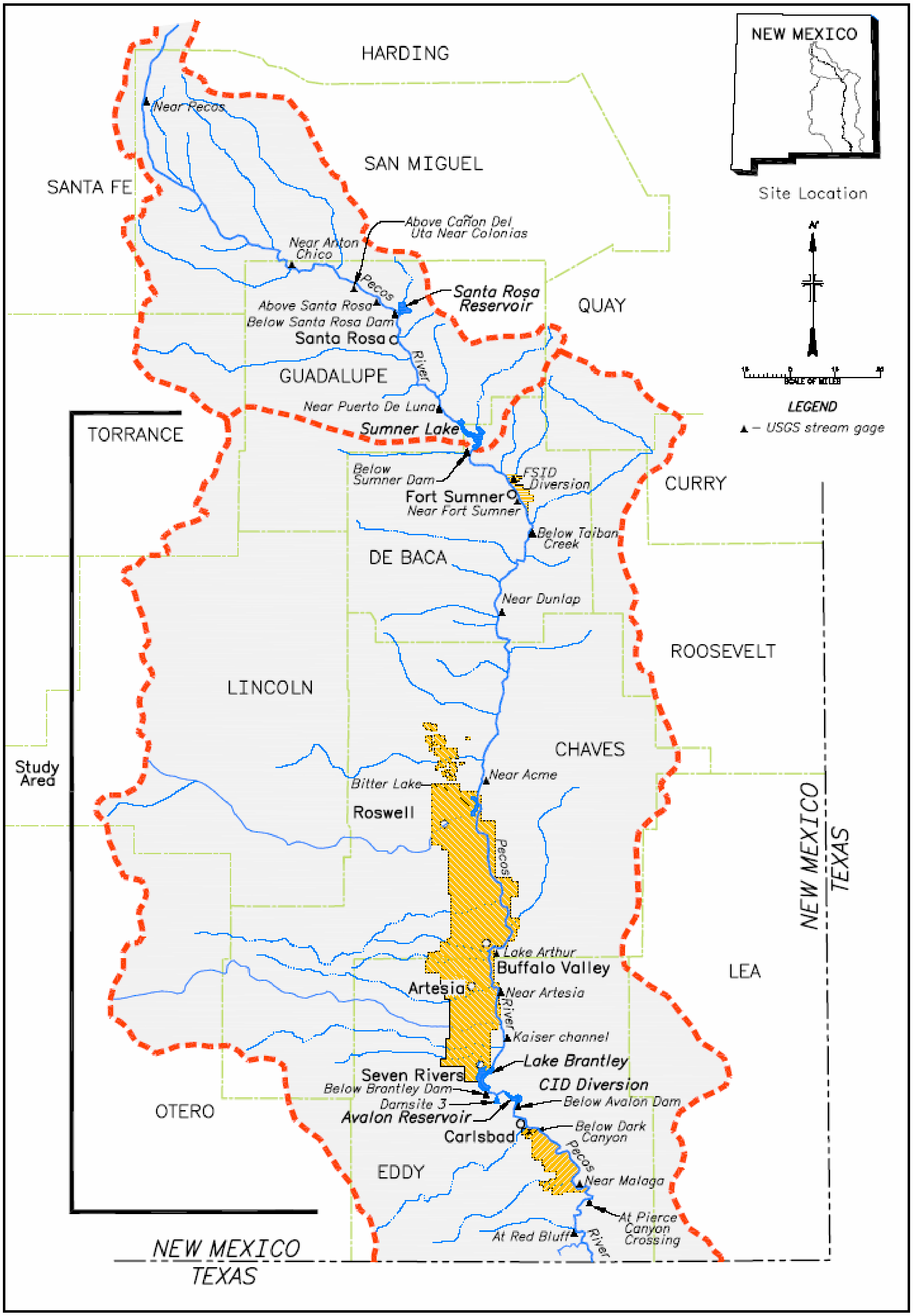
Appendix 4

Water Quality



Map 1: Map of the Pecos River Basin in New Mexico showing stream gage locations

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Water Quality Appendix

This section will present data on existing water quality in the Pecos River basin from Santa Rosa Lake to north Texas. Data for the description were retrieved from the U.S. Geological Survey's (USGS) National Water Information System (NWIS). There are water quality data available for 14 long-term USGS gages in the basin. To define the existing water quality of the basin, only data collected since storage began behind Brantley Dam in August 1988 were used. This restriction of the period of record eliminated 3 of the gages that were discontinued prior to the closure of Brantley Dam. The gages that were eliminated included those at Pecos (ended 1970), Sumner Dam (ended 1988), and Carlsbad (ended 1987).

Pecos River

Basin-wide Water Quality

The water quality of the Pecos River basin has been recently described by the New Mexico Water Quality Control Commission (NMWQCC, 2002a) in their 305(b) Report. This initial description is works from the summary in that report.

The headwaters are pristine with one exception, the abandoned Pecos (Terrero) Mine near the mouth of Willow Creek. Although the remainder of the basin is by no means pristine, it is supportive of its designated beneficial uses. The listed causes of nonsupport in the mainstem of the Pecos River as shown in NMWQCC (2002a) in the study area include:

> metals (most frequently aluminum, but also including mercury, primarily in lakes), turbidity, nutrients, pathogens, dissolved oxygen, stream bottom deposits, and total ammonia from municipal point sources, temperature, and conductivity.

This description will focus on the factors that can be affected by the operations of the Project and changes in those operations. These include total dissolved solids (TDS), *i.e.* specific conductance, metals, and siltation. Data to be used are summarized in Attachment 1, which also includes water quality standards and a comparison to the standards for each of the gages in the Pecos Basin within the Project area.

Figure 1 shows the median along with the 25th and 75th percentile specific conductance of the Pecos River from above the study area to a point beyond its southern end. Specific conductance is a measure of the ability of water to conduct electricity and is proportional to the dissolved solids (electrolytes) concentration in water. All of the data summarized in Figure 1 are based on the periods shown at the top of the summary tables in Attachment 1; this includes the period since the closure of Brantley Dam. The EC for the farthest upstream site, the Santa Rosa Lake inflow, is in the range of 390 to 895 µS/cm. The median EC and the spread between the 25th and 75 percentiles then increases to the site near Artesia. There is a subsequent decrease in both the median and the spread at the site below Brantley Dam, with a further decrease at the Dark

Canyon gage. The initial decrease is a reflection of the mixing of dilute and concentrated inflows that occurs within the reservoir. The net effect is a more uniform water quality over time. The additional decrease at the Dark Canyon gage reflects the influence of base flow from the relatively pristine Capitan Reef aquifer, as well as tributary inflows from the Guadalupe Mountain watersheds. Flow at the Dark Canyon gage also shows even less variation in specific conductance than the Brantley Reservoir release. NMWQCC (2002) indicates that the river in the reach upstream from the Dark Canyon gage is located is frequently dry; water at the gage on such occasions would consist of local gains from base flow.

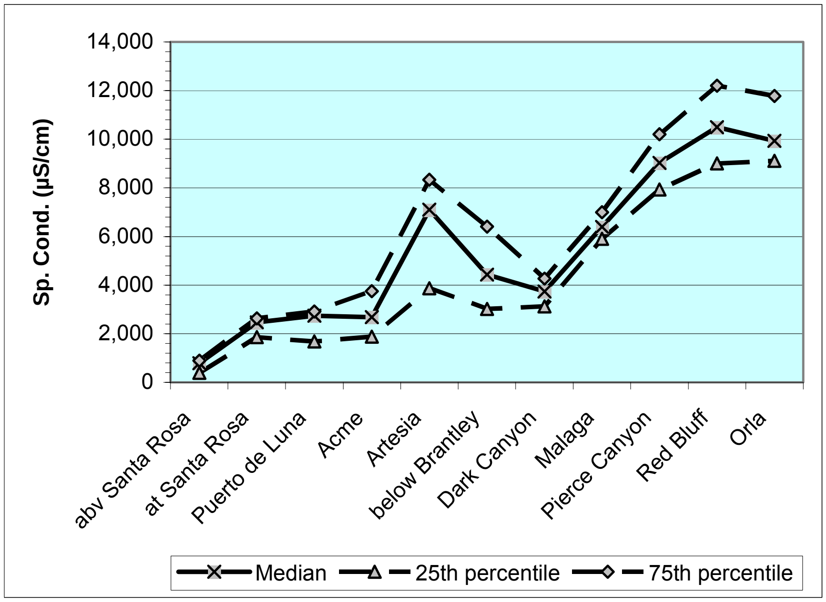


Figure 1: Specific conductance in the Pecos River basin between the Santa Rosa Lake inflow and Orla, Texas

Table 1 summarizes the results of a regression analysis of the flow and specific conductance data for each of the gages shown on Figure 1. The r^2-values in Table 1 reflect the relationships described above for the data in the plots. The lowest r^2-values are those for the Brantley outflow and the gage at Dark Canyon. Both the influence of a reservoir and the overwhelming predominance of base flow would reduce the influence of flow in determining the specific conductance. The relationship between flow and specific conductance reflects either the seasonal variation due to low specific conduc-

