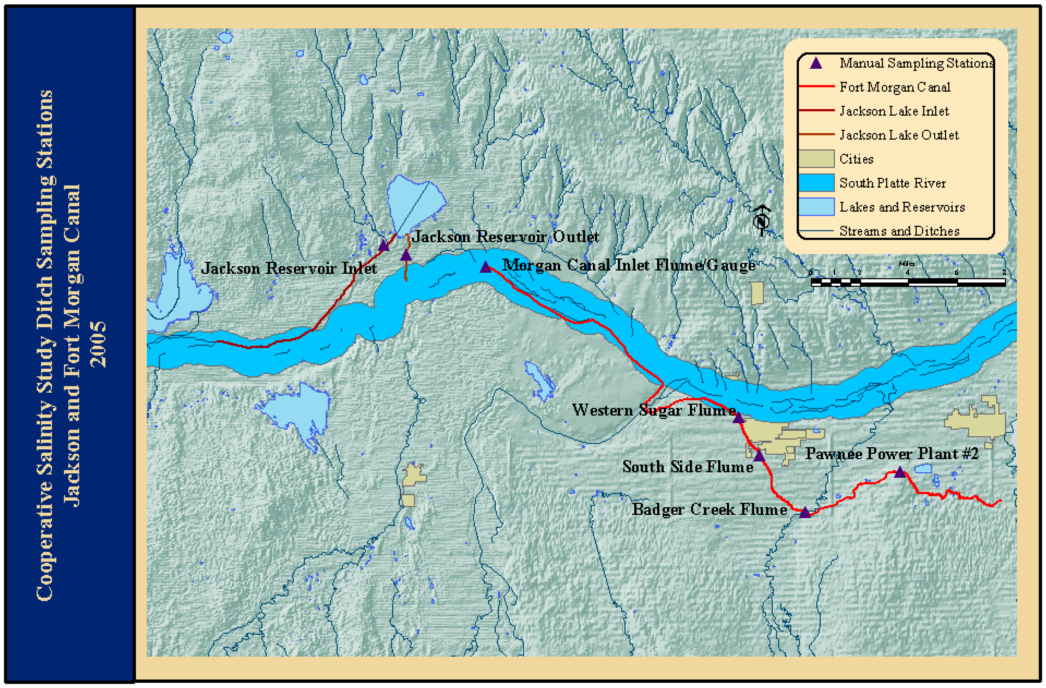


Figure 2.112 Annual Average EC_w with Distance Downstream
Bijou Canal

Jackson and Morgan Canal

Sampling of the Jackson and Morgan Canal System occurred from the Jackson Reservoir inlet to the end of the Morgan Canal at the Pawnee Power Plant directly east of Fort Morgan (Map 2.12). The average, standard deviation, maximum and minimum EC_w values are listed in Table 2.12, while the graphical representations are presented in Figures 2.113 - 2.120.



Map 2.12 Manual Sampling Stations – Jackson and Fort Morgan Canal

Site Description	Average EC_w (dS/m)	Average EC_w Standard Deviation (dS/m)	Maximum EC_w (dS/m) /week #	Minimum EC_w (dS/m) /week #
Jackson Reservoir Inlet	1.37	0.36	2.39 / 7	0.70 / 26
Jackson Outlet Gauge	1.37	0.04	1.43 / 39	1.31 / 29
Morgan Canal Inlet Flume/Gauge	1.21	0.26	1.45 / 37	1.72 / 23
Western Sugar Flume	1.27	0.26	1.46 / 37	0.73 / 23
Southside Flume	1.25	0.26	1.45 / 37	0.73 / 23
Badger Flume	1.24	0.27	1.47 / 37	0.72 / 23
Pawnee Power Plant #2	1.24	0.27	1.47 / 37	0.73 / 23

Table 2.12 Electrical Conductivity Statistics - Jackson and Fort Morgan Canal

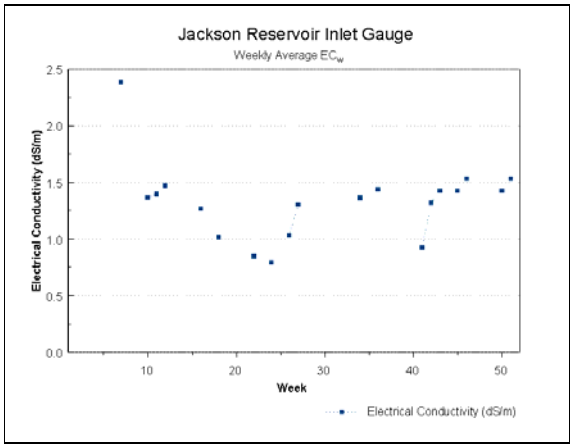


Figure 2.113 Weekly Average EC$_w$
Jackson Reservoir Inlet Gauge

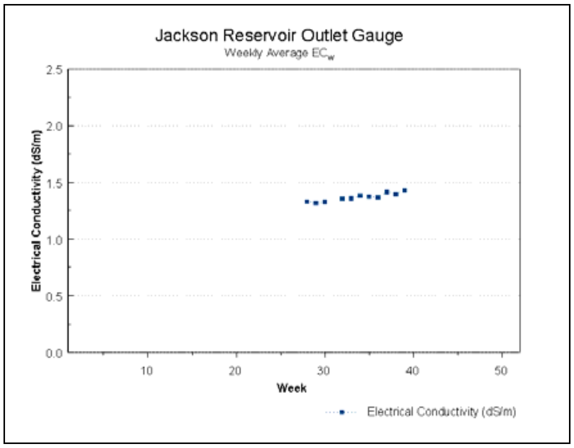


Figure 2.114 Weekly Average EC$_w$
Jackson Reservoir Outlet Gauge

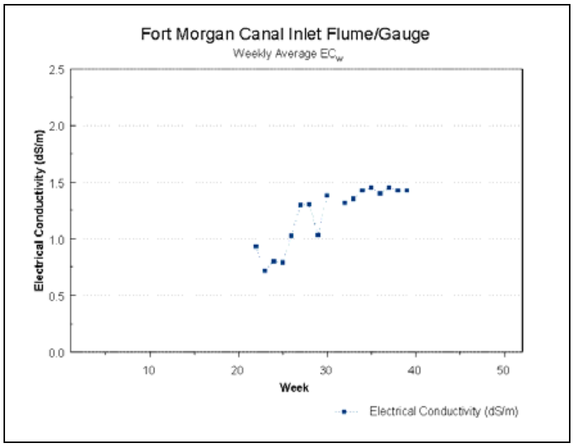


Figure 2.115 Weekly Average EC$_w$
Fort Morgan Canal Inlet Flume/Gauge

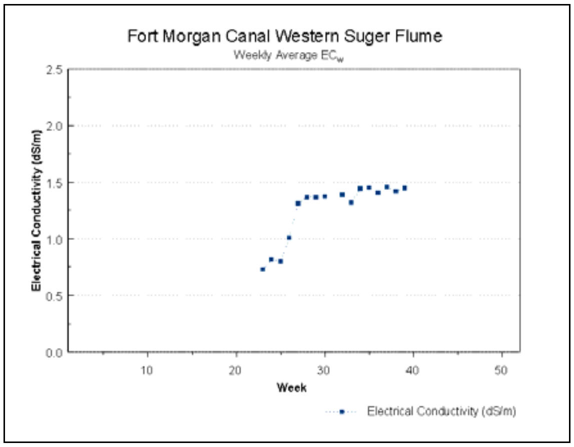


Figure 2.116 Weekly Average EC$_w$
Fort Morgan Canal Western Sugar Flume

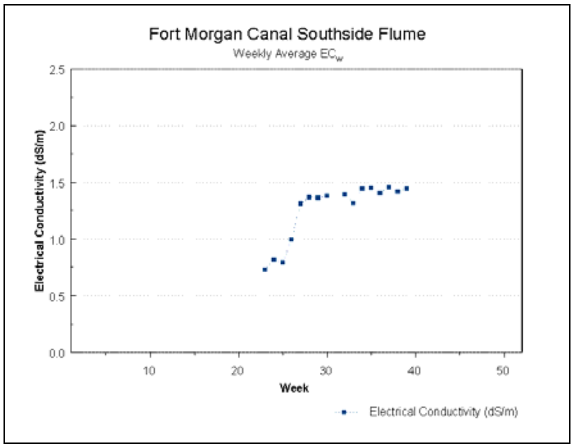


Figure 2.117 Weekly Average EC$_w$
Fort Morgan Canal Southside Flume

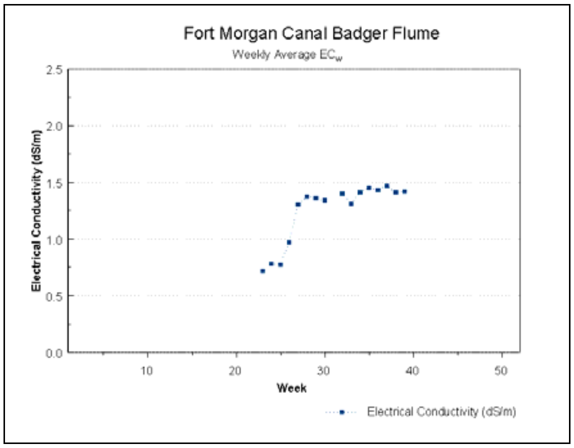


Figure 2.118 Weekly Average EC_w
Fort Morgan Canal Badger Creek Flume

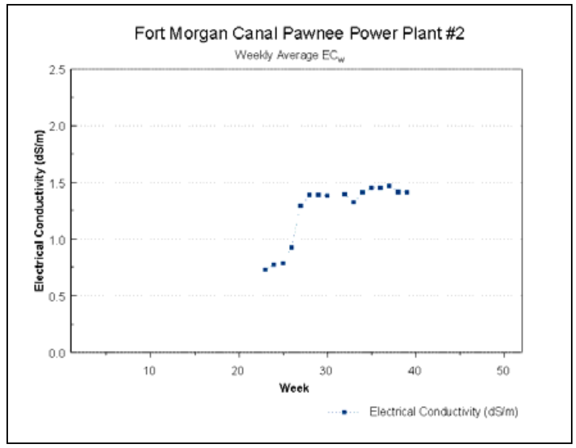


Figure 2.119Weekly Average EC_w
Fort Morgan Canal Pawnee Power Plant #2

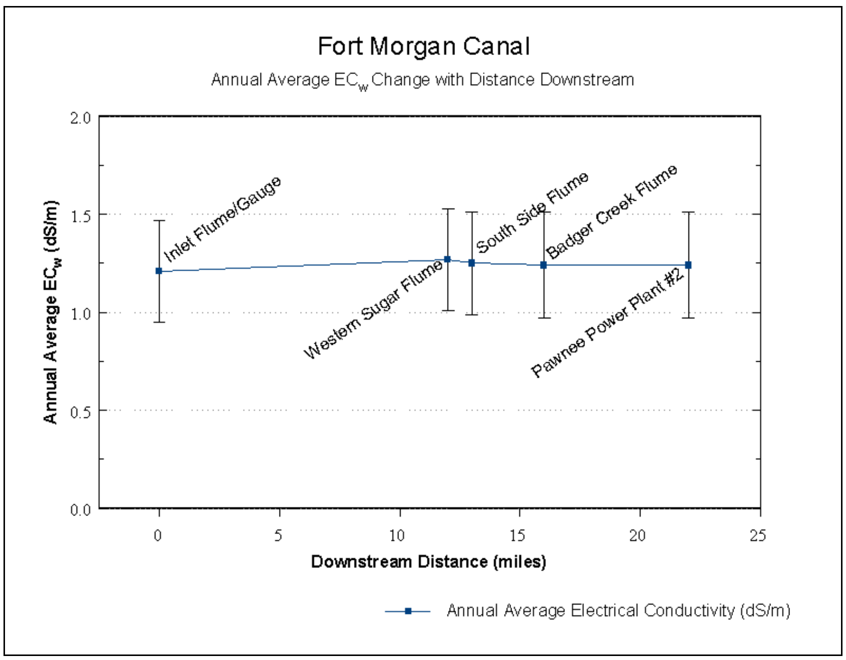
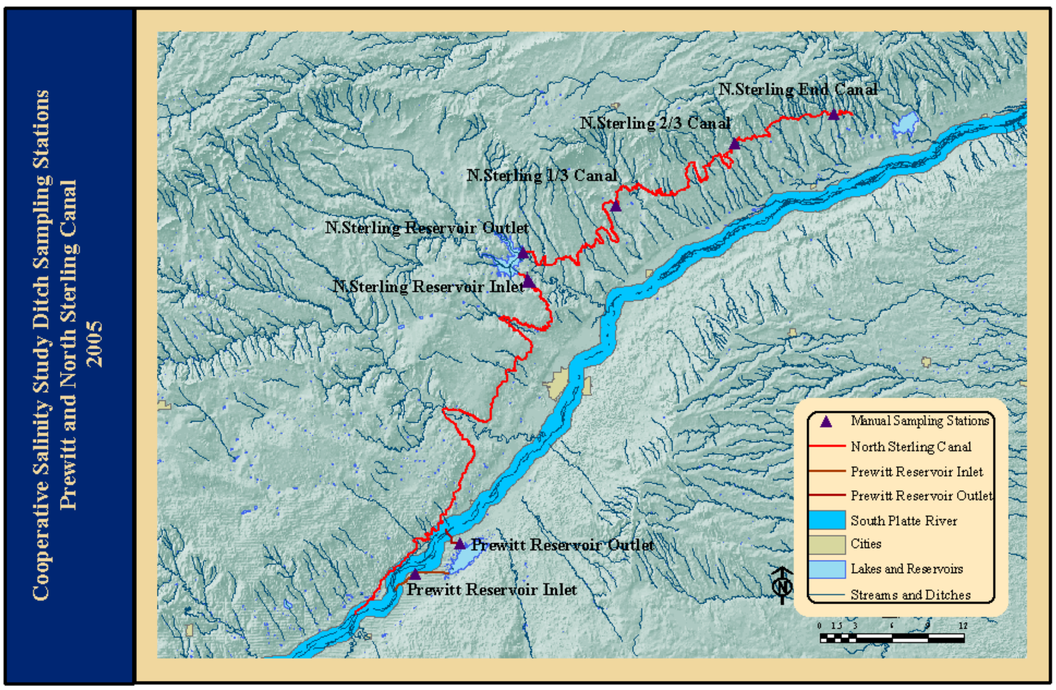


Figure 2.120 Annual Average EC_w with Distance Downstream
Fort Morgan Canal

Prewitt and North Sterling Canal

The Prewitt and North Sterling Irrigation System was monitored from its origin at the Prewitt Reservoir inlet to the end of the North Sterling Canal north of Crook (Map 2.13). The EC_w statistics are compiled in Table 2.13. Figures 2.121 - 2.128 graphically depict the temporal and spatial variations in EC_w levels throughout the system.



Map 2.13 Manual Sampling Stations – Prewitt and North Sterling Canal

Site Description	Average EC_w (dS/m)	Average EC_w Standard Deviation (dS/m)	Maximum EC_w (dS/m) /week #	Minimum EC_w (dS/m) /week #
Prewitt Reservoir Inlet Flume	1.71	0.36	2.11 / 14	0.93 / 41
Prewitt Reservoir Outlet Flume	1.48	0.03	1.55 / 39	1.42 / 27
North Sterling Reservoir Inlet	1.56	0.22	1.87 / 46	0.99 / 26
North Sterling Reservoir Outlet Flume	1.38	0.01	1.61 / 19	1.31 / 36
North Sterling 1/3 Canal	1.38	0.03	1.41 / 26	1.33 / 33
North Sterling 2/3 Canal	1.38	0.03	1.43 / 26	1.35 / 33
North Sterling End Canal	1.37	0.03	1.40 / 28	1.33 / 33

Table 2.13 Electrical Conductivity Statistics - Prewitt and North Sterling Canal

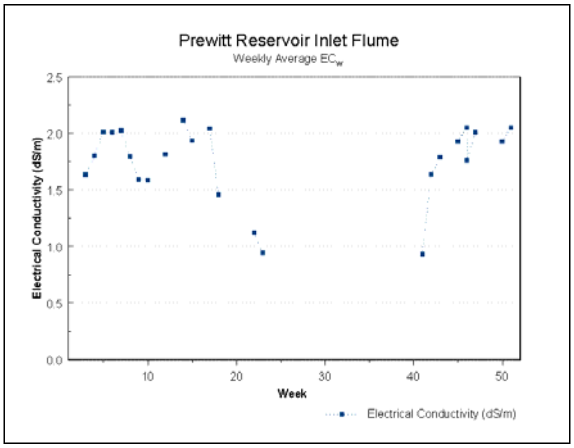


Figure 2.121 Weekly Average EC$_w$
Prewitt Reservoir Inlet Flume

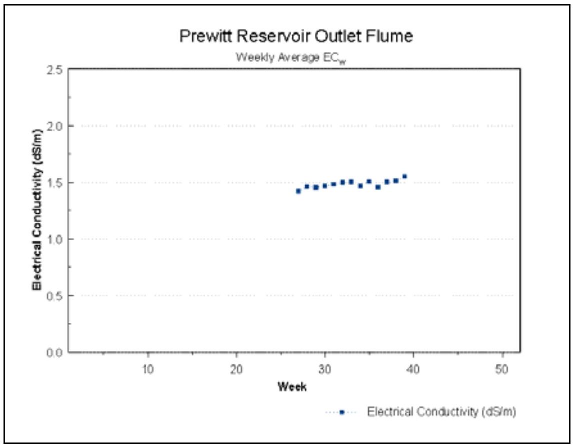


Figure 2.122 Weekly Average EC$_w$
Prewitt Reservoir Outlet Flume

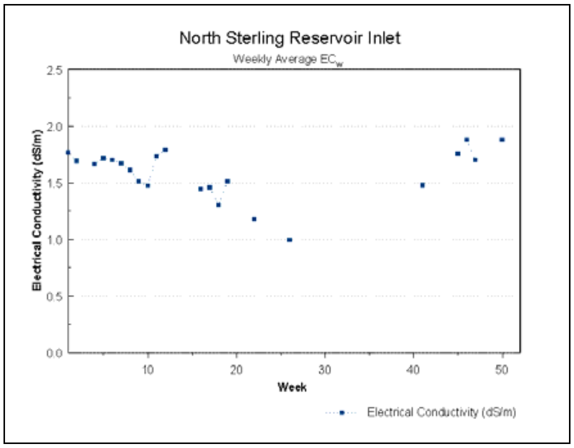


Figure 2.123 Weekly Average EC$_w$
North Sterling Reservoir Inlet

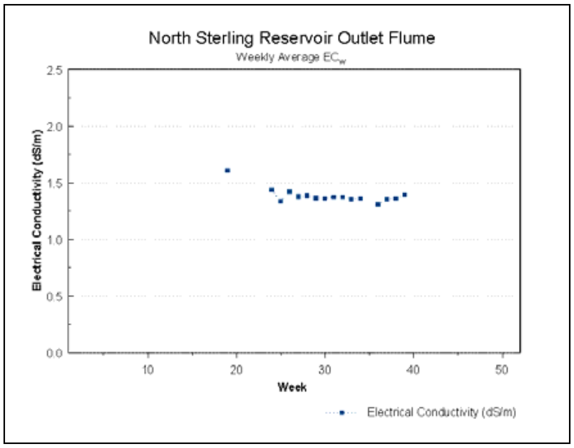


Figure 2.124 Weekly Average EC$_w$
North Sterling Reservoir Outlet Flume

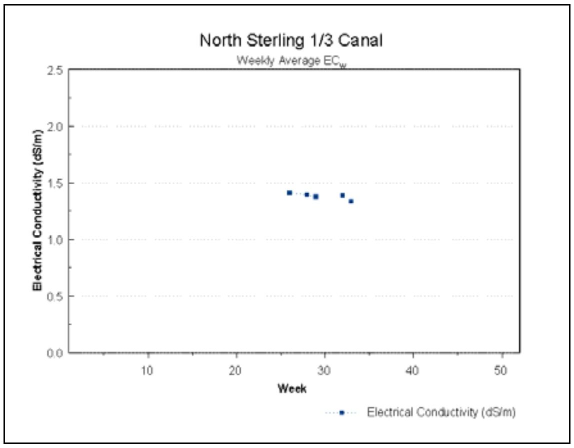


Figure 2.125 Weekly Average EC$_w$
North Sterling 1/3 Canal

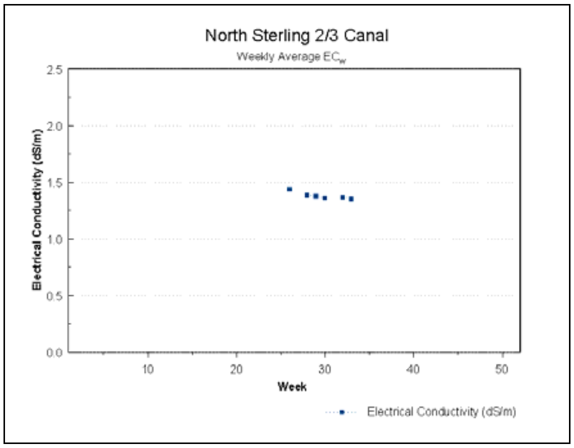


Figure 2.126 Weekly Average EC_w
North Sterling 2/3 Canal

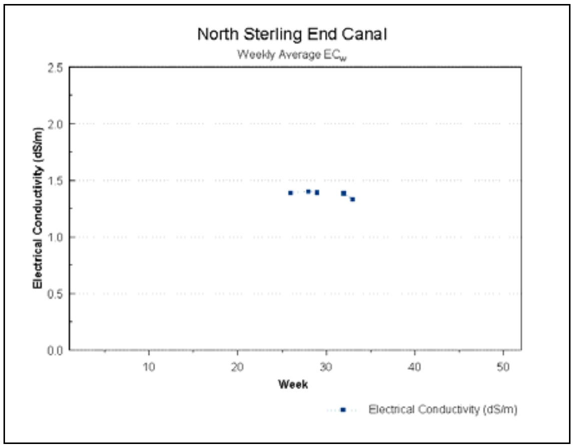


Figure 2.127 Weekly Average EC_w
North Sterling End Canal

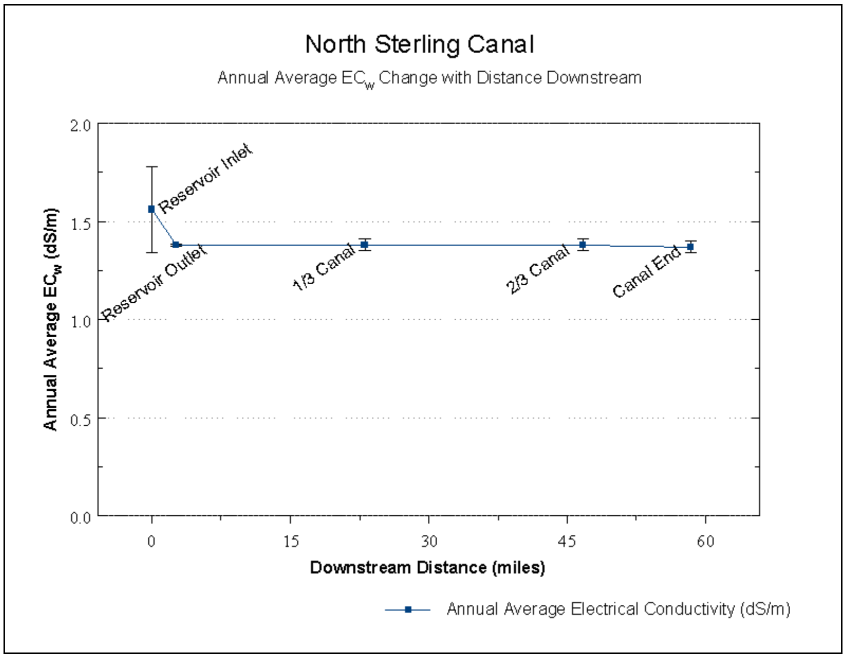
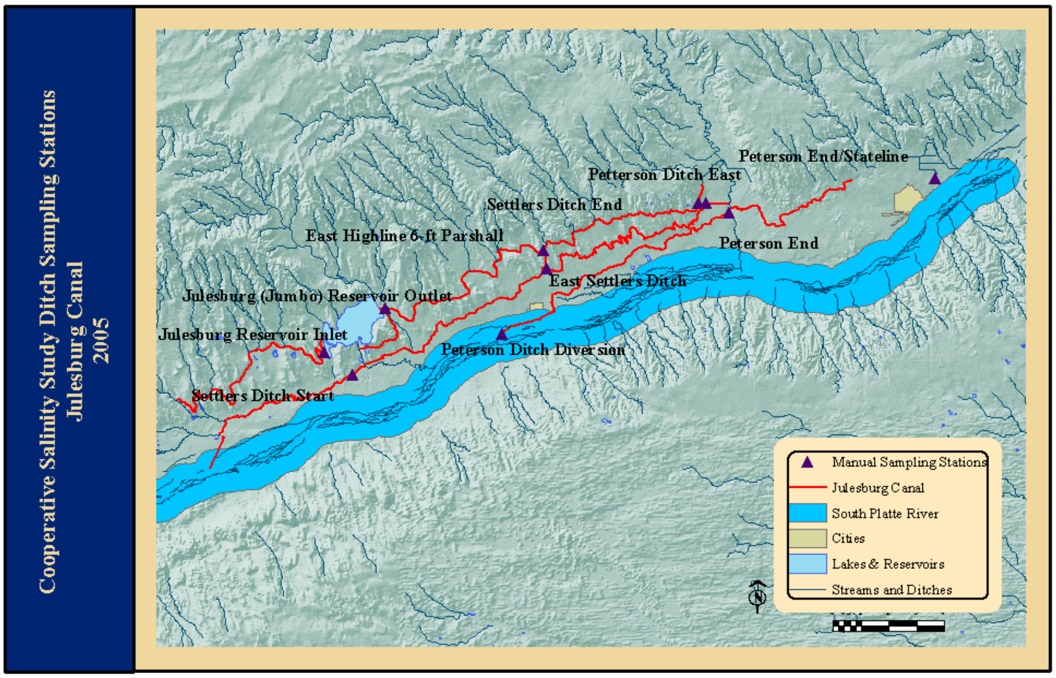


Figure 2.128 Annual Average EC_w with Distance Downstream
North Sterling Canal

Julesburg Canal

The Julesburg Canal was monitored at 10 locations ranging from the Julesburg Reservoir inlet to the end of the irrigation system at the Colorado/Nebraska state line. As shown in Map 2.14, this irrigation system is divided among three separate ditches, the Settlers, Highline and Peterson. In Table 2.14 the annual statistics for this system are displayed. Moreover, Figures 2.129 - 2.141 display graphical representations of changes in EC_w values with time and space.