Table 1. Logarithmic regressions of specific conductance on flow at 11 sites on the Pecos River

Location	r^2	Slope	Intercept	n	F	Prob. > F
above Santa Rosa	0.6943	-0.394626	8.047279	53	115.81	< 0.000001
at Santa Rosa	0.7073	-0.331327	8.304622	42	96.68	< 0.000001
Puerto de Luna	0.6904	-0.516690	10.135504	51	109.27	< 0.000001
Acme	0.5729	-0.228936	8.809516	39	49.63	< 0.000001
Artesia	0.7408	-0.465102	10.831268	52	142.87	< 0.000001
Brantley	0.2314	-0.147210	8.980483	42	12.04	0.001259
Dark Canyon	0.0898	-0.061015	8.367093	76	7.30	0.008527
Malaga	0.6214	-0.253799	9.781035	77	123.12	< 0.000001
Pierce Canyon Crossing	0.7652	-0.444435	10.93416	78	247.74	< 0.000001
Red Bluff	0.8069	-0.357685	10.749378	33	129.50	< 0.000001
Orla	0.4333	-0.097887	9.609246	55	40.53	< 0.000001

tance during spring snow melt runoff, the dilution of higher base-flow concentrations of dissolved solids by storm runoff, or a combination of both. In the case of a reservoir release, the dilution occurs in the reservoir; in the case of base flow, there is no dilution. Both cases show those influences in a lower r^2 for their specific conductance on flow regressions.

As can be seen in the tables in Attachment 1, there are no water quality standards for specific conductance anywhere in the Pecos basin. However, beginning with the gage at Puerto de Luna and continuing to Orla, with the lone exception of the Brantley release, there are standards for TDS, chloride, and sulfate.

Figure 1 shows 2 peaks in specific conductance in the Pecos Basin. The first peak occurs at Artesia and the second at the Red Bluff gage. The first peak in specific conductance reflects the effect of what is an apparent large salt load between the Acme and Artesia gages. This effect will be explored in more detail later in the Sumner Dam release section of this description. The second peak is the culmination of a gradual increase that begins at Malaga. These peaks in specific conductance are accompanied by a change in the composition of the dissolved solids in the river. These changes are shown on Figure 2, which presents plots of the percent composition of the cations and anions at each gage in the river.

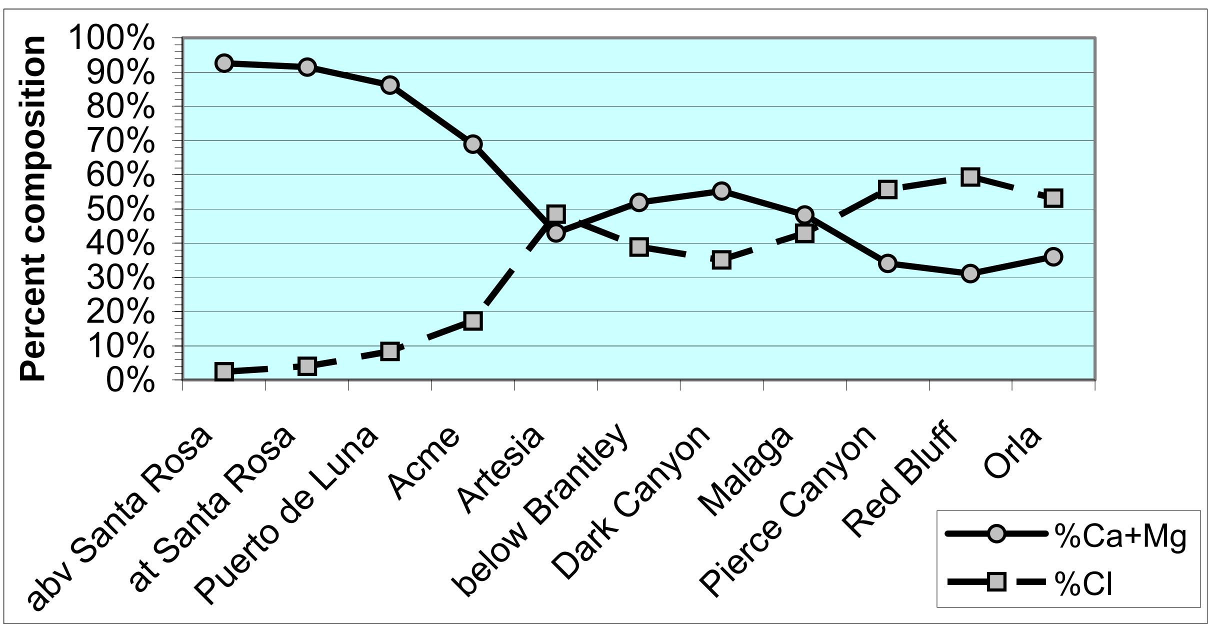


Figure 2: Median percent composition of cations and anions between the Santa Rosa inflow and Orla, Texas

The percent calcium plus magnesium (%Ca+Mg) on Figure 2 represents the percentage of the alkaline earth elements in the total cations, which also include the alkali elements, sodium and potassium (Na+K). Consequently, an decrease in the %Ca+Mg such as that which occurs between Santa Rosa and Artesia, could reflect either an increase in Na+K or a decrease in Ca+Mg. The specific conductance appears to remain fairly constant between the gage below Santa Rosa Lake and Acme, which would favor the loss of Ca+Mg. The pH is relatively high (see Attachment 1) and near or above 8.3, the saturation point of calcite ($CaCO_3$). This factor would favor the loss of Ca+Mg through calcite precipitation. Alternatively, at Artesia the specific conductance increases (Figure 1), which would favor an increase in Na+K, as has been documented in an earlier study by Mower *et al.* (1964). The decrease in the %Ca+Mg downstream from Dark Canyon (Figure 2) is caused by a documented loading of brine (specifically, NaCl) near Malaga (Kunkler, 1980).

The change in the anionic composition of the water adds confirmation to the above. There is an increase in the percent chloride (%Cl) between Santa Rosa and another beginning at Malaga. Unlike the %Ca+Mg, the %Cl does not represent the percentage in the total anions. The %Cl is only based on the sum of the chloride and sulfate concentrations, while the total anions would also include the carbonates. The carbonates were not included because there are no data at many of the stations, including the stations below Brantley, Dark Canyon, Malaga, and Pierce Canyon Crossing. Because of the lack of data on carbonates, these stations also do not have TDS data. But based on the data that are included on Figure 2, each decrease in the %Ca+Mg is accompanied by an increase in the %Cl, and *vice versa*. This factor further supports the increased loading of NaCl as the main factor in changing the ionic composition of the water as it proceeds downstream.

Table 2 shows a statistical comparison, based on Kruskal-Wallis tests, of the specific conductance of adjacent sites. There are significant differences among all of the adjacent sites, except for the Puerto de Luna to Acme and Red Bluff to Orla couples. To see the more dramatic changes, double-digit X^2-values can be used as a flag. Double-digit X^2-values occur in the following reaches: above Santa Rosa to at Santa Rosa, Acme to Artesia, Dark Canyon to Malaga, and Malaga to Pierce Canyon Crossing (Table 2). All of these reaches were noted in the discussion of Figure 1 with the exception of the first reach, which essentially encompasses Santa Rosa Lake. The median specific conductance values shown in Table 2 show an increase from around 800 μS/cm to about 2,400 μS/cm in the Santa Rosa Lake reach of the Pecos River. In the Acme to Artesia reach, the median specific conductance increases from about 2,700 to over 7,000 μS/cm. Below this reach, there is a decrease in specific conductance as was described above. The last of the large increases occurs between Dark Canyon and Malaga, where the median specific conductance increases from a little over 3,700 to 6,400 μS/cm, followed by a further increase to about 9,000 μS/cm between there and Pierce Canyon Crossing.

It was noted above that specific conductance is a surrogate for TDS. It was also noted above that there were no TDS data at a number of the sites. The relationships between TDS and specific conductance for the 6 sites from which there are TDS data are shown

Table 2. Comparison of specific conductance between adjacent sites (1988-2001)							
Sites		Sp. Cond. (µS/cm)					
Upstream (1)	Downstream (2)	Median 1	Median 2	n 1	n 2	X^2	Prob. > X^2
above Santa Rosa	at Santa Rosa	791	2,425	55	46	35.830	< 0.000001
at Santa Rosa	P. de Luna	2,425	2,740	46	51	8.026	0.004611
P. de Luna	Acme	2,740	2,680	51	39	3.373	0.066292
Acme	Artesia	2,680	7,100	39	53	31.249	< 0.000001
Artesia	Brantley	7,100	4,430	53	45	9.048	0.002630
Brantley	Dark Canyon	4,430	3,735	45	79	5.055	0.024554
Dark Canyon	Malaga	3,735	6,400	79	79	92.634	< 0.000001
Malaga	Pierce Canyon Xing	6,400	9,030	79	79	60.676	< 0.000001
Pierce Canyon Xing	Red Bluff	9,030	10,500	79	34	7.608	0.005809
Red Bluff	Orla	10,500	9,910	34	55	0.281	0.596038

in Table 3. There are very good relationships, *i.e.* r^2 greater than 0.9, at 4 of the 6 sites. sites. The r^2 of the regressions are between 0.8 and 0.9 at the remaining 2 sites. The slopes of the regression equations range from 0.638 and 0.814 (Table 3). Hem (1985) notes that the range of slopes in his report was between 0.54 to 0.96, and that higher values represent waters high in sulfate. The slopes of the regressions show a decreasing slope from generally about 0.8 upstream from Sumner Lake to about 0.6 closer to the state line (Table 3). This decreasing trend in the regression generally agrees with the increasing chloride (decreasing sulfate) trend shown on Figure 2.

Table 3. Regressions of TDS on EC at 6 sites on the Pecos River						
Location	r^2	Slope	Intercept	n	F	Prob. > F
above Santa Rosa	0.9300	0.773884	21.541022	34	425.26	< 0.000001
Puerto de Luna	0.8198	0.814004	221.344747	48	209.21	< 0.000001
Acme	0.9386	0.678344	235.081545	36	519.99	< 0.000001
Artesia	0.9471	0.650341	296.639521	48	824.34	< 0.000001
Red Bluff	0.9637	0.708482	-569.268181	29	716.81	< 0.000001
Orla	0.8727	0.638375	515.976343	46	301.70	< 0.000001

Based on the earlier comparisons, it is obvious that there are many more specific conductance observations than there are TDS samples. The specific conductance can be used to generate TDS data using a regression relationship. Figure 3 shows a regression relationship between TDS and specific conductance using all of the available data collected since September 1988 at all of the stations in the Pecos Basin. The regression relationship is 98 percent accurate in generating TDS data from specific conductance observations. The slope of the regression line is intermediate between those shown for stations between Acme and Orla and overestimates the lower TDS values found in the basin defined by the first 2 regressions in Table 3. At the scale of Figure 3, the overestimates are not obvious but amount to about a factor of 2 for TDS less than 1000 mg/L.

To better estimate the lower TDS concentrations at sites in the basin above Sumner Lake, the data set was subdivided based on the location relative to Sumner Lake. The resulting 2 regressions are plotted on Figure 4. The major difference between the 2 regression approach as opposed to the single regression has to do with the predicted TDS at lower values of specific conductance. The single basin-wide regression shown on Figure 3 overpredicts the TDS in the upper basin at the gage above Santa Rosa by several hundred mg/L; the data from above Santa Rosa have specific conductance readings less than 1000 µS/cm. This result is better illustrated by the trend lines on Figure 5, which shows plots of the predicted TDS concentrations from the “Above Sumner” regression and the “Basin-wide” regression against the observed TDS. The reason for the difference is inherent in the least squares regression calculation in that greater weight is given to the larger values. Smaller values do not contribute as much to the sum of squares and residuals tend to be smaller.

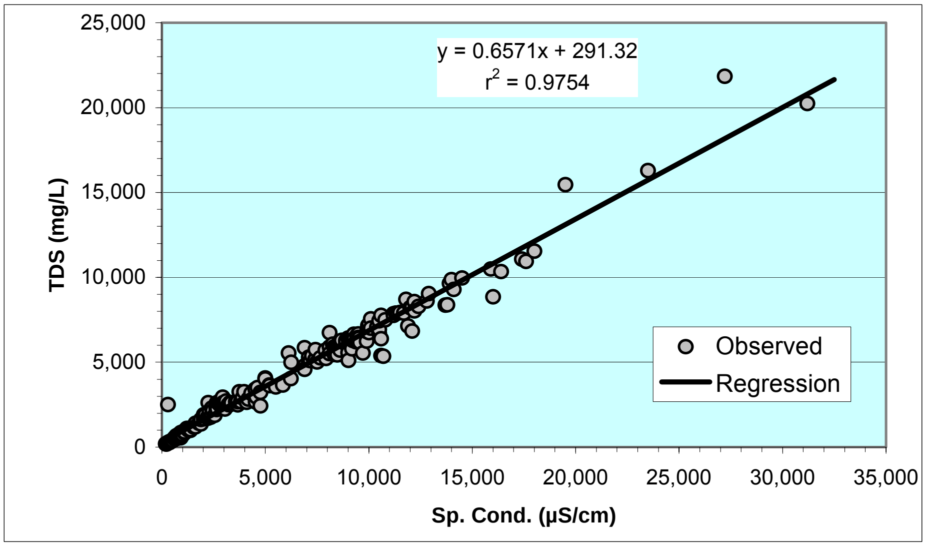


Figure 3: Relationship between TDS and specific conductance based on combined basin-wide data

In the case of the regression derived from the data from below Sumner Lake, the predicted values show little difference from those from the basin-wide regression. This is illustrated on Figure 6, which shows similar plots for the “Below Sumner” regression and the “Basin-side” regression to those shown on Figure 5. The predicted values from the “Below Sumner” and “Basin-wide” regressions are nearly overlain on the plot. The degree of overlap is so great that the size of the trend line and the dots representing the predicted TDS values from the “Below Sumner” regression had to be enlarged in order to make them show on the plot.

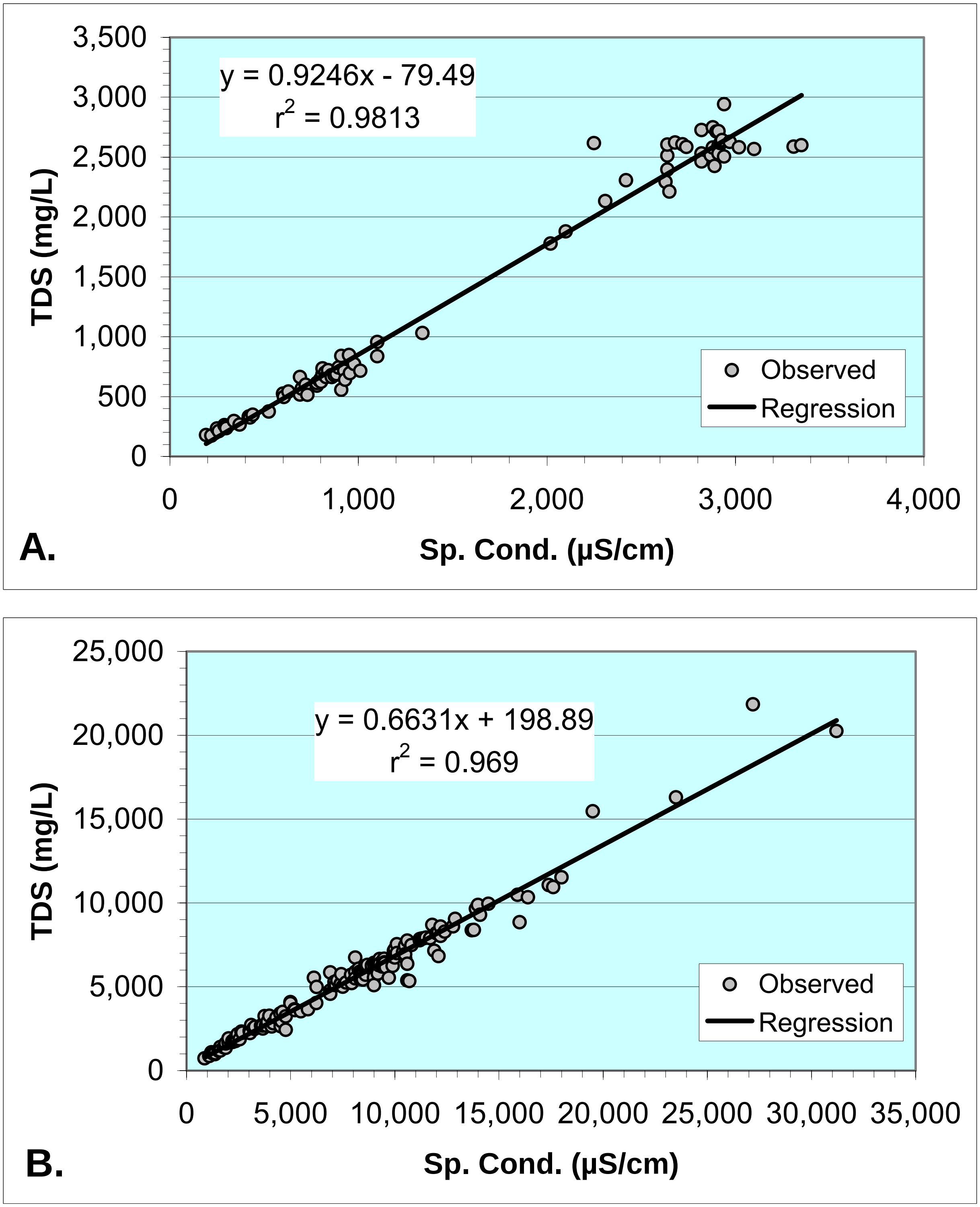


Figure 4: Regressions of TDS on specific conductance for sites above and below Sumner Lake: **A.** above Sumner Lake; **B.** below Sumner Lake