Map 2.14 Manual Sampling Stations – Julesburg Canal

Site Description	Average EC_w (dS/m)	Average EC_w Standard Deviation (dS/m)	Maximum EC_w (dS/m) /week #	Minimum EC_w (dS/m) /week #
Julesburg Reservoir Inlet Gauge	2.04	0.29	2.57 / 6	1.14 / 24
Settlers Ditch Start	2.60	0.19	3.22 / 24	2.43 / 26
Julesburg (Jumbo) Reservoir Outlet Canal	1.97	0.08	2.18 / 19	1.86 / 27
Peterson Ditch Diversion	2.09	0.28	2.27 / 35	1.20 / 24
East Settlers Ditch	2.09	0.12	2.36 / 22	1.88 / 24
East Highline 6-footParshall	1.95	0.07	2.06 / 39	1.87 / 29
Harry Highline Ditch	1.96	0.01	2.10 / 39	1.86 / 26
Settlers Ditch End	2.03	0.08	2.19 / 39	1.90 / 28
Peterson Ditch East	2.10	0.15	2.32 / 23	1.60 / 24
Peterson End/Stateline Ditch	2.17	0.23	2.47 / 32	1.45 / 24

Table 2.14 Electrical Conductivity Statistics - Julesburg Canal

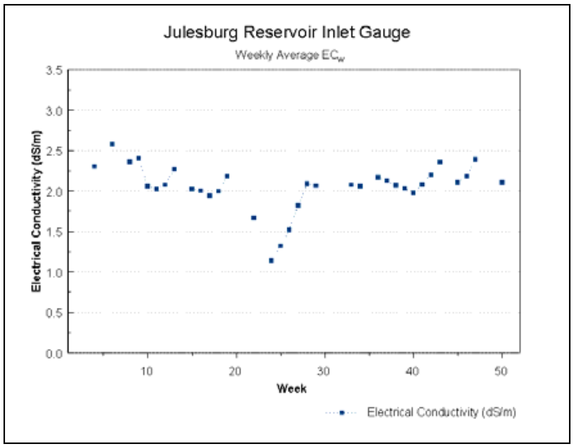


Figure 2.129 Weekly Average EC_w
Julesburg Reservoir Inlet Gauge

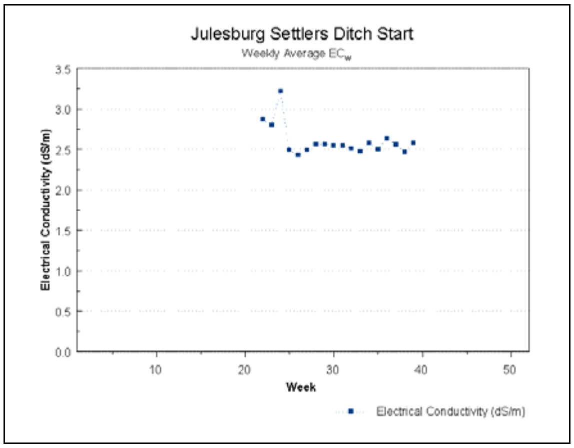


Figure 2.130 Weekly Average EC_w
Julesburg Settlers Ditch Start

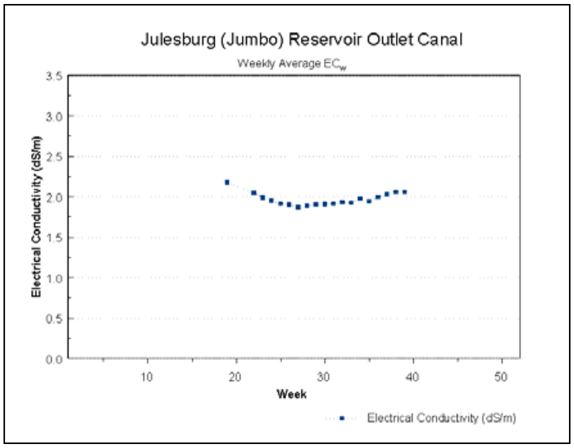


Figure 2.131 Weekly Average EC_w
Julesburg (Jumbo) Reservoir Outlet Canal

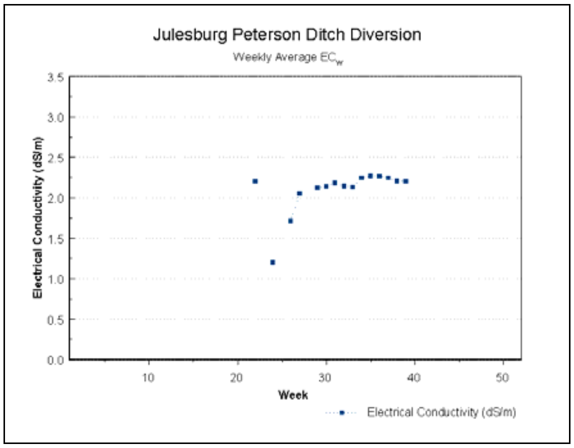


Figure 2.132 Weekly Average EC_w
Julesburg Peterson Ditch Diversion

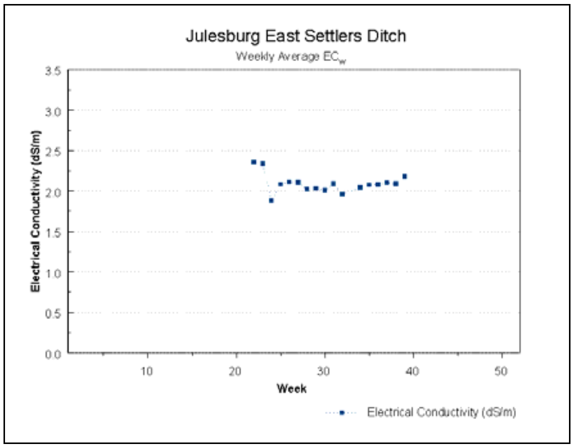


Figure 2.133 Weekly Average EC_w
Julesburg East Settlers Ditch

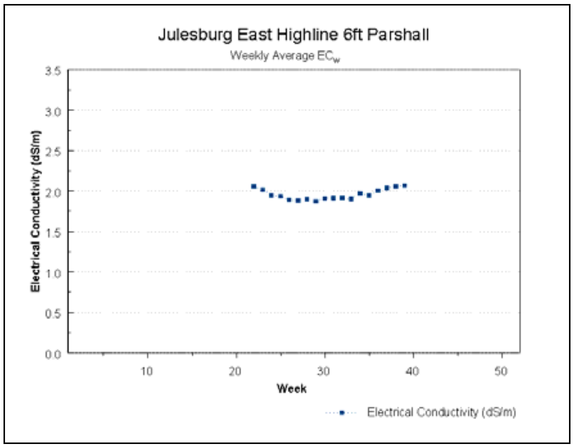


Figure 2.134 Weekly Average EC_w
Julesburg East Highline 6-foot Parshall

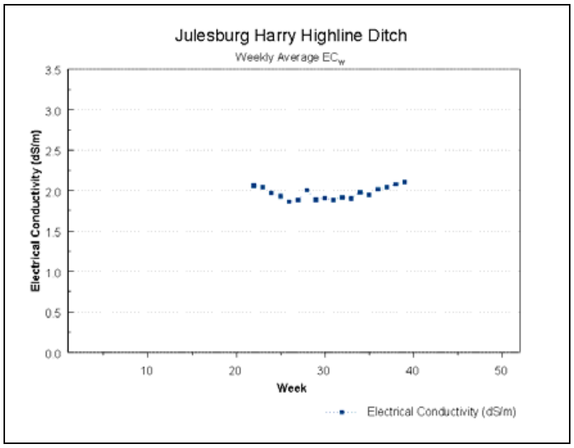


Figure 2.135 Weekly Average EC_w
Julesburg Harry Highline Ditch

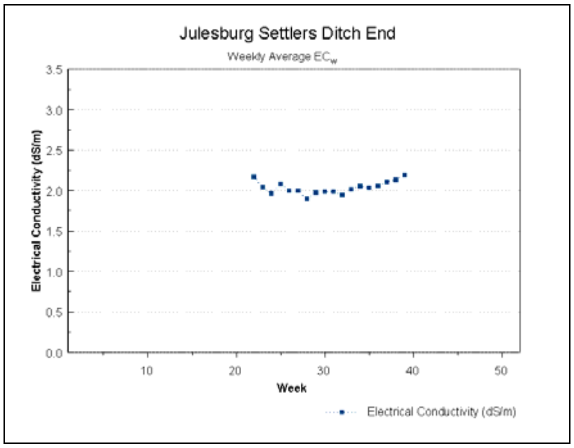


Figure 2.136 Weekly Average EC_w
Julesburg Settlers Ditch End

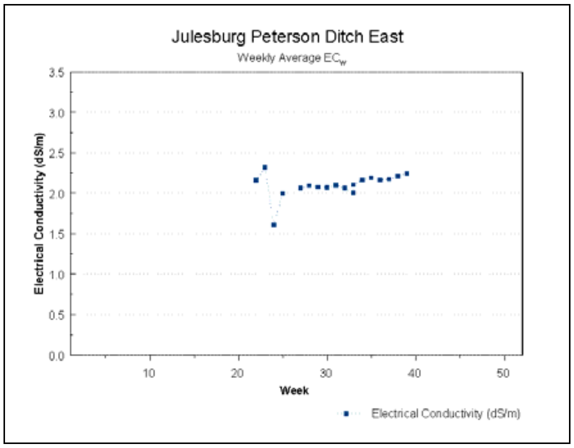


Figure 2.137 Weekly Average EC_w
Julesburg Peterson Ditch East

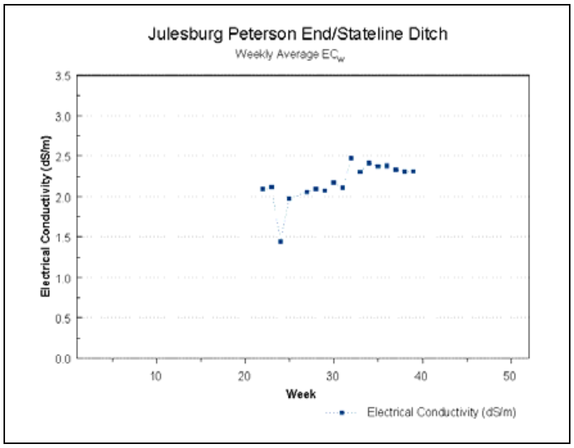


Figure 2.138 Weekly Average EC_w
Julesburg Peterson End/Stateline Ditch

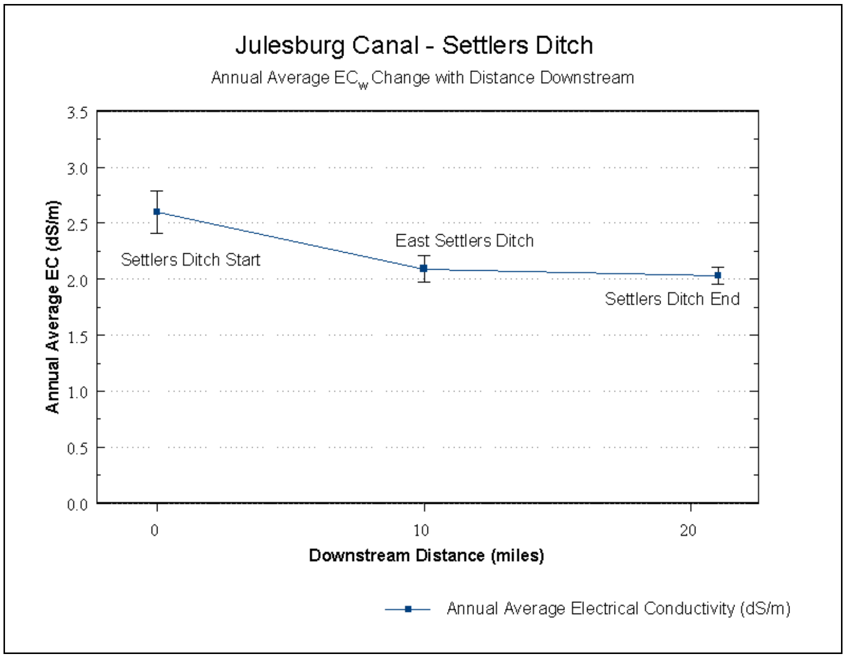


Figure 2.139 Annual Average EC_w with Distance Downstream
Julesburg Canal – Settlers Ditch

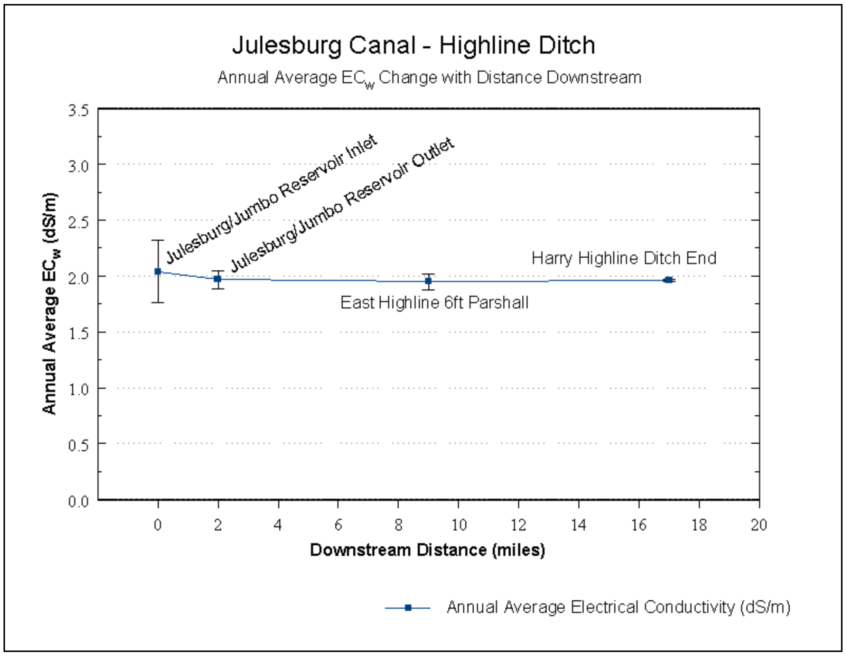


Figure 2.140 Annual Average EC_w with Distance Downstream
Julesburg Canal – Highline Ditch

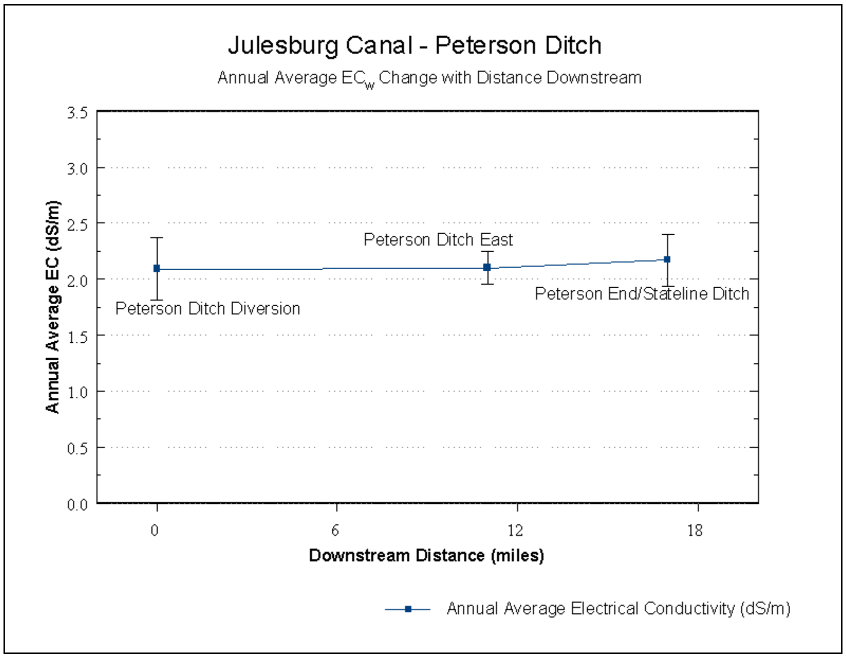


Figure 2.141 Annual Average EC_w with Distance Downstream
Julesburg Canal – Peterson Ditch

2.4 Total Dissolved Solids Sampling

To compile a broad database including information as to the composition of salts and their relative concentrations throughout the Lower South Platte Basin, bi-yearly TDS sampling events have been implemented. Immediately following spring run-off in May and during the height of irrigation season in August, grab samples were taken at 10 stream sampling locations and sent to an outside laboratory to be tested via ion chromatography for a wide variety of commonly-occurring ions. Five samples were taken along the South Platte River from Henderson to Julesburg and one sample was taken on each major South Platte tributary; these tributaries include the Cache la Poudre, Big Thompson and Little Thompson Rivers, and the Saint Vrain and Boulder Creeks. Results from these sampling events are displayed in Tables 2.15 and 2.16.

With only a few exceptions, TDS concentrations increased significantly from the sampling event conducted in May compared to the one in August, as well as with increased distance downstream. One can attribute these trends, in part, to the diluting influence of spring runoff. In addition, this trend can be further explained by the compounding result of irrigation return flows during the summer months; the more times the water is used, the greater its opportunity to collect dissolved salts.

There are a few notable exceptions to these observed trends. The overall salt concentrations measured at the South Platte River in Julesburg are comparatively exceptionally low during the August sampling event. This could be attributed to either sampling error or a release into the South Platte River that occurred below the sampling event at Sterling. Additionally, exceptionally high TDS salt concentrations were recorded at Boulder Creek across 75th Street near Boulder in August. Again, this could be attributed to inconsistent sampling. There is a wastewater effluent outflow located at this site. If one set of samples was taken above the confluence of the effluent stream and Boulder Creek but not the other, this discrepancy could easily be explained. If both were taken below the confluence but an exceptionally large amount of water had recently been treated or there was some other diluting event this would also skew the results. Lastly, the Little Thompson River at Milliken showed exceptionally high dissolved salt concentrations during the spring sampling run when compared to the rest of the system. This is consistent with both the results from last year's TDS sampling event as well as the weekly EC_w monitoring at this site.

It should be noted that statistical significance is not obtained via obtaining grab samples on a bi-annual basis. These results should be interpreted as only representing a rough, preliminary assessment of the overall TDS concentrations throughout the system.

Site Information		Parameters Tested (ppm)											Approximation of Total Salts (ppm)
Site Description	**Site Abbreviation**	**Na^+**	**K^+**	**Ca^{2+}**	**Mg^{2+}**	**$CaCO_3$ (hardness)**	**NO_3-N**	**SO_4-S**	**Cl^-**	**CO_3^{2-}**	**HCO_3^- (bicarbonate)**	**$CaCO_3$ (alkalinity)**	**TDS**
Cache la Poudre at Greeley near Airport	CLAGRECO	7	1	12	4	47	< 0.1	3	10	< 1	33	27	96
Big Thompson near La Salle	BIGLASCO	24	2	24	11	106	1.3	22	18	< 1	68	56	222
Little Thompson at Milliken across Hwy 257	LTMIL257	156	5	170	106	867	4.0	261	24	< 1	283	232	1236
Saint Vrain near Platteville	SVCPLACO	37	3	62	26	263	1.2	67	10	< 1	106	87	426
Boulder Creek across 75th Street near Boulder	BOCNORCO	77	6	102	42	430	5.0	115	34	< 1	213	174	708
South Platte at Henderson	PLAHENCO	51	7	37	10	134	3.6	27	45	< 1	97	80	354
South Platte near Kersey	PLAKERCO	39	4	40	15	163	2.2	36	30	< 1	103	84	330
South Platte at Fort Morgan	PLAMORCO	65	6	68	25	274	2.2	67	44	< 1	164	134	528
South Platte at Sterling	PLASTRCO	141	12	140	52	567	2.1	166	77	< 1	284	233	1032
South Platte at Julesburg (Channel 1)	ONEJURCO	212	21	223	64	824	2.8	273	113	< 1	301	247	1452

Table 2.15 Total Dissolved Solids Testing, May 2005

Site Information		Parameters Tested (ppm)											Approximation of Total Salts (ppm)
Site Description	**Site Abbreviation**	**Na^+**	**K^+**	**Ca^{2+}**	**Mg^{2+}**	**$CaCO_3$ (hardness)**	**NO_3-N**	**SO_4-S**	**Cl^-**	**CO_3^{2-}**	**HCO_3^- (bicarbonate)**	**$CaCO_3$ (alkalinity)**	**TDS**
Cache la Poudre at Greeley near Airport	CLAGRECO	95	5	128	72	620	3.3	147	24	< 1	264	216	954
Big Thompson near La Salle	BIGLASCO	12	1	35	12	138	< 0.1	22	12	4	65	53	246
Little Thompson at Milliken across Hwy 257	LTMIL257	80	6	97	47	438	3.0	109	38	< 1	229	188	756
Saint Vrain near Platteville	SVCPLACO	116	5	137	79	672	3.8	183	23	< 1	271	222	1068
Boulder Creek across 75th Street near Boulder	BOCNORCO	220	20	218	59	791	2.8	251	113	< 1	288	236	1500
South Platte at Henderson	PLAHENCO	78	9	63	13	212	3.9	44	74	< 1	152	124	552
South Platte near Kersey	PLAKERCO	105	8	99	42	422	5.0	100	69	< 1	228	187	822
South Platte at Fort Morgan	PLAMORCO	138	11	131	50	533	3.4	137	85	30	229	189	1020
South Platte at Sterling	PLASTRCO	166	14	156	57	628	2.2	182	92	30	228	188	1194
South Platte at Julesburg (Channel 1)	ONEJURCO	103	6	87	49	422	3.6	109	51	< 1	238	195	810

Table 2.16 Total Dissolved Solids Testing, August 2005

To make educated guesses as to the originating salt compounds, the part-per-million (ppm) concentrations displayed in Tables 2.15 and 2.16 were converted to milliequivalents per liter (meq/L). This is a convenient means of expressing concentrations when the analytes are dissolved and disassociated in solution. To convert from ppm to meq/L, one must divide the measured ppm by the equivalent weight of the element in question. For example, Equation 2.3 demonstrates how to calculate the equivalent weight of magnesium (Mg^{2+}), which has a molecular weight equal to 24 and a valence of +2:

$$\frac{24 gramsMg^{2+}}{moleMg^{2+}} * \frac{1 moleMg^{2+}}{2 equivalents} = \frac{12 gramsMg^{2+}}{equivalent} = \frac{12 mgMg^{2+}}{meq} \quad .$$

Equation 2.3 Equivalent Weight Example Calculation

Once the equivalent weight is calculated, divide this value by the reported ppm concentration to arrive at the meq/L. Assuming there was a reported 72 ppm Mg^{2+}, Equation 2.4 illustrates the conversion to a meq/L concentration:

$$72\, ppmMg^{2+} = \frac{72 mgMg^{2+}}{L} * \frac{meq}{12 mgMg^{2+}} = 4 \frac{meq}{L} .$$

Equation 2.4 Conversion from a ppm to a meq/L Concentration

By then comparing the cations and anions with the highest meq/L concentrations at each site, one can predict what the salt compounds likely were before dissolution. Following this method, Table 2.17 contains a list of possible contributing salt compounds for each site during the two sampling events.

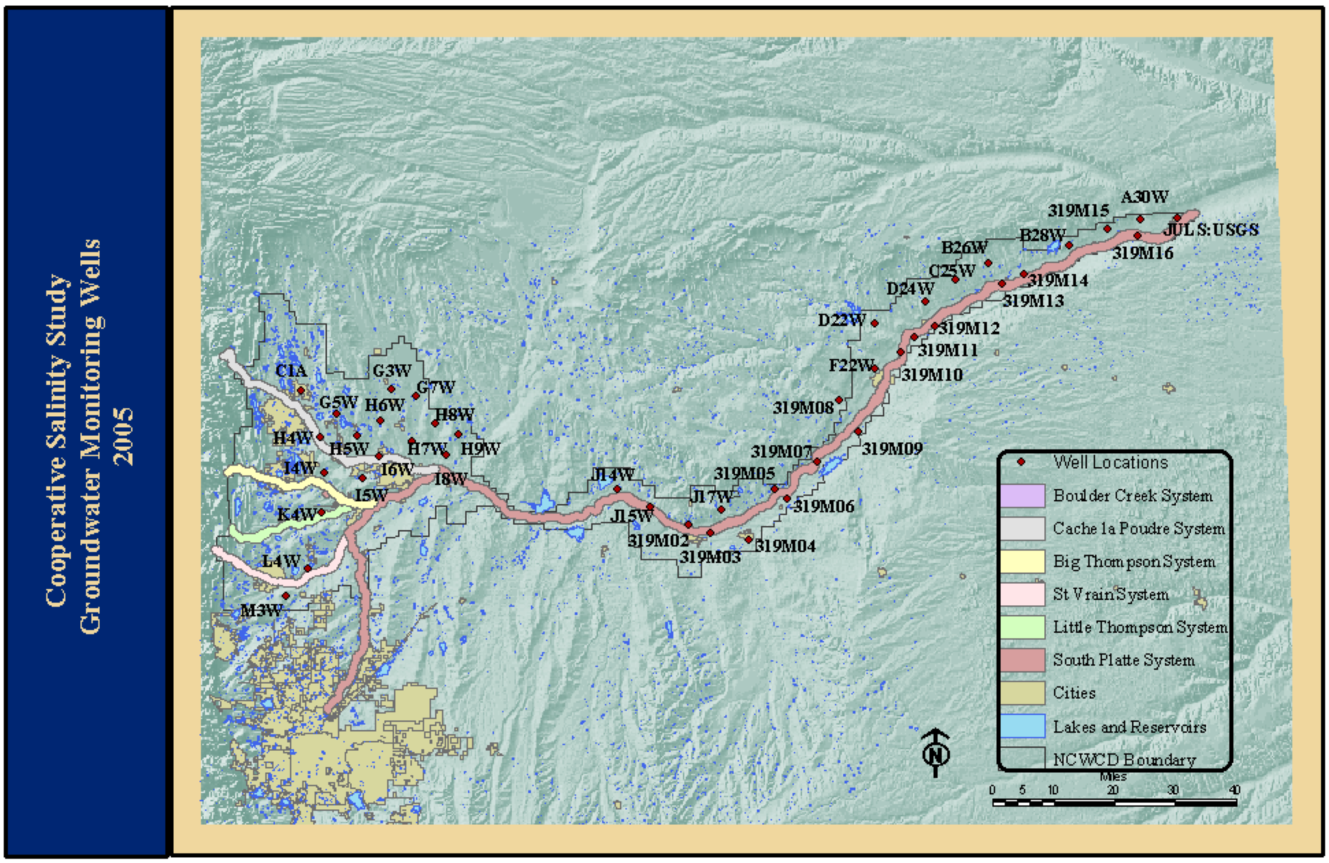
Site Information		Predicted Salts Compounds	
Site Description	Site Abbreviation	May Sampling Event	August Sampling Event
Cache la Poudre at Greeley near Airport	CLAGRECO	magnesium / sodium bicarbonate	calcium sulfate
Big Thompson near La Salle	BIGLASCO	calcium / magnesium sulfate	sodium / calcium sulfate
Little Thompson at Milliken across Hwy 257	LTMIL257	sodium bicarbonate	calcium sulfate
Saint Vrain near Platteville	SVCPLACO	calcium sulfate	calcium / magnesium sulfate
Boulder Creek across 75th Street near Boulder	BOCNORCO	calcium sulfate	sodium / calcium sulfate
South Platte at Henderson	PLAHENCO	calcium sulfate	sodium bicarbonate
South Platte near Kersey	PLAKERCO	calcium / magnesium sulfate	calcium sulfate
South Platte at Fort Morgan	PLAMORCO	sodium sulfate	sodium / calcium sulfate
South Platte at Sterling	PLASTRCO	calcium sulfate	calcium sulfate
South Platte at Julesburg (Channel 1)	ONEJURCO	sodium / calcium sulfate	unable to predict

Table 2.17 Predicted Salt Compounds

3. Groundwater Sampling

3.1 Introduction and Overview

A total of 42 groundwater wells were monitored for EC_w and depth during 2005. Six new wells were added to the sampling schedule from 2004. These wells were purged in the spring and monitoring began during the summer months. The range of the monitoring wells spans the entire District boundaries. The various locations and well identifications are presented in Map 3.1.



Map 3.1 Groundwater Monitoring Wells

Well Drilling

In order to increase the scope of the groundwater monitoring, several new wells were added to the sampling schedule in 2005. The District utilized a 1969 Central Mine Equipment-55 (CME-55) Drill retrofitted with a John Deere 4-cylinder diesel motor to drill the new monitoring wells. The CME-55 is equipped with a CME keyed coupling, hard-surfaced, hollow-stem auger (3.75-inch ID x 7.125-inch OD x 5-foot length) and a hollow auger head with an expandable disk and spring (3.75 x 7.75-inch OD). This machinery is mounted on a 1965 Ford 2-ton, 4-wheel drive pickup, as pictured in Figure 3.1.

Figure 3.1 Well Drilling Rig

After contacting the appropriate utility agencies to ensure the area of interest is clear from buried lines, the District follows the following hollow-stem auger drilling method:

1) Drill a hole approximately 10-20 feet past the point at which wet tailings are first identified;
2) Fill the hollow auger with water to prevent slurry from entering the hollow stem when the expandable disk is knocked out;
3) Lower the center hexagon drive system through the hollow auger and punch out the expandable disk from the auger head;
4) Place a 2-inch PVC casing, equipped with 10 to 20 feet of 0-010-inch slotted screening at the bottom, down the hollow stem;
5) Fill the PVC casing with water;
6) As the auger is pulled, slowly fill the area between the hollow-stem auger and the PVC casing with 10-20 millimeter silica sand;
7) Remove the first auger when a sufficient amount of silica sand has been filled in the hole to cover the first five feet of screen;

8) Continue backfilling the hole with silica sand until reaching 10 feet below the ground surface;
9) Add pellet bentonite to within 2 feet of the ground surface;
10) Place protective covering over the PVC casing; and
11) Fill the remainder of the hole with concrete, creating a slightly concave uppermost surface to encourage water flow away from the well stem.

While following the above procedure, the District has encountered a few obstacles. At times, the expandable disk has dislocated during the drilling process, allowing the hollow auger to be filled with tailings. In such situations, the drilling process has been forced to begin again. The reverse of this situation has also been encountered; the expandable disc has not punched out of the auger head at the appropriate time. The solution to this issue has been to either raise the auger up a foot and try again or raise the auger all the way up, lubricate the expandable disc and ring and reattempt the drilling process. The District has also experienced problems drilling through hard, compacted shale layers; the associated heat generated caused materials to bake onto auger flights. In response, the following three procedures have been attempted in order to remedy the situation: 1) the auger has been pulled, materials removed and drilling proceeded at slower speeds, 2) water has been poured down the drilled hole in an attempt to cool materials, and 3) augers have been reversed in attempts to dislodge materials from auger flights. Lastly, the District has met with problems associated with slurry entering the auger hole after the expandable disc has been removed. The installed casing has been pulled away when attempting to remove the augers. The response to this issue has been to remove the auger and casing and attempt the process again.

Groundwater Data Analysis Procedure

Groundwater electrical conductivity and depth data were aggregated by inverse distance weighting (IDW) analysis over 5-mile square areas. IDW is an interpolation technique in which estimates are made based on the values of neighboring points. The premise of IDW interpolation relies upon the weighing of data points by the inverse of their distance to the estimation point or area (Childs). This approach has the effect of giving more influence to nearby data points than to those farther away. IDW interpolation is explained mathematically in Equation 3.1:

$$v_0 = \frac{\sum_{i=1}^{N(v_0)} \frac{1}{d_i^P} v_i}{\sum_{i=1}^{N(v_0)} d_i^P},$$

Equation 3.1 Inverse Distance Weighting Interpolation

where v_0 = estimated value at (x_0, y_0, z_0),
$N(v_0)$ = the number of data points in the neighborhood of v_0,
d_i = the distance between (x_0, y_0, z_0) and (x_i, y_i, z_i),
v_i = a neighboring data value at (x_i, y_i, z_i) and
P = the power.