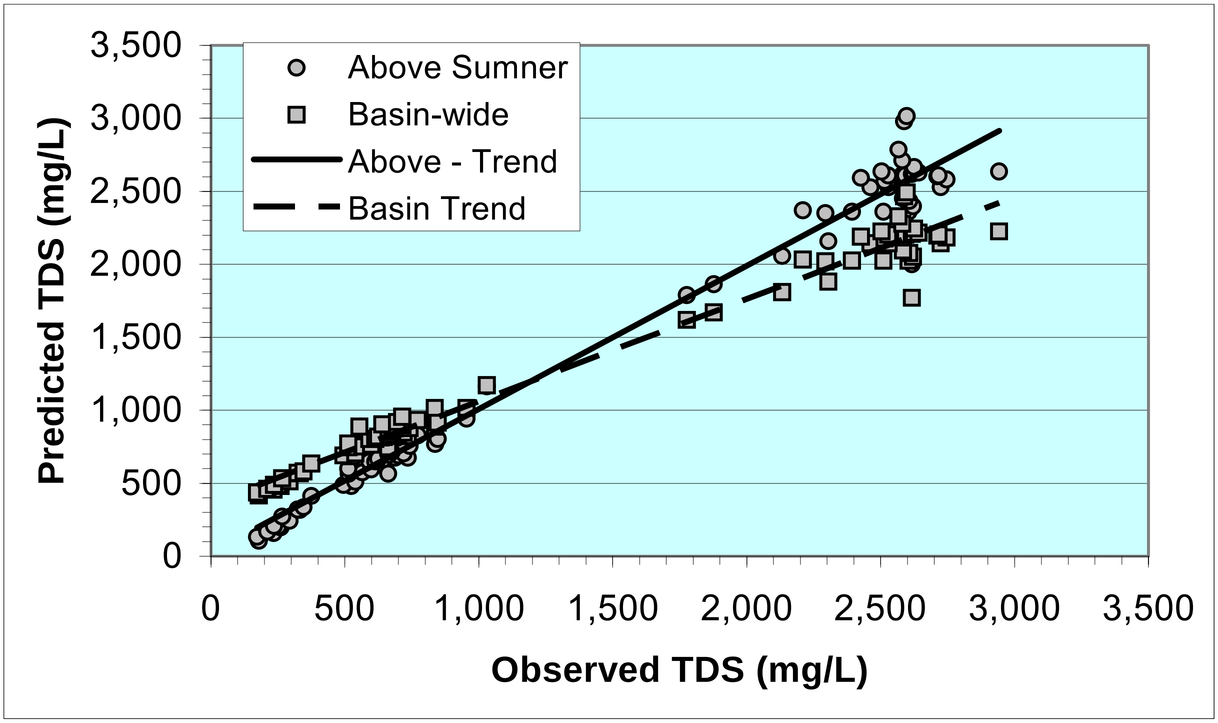


Figure 5: Comparison of the predicted values from the "Above Sumner" TDS regression and those from the "Basin-wide" regression

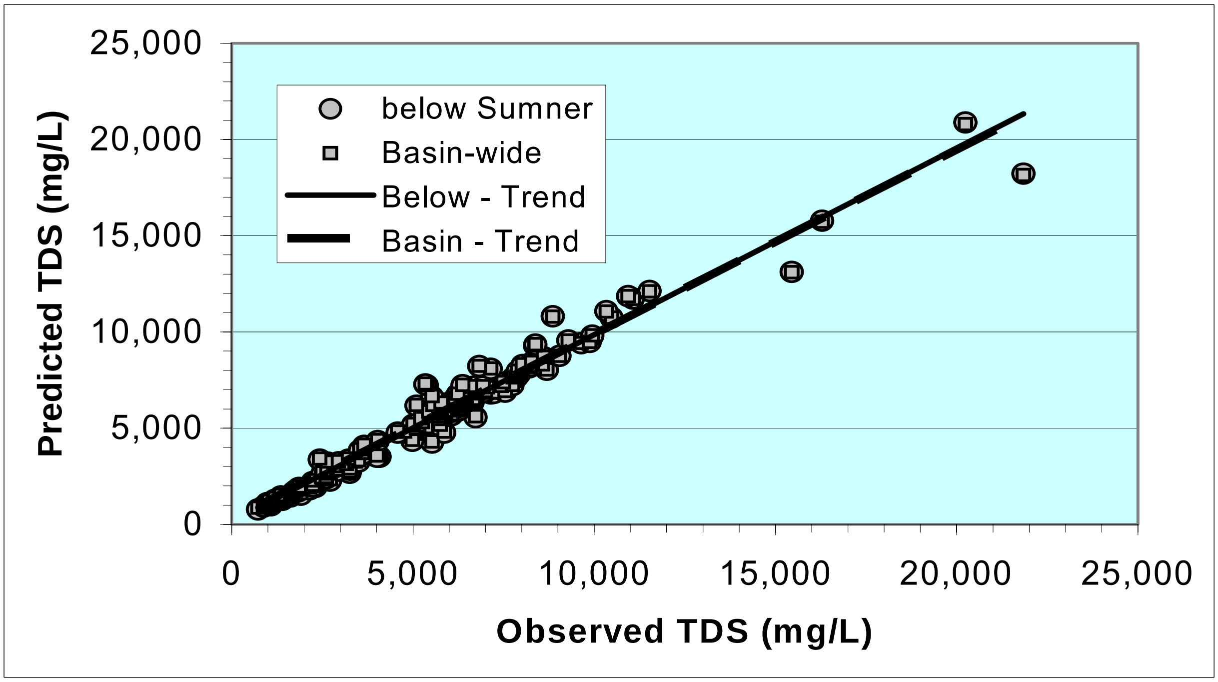


Figure 6: Comparison of the predicted values from the "Below Sumner" TDS regression and those from the "Basin-wide" regression

Comparison to Water Quality Standards

Water quality standards for each reach of the Pecos River are listed in the tables in Attachment 1. The standards for New Mexico are taken from NMWQCC (2002b). The Texas water quality standards were taken from TNRCC (2000). Table 4 summarizes the standards comparison that is shown in detail in the attachment, based only on the standards that were exceeded. Most of the standards included in Table 4 are based on aquatic life criteria. Exceptions to this include the standards for boron and vanadium, which are based on irrigation water criteria. (The cobalt standard in Attachment 1 is also based on an irrigation criterion.) The use of water quality standards is only intended to provide a point of reference for the water quality evaluation. For example, the State of New Mexico evaluation is based on data from the most recent 5 years only (NMWQCC, 2002a).

Table 4. Location, standard, and number of times the standard was exceeded between Sept. 1988 and Aug. 2001 in the Pecos River Basin

Site	Pollutant	Standard	No. of Obs.	No. < D.L.	No. > Std.
above Santa Rosa	Aluminum (µg/L as Al)	87	29	7	5
	Fecal Coliform .7 µm -mf (Col./100 mL)	400	29	23	6
at Santa Rosa	None	—	—	—	0
Puerto de Luna	Mercury (µg/L as Hg)	0.012	13	9	4
	Fecal Coliform .7 µm -mf (Col./100 mL)	400	31	12	3
Acme	Aluminum (µg/L as Al)	87	7	0	2
	Mercury (µg/L as Hg)	0.012	14	10	4
Artesia	Boron (µg/L as B)	750	52	0	1
	Mercury (µg/L as Hg)	0.012	14	9	5
Brantley Dam	None	—	—	—	0
Dark Canyon	None	—	—	—	0
Malaga	Temperature (°C)	32.2	79	N/A	1
	pH, Standard Units	6.6-9	75	N/A	1
	Boron (µg/L as B)	750	68	0	2
Pierce Canyon Crossing	Boron (µg/L as B)	750	68	0	8
Red Bluff	Aluminum (µg/L as Al)	87	23	8	3
	Lead (µg/L as Pb)	H[1]	12	11	1
	Mercury (µg/L as Hg)	0.012	12	3	9
	Vanadium (µg/L as V)	100	25	2	2
Orla	Temperature (°C)	32.2	55	N/A	1

[1] H - indicates a hardness dependent standard that varies from sample to sample

No standards were exceeded at the sites at Santa Rosa, below Brantley Dam, or below Dark Canyon. Although there were very high concentrations of TDS, sulfate, and chloride present in the Pecos River, none of the standards for these constituents were exceeded. The concentrations of all three constituents increase as one proceeds downstream. The standards for TDS, chloride, and sulfate likewise increase enough that their standards are not exceeded even though there are very high concentrations present.

The mercury standard was exceeded more than any other, both in terms of the frequency (22 times) and the number of sites (4) at which it was exceeded. The standard for mercury is well below the detection limit (D.L.) that was available for all of the samples used as a basis of comparison, *i.e.* 0.1 μg/L. Consequently, any time there was measurable mercury in a sample, the standard was exceeded. For the most part, sites at which the mercury standard was not exceeded were those for which there were no mercury data.

Greystone (1997) investigated mercury transport in the Pecos River for the U.S. Army Corps of Engineers. Their results, based on a detection limit less than the water quality standard (*i.e.* 0.005 μg/L), showed that mercury remained below the standard throughout the upper basin. Elevated mercury was only found at a site just north of Acme, indicating a mercury source between there and Sumner Lake, the next upstream site.