This analysis was performed in ArcGIS 9.0 where the *z* values were set equal both to the EC_w and depth records at each well coordinate, the power set equal to 2 and the output cell size assigned to 5-mile blocks.

3.2 Groundwater Electrical Conductivity Analysis

The District monitors 42 wells for EC_w. During the summer months when there are two interns dedicated solely to the field aspect of this project, data is collected from the wells on a weekly basis. During the rest of the year, data is gathered monthly. As reviewed in Section 5, Quality Assurance and Quality Control, the District's well monitoring protocol requires each well to be pumped for a minimum of five minutes. This helps assure a representative sample is tested and that samples are not taken from a stagnant column of water.

The District currently utilizes a Grundfos Rediflow, a Proactive Monsoon and two Proactive Tsunami pumping systems, with the latter being used solely for back-ups. The well water is routed through a PVC flow cell in which the instruments measuring EC_w are inserted. This pumping and sampling set-up is pictured in Figure 3.2. Additionally, Table 3.1 displays the average, standard deviation, maximum and minimum EC_w values for each well.

Figure 3.2 Well Electrical Conductivity Monitoring

Well Identification	Groundwater Electrical Conductivity (dS/m)			
	Annual Average	Standard Deviation	Maximum / Month	Minimum / Month
319M02[1]	2.43	0.21	2.87 / May	2.05 / October
319M03[1]	1.87	0.25	2.21 / July	1.55 / August
319M04[1]	2.58	0.16	2.87 / January	2.26 / December
319M05[1]	1.69	0.05	1.82 / January	1.61 / November
319M06[1]	2.00	0.15	2.26 / January	1.83 / July
319M07[1]	1.62	0.07	1.78 / March	1.56 / February
319M08[1]	1.91	0.08	2.15 / November	1.83 / June
319M09[1]	1.61	0.03	1.68 / October	1.56 / March
319M10[1]	2.99	0.06	3.11 / March	2.85 / November
319M11[1]	3.91	1.13	5.52 / November	2.00 / April
319M12[1]	0.89	0.08	1.09 / October	0.80 / March
319M13[1]	3.70	0.62	4.10 / September	2.83 / July
319M14[1]	3.47	0.23	3.82 / November	3.11 / February
319M15[1]	2.30	0.04	2.33 / September	2.26 / April
319M16[1]	2.37	0.22	2.52 / June	2.25 / July
A30W[1]	1.46	0.18	1.73 / June	1.35 / September
B26W[1]	2.45	0.30	2.70 / July	1.33 / March
B28W[1]	2.03	0.03	2.11 / August	2.00 / April
C1A[1]	0.61	0.01	0.65 / July	0.59 / December
C25W[1]	2.72	0.34	3.35 / August	2.44 / January
D22W[1]	2.39	0.08	2.56 / August	2.28 / April
D24W[1]	1.72	0.16	1.85 / January	1.10 / March
F22W[1]	2.04	0.07	2.19 / February	1.99 / July
G3W[1]	2.57	1.28	3.85 / June	2.19 / January
G5W[1]	2.70	0.12	3.20 / April	2.59 / October
G7W[1]	0.69	0.61	2.68 / July	0.47 / May
H4W	1.34	0.16	1.45 / July	0.56 / April
H5W[1]	3.24	0.25	4.00 May	3.17 / Nov. & Sept.
H6W[1]	1.71	0.26	2.59 / January	1.49 / October
H7W[1]	1.41	0.10	1.56 / June	1.37 / August
H8W[1]	3.01	0.25	4.11 / June	2.43 / May
H9W[1]	3.89	0.19	4.28 / January	3.78 / December
I5W[1]	0.88	0.01	0.92 / August	0.87 / January
I6W[1]	2.02	0.06	2.21 / July	2.00 / December
I8W[1]	1.77	0.11	2.06 / December	1.78 / August
J14W[1]	2.64	0.45	3.36 / August	2.00 / January
J15W[1]	2.55	0.12	2.68 / May	2.32 / December
J17W[1]	3.99	0.09	4.37 / September	3.97 / August
K4W[1]	4.15	0.43	5.98 / August	3.98 / February
L4W[1]	3.50	1.07	4.88 / September	0.97 / April
M3W[1]	2.18	0.71	4.70 / September	1.33 / October
USGSJULS[1]	2.28	0.07	2.64 / July	2.27 / December

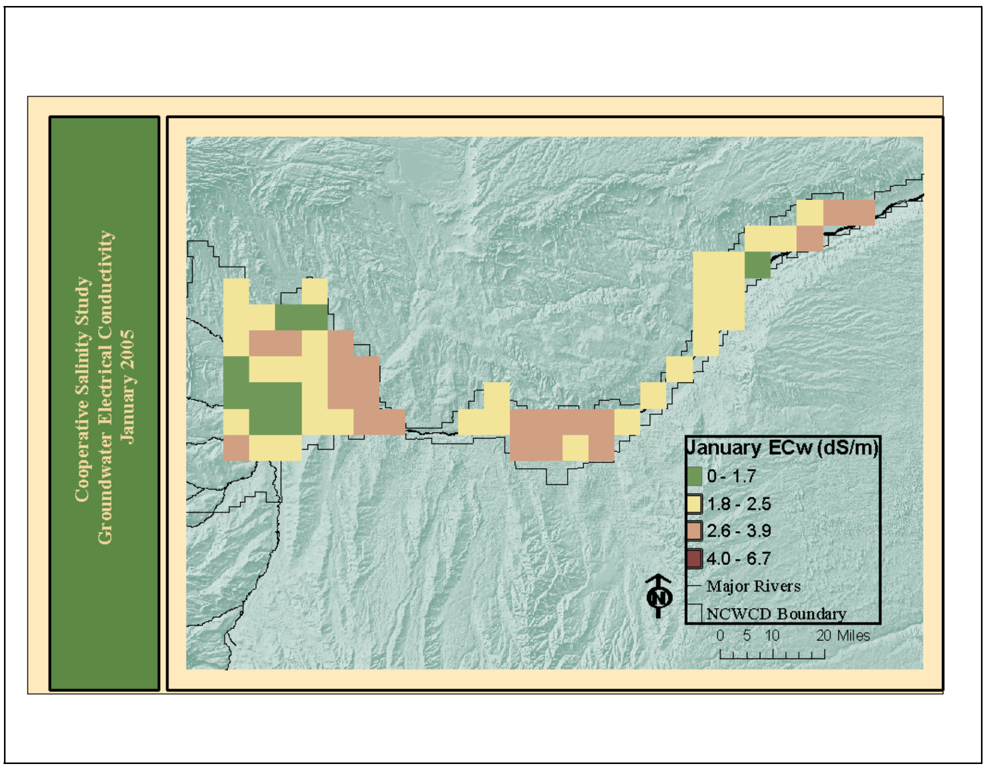
Table 3.1 Groundwater Monitoring Wells - Electrical Conductivity Statistics

[1]Incomplete annual record; EC_w data not collected for every month

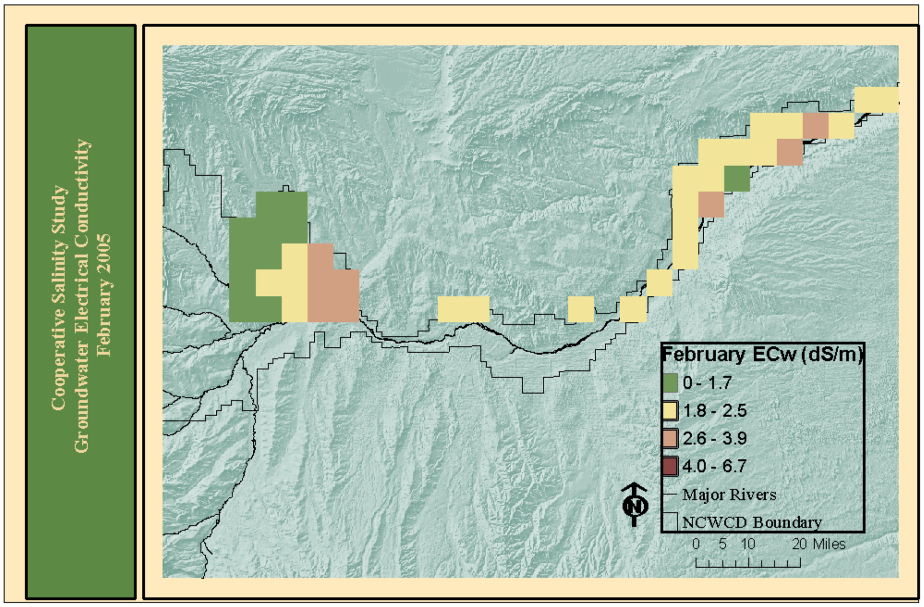
Pictured in Maps 3.2 - 3.13 are the results of the IDW interpolation for EC_w performed on a monthly basis. The numerical divisions used in the map legends were chosen based on well-established and recognized values for crop tolerance and yield reduction potential for corn (*Zea mays*). These tolerances are listed in Table 3.2.

EC_w (dS/m)	Potential Yield Loss (%)
1.7	10
2.5	25
3.9	50
6.7	100

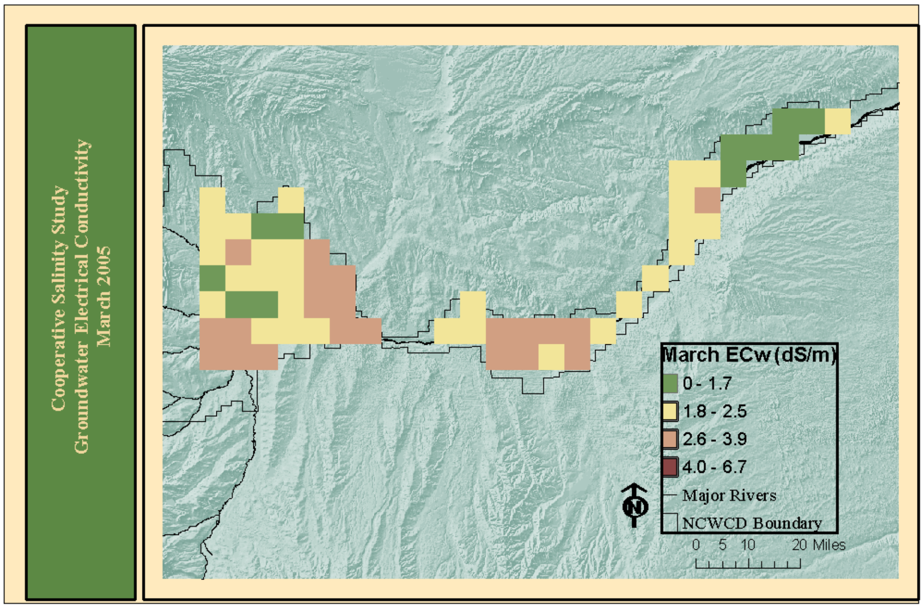
Table 3.2 Crop Tolerance and Yield Potential for Corn



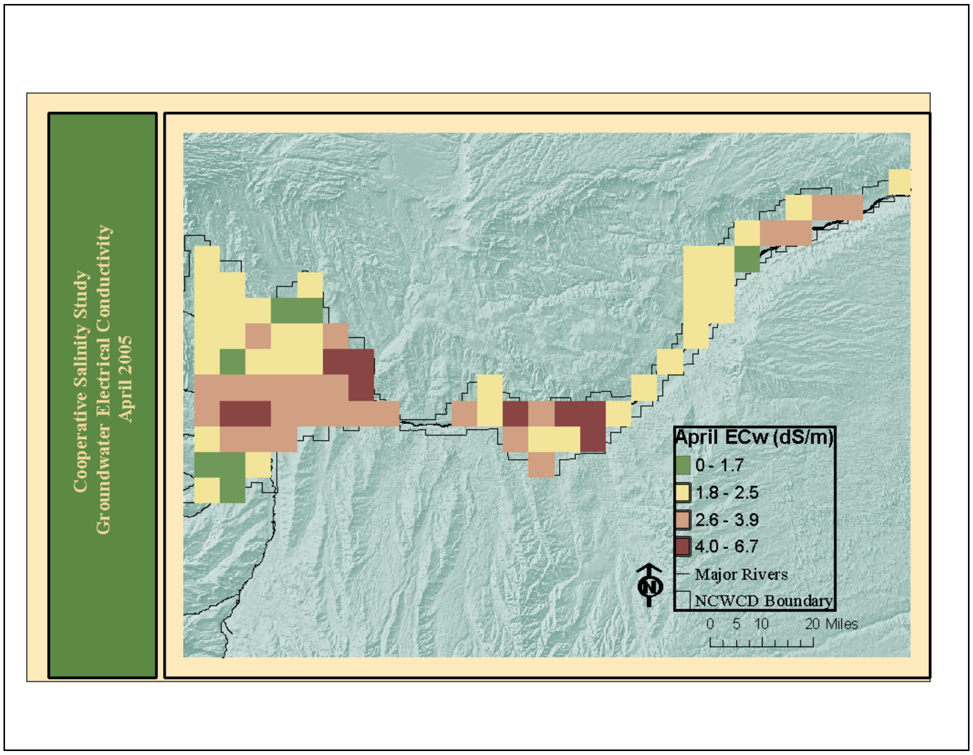
Map 3.2 January EC_w Values



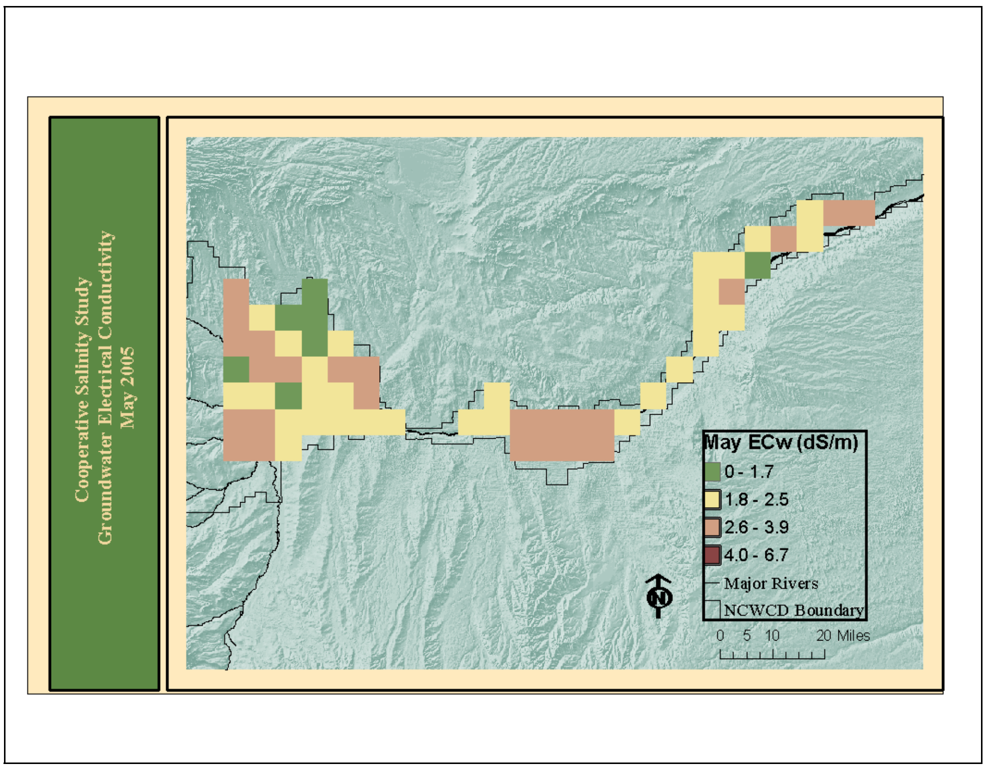
Map 3.3 February EC_w Values



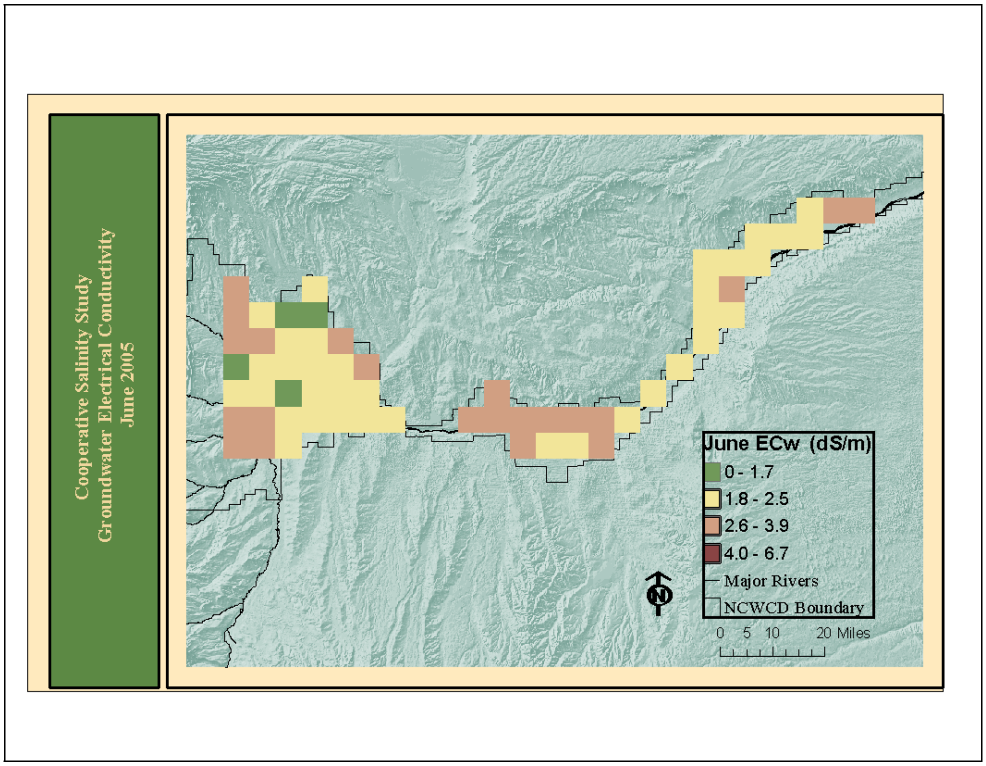
Map 3.4 March EC_w Values



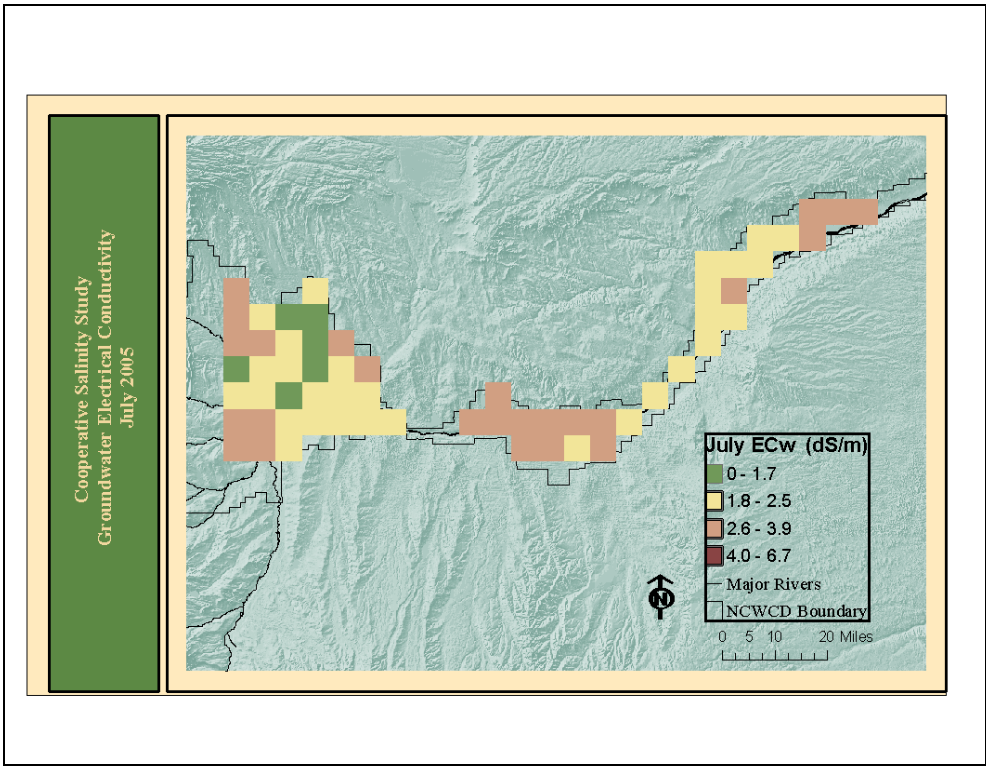
Map 3.5 April EC_w Values



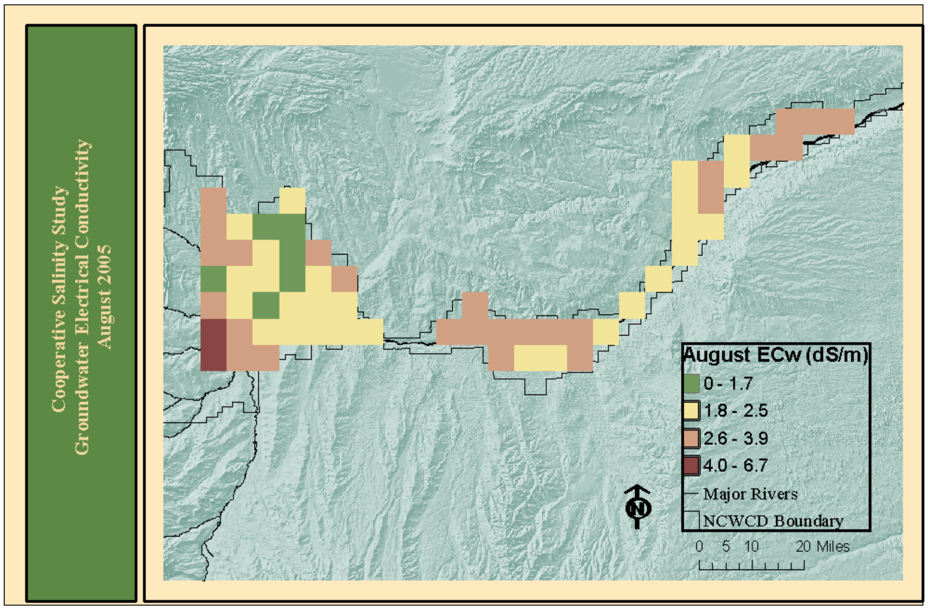
Map 3.6 May EC_w Values



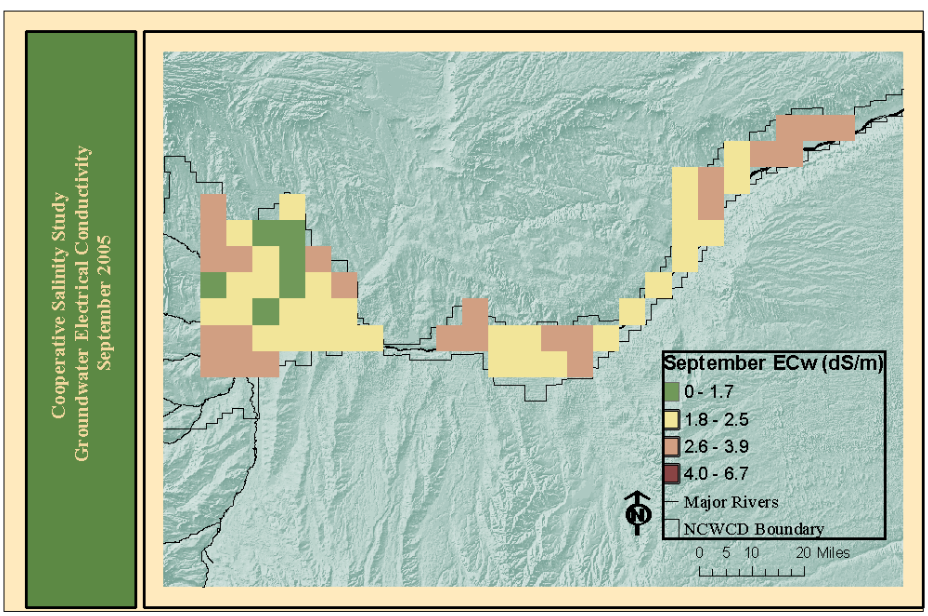
Map 3.7 June EC_w Values



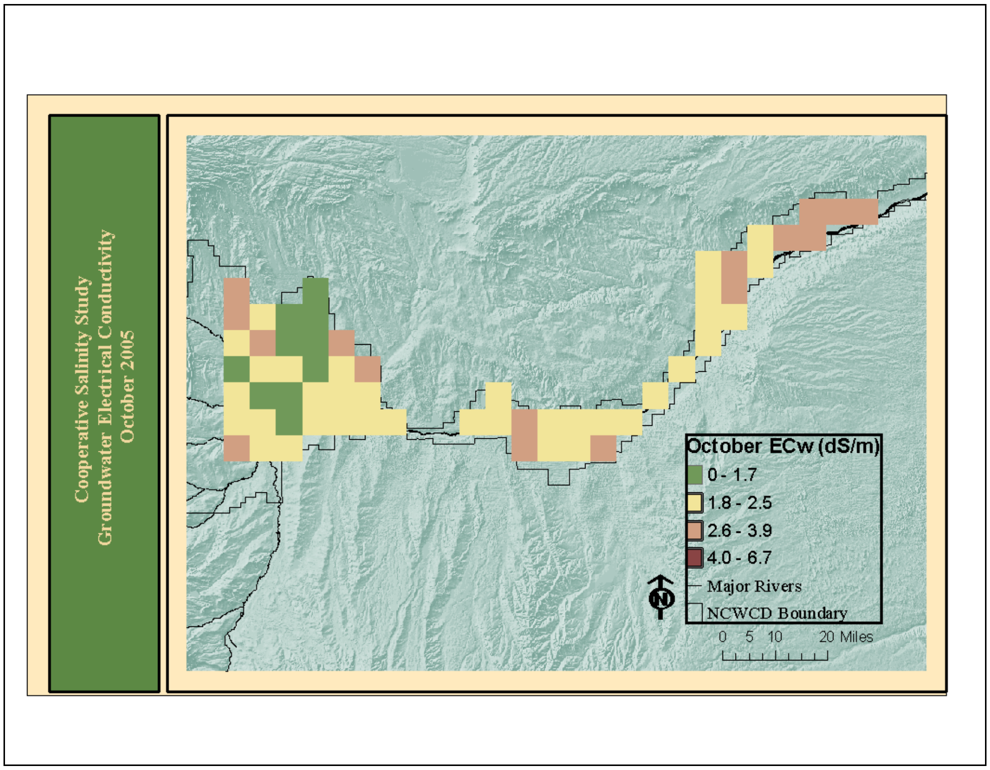
Map 3.8 July EC_w Values



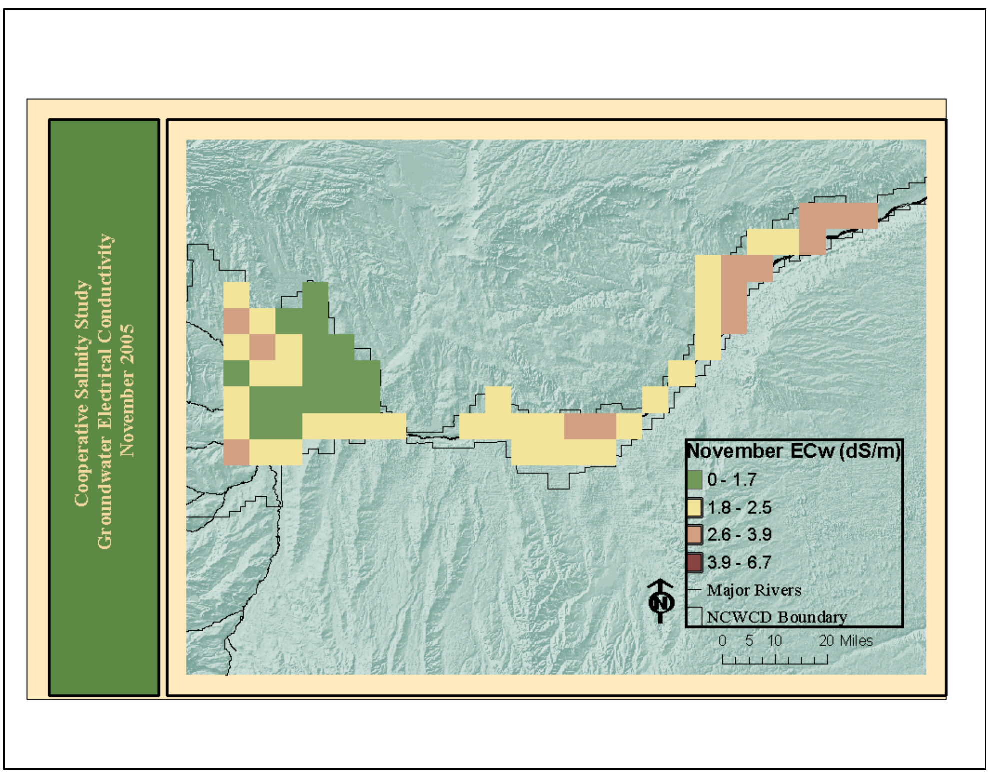
Map 3.9 August EC_w Values



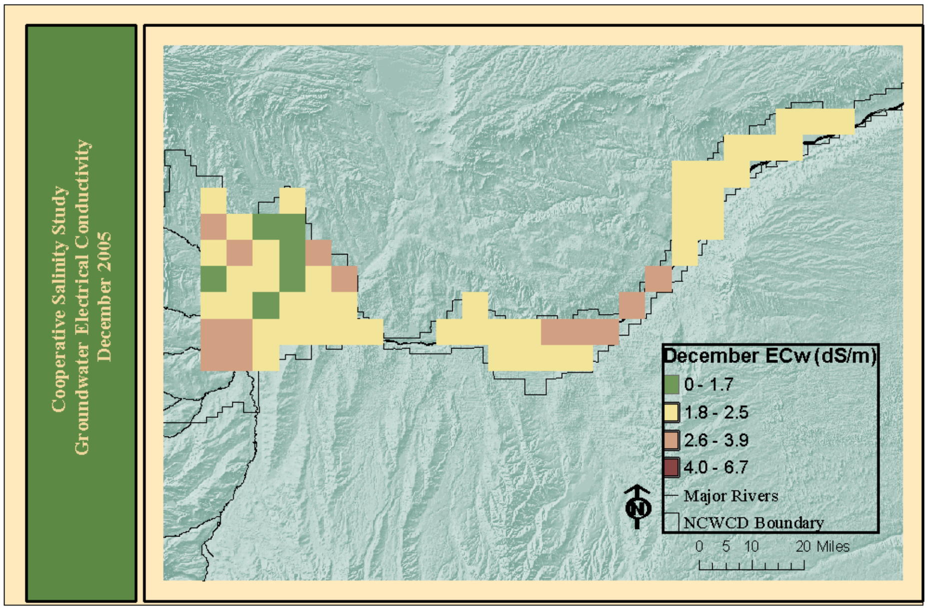
Map 3.10 September EC_w Values



Map 3.11 October EC_w Values



Map 3.12 November EC_w Values



Map 3.13 December EC_w Values

3.3 Groundwater Depth Analysis

The elevations of all wells monitored by the District are measured regularly. This is done as part of an effort to identify areas where shallow groundwater tables exist and may pose potential problems associated with increased electrical conductivity levels. Shallow groundwater is commonly characterized as any area where the water table is within 20 feet of the ground surface (California State). These areas are often at risk of salt accumulation due to inadequate drainage.