Boron exceeded the irrigation standard at 3 of the 11 sites shown in Table 4. The sites include those at Artesia, Malaga, and Pierce Canyon Crossing. The site of most concern to the EIS is the one at Artesia, which is the nearest site located above Brantley Reservoir. However, the boron standard was only exceeded once at Artesia and was not exceeded at the sites below Brantley Dam or the next site below Dark Canyon (Table 4 and Attachment 1: tables 1-6 and 1-7). The reservoir provides dilution by mixing the lower and higher concentration waters throughout the year. This can be illustrated by the median specific conductance at Artesia and below Brantley Dam. The former is 7,100 μS/cm, while the latter is 4,430 μS/cm (see Attachment 1). The equivalent boron concentrations are 355 and 245 μg/L respectively, indicating a more than 100 μg/L reduction in the boron concentration in Brantley Reservoir.

Aluminum also exceeded its standard, which is based on an aquatic life criterion, at 3 sites. The sites included those above Santa Rosa, at Acme, and at Red Bluff (Table 4). These 3 sites are widely dispersed throughout the Pecos Basin. The standard was not exceeded at the intermediate sites.

There were 2 other standards that were exceeded at 2 sites each in the basin. The temperature standard was exceeded at 2 sites in the lower basin, including Malaga and Orla, Texas (Table 4). In each case there was only 1 time that the standard was exceeded. The fecal coliform standard was also exceeded at 2 sites, both of which were in the basin above Sumner Lake (Table 4), including 6 of 29 samples above Santa Rosa and in 3 of 31 samples at Puerto de Luna. The fecal coliform standard is based on a recreation criterion. The only other times that water quality standards were not met were at Malaga (pH) and Red Bluff (lead and vanadium).

Sumner Dam Releases

In 1995 and 1996, water quality measurements were made at 14 cross-sections in the Pecos River between Fort Sumner Irrigation District and Brantley Reservoir at various releases from Sumner Dam (FLO, 1997). The measurements consisted of temperature, D.O., specific conductance, and pH. TDS was estimated from the specific conductance measurements by multiplying by a conversion factor of 0.64. This section of the EIS will evaluate the relationship between Sumner Dam releases and specific conductance at various sites along the Pecos River in the river between Fort Sumner and Brantley Reservoir. This reach of the river is the most likely to be affected by operational changes.

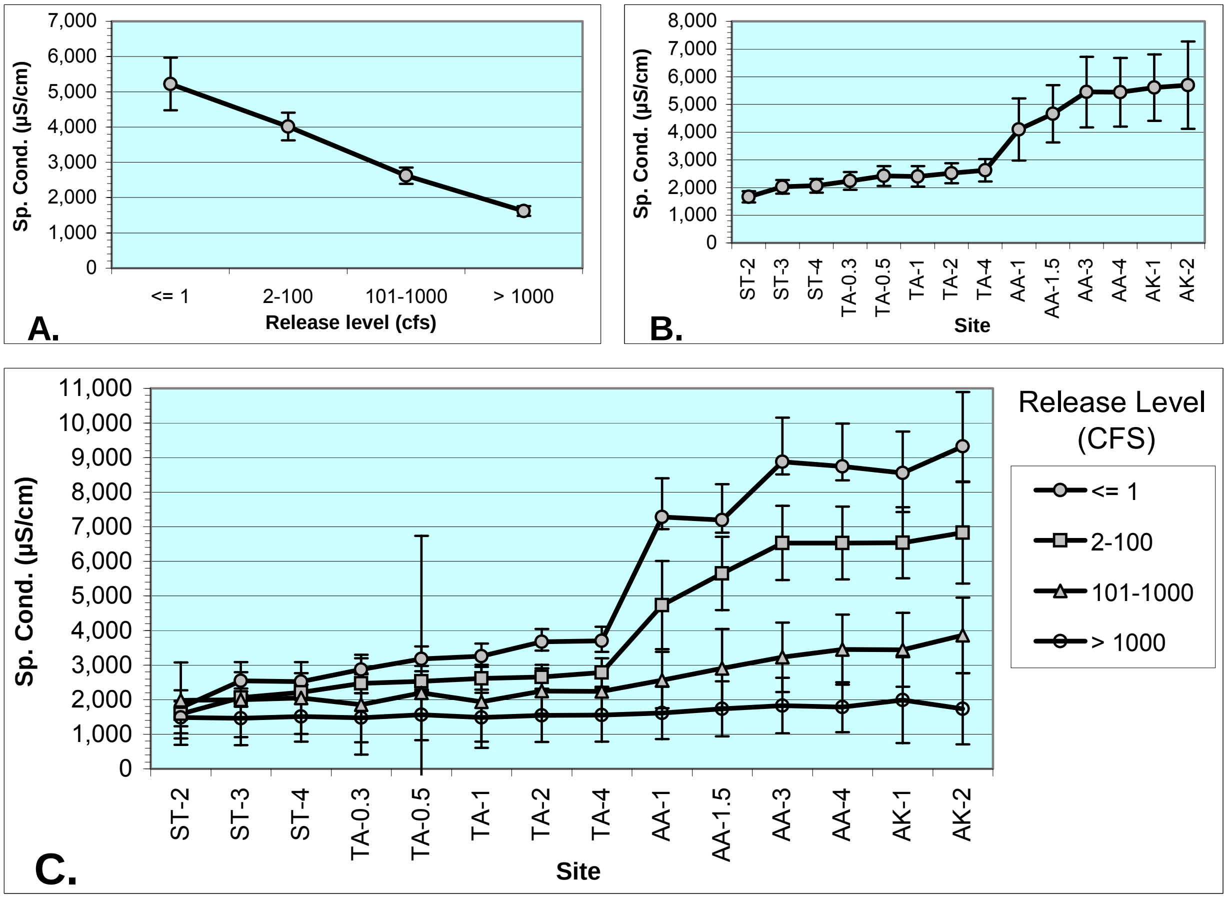
The data collected in 1995-96 were entered into a two-way analysis of variance (ANOVA) to evaluate the significance of the effects of flow, *i.e.* release level, and distance from Sumner Dam as measured by site in relation to the measured specific conductance of the Pecos River. The results are summarized in Table 5. Flow as entered into the ANOVA was based on release levels of #1, 2-100, 101-1000, and >1000 ft^3/s. Although both flow and site are statistically significant, the more significant factor is flow. Of even more interest is the fact the there is also a significant interaction between flow and distance from the release point at Sumner Dam. The various effects and a tabulation of the distance of each site from Sumner Dam for each of the sites appear on Figure 7.

Table 5. Two-way Analysis of Variance of flow (4 levels) and site (14 levels) on specific conductance of the Pecos River between Sumner Dam and Brantley Reservoir

Source	df	Mean Square	F-ratio	Prob. > F
Flow	3	167,886,000	175.865	< 0.000001
Site	13	37,985,300	39.791	< 0.000001
Flow x Site	39	7,397,050	7.749	< 0.000001
Error	242	954,627		

Figure 7A shows an almost linear decrease in specific conductance with increases in releases from Sumner Dam. There is also a decrease in the size of the confidence interval about the mean specific conductance as flow increases. The way the flow intervals are defined makes the scale of the *x*–axis essentially logarithmic.

The plot of specific conductance with distance from Sumner Dam indicates an increase between sites TA-4 and AA-1 (Figure 7B). Recall from Figure 1 that there was an increase in specific conductance between the Acme and Artesia gages. Site TA-2 is the Acme gage. Site TA-4 is located at the Highway 380 Bridge, and site AA-1 is located at the Dexter Bridge. The reach receives inflow from Bitter Creek and Bitter Lakes (FLO, 1997). Farther downstream, the specific conductance continues to increase in the next 2 reaches before leveling off at AA-3, the Artesia gage. The next 2 reaches downstream from AA-1 are each described as receiving inflow from several drainage ditches by FLO (1997). These results indicate that there is more than one source of saline inflows between the Acme and Artesia. The leveling of the specific conductance between AA-3, the Artesia gage, and AK-1 indicates that the specific conductance at the Artesia gage is reasonably representative of that of the Brantley inflow.



Site Designations and Distance (miles) from Sumner Dam

Site	Distance	Site	Distance	Site	Distance	Site	Distance	Site	Distance
ST-2	18.4	TA-0.3	49.1	TA-2	100.7	AA-1.5	148.7	AK-1	206.0
ST-3	27.4	TA-0.5	61.9	TA-4	114.0	AA-3	177.0	AK-2	214.0
ST-4	33.6	TA-1	79.6	AA-1	128.2	AA-4	195.2		

Figure 7: Specific conductance of the Pecos River between Sumner Dam and Brantley Reservoir in relation to flow and distance from the dam as a function of the releases from the dam

Table 5 also indicates that there is a significant interaction effect between the Sumner release and distance from Sumner Dam. This interaction effect is illustrated on Figure 7C. At base flow, which is represented by a release of #1 ft^3/s, there is a small increase in specific conductance between the dam and station TA-4, at which point there is a very large increase in specific conductance. As the releases are increased, the increase in specific conductance becomes less pronounced and is virtually absent at releases of greater than 1,000 ft^3/s from Sumner Dam. In other words, the distance effect on specific conductance of the Pecos River changes with changes in the release from Sumner Dam.