Groundwater elevations are monitored both manually and with dedicated level loggers. The manual readings are taken prior to pumping the wells. This occurs on a weekly basis during the summer months and on a monthly basis during the remainder of the year. Additionally, the District has 22 level loggers installed and continuously monitoring elevations. These include both In-Situ miniTrolls (miniTrolls) and Global WL 16 Water Level Loggers (WL 16s).

The miniTrolls have performed well, providing accurate data sets with minimal maintenance. Three times a year the batteries are changed and data are downloaded. The only problems encountered in this process have been occasional difficulties in connecting to the loggers. This has been attributed to the elastomer failing to make a good connection. One remedy for this problem has been to remove the elastomer, flatten it out by rolling, and then reinsert it in the correct position.

The WL 16s have proven more difficult in terms of general maintenance and accurate data collection. The District's main issues with these loggers have been related to the electrical component plastic housing equipped with a stainless steel jacket glued to the top. The glue came apart on several occasions causing wires to be pulled from the circuit board. All these instruments have since been retrofitted; the plastic housings were replaced, all connections going from the cable to the internal circuit board were un-soldered and re-soldered and the stainless steel jackets were reattached to the housings via glue and heat shrinking. This attempt to fix the WL 16s has not proven successful in the majority of cases. Some of these retrofitted loggers have read for short periods of time before quitting, while others recorded stagnant water levels in situations where the water table was dynamic. Furthermore, on several occasions batteries were depleted prior to the factory recommended 4-month time period for replacement. While the District does have a few of these loggers currently installed in the field and functioning well, overall it has not experienced great success with the WL16s.

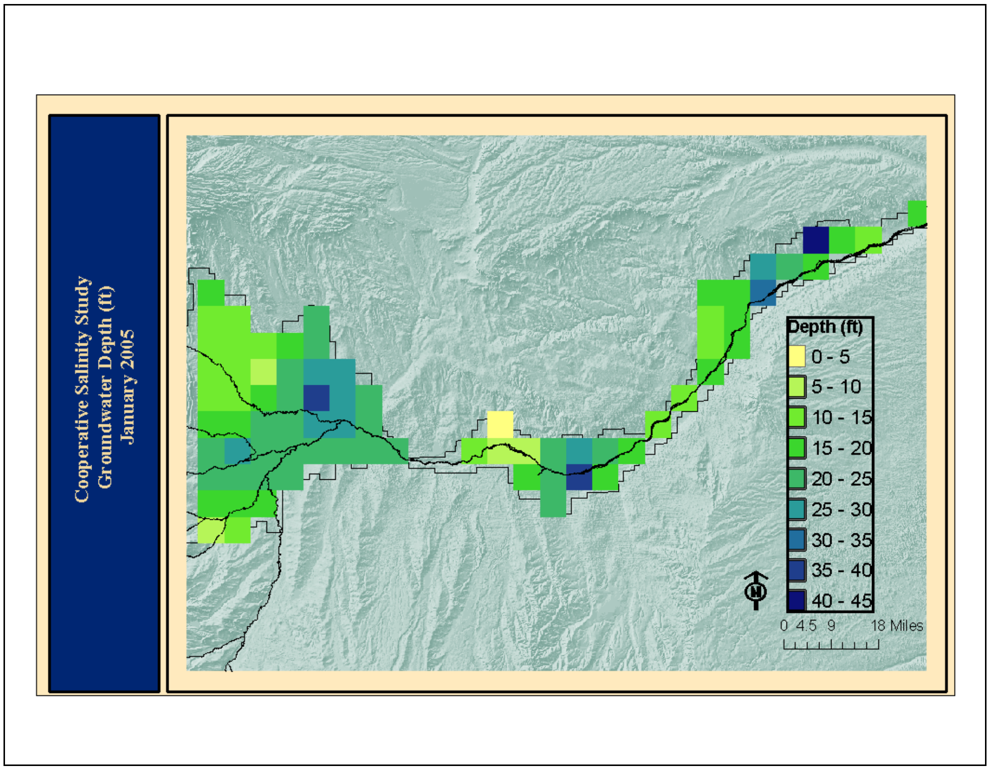
Located in Table 3.3 are yearly statistics for depth measurements. Listed are the average depths, standard deviations, the maximum/minimum depth recordings and the months in which they occurred. Additionally, Maps 3.14 - 3.25 present a pictorial analysis of changes in groundwater depth with space and time. This analysis was performed using the IDW interpolation method previously explained.

Well Identification	Groundwater Depth (ft)			
	Annual Average	Standard Deviation	Maximum Depth below Surface / Month	Minimum Depth below Surface / Month
319M02[2]	23.4	1.2	25.1 / March	21.7 / March
319M03[2]	35.6	1.4	37.7 / February	33.7 / September
319M04[2]	12.2	0.6	13.0 / February	11.3 / September
319M05[2]	17.9	0.7	18.8 / February	16.8 / July
319M06[2]	18.9	0.9	19.8 / August	17.7 / October
319M07[2]	8.7	0.9	9.7 / November	6.8 / June
319M08[2]	16.3	0.9	17.5 / November	15.3 / June
319M09[2]	18.2	0.9	19.4 / August	16.8 / April
319M10[2]	4.8	0.4	5.3 / August	4.1 / July
319M11[2]	5.3	0.4	5.9 / November	4.8 / April
319M12[2]	37.2	1.2	38.9 / October	35.5 / September
319M13[2]	6.5	0.5	7.1 / November	6.0 / September
319M14[2]	5.9	0.6	6.7 / November	4.7 / February
319M15[2]	18.3	3.6	24.3 / April	13.4 / September
319M16[2]	6.7	0.6	7.5 / October	5.9 / September
A30W[3]	14.8	2.1	17.3 / February	11.8 / September
B26W[3]	40.9	4.9	47.5 / April	34.8 / September
B28W[3]	15.3	5.9	23.0 / April	7.7 / September
C1A[3]	19.5	0.9	20.5 / May	18.0 / September
C25W[3]	21.2	1.2	22.5 / June	19.6 / November
D22W[3]	14.8	1.4	16.8 / May	12.3 / September
D24W[3]	30.8	0.1	30.9 / January	30.5 / December
F22W[2,3]	10.3	5.0	10.9 / January	7.7 / July
G3W[2]	5.5	1.5	9.2 / January	4.1 / September
G5W[2]	5.6	0.3	6.25 / May	5.2 / October
G7W[2]	21.4	1.2	22.3 / December	19.1 / June
H4W[2,3]	12.0	0.2	12.0 / March	7.6 / August
H5W[2]	9.5	0.9	11.4 / May	8.9 / December
H6W[3]	16.5	5.5	21.1 / March	14.8 / November
H7W[3]	39.8	0.6	41.3 / May	39.2 / January
H8W[2]	17.4	1.2	18.6 / July	16.0 / May
H9W[3]	22.1	1.1	23.4 / May	20.4 / December
I5W[2,3]	22.6	0.7	23.6 / July	21.5 / November
I6W[2]	17.5	0.7	17.9 / October	16.5 / July
I8W[2]	6.5	1.5	8.6 / November	4.6 / August
J14W[2]	4.2	1.2	5.4 / January	2.5 / October
J15W[2]	7.7	0.6	8.8 / April	6.6 / July
J17W[3]	25.0	0.7	25.7 / July	23.9 / October
K4W[3]	31.4	0.2	31.6 / July	30.9 / September
M3W[3]	9.8	0.6	11.2 / August	8.9 / October
USGSJULS[2]	15.1	1.3	16.8 / October	13.4 / July

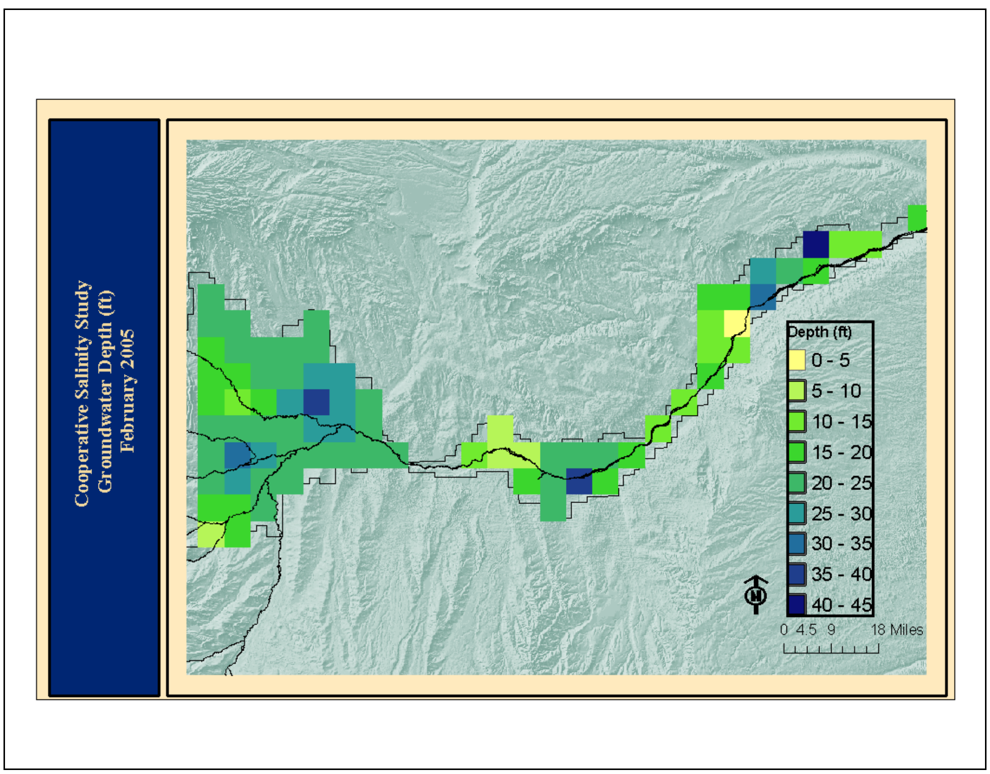
Table 3.3 Groundwater Monitoring Wells - Depth Measurement Statistics

[2] Incomplete annual record; depth data not collected for every month

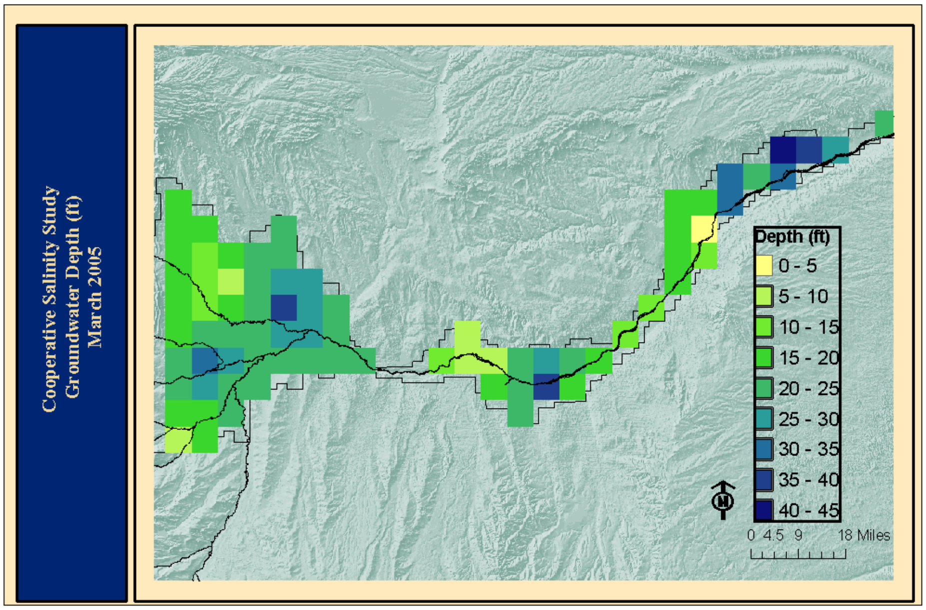
[3] Depth data gathered via automated data loggers