Based on the interaction effect of the specific conductance at the various sites with the release from Sumner Dam, a series of regression relationships were explored. Plots of the data against the release from Sumner Dam and the associated specific conductance at each site appear in Attachment 2. For each site, there are 2 plots. The upper plot shows the actual release from Sumner Dam and the associated specific conductance, while the lower plot shows the similar relationship between the specific conductance and the release as coded in the ANOVA summarized in Table 5. Attachment 2 shows only the best result. The full analysis included a linear bivariate regression, a log-log regression, and 2 semi-log regressions, the latter with the independent and dependent variables being individually log transformed for both the releases and the release codes. Only the best regression for the individual release and the coded release appear in Attachment 2. The best overall regressions are summarized in Table 6.

Table 6. Regressions of specific electrical conductance (EC) on flow at 14 stations on the Pecos River

Site	Dependent Variable (y)	Independent Variable (x)	F	Prob. > F	Equation	r^2
ST-2	Ln EC	Release Code	0.3932	0.538071	none	0.020277
ST-3	Ln EC	Release Code	13.8019	0.001468	$y = e^{(8.016-0.1835x)}$	0.420765
ST-4	EC	Release Code	12.9522	0.002214	$y = 2835-305.8x$	0.432428
TA-0.3	EC	Release Code	22.3919	0.000145	$y = 3366-462x$	0.540973
TA-0.5	EC	Release Code	26.1813	0.000072	$y = 3635-507.8x$	0.592588
TA-1	EC	Release Code	32.8533	0.000016	$y = 3803-575.8x$	0.633581
TA-2	EC	Release Code	44.3475	0.000002	$y = 4131-646.4x$	0.689187
TA-4	EC	Release Code	34.9484	0.000007	$y = 4287-682.6x$	0.624654
AA-1	Ln EC	Release Code	45.1343	0.000002	$y = e^{(9.384-0.5002x)}$	0.692942
AA-1.5	Ln EC	Release	64.1025	< 0.000001	$y = e^{(8.684-0.0010x)}$	0.753239
AA-3	Ln EC	Release Code	89.8660	< 0.000001	$y = e^{(9.760-0.5482x)}$	0.810582
AA-4	Ln EC	Release	106.4391	< 0.000001	$y = e^{(8.868-0.0012x)}$	0.835215
AK-1	Ln EC	Release	75.2456	< 0.000001	$y = e^{(8.856-0.0011x)}$	0.790017
AK-2	Ln EC	Release	106.6965	< 0.000001	$y = e^{(8.948-0.0013x)}$	0.876743

There are several observations that can be made from Table 6 that are not readily evident from Attachment 2. At stations nearer the dam, the coded release is a better measure than the actual release in predicting specific conductance. As can be seen from Attachment 2, the coded release treats each set of releases as a set of replicates. The resulting specific conductance values are then measures of the variability that can be expected within a bracket of release levels. The second observation is that the r^2's of the various regressions increase with distance from the dam. This result is a reflection of the increasing spread between the specific conductance data with distance from the dam that is illustrated on Figure 7C. The regressions proceed from a nonsignificant regression at site ST-2 to one in which about 88 percent of the variation in specific conductance at site AK-2 can be explained by the release (Table 6). The third observation is that most of the best regressions between the release and specific conductance at sites nearest the dam are represented by linear (as used here, arithmetic, rather than exponential) relationships between the specific conductance and the coded release. Beyond station TA-4, log transformed specific conductance data show the better relationship, mostly to the actual release rather than the coded values.

Reservoirs

The New Mexico 303(d) list includes each of the reservoirs (Santa Rosa, Sumner, and Brantley) involved in the Carlsbad EIS (NMWQCC, 2002c). All 3 reservoirs are listed for exceeding mercury fish consumption guidelines. The source of the mercury in each case is listed as atmospheric deposition. However, as was noted above, Greystone (1997) observed a source of mercury between Sumner Dam and Brantley Reservoir that could be the more important source for Brantley Reservoir fish.

Santa Rosa Lake is also listed for having excessive nutrients and siltation. The sources for these pollutants are listed as agriculture (primarily, grazing related) and recreation (road/parking lot runoff). Nutrients (nitrogen and phosphorus) are usually associated with runoff fields containing fertilizer, but can also originate from the breakdown and erosion of livestock manure.

In addition to the nutrients and siltation listed for Santa Rosa Lake, Sumner Lake includes nuisance algae. Nuisance algae are usually a reflection of excessive nutrients. In addition to agriculture and recreation, the sources or causes of the noncompliance with standards include reduction in riparian vegetation, bank destabilization, and additional unknown causes.

Brantley Reservoir is only listed for exceeding mercury fish consumption guidelines. However, there have been 2 fish kills in the reservoir in the last 6 months (Personal communication, January 13, 2003, from Shawn Denny, Southwest Area Fisheries Manager, New Mexico Department of Game and Fish, Roswell, New Mexico, to J. Yahnke, Bureau of Reclamation, Denver, Colorado). The cause of the fish kills were golden algae (*ibid.*). Fish kills in the Pecos Basin at Red Bluff Reservoir in 1988 and in the Pecos River just south of Red Bluff in April 2002 were attributed to the golden alga, *Prymnesium parvum* (NMDGF, 2002). *P. parvum* toxicity has been associated with nutrient stress (Johansson, 2000), in particular, by phosphorus (WADF, 1997).

Brantley Reservoir

Detailed data on reservoirs in the Pecos Basin are confined to Brantley Reservoir. The New Mexico State University's Carlsbad Environmental Monitoring and Research Center (CEMRC) has been monitoring the water quality in Brantley Reservoir under contract with Reclamation since 1997. Depth profiles of temperature, specific conductance, and dissolved oxygen (D.O. - concentration and percent saturation) have been measured weekly since 1997 (CEMRC, 1998; 1999; 2000; 2001; 2002). Profiles from the 1st week of each month have been selected from the weekly data and profiles of temperature-specific conductance and temperature-D.O. are plotted in Attachment 3.

Water quality in reservoirs is greatly affected by density. Density differences within reservoirs can result in layers that differ greatly in water quality. For example, the surface of a reservoir is constantly in contact with the atmosphere, which provides a ready source of oxygen. Alternatively, the deeper layers will be isolated from the atmosphere if there are density layers present. Under these circumstances, the deeper layers may become depleted in dissolved oxygen. This happens frequently in Brantley Reservoir, as will be shown later.

In most cases density is controlled by the temperature of the water in the reservoir, but density can also be controlled by dissolved and suspended solids. In Brantley Reservoir dissolved solids are frequently a factor in controlling the density of water and isolating the deeper layers for prolonged periods during each year. Yahnke (1997) showed that saline winter inflows to Brantley Reservoir follow the inundated river channel and accumulate near the dam. Complete mixing does not occur near the dam until that saline layer is drawn off. In early spring, inflows are less saline than the reservoir and the inflows form a layer on the surface of the reservoir that gradually mixes longitudinally and laterally with the surface layer of the reservoir. Much of the way in which the inflow was distributed in the reservoir was dictated by its difference in salinity from the water already resident in the reservoir.

The data included in Attachment 3, which amount to about ¼ of what are available, illustrate the amount of variation that occurs in the temperature, D.O., and specific conductance regimes in Brantley Reservoir from month to month and year to year. Table 7 provides annual summaries for selected data from the reservoir.

The first thing of note in Table 7 is the fact that there are 30 observations in 1997, but 50 to 52 in the other years. This result is a reflection of the fact that the data collection in 1997 began in June. There are no data available for the first 5 months of the year. Nevertheless, the median inflow EC's are similar in 1997 and 1998. Alternatively, the median D.O. in 1997 is much lower than any of the other years, all of which have a similar median D.O. concentration. The low median appears to be the result of the absence of measurements from the early months of 1997, *i.e.* sampling bias, rather than any real difference between 1997 and the other years.

In addition to the similarity of the median inflow EC's of 1997 and 1998, those of 1999 and 2000 are also similar, both roughly equal to 5,000 µS/cm (Table 7). The median inflow EC for 2001 is roughly ⅓ again as great as the 1999/2000 data. In other words the median inflow EC increased over the 5-year period. Alternatively the minimum and maximum inflow EC fluctuated during the period, although both were somewhat higher in 2001 than in any of the preceding years. The median outflow EC also generally increased throughout the monitoring period. The minimum and maximum outflow followed the pattern of the inflow EC. The outflow EC's were lower than the inflow EC's in most years (Table 7).

The bottom D.O. (dissolved oxygen) data are probably of most interest from a biological perspective. A minimum of 3 mg/L is usually considered necessary for the support of fish. As can be seen by the minimum values, D.O. concentrations in the bottom waters of Brantley Reservoir fell below 1 mg/L in all 5 years and drive fish to more oxygenated

Table 7. Summary statistics – Brantley Reservoir data collected by the CEMRC from June 1997 through December 2001

Year	Statistic	Inflow EC (µS/cm)	Depth (ft.)	Mean EC (µS/cm)	Outflow EC (µS/cm)	Bottom D.O. (mg/L)
1997	Minimum	1,212	32.5	1,971	2,145	0.11
	Median	3,984	37.0	2,917	3,160	0.38
	Maximum	8,308	45.2	5,795	6,444	10.10
	No. of Obs.	30	30	30	30	30
1998	Minimum	921	30.0	1,561	1,580	0.21
	Median	3,935	38.8	3,196	4,057	4.90
	Maximum	9,207	46.0	5,733	6,488	11.94
	No. of Obs.	52	52	52	52	51
1999	Minimum	1,041	30.0	2,622	2,900	0.20
	Median	5,017	40.0	4,264	4,735	4.52
	Maximum	8,108	44.0	6,032	6,830	11.00
	No. of Obs.	52	52	52	52	52
2000	Minimum	1,171	32.5	1,847	1,910	0.00
	Median	4,963	38.0	3,744	4,580	4.14
	Maximum	9,728	44.7	6,059	6,550	11.28
	No. of Obs.	52	52	52	52	52
2001	Minimum	1,456	24.9	3,035	3,134	0.17
	Median	7,622	37.1	4,614	5,324	4.35
	Maximum	11,496	42.6	6,670	7,139	11.71
	No. of Obs.	50	50	50	50	50

layers of the reservoir. Such a deep-water D.O. concentration would also restrict bottom-dwelling invertebrate species to those tolerant of low D.O., such as *Tubifex* sp. worms.

The very low bottom D.O. concentrations (< 1 mg/L) are usually present in the summer. This phenomenon is illustrated on Figure 8, which shows plots of weekly surface and bottom D.O. concentrations in Brantley Reservoir. The plot also shows the beginnings of each of the “seasons” as used in this report. The “seasons” were defined based on months as taken by the general conditions shown by the plots in Attachment 3. The splits on this basis are generalized and somewhat imperfect in defining conditions in some years, as illustrated by the fact that D.O. declines during what is defined as the mixed condition is some of the years, particularly prior to the summer of 2001 (Figure 8).

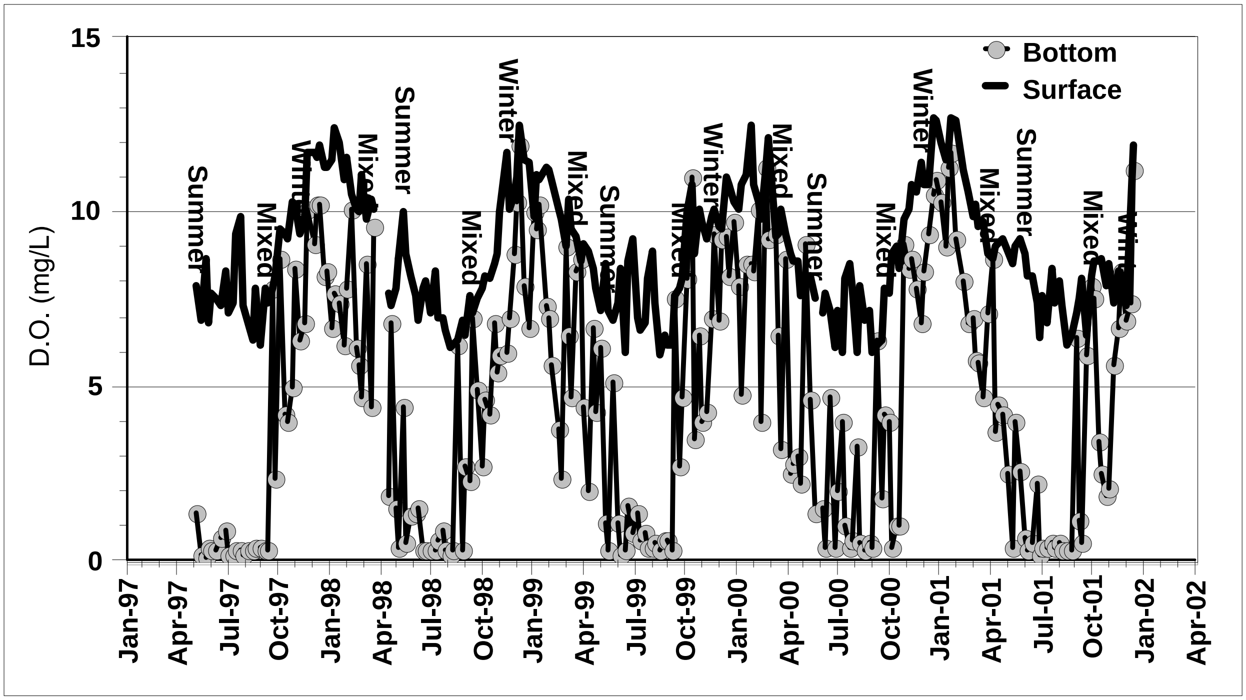


Figure 8: Surface and bottom dissolved oxygen concentrations in Brantley Reservoir from 1997 through 2001

Brantley outflow EC relationships

Reclamation has monitored the EC of the inflow and outflow at Brantley Reservoir since 1993. The complete data set is plotted on Figure 9. Based on data collected during the years 1993-1995, Yahnke (1997b) showed that there was a net loss of salt within Brantley Reservoir. Such a salt loss would cause a decrease in EC. That salt loss in Brantley Reservoir is reflected in the difference in the maximum EC on the *y*–axis of the inflow and outflow plots on Figure 9. The *y*–axis of the inflow plots shows a maximum EC of either 10,000 or 12,000 µS/cm, while all of the outflow plots show a maximum EC of 8,000 µS/cm on the *y*–axis. The data for 1997 through 2001 indicate that the salt loss observed in 1993-1995 was also occurring in the more recent years.

The other difference between the inflow and outflow EC that is evident on Figure 9 is the degree of variability in the two EC data sets. The inflow EC is shows a much higher degree of variation than the outflow EC. The inflow EC shows the much greater degree of variation because of the flow dependent dilution effect described under the Sumner Dam release topic above. The decrease in variability in the outflow EC reflects the mixing of the higher and lower EC water within the reservoir. Because of these different influences, there does not appear to be a good relationship between the inflow and outflow EC in Brantley Reservoir.

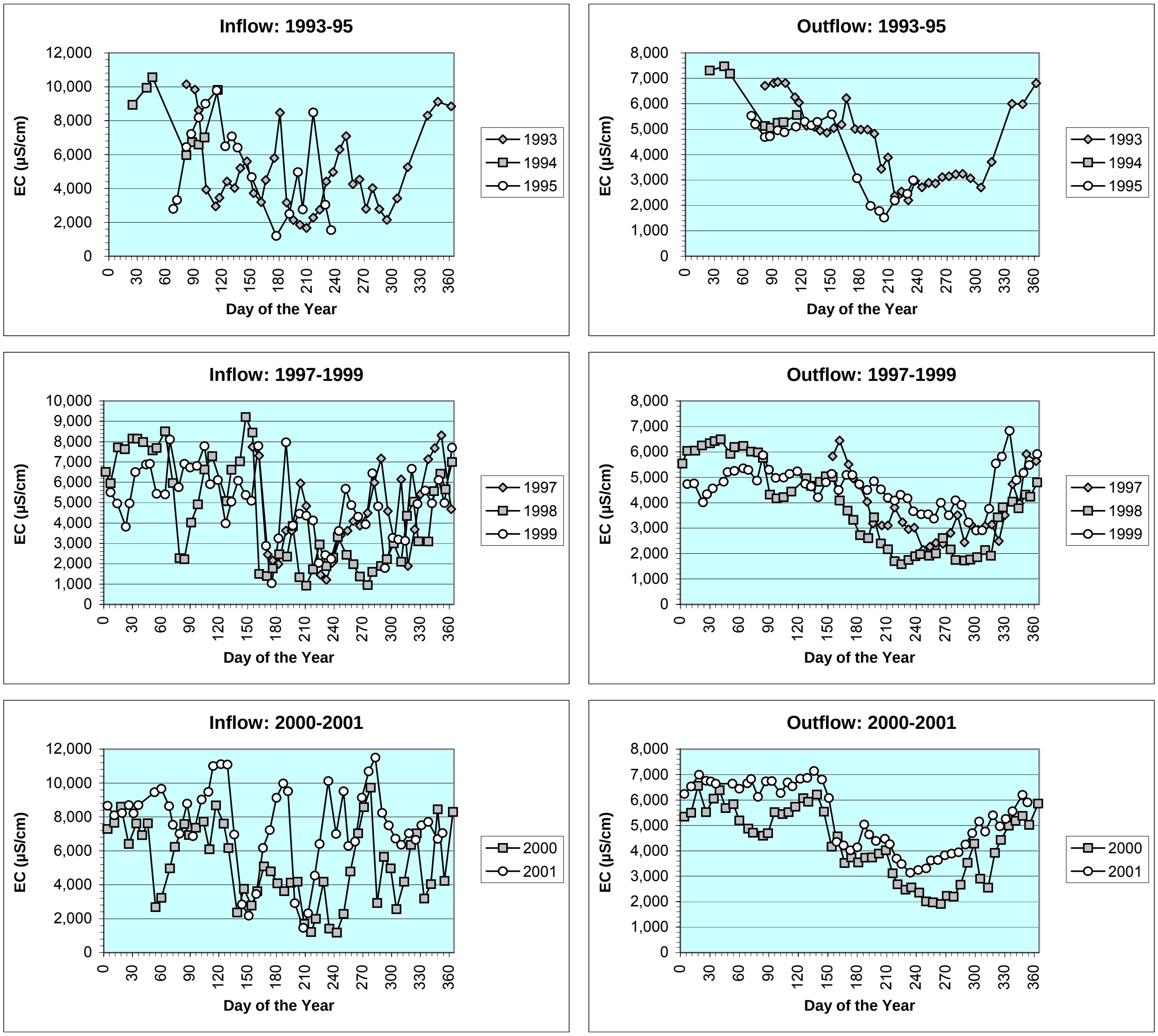


Figure 9: Inflow and outflow specific electrical conductance at Brantley Reservoir since 1993