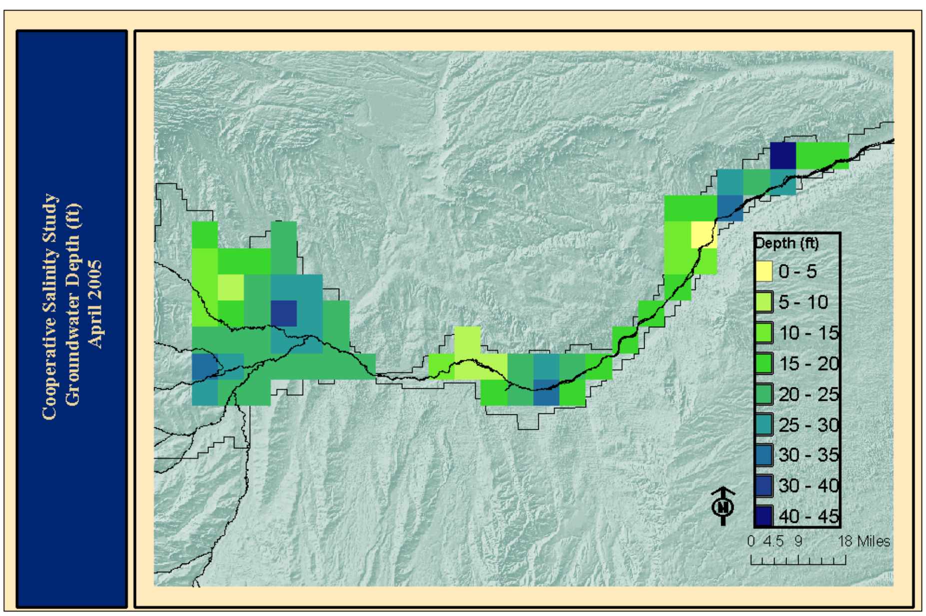
Map 3.14 January Groundwater Depths



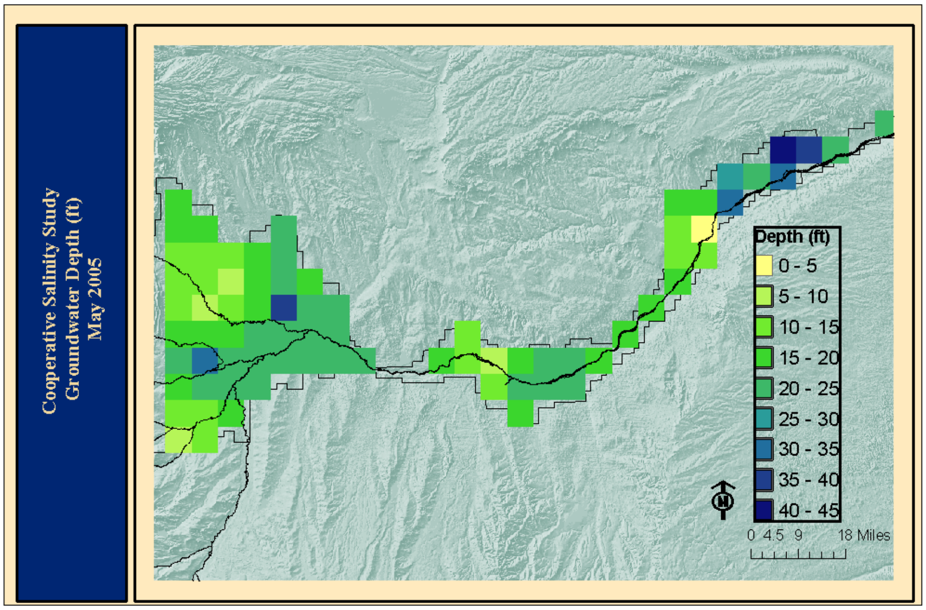
Map 3.15 February Groundwater Depths



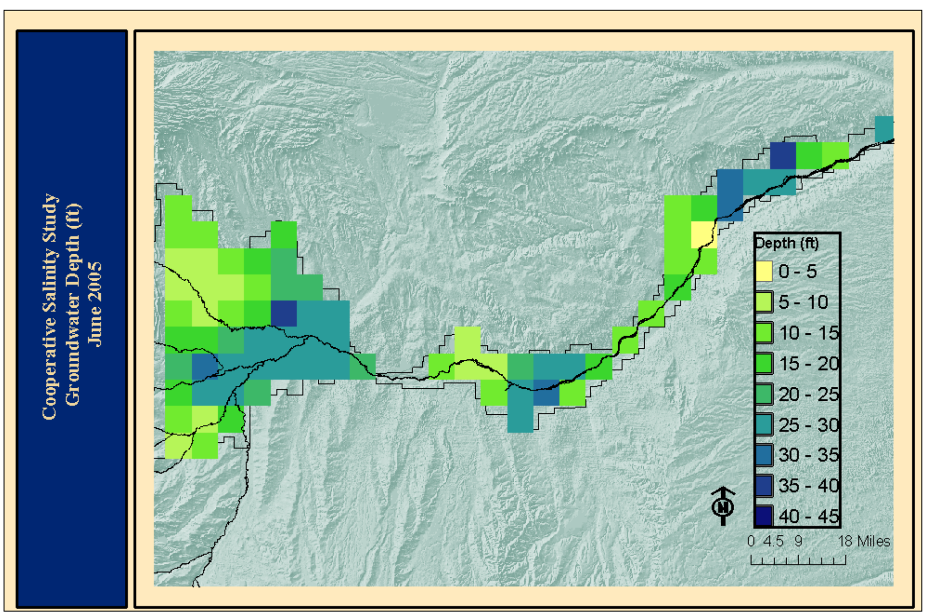
Map 3.16 March Groundwater Depths



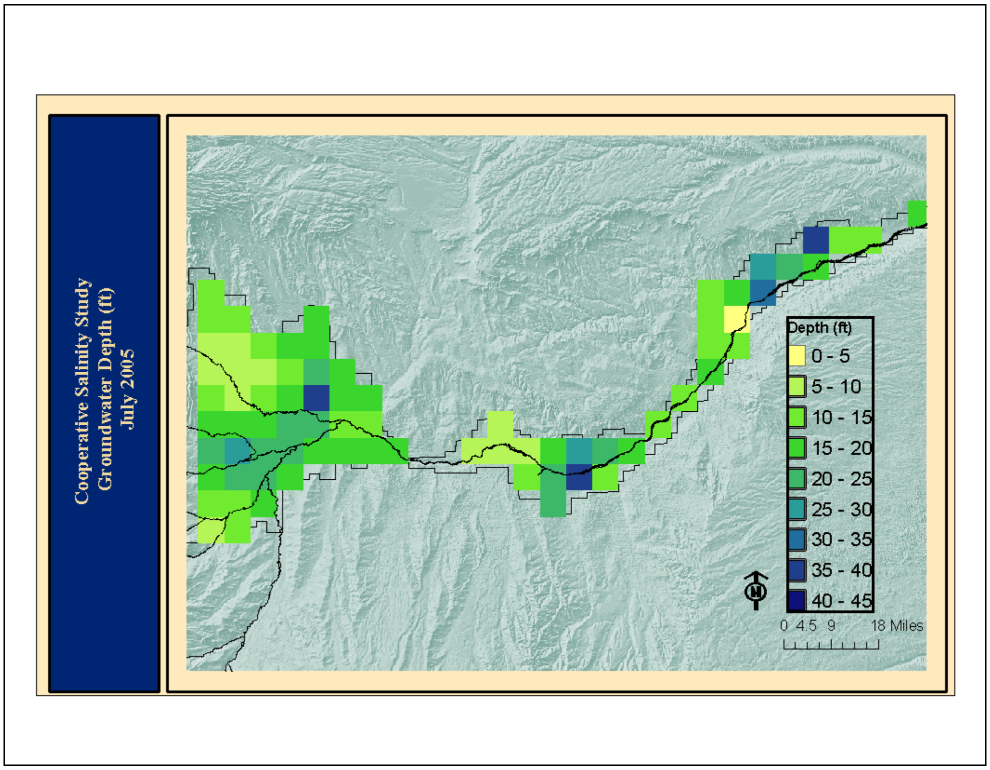
Map 3.17 April Groundwater Depths



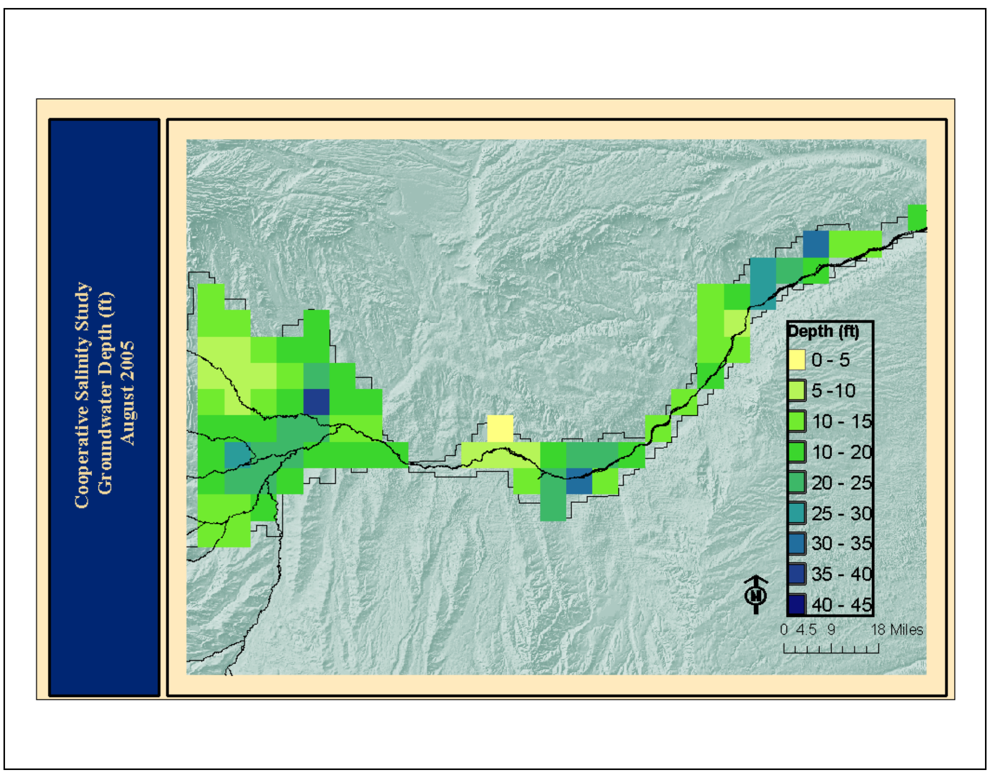
Map 3.18 May Groundwater Depths



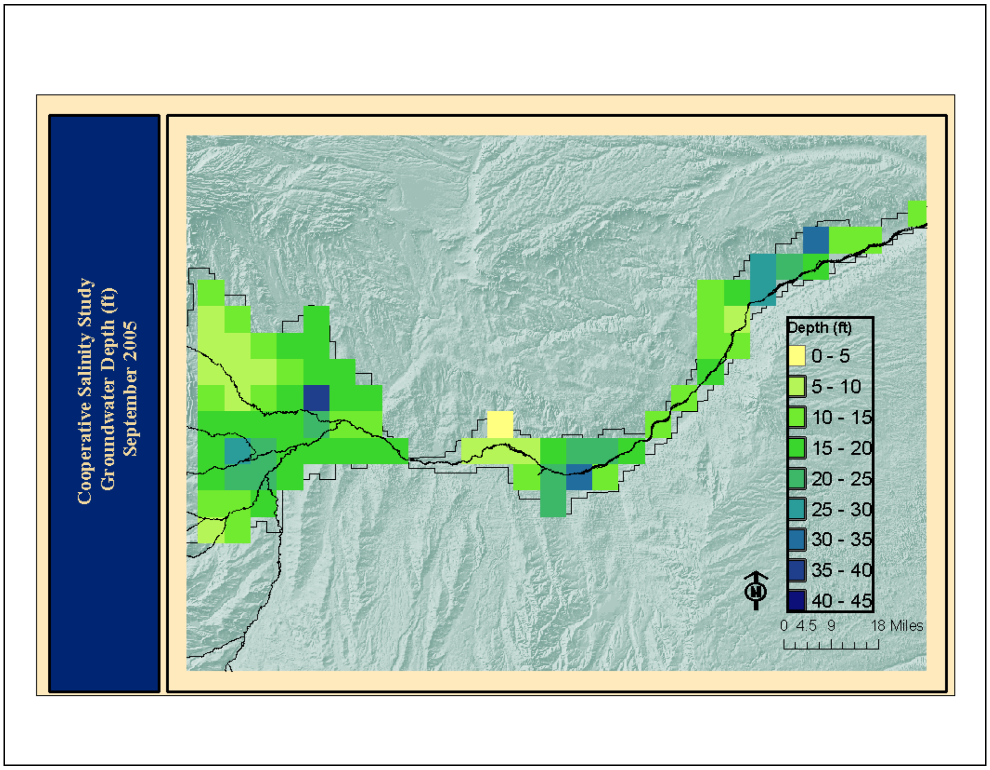
Map 3.19 June Groundwater Depths



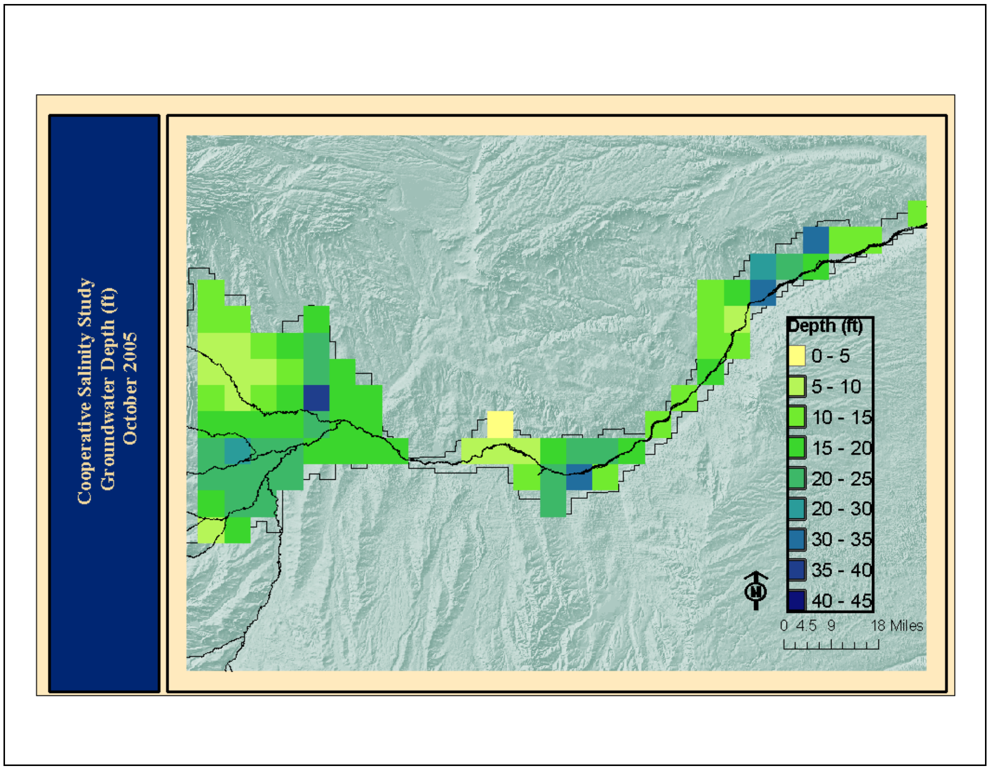
Map 3.20 July Groundwater Depths



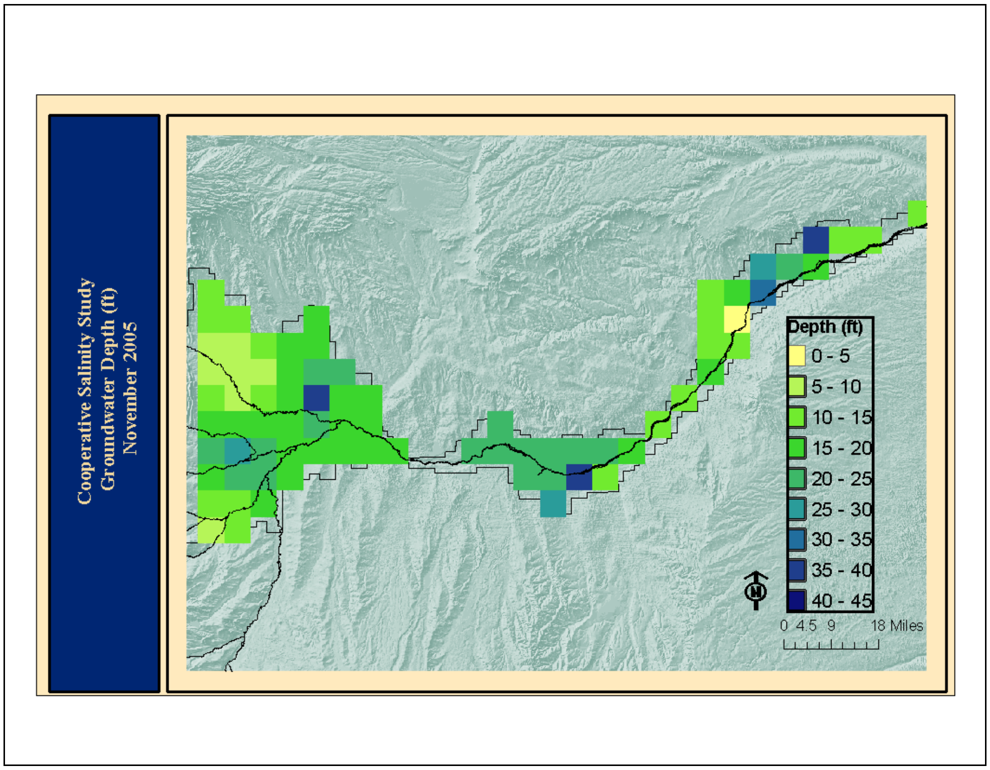
Map 3.21 August Groundwater Depths



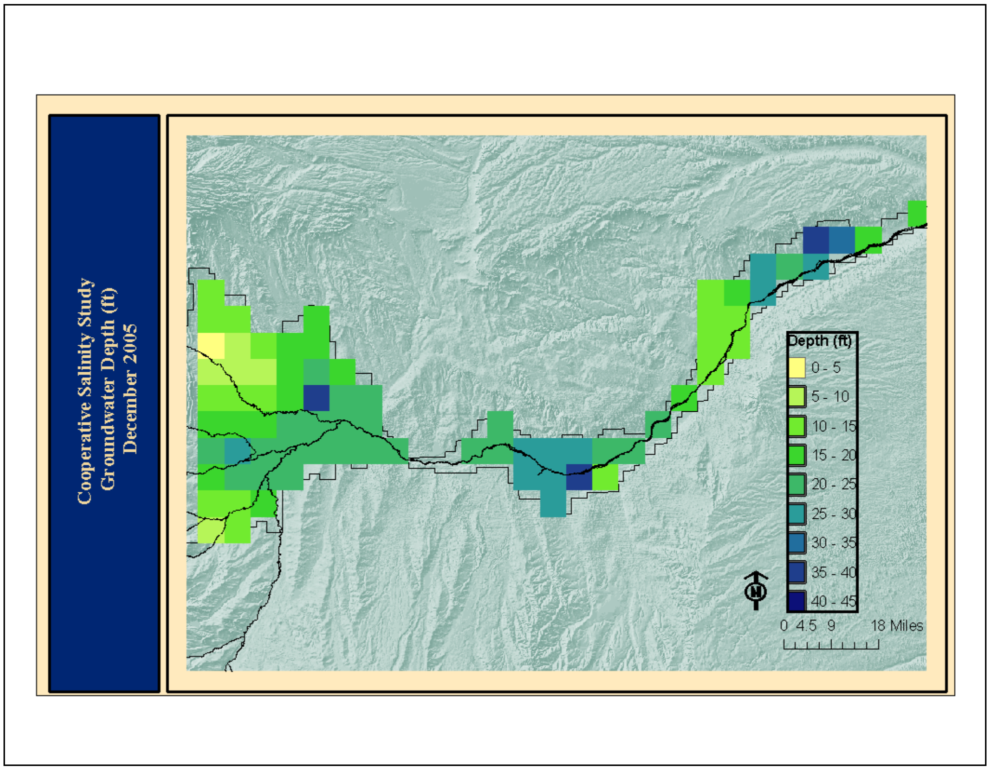
Map 3.22 September Groundwater Depths



Map 3.23 October Groundwater Depths



Map 3.24 November Groundwater Depths



Map 3.25 December Groundwater Depths

3.4 Groundwater Electrical Conductivity and Depth Analyses Combined

It is often the case that electrical conductivity levels will increase with decreasing water table elevation as measured from the ground surface. This inverse relationship is usually attributed to inadequate drainage associated with shallow groundwater tables (Sedema and Rycroft). To test our data against this theory, Figures 3.3 – 3.43 illustrate monitored ECw levels graphed in conjunction with measured depths.

While many of the monitored wells neatly subscribe to the expected trend (i.e. the lower the EC_w readings the greater the measured depth), not all the data conform to this pattern. At a few of the monitored wells the inverse of this trend was observed; as the groundwater elevation decreased so did the EC_w levels. Furthermore, some wells show no inclination towards following any obvious patterns in relation to EC_w and elevation. This is the first year in which these trends have been explored. It is therefore possible that in future years additional data collected will reveal trends that are not apparent with only one year of analysis.

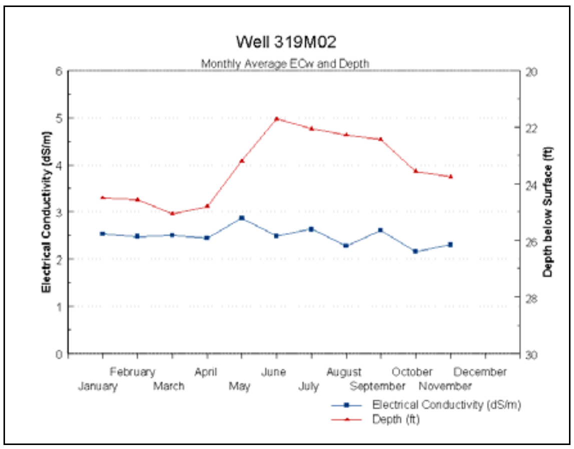


Figure 3.3 Monthly Average EC_w and Depth 319M02

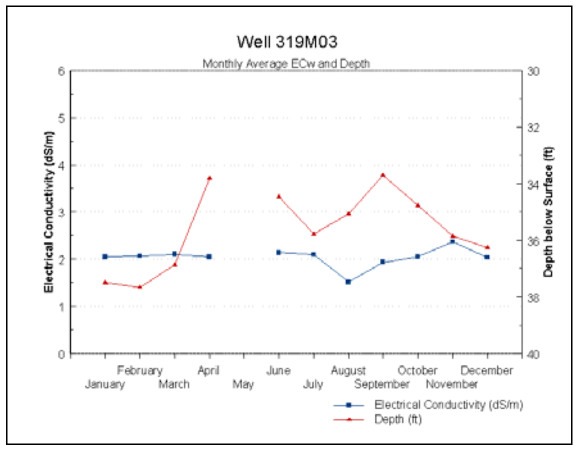


Figure 3.4 Monthly Average EC_w and Depth 319M03

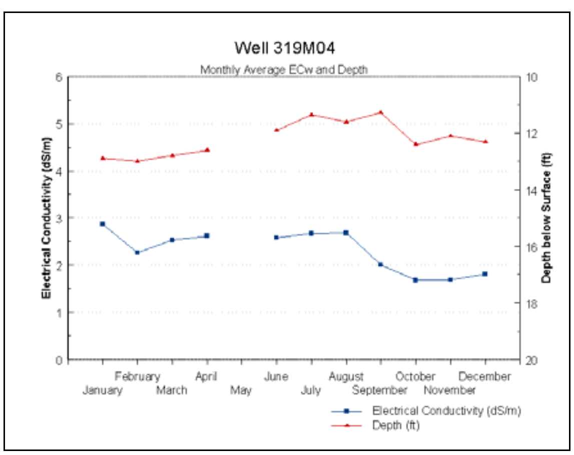


Figure 3.5 Monthly Average EC_w and Depth 319M04

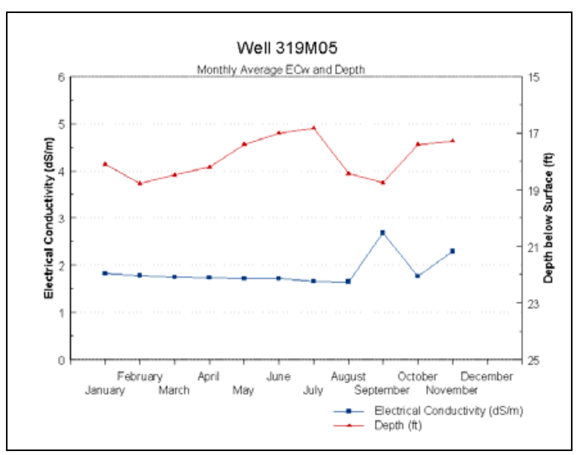


Figure 3.6 Monthly Average EC_w and Depth 319M05

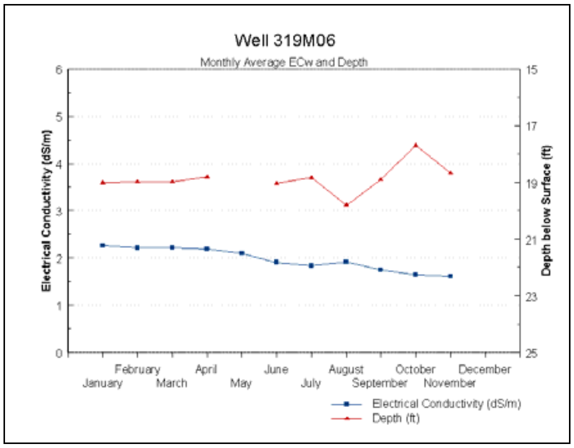


Figure 3.7 Monthly Average EC_w and Depth 319M06

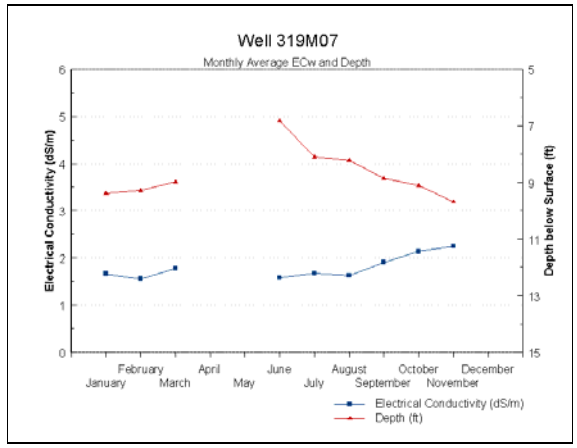


Figure 3.8 Monthly Average EC_w and Depth 319M07

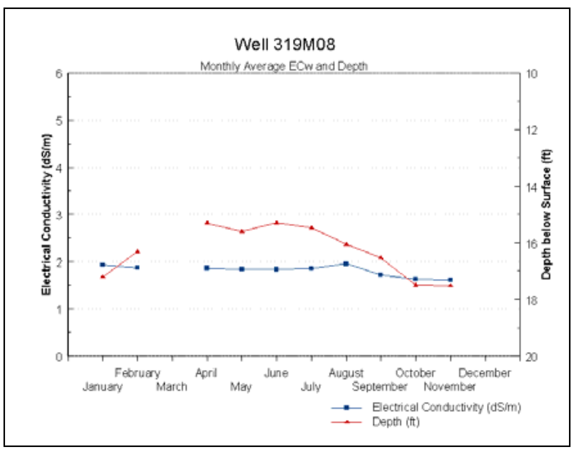


Figure 3.9 Monthly Average EC_w and Depth 319M08

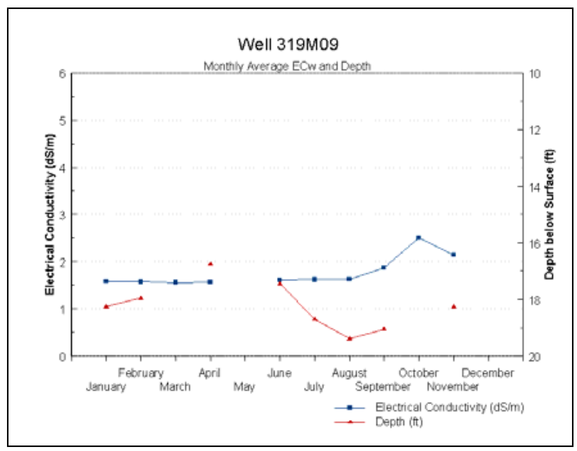


Figure 3.10 Monthly Average EC_w and Depth 319M09

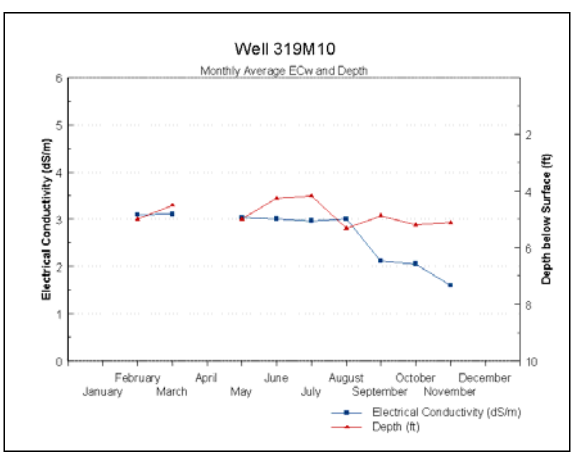


Figure 3.11 Monthly Average EC_w and Depth 319M10

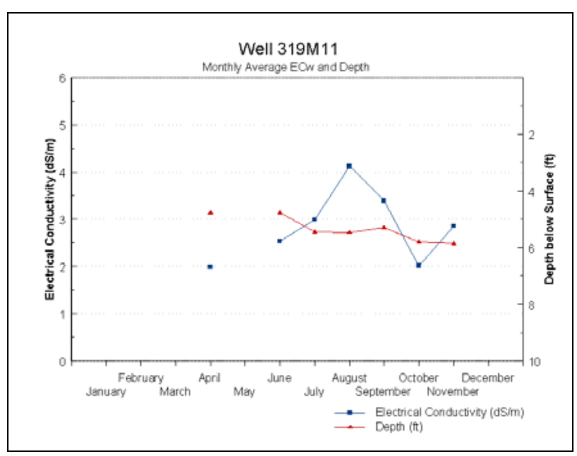


Figure 3.12 Monthly Average EC_w and Depth 319M11

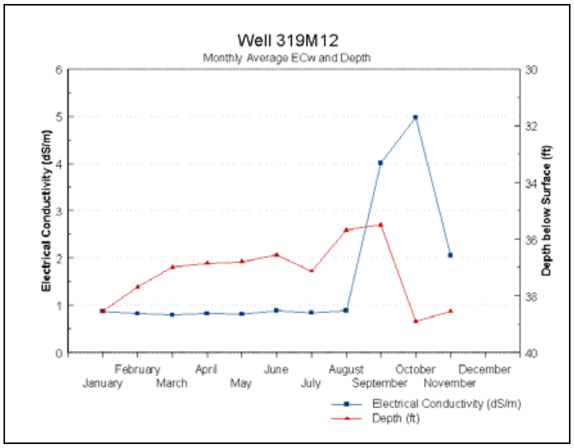


Figure 3.13 Monthly Average EC_w and Depth 319M12

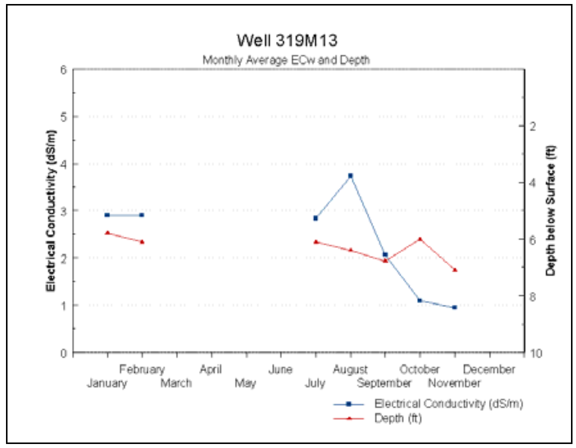


Figure 3.14 Monthly Average EC_w and Depth 319M13

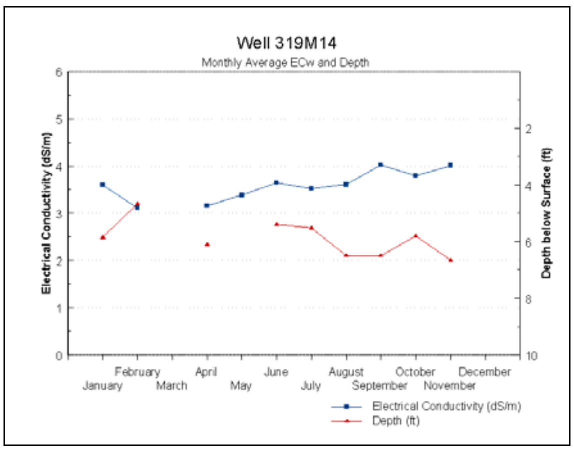


Figure 3.15 Monthly Average EC_w and Depth 319M14

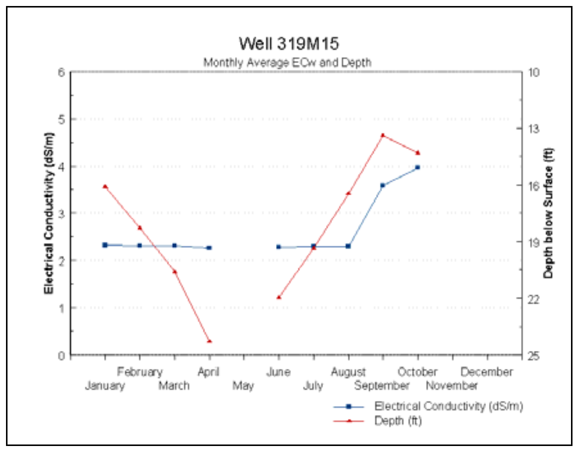


Figure 3.16 Monthly Average EC_w and Depth 319M15

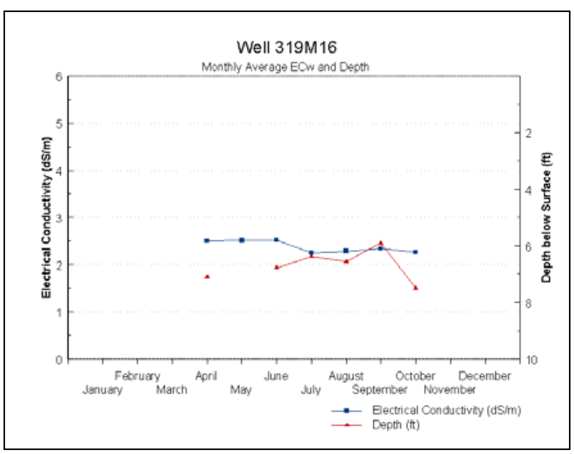


Figure 3.17 Monthly Average EC_w and Depth 319M16

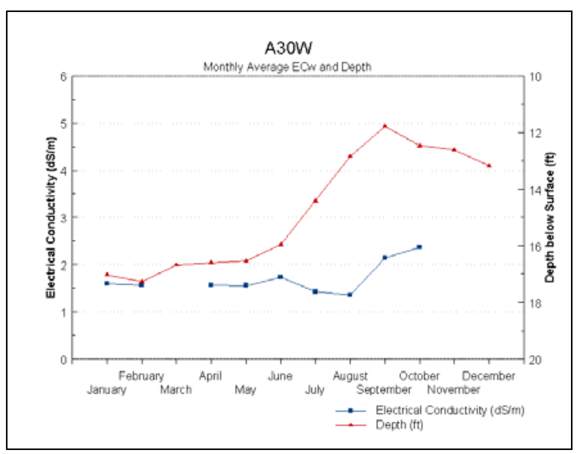


Figure 3.18 Monthly Average EC_w and Depth A30W

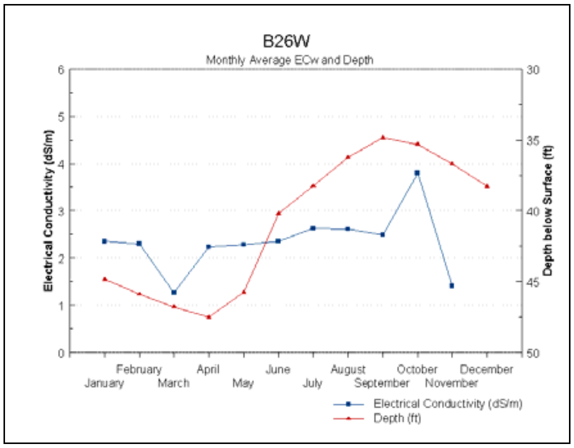


Figure 3.19 Monthly Average EC_w and Depth B26W

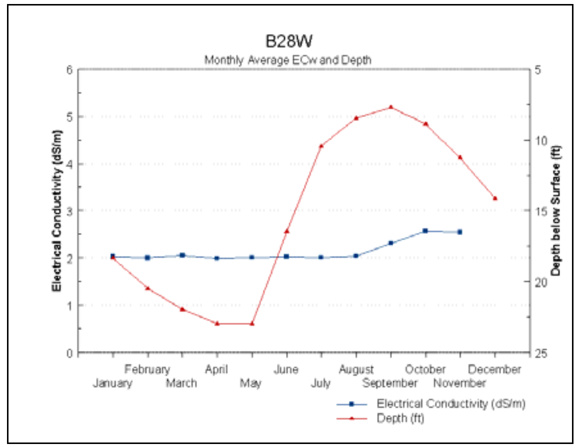


Figure 3.20 Monthly Average EC_w and Depth B28W

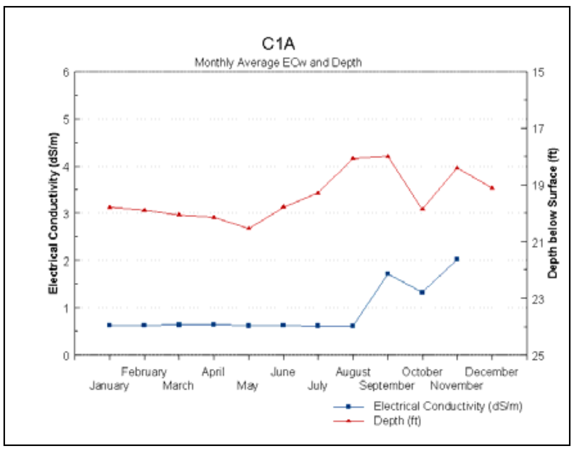


Figure 3.21 Monthly Average EC_w and Depth C1A

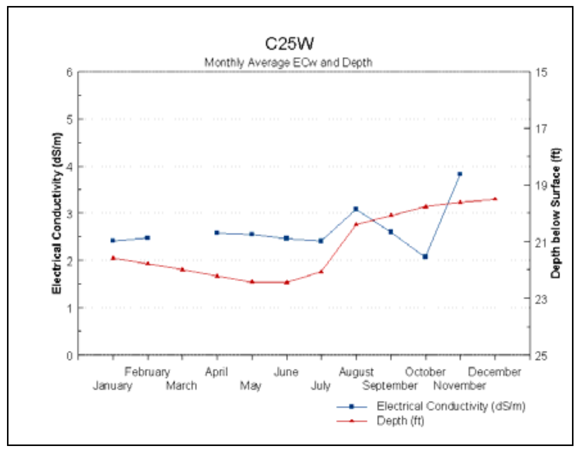


Figure 3.22 Monthly Average EC_w and Depth C25W

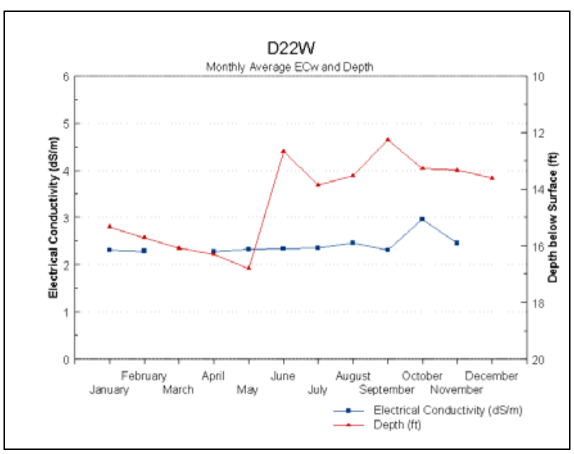


Figure 3.23 Monthly Average EC_w and Depth D22W

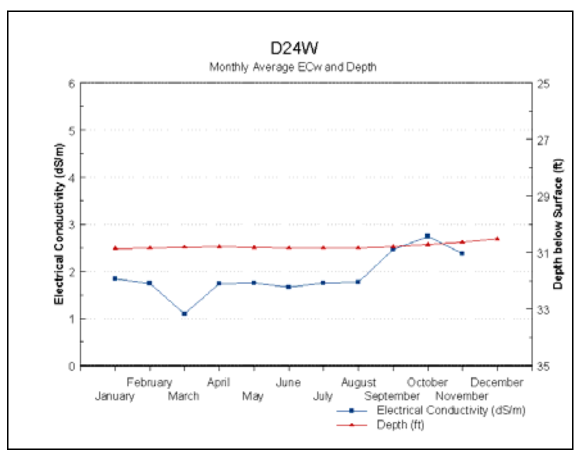


Figure 3.24 Monthly Average EC_w and Depth D24W

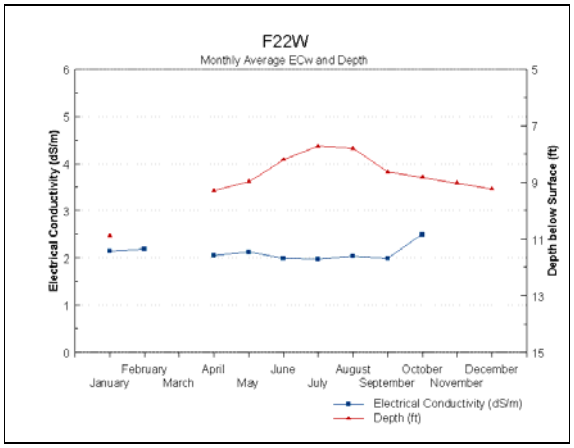


Figure 3.25 Monthly Average EC_w and Depth F22W

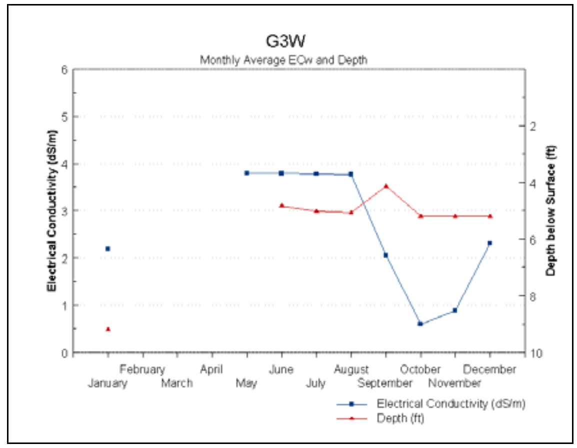


Figure 3.26 Monthly Average EC_w and Depth G3W

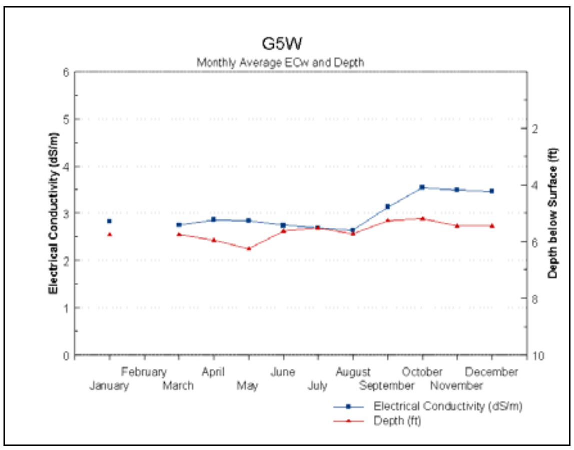


Figure 3.27 Monthly Average EC_w and Depth G5W

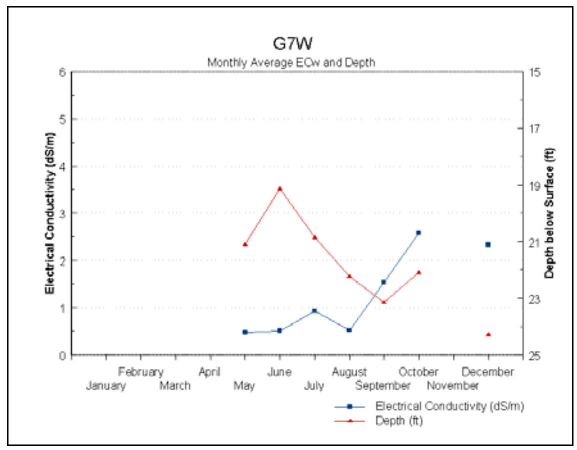


Figure 3.28 Monthly Average EC_w and Depth G7W

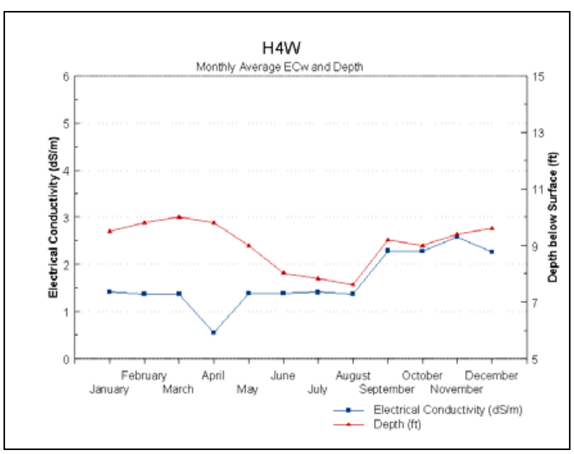


Figure 3.29 Monthly Average EC_w and Depth H4W

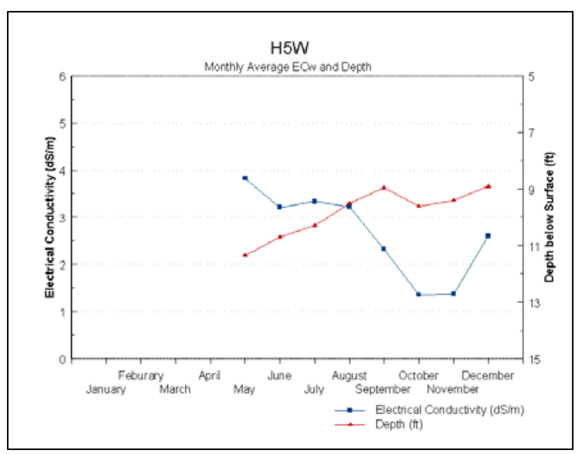


Figure 3.30 Monthly Average EC_w and Depth H5W

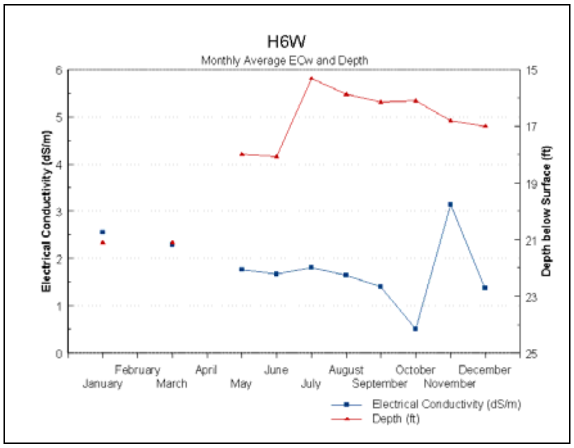


Figure 3.31 Monthly Average EC_w and Depth H6W

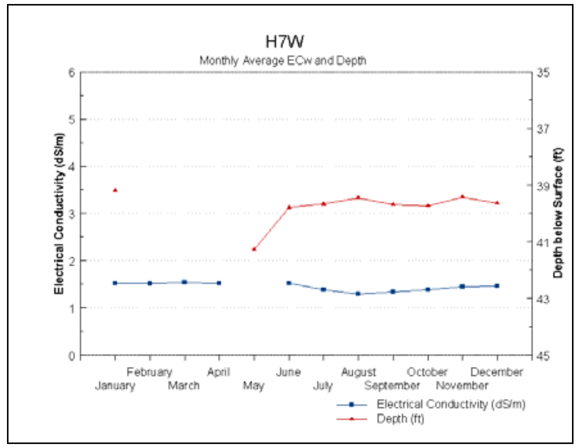


Figure 3.32 Monthly Average EC_w and Depth H7W

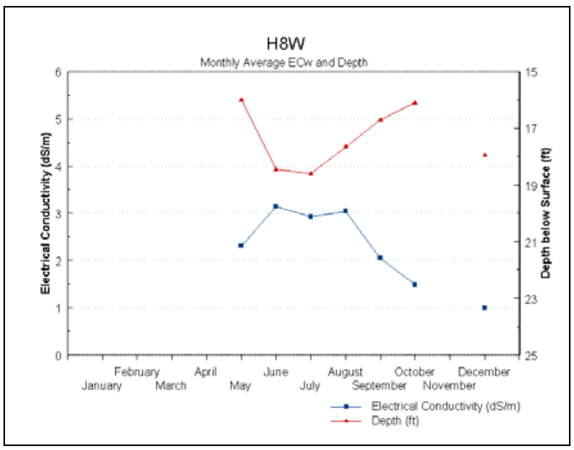


Figure 3.33 Monthly Average EC_w and Depth H8W

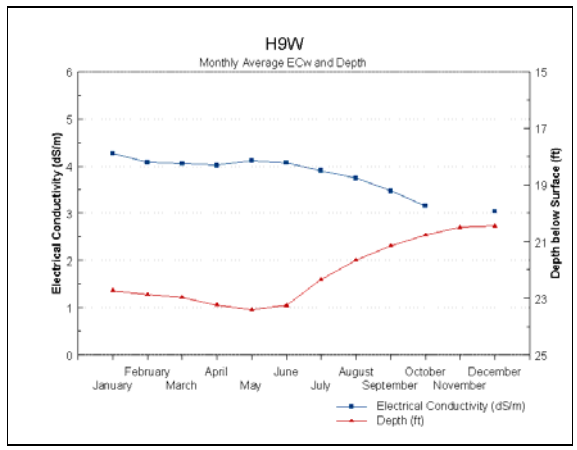


Figure 3.34 Monthly Average EC_w and Depth H9W

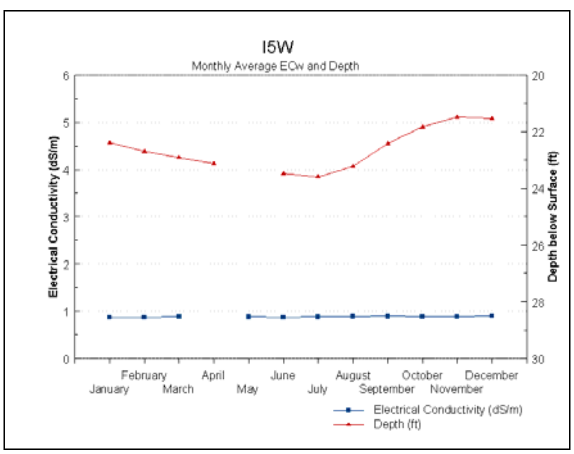


Figure 3.35 Monthly Average EC_w and Depth I5W

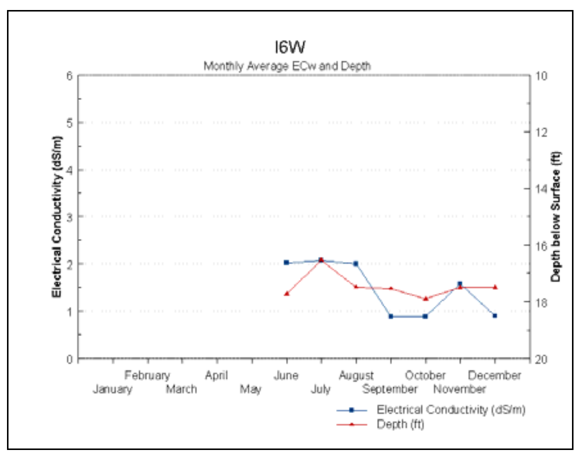


Figure 3.36 Monthly Average EC_w and Depth I6W

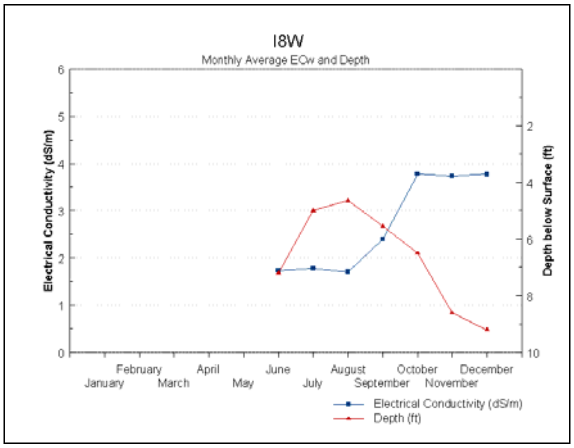


Figure 3.37 Monthly Average EC_w and Depth I8W

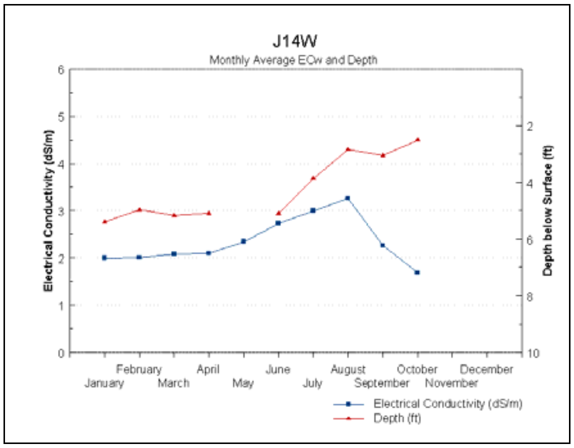


Figure 3.38 Monthly Average EC_w and Depth J14W

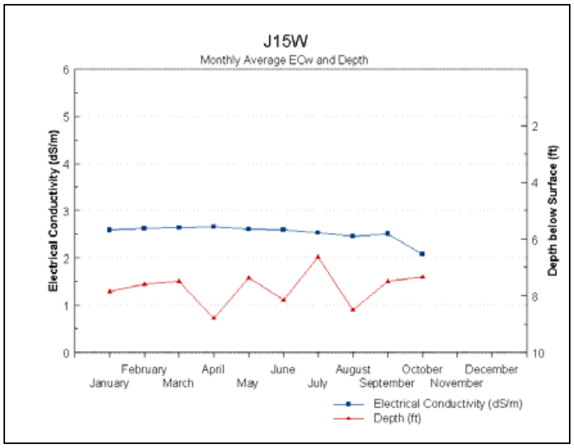


Figure 3.39 Monthly Average EC_w and Depth J15W

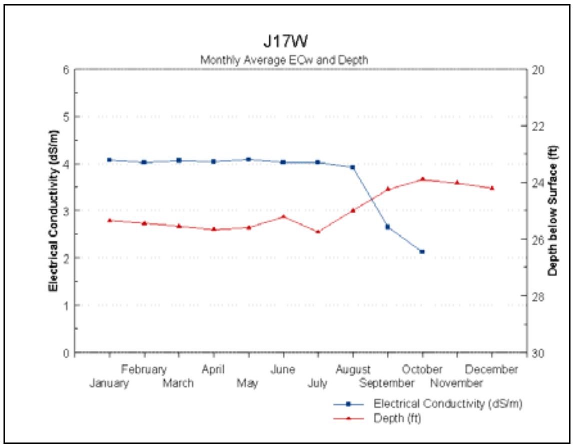


Figure 3.40 Monthly Average EC_w and Depth J17W

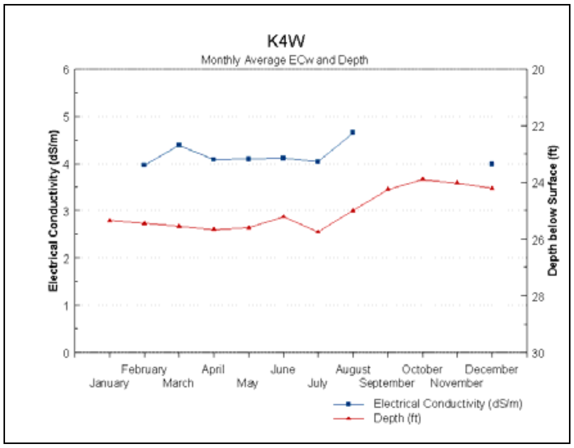


Figure 3.41 Monthly Average EC_w and Depth K4W

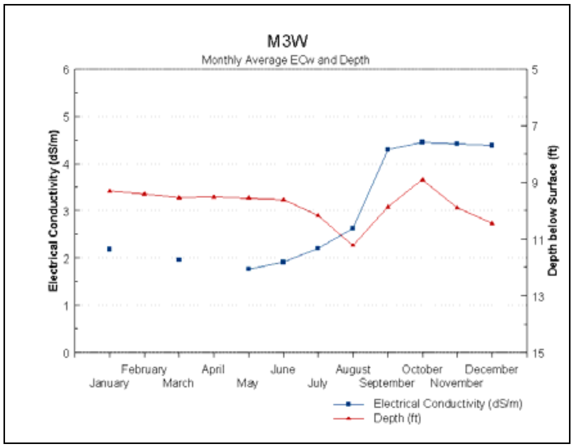


Figure 3.42 Monthly Average EC_w and Depth M3W

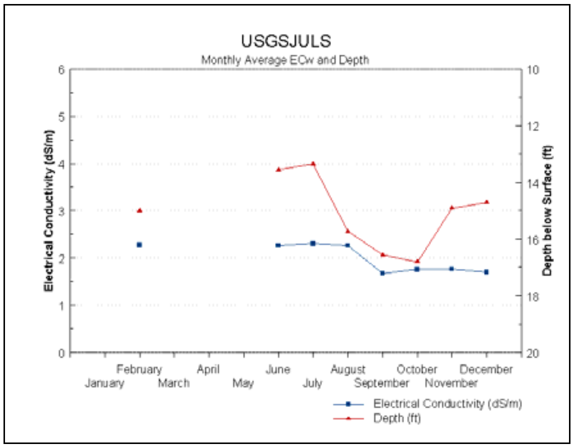


Figure 3.43 Monthly Average EC_w and Depth
USGSJULS

4. Soil Electrical Conductivity Surveying

4.1 Introduction and Overview

The purpose of the soil salinity surveys is to assess average agricultural soil electrical conductivity (EC_e) within District boundaries. Overall, farmland within District boundaries has not experienced serious soil salinity problems, especially when compared to the Colorado Arkansas or the California Imperial Valleys. It has, however, been deemed important to assess average values throughout the Lower South Platte Basin in order to establish a baseline. Furthermore, while soil salinity may not be a District-wide issue, pockets do exist where high EC_e values result in adverse growing conditions. These surveys have allowed the District to identify some of the problem areas where farmers face the risk of decreased crop yields attributed to elevated EC_e.

4.2 Soil Survey Methods

Field Procedures

During the 2005 sampling year, soil salinity surveys were conducted via two methods. During the first half of the year, the District surveyed fields using a Geonics Incorporated Electromagnetic Induction Meter Dual-Dipole (EM38-DD) mounted onto a Salinity Assessment Module (SAM), as pictured in Figure 4.1.

Figure 4.1 SAM Equipped with an EM38-DD

This method works in conjunction with the Sampling, Assessment and Prediction Model (ESAP) software developed by Scott M. Lesch and the George E. Brown, Jr. Salinity Laboratory. The initial field survey is carried out by pulling the EM38-DD through fields on transects spaced approximately 40 feet apart. This survey and the associated software identify where the greatest differentials between individual parameters exist. The differentials measured may be soil salinity, moisture, texture, and/or temperature; what the EM38-DD reads depends on what parameter displays the most variation. Based on this information, 6, 12 or 20 statistically optimal sampling locations (the number of locations is user defined, the District has typically opted for 12 locations per field) are identified using a statistical methodology known as a response surface sampling design (Lesch, et al.). Soil cores are then taken at these pre-selected locations and brought into the laboratory for analysis. Once the cores have been analyzed, the laboratory data are uploaded into the ESAP software to calculate a field/laboratory correlation coefficient. Following this method, the laboratory data are ideally only used to validate the field data; a high correlation coefficient confirms a successful soil survey was performed.

However, the District encountered problems with these correlation coefficients as field and laboratory data were too often not corresponding with each other. After recalibrating all field and laboratory instruments and conducting a meticulous inventory of all procedures, the District was unable to pinpoint possible causes of the discrepancy between field and laboratory data. At this point, Scott M. Lesch (ESAP developer) was consulted. He concluded that correct procedures were being adhered to throughout the entirety of the process and that the District must be surveying fields containing parameters or sets of parameters not recognized by the ESAP software. Lacking the expertise and resources necessary to further explore this avenue, the decision was made to use the laboratory data, rather that the EM38-DD data, to generate soil surface EC_e maps.

In order to create soil surface EC_e maps based only on laboratory data, the District decided to continue the soil survey process during the second half of the year via a grid sampling method. This process involves an initial mapping of field boundaries using a Trimble AgGPS 160 Portable Computer (AgGPS 160) mounted on the SAM. The surveyor then enters the desired grid size, depending on the field acreage, and the AgGPS 160 generates a point within each grid where a soil core should be taken. While grid sampling alleviates the problems encountered with the EM38-DD and ESAP, it significantly increases the laboratory work load. The EM38-DD surveys typically required 12 soil cores be collected and analyzed. The grid sampling method, on the other hand, can require up to four times as many samples to be collected.

Additional soil surveying obstacles were encountered in association with the actual collection of soil cores. In the past, cores were collected in 4-foot Polyethylene Terephthalate Glycol plastic liners (PETGs). These liners were inserted into a stainless steel tube on the SAM and then pushed into the ground at the desired collection locations using a Giddings Hydraulic Soil Sampling Coring and Drilling machine. This method frequently resulted in the PETGs plugging up and /or the entire rig lifting up off the ground due to the presence of dense, impervious soil layers. A satisfactory solution to this problem has been to abandon the PETGs and collect the cores one foot at a time using the stainless steel tubing. Following this method, the first foot is collected and saved in a plastic bag. The same hole is then re-entered for the next three feet, with each sample collected in individual bags. This process is pictured in Figure 4.2.

Figure 4.2 Soil Core Collection

Laboratory Procedures

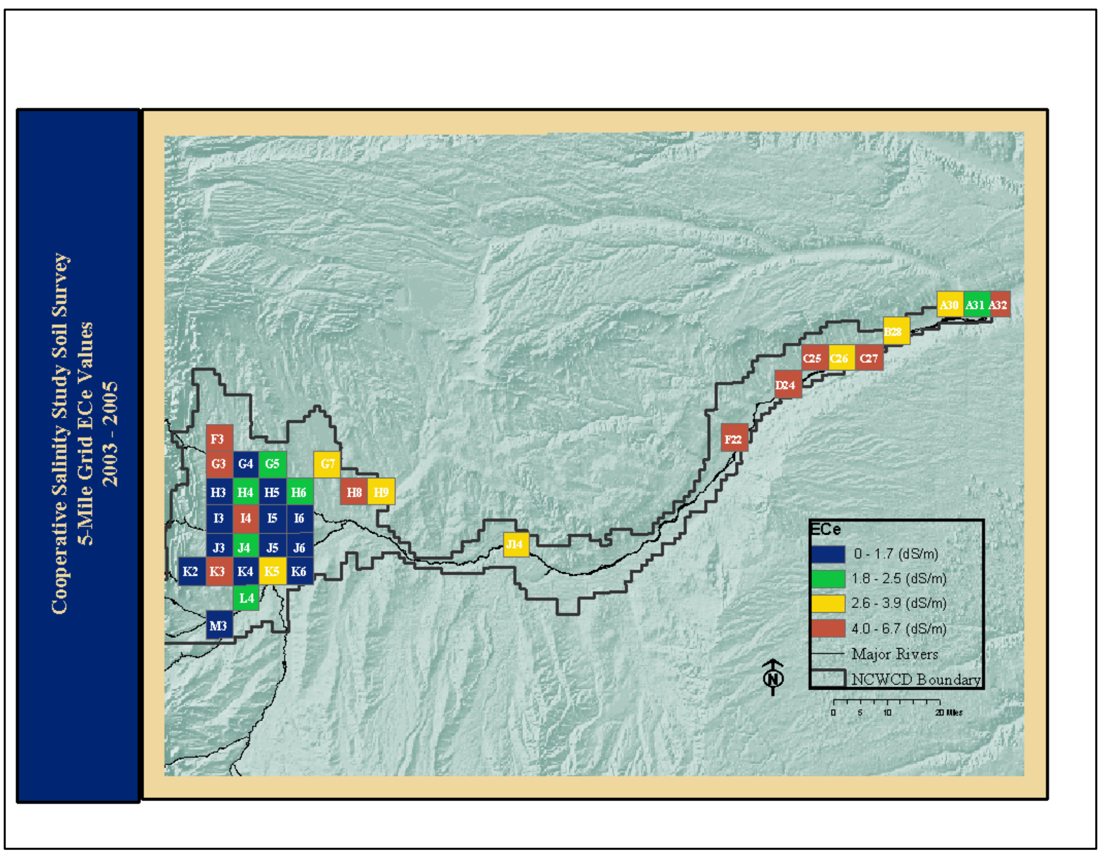
Once the soil cores are brought from the field into the laboratory, they are immediately placed in a refrigerator (while in transit, samples are stored in coolers). From the refrigerator they are sorted on large metal sheets and placed on drying racks where they remain for a minimum of 48 hours. The District has performed tests in previous years as to how long samples can be held prior to drying. It has been concluded that soil samples can be held for at least two weeks without adversely affecting the measured EC_e.

Following the drying process, samples are stored in covered plastic cups until time allows for the analysis to proceed. Additionally, a portion of each core is saved in a plastic bag for long-term storage. From the soils stored in cups, pastes are made according to accepted and established procedures. These pastes are stored for 48 hours prior to being analyzed via a Hach Soil and Irrigation Water Test Kit, model SIW-1. The Hach kit measures the percent saturation, soil electrical conductivity, temperature, pH and sodium adsorption ratio. This data, coupled with the coordinates gathered using the AgGPS 160, are used to generate soil surface EC_e maps for the individual fields surveyed.

4.3 Surveyed Fields

The fields chosen for this study were selected on a random basis. A five-mile grid was placed over the District boundaries and random points corresponding to fields were selected within each of those grid squares. In many cases, a groundwater observation well was also placed near the field to obtain a pairing of soil and groundwater electrical conductivity values. Map 4.1 displays all of the fields successfully sampled from 2003 to 2005; the fields surveyed are represented by their grid locations. Moreover, Table 4.1 highlights the statistics from the 2005 surveyed fields that have been analyzed in the laboratory, while Figures 4.3 – 4.15 display their probable EC_e. It should be noted that the soil samples collected from fields via grid sampling in the fall of 2005 have yet to be analyzed. This data will be included in the 2006 annual report.

An EC_e value, determined by laboratory and/or field data, has been assigned to the five-mile square in which the surveyed fields are located. It should be noted that soil salinity can be highly variable, even within a relatively small area. It is dependent on several factors including, but not limited to, existing soil parent material, groundwater elevation, local climate and weather conditions, crop management practices and water resources (Cardon and Davis). Therefore, assigning an overall EC_e value to a five-mile area based on data gathered from one to three fields within the given area will likely not yield a representative salinity assessment for the entirety of the grid.



Map 4.1 EC_e Values (2003 – 2005)

Field	Acreage	0-1 foot Average EC_e (dS/m)	1-2 feet Average EC_e (dS/m)	2-3 feet Average EC_e (dS/m)	3-4 feet Average EC_e (dS/m)	0-4 feet Average EC_e (dS/m)	Standard Deviation (dS/m)	Classification	See Figure
A30F	55	2.03	2.80	2.95	2.91	2.67	1.00	Nonsaline	4.3
A31FE	35	1.97	2.19	2.39	2.99	2.43	0.97	Nonsaline	4.4
A31FW	35	2.05	2.32	2.90	3.30	2.64	1.22	Nonsaline	4.5
A32F	121	3.57	4.36	4.74	5.25	4.48	1.30	Saline	4.6
B28F	50	2.41	3.84	4.04	4.62	3.77	1.38	Nonsaline	4.7
C25F	50	4.16	5.65	3.08	6.04	5.48	2.63	Saline	4.8
C26F	40	2.60	3.09	3.53	3.92	3.31	0.82	Nonsaline	4.9
C27F	112	3.36	4.58	3.18	2.82	3.49	1.42	Nonsaline	4.10
D24F	50	3.02	4.98	5.73	5.56	4.82	1.97	Saline	4.11
F22F	65	4.70	5.24	5.01	4.21	4.79	2.24	Saline	4.12
G3F	35	6.07	6.59	6.81	6.38	6.46	0.73	Saline	4.13
H8F	120	2.65	4.23	5.06	NA[1]	4.04	1.94	Saline	4.14
J14F	50	3.25	2.86	3.40	3.46	3.32	1.73	Nonsaline	4.15

Table 4.1 Depth Specific EC_e and Average Statistics for 2005 Surveyed Fields

[1] Due to field conditions, soil samples were not collected at a 3-4 foot depth.

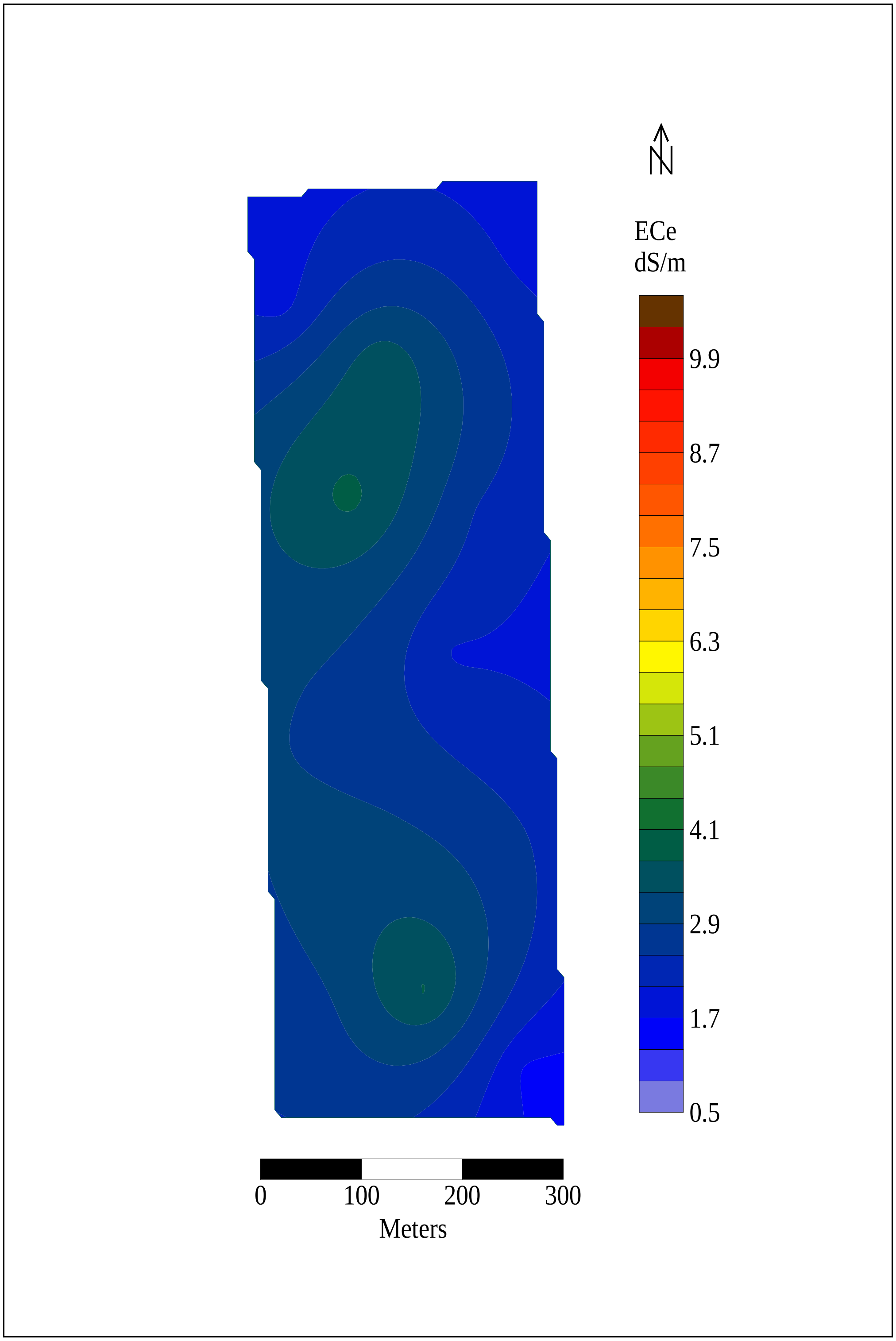


Figure 4.3 Probable Average EC_e for Field A30F

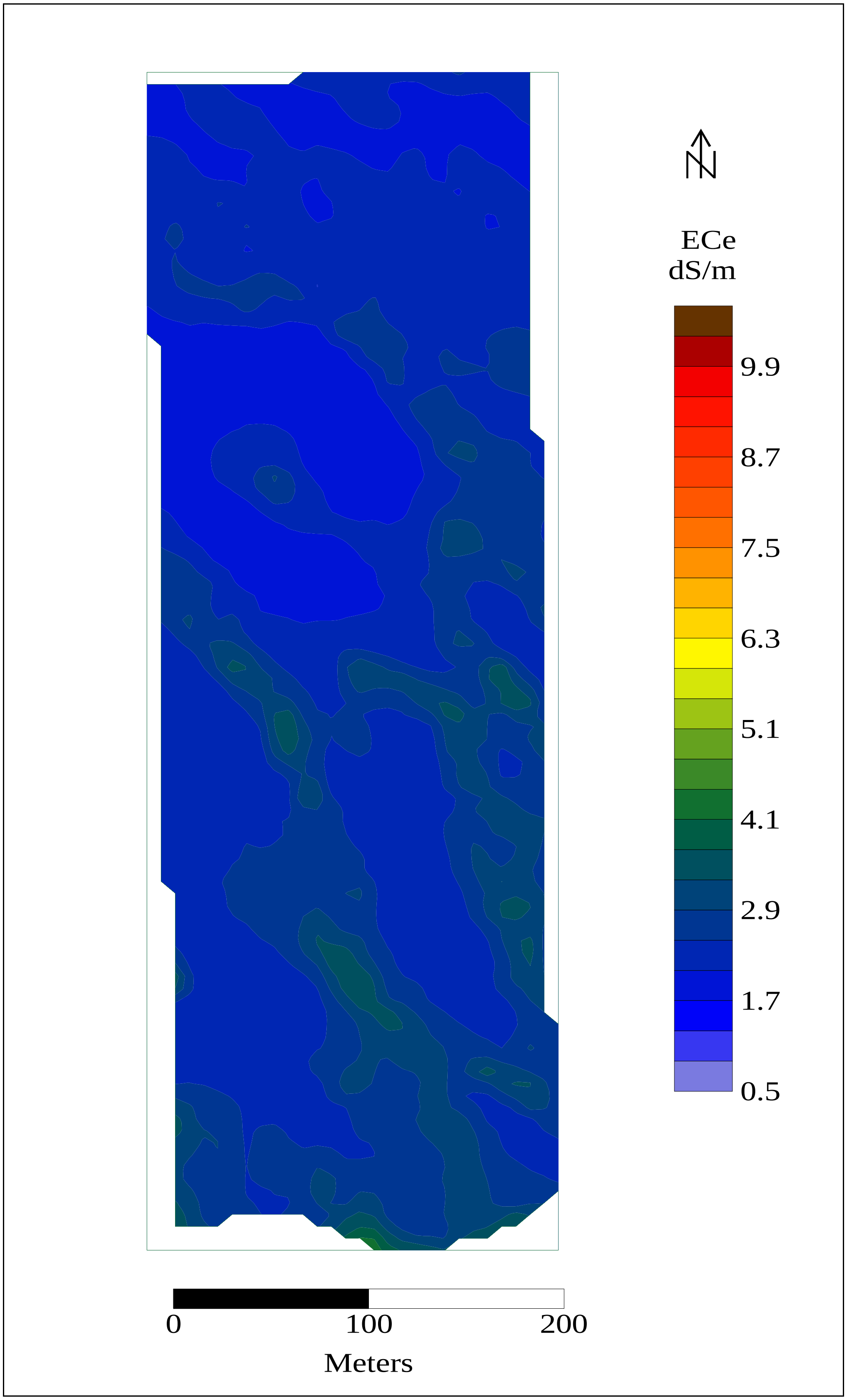


Figure 4.4 Probable Average EC_e for Field A31FE

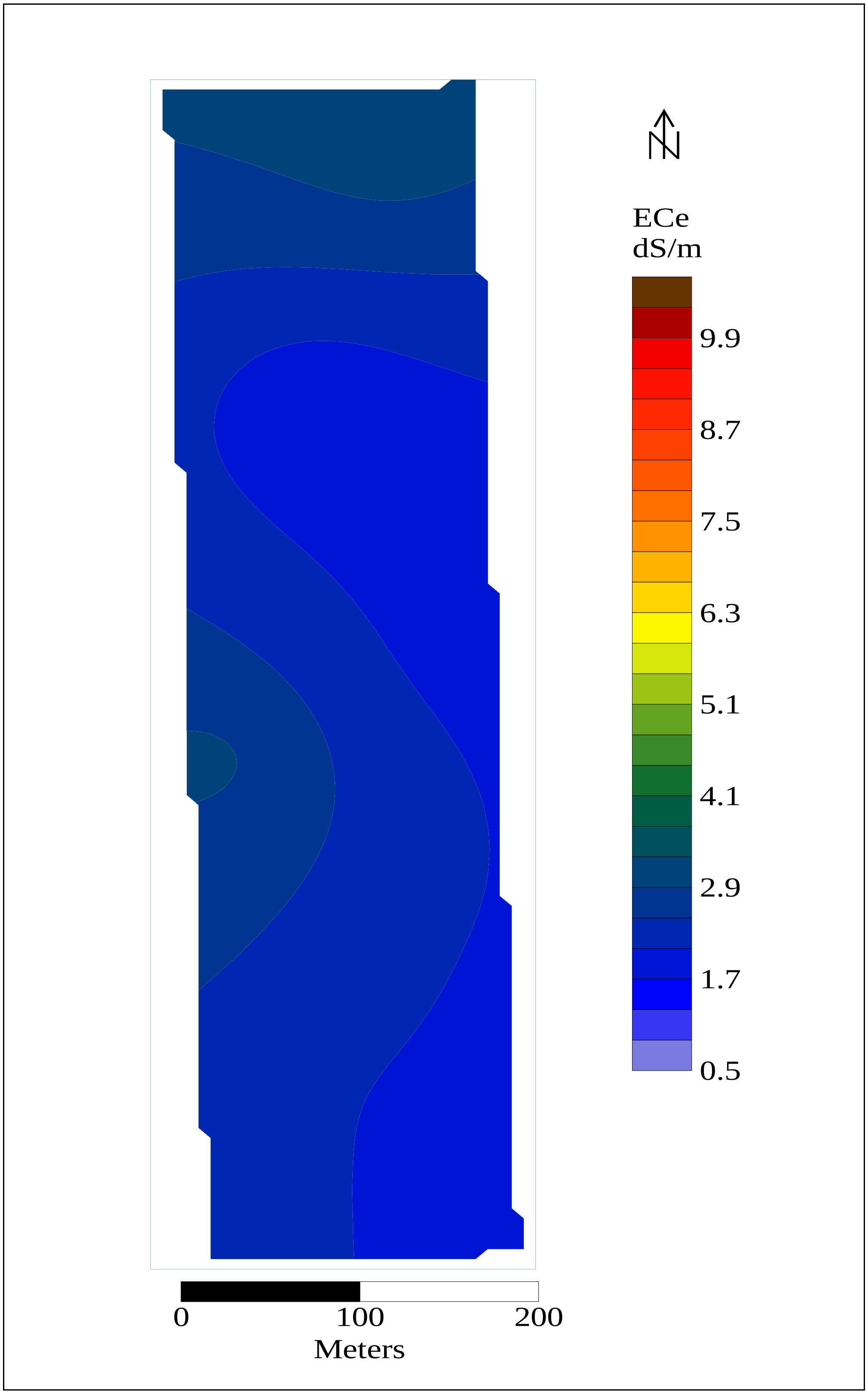


Figure 4.5 Probable Average EC_e for Field A31FW

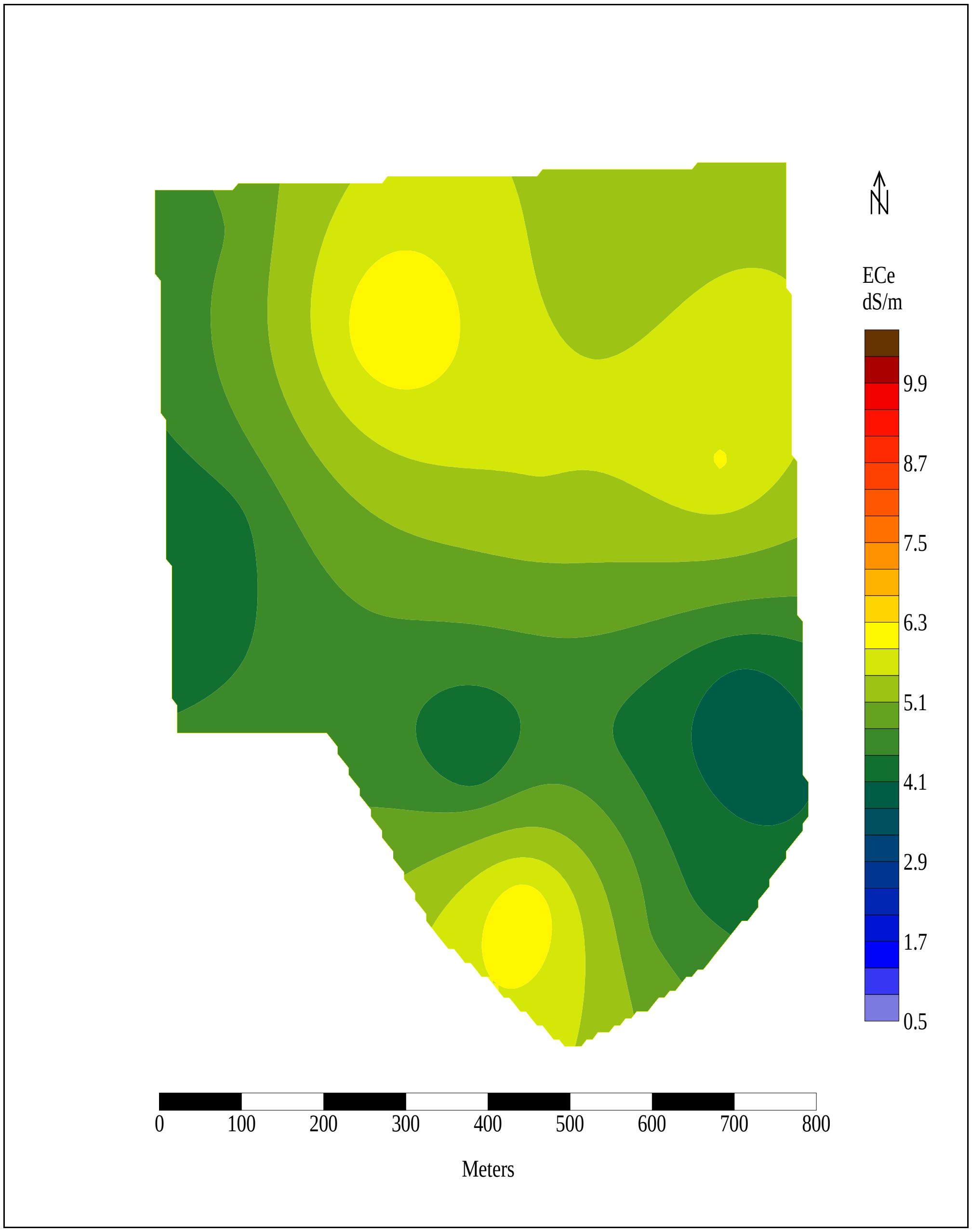


Figure 4.6 Probable Average EC_e for Field A32F

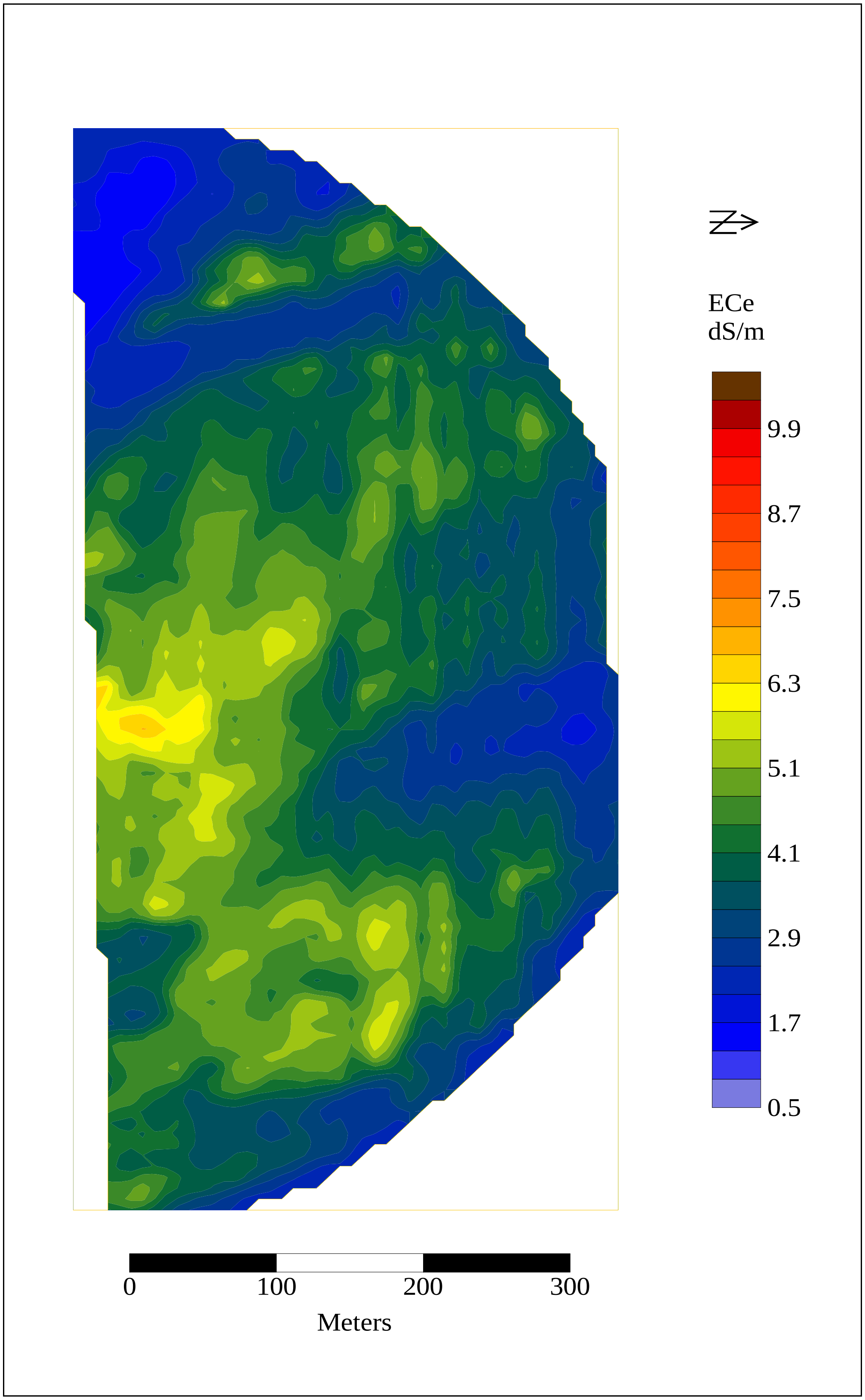


Figure 4.7 Probable Average EC_e for Field B28F

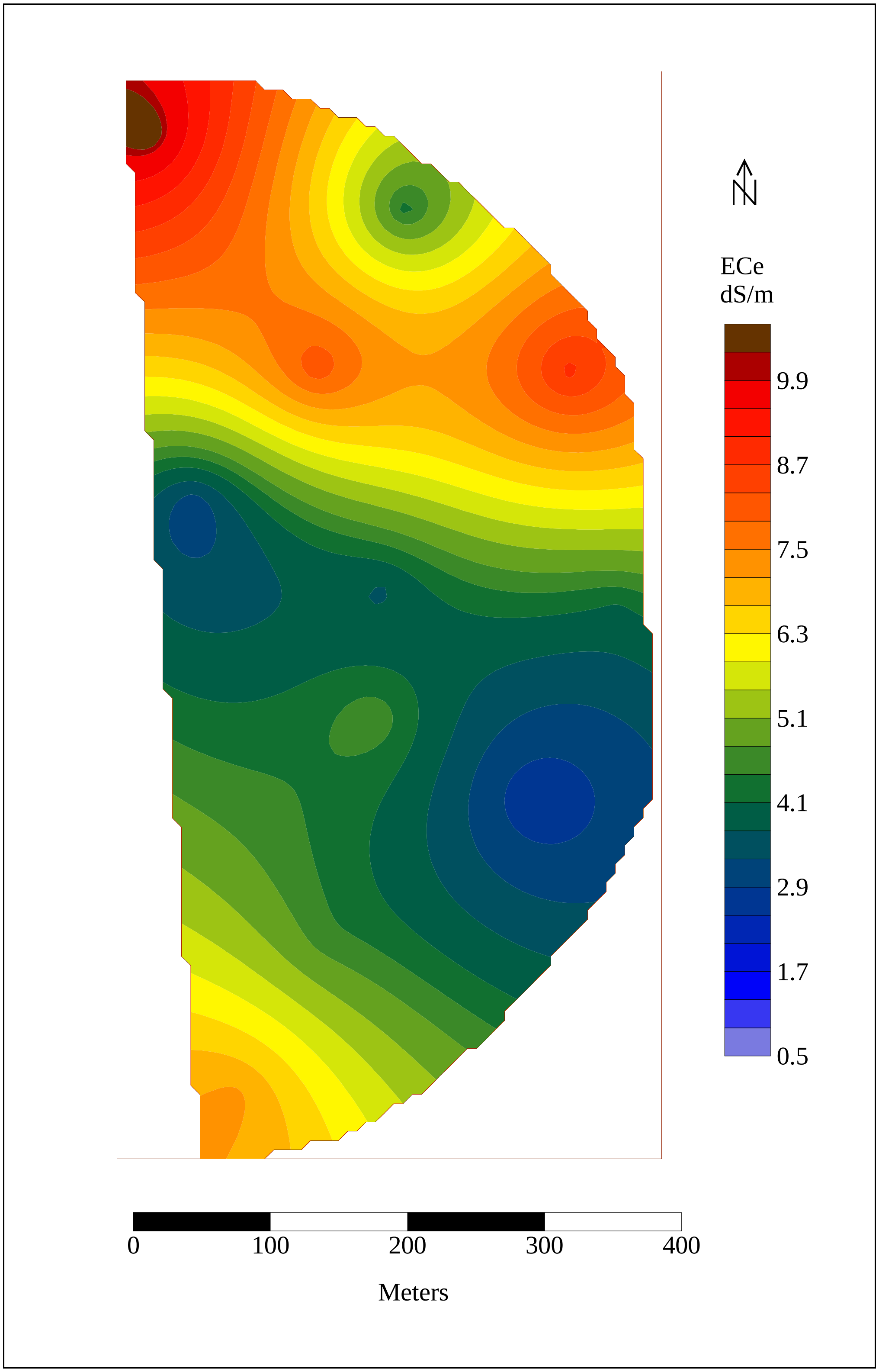


Figure 4.8 Probable Average EC_e for Field C25F

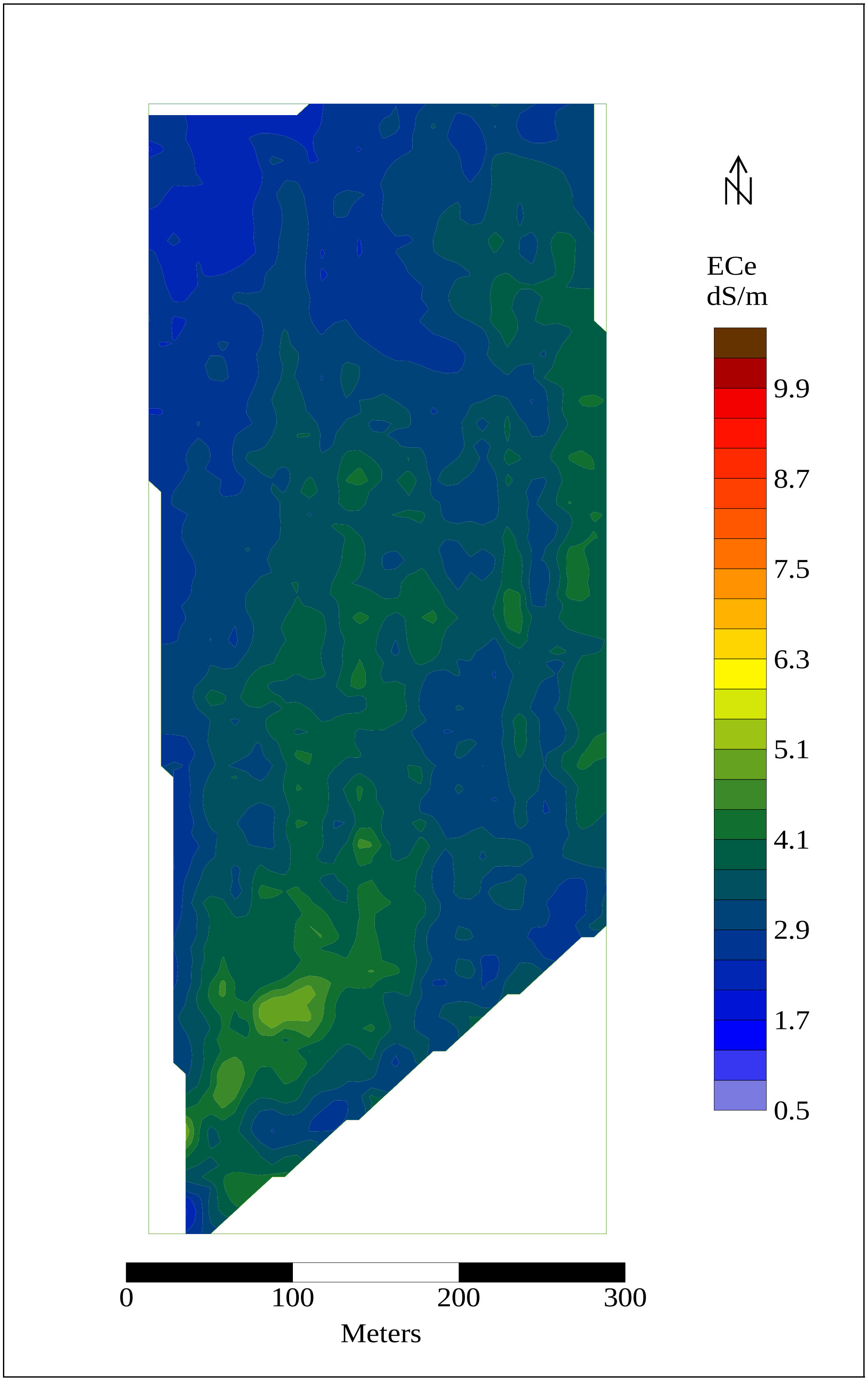


Figure 4.9 Probable Average EC_e for Field C26F

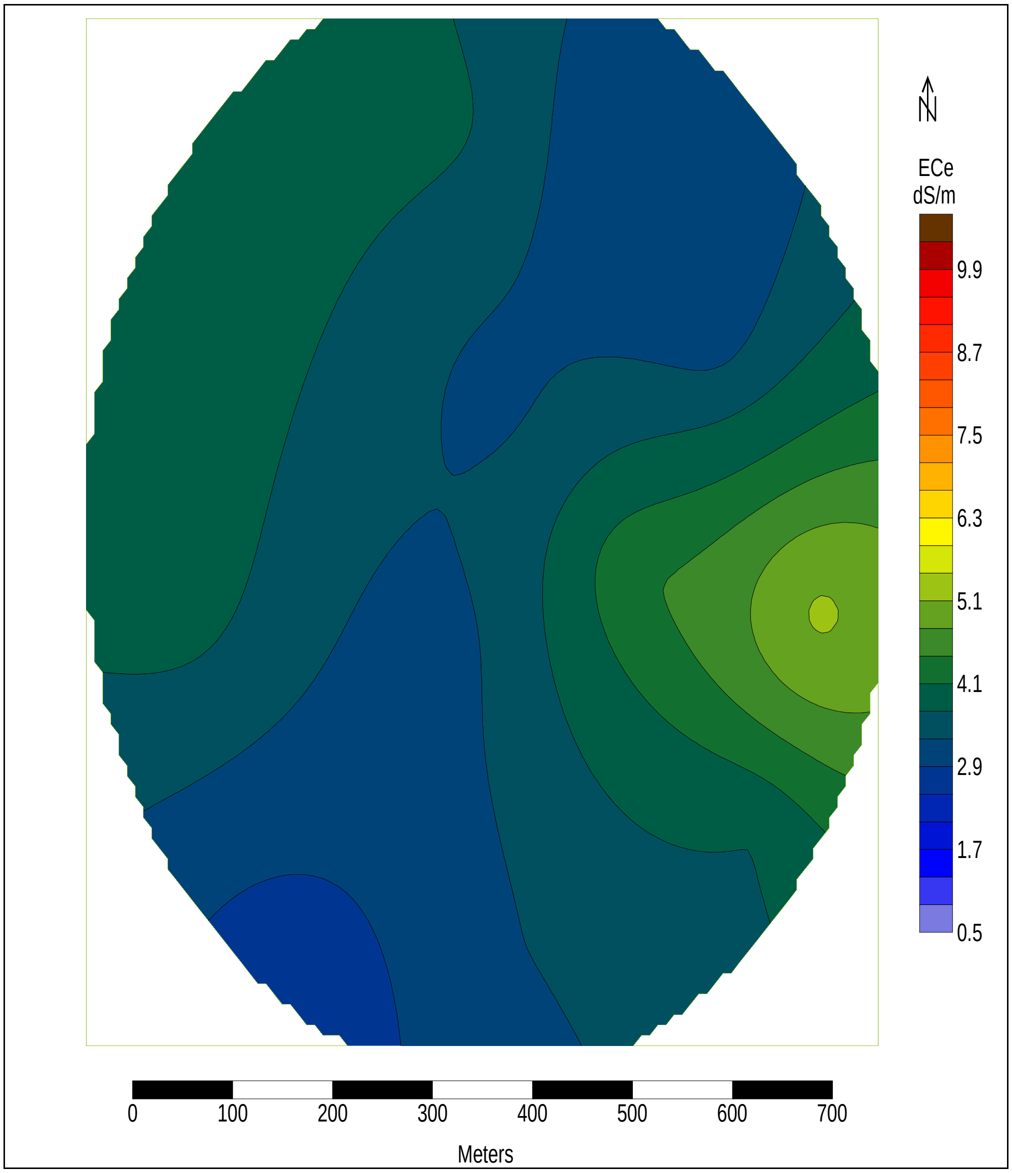


Figure 4.10 Probable Average EC_e for Field C27F

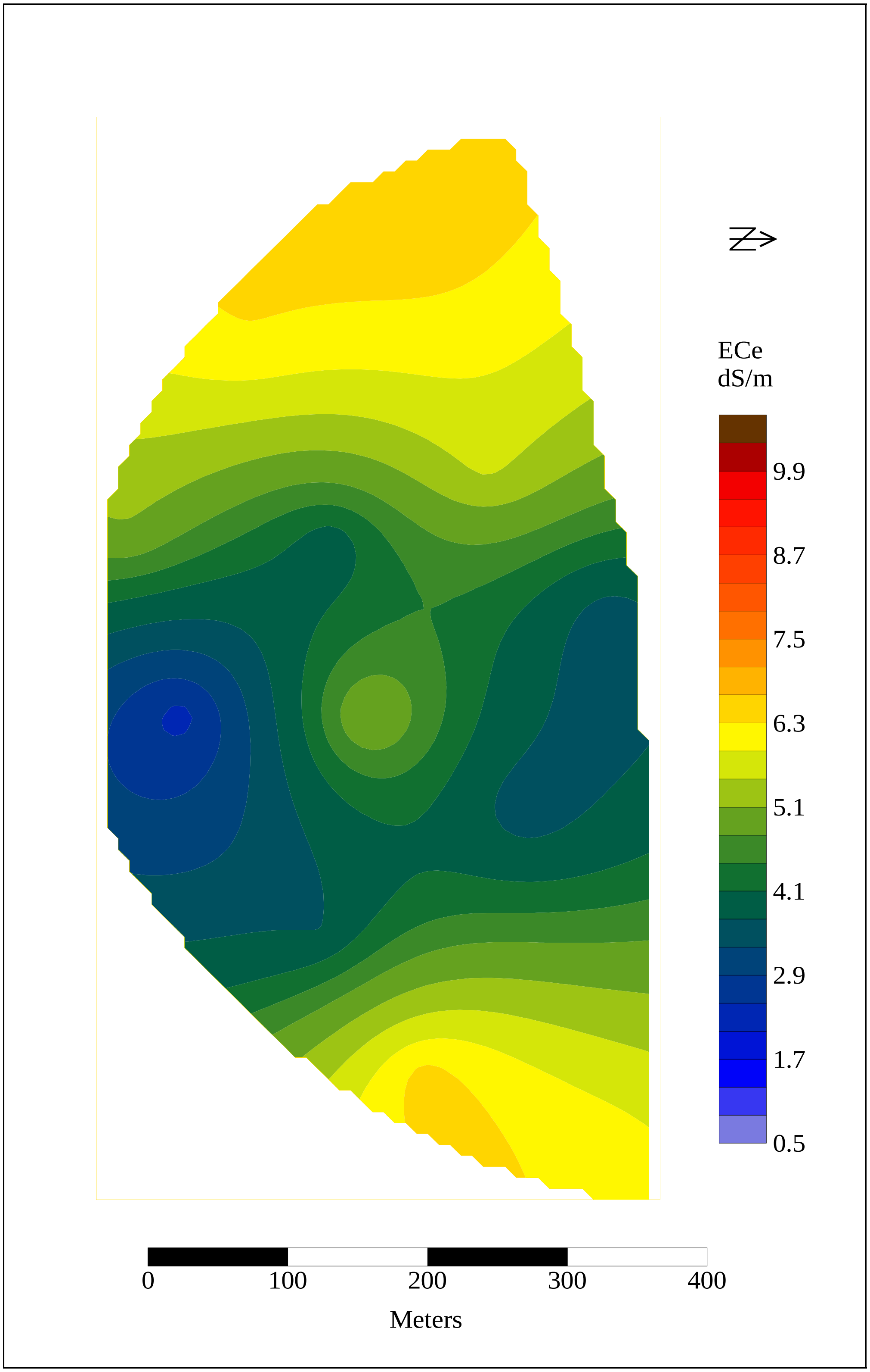


Figure 4.11 Probable Average EC_e for Field D24F

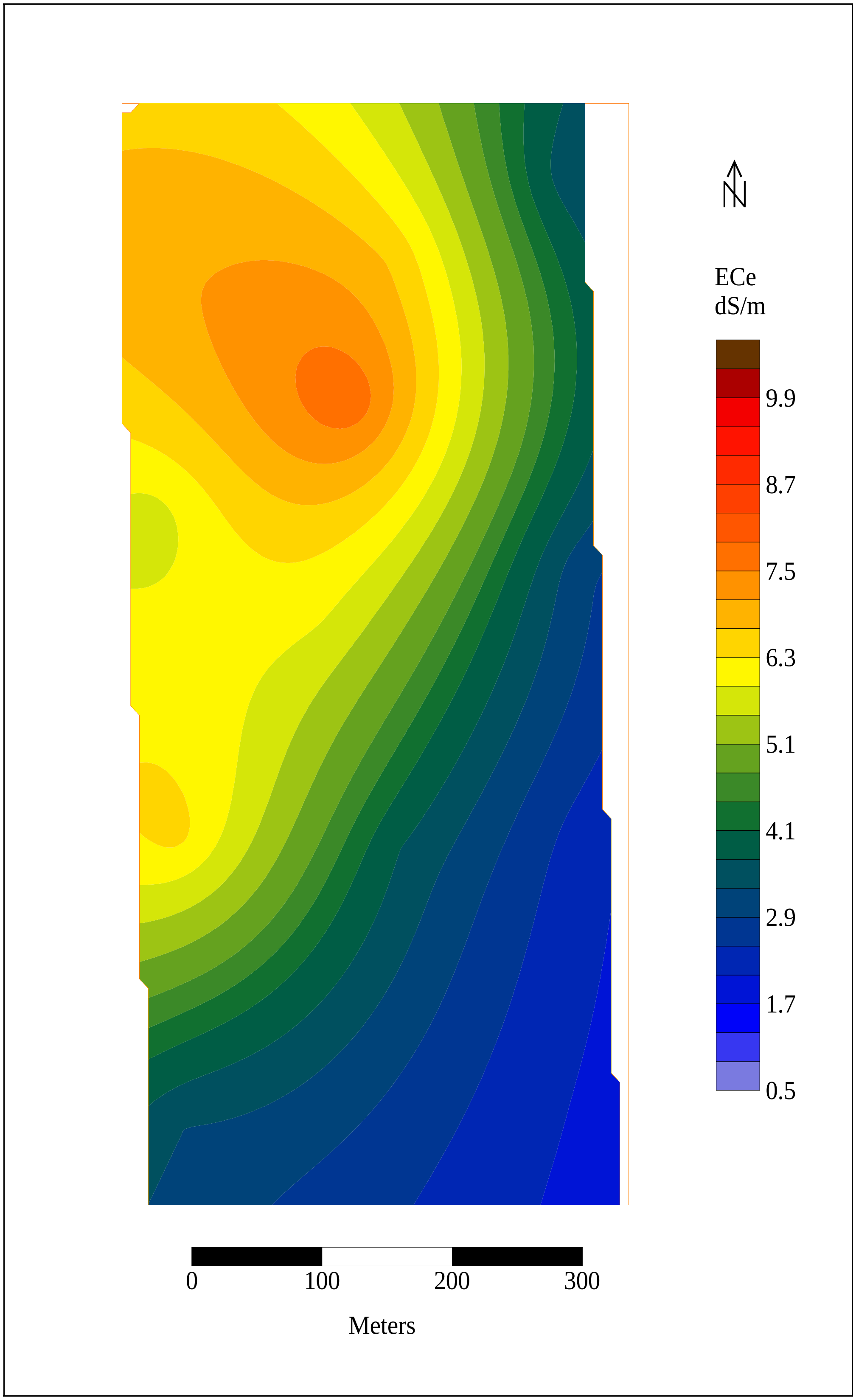


Figure 4.12 Probable Average EC_e for Field F22F

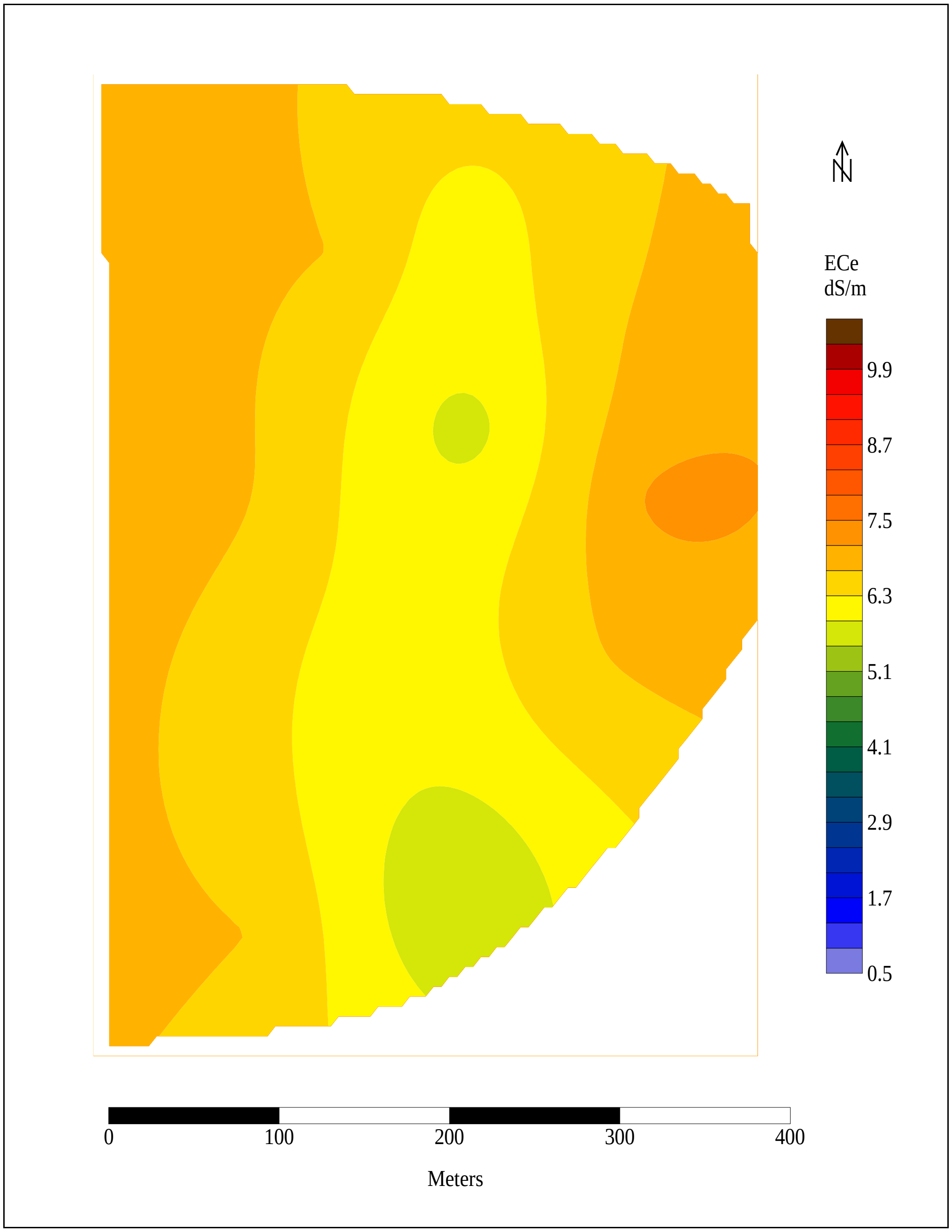


Figure 4.13 Probable Average EC_e for Field G3F

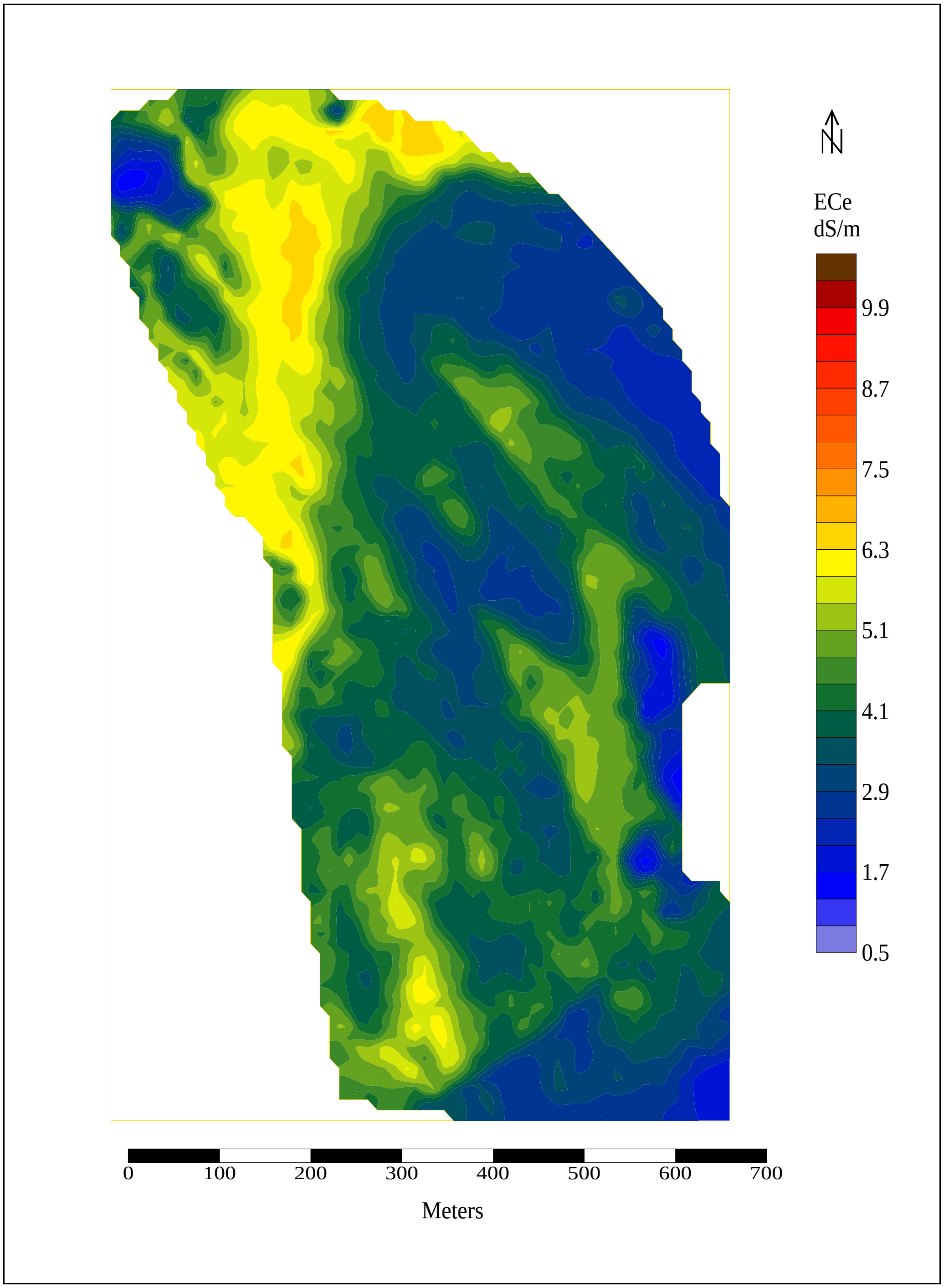


Figure 4.14 Probable Average EC_e for Field H8F

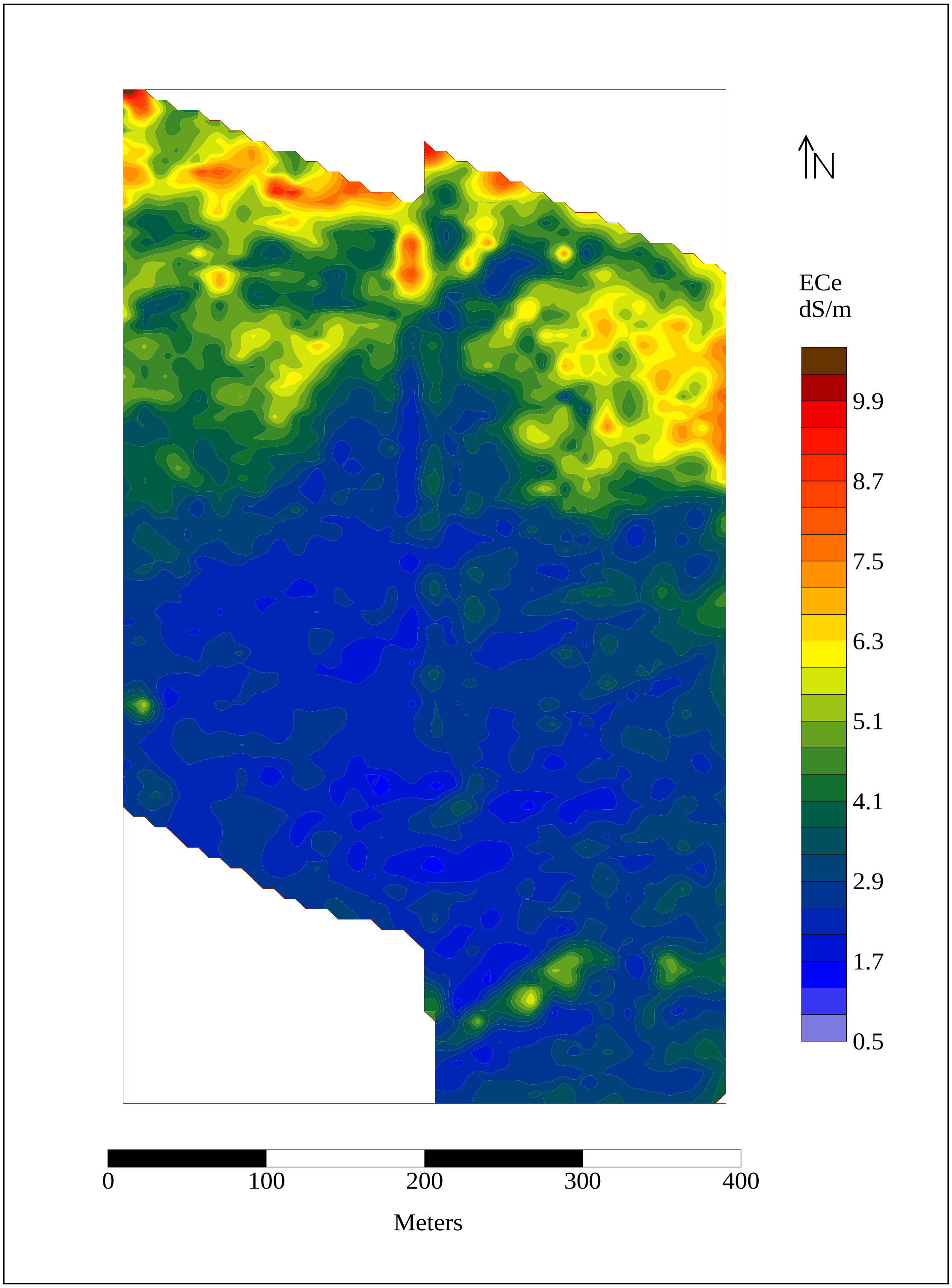


Figure 4.15 Probable Average EC_e for Field J14F

5. Quality Assurance and Quality Control

As in any study, it is crucial to implement and adhere to quality assurance and quality control guidelines. Such guidelines help ensure the collected and analyzed data are valid and meaningful.

5.1 Surface Water Electrical Conductivity Sampling

Automated Electrical Conductivity Sampling Calibrations and Procedures

In an attempt to improve the accuracy of the data gathered from automated stations, the District has implemented a rigorous calibration and maintenance schedule. The Campbell Scientific CS547As (CS547A), the instruments installed at automated monitoring stations, undergo annual three-point calibrations in the laboratory. Additionally, each site is visited on a monthly basis and any necessary maintenance, such as cleaning or readjustment of the sensor in the streamflow, is carried out. At this time, a field calibration check is also performed. This is achieved via lowering a YSI 30 Salinity/Conductivity/Temperature Instrument into the streamflow directly corresponding to the location of the CS547A. These readings are used to either validate the accuracy of the automated data or to alert the District to any problems.

Manual Electrical Conductivity Sampling Calibrations and Procedures

The District has implemented precise calibration and sampling protocols to help ensure data from the District's manual sampling stations are accurate and methods are consistent.

The primary manual sampling probe utilized for surface water monitoring, the In-Situ Multi-Parameter Troll 9000 (In-Situ), is calibrated on a weekly basis. In-Situ, Inc., recommends calibrations be performed using its Quick-Cal Solution, a single solution for calibrating conductivity, pH and dissolved oxygen at the same time. However, at 25^{0} C the Quick-Cal conductivity value is equal to 8.0 dS/m. This is well beyond the range of conductivity values most frequently encountered in the field. Moreover, this solution only allows for a one-point calibration to be performed. The District considers a more accurate calibration is achieved using values closer to those encountered in the field and more than one point by which to calculate a slope where possible. Therefore, conductivity calibrations are performed using a 1.413 dS/m solution, and two-point calibrations are performed for pH and dissolved oxygen using 4.00 and 7.00 buffers and a sodium sulfide solution and water, respectively.

The In-Situ calibrations are verified every morning prior to being taken into the field; calibration checks are performed for both conductivity and pH. When the instruments do not read within the factory-specified acceptable ranges (2 μS or ± 0.5 percent, whichever is greater, for the conductivity probe, and ± 0.9 units for the pH probe), the individual sensors are recalibrated.

Hydrolab Multi-Probe Quantas are used as back-up instruments when the In-Situs are not available. These instruments are calibrated as use necessitates and, as with the In-Situs, calibrations checks are performed prior to all use.

In addition to the calibration procedures discussed above, the following protocols have been implemented in order to best maintain the instruments and collect consistent surface water data:

1) Probes are stored in a pH 4.00 buffer solution.
2) Probes are stored and transported at a downward angle.
3) Probes are transported in PVC sleeves containing water, located in the beds of sampling trucks.
4) A thorough rinse of probes with deionized water is performed prior and subsequent to all use.
5) Sampling is conducted across the entire transect of streamflow.
6) Instruments are allowed to fully stabilize prior to recording a reading (as indicated by the HydroPlus CE software installed on the In-Situ RuggedReaders).

Total Dissolved Solids Sampling Procedures

Bi-annual grab samples are collected from 10 stream sites and sent to an outside laboratory for a complete TDS analysis. The samples are collected with a scoop attached to a long rod. This allows the sampler to reach out into the streamflow for sample collection. The plastic storage bottles used to transport the TDS samples are initially rinsed with deionized water and then rinsed three times with the stream water to be tested. Once collected, the samples are kept in a cooler until they are analyzed.

5.2 Groundwater Electrical Conductivity and Depth Sampling

As with the stream sites, care is taken when monitoring groundwater wells to ensure data is valid and consistent. This begins with a precise calibration of the monitoring instruments. The same multi-probes utilized for manual surface water sampling are also used for groundwater monitoring; all calibration and maintenance procedures are identical to those listed above.

In order to collect consistent electrical conductivity data from monitoring wells, the District has defined guidelines that all sampling personnel are instructed to follow. This includes the instrument care and maintenance protocols previously outlined, in addition to specific well pumping procedures. Each well must be pumped for a minimum of five minutes in order to ensure the water sample is not taken from stagnant water. Furthermore, the multi-probes must be inserted into a PVC flow cell and readings are taken while the pump remains on and well water is flowing through the PVC. Lastly, a thorough rinsing of the pump and multi-probes must conclude each pumping session. Strict adherence to these guidelines guarantees the data collected are as accurate as possible.

Many of these wells are equipped with level loggers. The District currently uses In-Situ Mini-Trolls (miniTrolls) and Global WL 16 Water Level Loggers (WL 16s) to monitor depth. Both level loggers are equipped with vented cables to help avoid errors related to barometric pressure changes. Batteries for both are changed three times annually. The mini-Troll's calibrations are checked yearly. A reference level is initially entered and the loggers are programmed to measure changes from that reference. When the batteries are changed out and data downloaded, the readings are checked against a manual depth reading. If this reading does not match that of the logger, a new reference depth is measured and entered. Assuming, however, the depths equate, the last logger reading is re-entered and used as the new reference level. The WL16s are also checked annually, yet the only calibration performed is done prior to deployment. The calibration for the WL 16s requires the cable length to be precisely measured to two decimal places. This number is entered into the associated software. These loggers then record depth referenced to the height of the water above the bottom of the sensor based on the measured cable length.

5.3 Soil Electrical Conductivity Surveying

Soil Survey Field Calibration and Procedures

The District surveyed fields using two distinct methods. Surveying was carried out via a Geonics Incorporated Electromagnetic Induction Meter Dual-Dipole (EM38-DD) in conjunction with Sampling, Assessment and Prediction Model software. The District also surveyed fields utilizing a grid sampling method. The latter method requires no field calibration; the calibration procedures described only relate to the former sampling method. The EM38-DD requires calibration at least three to four times per day, as detailed in the operating manual. In addition to these calibrations, the District began implementing an additional step to ensure consistent readings. Before the survey was completed, the very first swath monitored was retested and the two sets of numbers were compared against each other.

Soil Survey Laboratory Calibration and Procedures

Once soil samples are brought into the laboratory, precise guidelines are adhered to regarding hold-times, handling, and analysis procedures. Samples are kept refrigerated for no longer than two weeks. This time frame is implemented to ensure that any microbial activity within the soils is optimally minimized so as not to adversely affect the results of the soil analysis. From the refrigerator, the soil samples are placed on drying racks for a minimum of 48 hours. Once dried, samples are split, with a sufficient portion of each sample being retained in covered plastic cups to make pastes, while the remainder of each sample is stored in plastic bags for long-term storage. From the soil stored in the plastic cups, a soil paste is mixed and held for two days prior to analysis. This holding time allows for all salts adhering to soil particles to dissociate and dissolve in the soil water. In mixing the soil paste, close attention is paid to ensure it meets the following requirements:

1) Glistens as it reflects light;
2) Flows slightly when container is tipped;
3) Slides freely and cleanly off a spatula;
4) Consolidates easily by tapping or jarring the container after a trench is formed in the paste; and
5) Free water does not form when paste is allowed to sit (Richards).

Once the soil paste has been held for two days, the analysis procedure continues. The percent saturation, soil electrical conductivity, temperature, pH and sodium adsorption ratio are all measured using a Hach Soil and Irrigation Water Test Kit, model SIW-1. This test kit and all associated instruments are calibrated on a daily or bi-daily basis, as use necessitates. To further validate the District's laboratory calibrations and procedures, 10 percent of all samples are sent to an outside laboratory to be retested and compared against District laboratory results.

6. Budget/Expenses Summary

Outlined in Table 6.1 is a summary of the cooperative salinity program budget/expenses for the 2005 fiscal year. While the total budget, including District and Reclamation funds, is approximately $250,000, the expenses sum to just over $358,000. To make up for this difference, the District contributed an additional $100,700 to the study.

Task category	Total Budget	Expenses	Difference
Technical specialist/consultants	$101,500	$160,699	($59,199)
Field technicians	$29,170	$ 54,524	($25,354)
Vehicle usage	$28,000	$56,858	($28,858)
Field computers & cell phones	$1,200	$1,200	$0
Water quality probes & test kits	$0	$0	$0
Portable flow meters & equipment	$7,100	$8,758	($1,658)
Data loggers, sensors, telemetry, etc.	$13,340	$13,461	($121)
Remote site telemetry operation/maintenance	$6,000	$7,495	($1,658)
GPS units	$0	$0	$0
DDEM-38 probes	$0	$0	$0
Salinity rig & hydraulic soil sampling unit	$4,000	$5,820	($1,820)
Groundwater monitoring wells	$0	$1,860	($1,860)
Cooperative efforts with other organizations	$0	$0	$0
Interagency coordination/travel/training	$3,000	$0	$3,000
Yield sampling/monitoring equipment	$0	$0	$0
Laboratory /GIS specialist	$48,850	$36,448	$12,402
Laboratory supplies, reagents, etc.	$10,470	$10,960	($490)
On-farm irrigation systems cost share (50%)	$0	$0	$0
Presentations, fact sheets, etc.	$1,250	$0	$1,250
Field days, BMP workshops, etc.	$2,500	$0	$2,500
PC projector, laptop, software, etc.	$0	$0	$0
Web page programming	$1,000	$0	$1,000
Total	**$257,380**	**$358,083**	**($100,703)**

Table 6.1 Summary of Budget/Expenses for Fiscal Year 2005

7. Conclusion

In 2005 the District completed its fifth year of the seven-year study examining surface water, groundwater, and agricultural soil salinity levels throughout the Lower South Platte Basin. Significant amounts of data were successfully collected and analyzed. This allowed the District to significantly expand its salinity database and in turn, its understanding of salinity issues throughout District boundaries.

Surface water data collection in 2005 remained relatively consistent from the sampling schemes, schedules and procedures adhered to in recent years. In the District's continuing effort to record the most accurate data possible, a few additional quality assurance and quality control measures were employed in terms of the automated stations. Moreover, difficulties with the primary manual data collection instruments resulted in the implementation of new and exacting calibration, maintenance and handling guidelines. Lastly, a few canal monitoring stations were removed from the sampling schedule due to a redundancy in values observed in previous years and to the need to free up resources. This trend may continue in 2006; the number of sampling stations may be decreased along systems in which little to no changes are observed with increased distance downstream.

The District monitored 42 groundwater monitoring wells in 2005 for electrical conductivity and depth. In 2004 the District drilled several new wells. In 2005 these wells were purged and added to the sampling scheme, increasing the scope of the groundwater monitoring by approximately 17 percent.

Agricultural soil surveys were successful in 2005 in terms of the number of fields from which the District was able to collect data, 30 fields in total and approximately 1,800 acres. Problems, however, were realized in terms of consistently achieving acceptable correlations between field EM38-DD and ESAP results and laboratory data. As a result, the District implemented a grid sampling scheme during the second half of 2005. Thirteen of the 30 fields completed were surveyed using the EM38-DD in conjunction with ESAP, while the remaining 17 were surveyed according to a grid sampling method.

The Cooperative Salinity Program website, www.ncwcd.org, continues to grow. Currently all of the automated monitoring station data are available from the website. The published Annual Summary Reports, as well as information regarding the different aspects of the project, are also accessible via the website. The District plans to continue its development of the website with the possible addition of groundwater and soil survey data.

The District is greatly appreciative of the continued support from Reclamation and other cooperating entities in this effort and looks forward to the challenges and successes that await with the 2006 sampling year.

8. Works Cited

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