The first column of Table 8 shows a set of correlations between the outflow and a variety of other variables based primarily on inflow and physical reservoir measurements. Temporal measures, including the date, year, month, and the above described season. The outflow EC shows extremely significant correlations, *i.e.* probability of a greater r occurring by chance alone of < 0.000001 or less than one in a million, with year, month, season, the inflow EC and temperature, the surface and outflow temperature, and the bottom D.O. The best relationship is the inverse correlation with season, which has an r of -0.59. Although the relationship is extremely significant, the amount of variation in the outflow that is explained by the season variable only amounts to about 35 percent. Furthermore, season by itself would not be affected by any of the alternatives, although the relationship between season and the outflow EC could be affected.

Table 8. Correlations between measures of Brantley Reservoir EC and various physical and temporal factors

Factor	Statistic	Outflow EC	Bottom EC	Average EC	EC: O - I	EC Diff.
Date	r	0.2528	0.2640	0.2856	-0.2502	0.0647
	Prob > r	0.000086	0.000040	0.000008	0.000102	0.322624
	n	236	236	236	236	236
Flow	r	-0.0778	-0.0174	-0.0877	0.5971	-0.1170
	Prob > r	0.245954	0.795181	0.191075	< 0.000001	0.080593
	n	224	224	224	224	224
Reservoir Content	r	-0.0689	-0.1374	-0.0539	0.1981	0.1576
	Prob > r	0.304841	0.039971	0.422182	0.002898	0.018293
	n	224	224	224	224	224
Year	r	0.3606	0.3590	0.4024	-0.2409	0.0814
	Prob > r	< 0.000001	< 0.000001	< 0.000001	0.000187	0.212948
	n	236	236	236	236	236
Month	r	-0.5203	-0.4607	-0.5621	-0.0373	-0.0821
	Prob > r	< 0.000001	< 0.000001	< 0.000001	0.568669	0.208705
	n	236	236	236	236	236
Season	r	-0.5919	-0.4875	-0.4675	0.1140	-0.0453
	Prob > r	< 0.000001	< 0.000001	< 0.000001	0.080631	0.488902
	n	236	236	236	236	236
Inflow EC	r	0.5533	0.4674	0.5614	-0.8283	0.1676
	Prob > r	< 0.000001	< 0.000001	< 0.000001	< 0.000001	0.009892
	n	236	236	236	236	236
Inflow Temperature	r	-0.4267	-0.3385	-0.2665	0.1211	0.0214
	Prob > r	< 0.000001	< 0.000001	0.000034	0.063310	0.743973
	n	236	236	236	236	236
Depth	r	-0.0160	-0.0259	0.0085	0.2350	-0.0081
	Prob > r	0.806705	0.692137	0.896454	0.000270	0.901288
	n	236	236	236	236	236
Depth Class	r	0.0066	0.0023	0.0311	0.2511	-0.0290
	Prob > r	0.920170	0.971739	0.634076	0.000096	0.657182
	n	236	236	236	236	236
Stratification	r	-0.0931	0.0890	-0.1507	0.1720	-0.7670
	Prob > r	0.153991	0.172753	0.020583	0.008094	< 0.000001
	n	236	236	236	236	236
Surface Temperature	r	-0.5244	-0.4252	-0.3775	0.1573	-0.0135
	Prob > r	< 0.000001	< 0.000001	< 0.000001	0.015602	0.836646
	n	236	236	236	236	236
Outflow Temperature	r	-0.5586	-0.4537	-0.4101	0.1241	-0.0150
	Prob > r	< 0.000001	< 0.000001	< 0.000001	0.056950	0.818481
	n	236	236	236	236	236
Bottom D.O.	r	0.4314	0.2602	0.3286	-0.1962	0.2758
	Prob > r	< 0.000001	0.000054	< 0.000001	0.002524	0.000018
	n	235	235	235	235	235
Temperature Difference	r	-0.1775	-0.1706	-0.2827	-0.0461	-0.1117
	Prob > r	0.006256	0.008619	0.000010	0.480797	0.086731
	n	236	236	236	236	236

There is also an extremely significant relationship between the inflow and outflow EC. The correlation alone, like the one for season, does not show a high degree of explanation of the outflow EC, only about 31 percent. Although the individual variables may not do a good job of explaining the variation in the outflow EC, a combination of variables included in Table 8 may work better. This was investigated by entering temporal variables along with variables that could be extracted from and operations model of the alternatives into a stepwise multiple regression analysis. The resulting best model predictions are plotted against the observed data on Figure 10. Based on the R^2, the model explains about 62 percent of the variation in the outflow EC. The equation is also shown on Figure 10 and includes the season and month, the inflow (Q_i), the inflow EC (EC_i), and a variable that was not mentioned earlier, the reservoir content (cont on Figure 10). There was no significant individual correlation between the outflow EC and the reservoir content (Table 8), but the reservoir content becomes significant relative to the other variables included in the multiple regression.

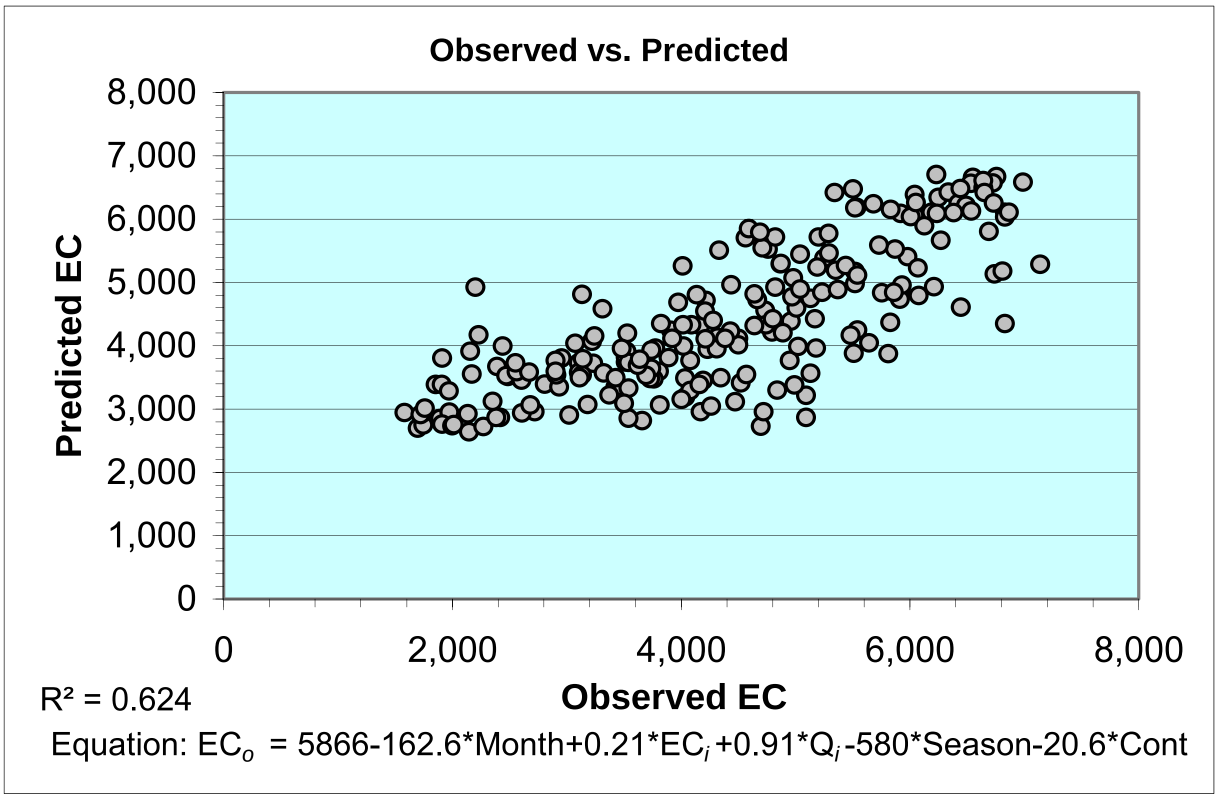


Figure 10: Observed vs. predicted EC in the Brantley Reservoir outflow based on the “best fit” model developed by stepwise multiple regression analysis

The other variables shown on the first line of Table 8 include the bottom EC, the average EC, EC: O-I, which is the difference between the inflow and outflow EC, and the EC difference through the water column, *i.e.* difference between the surface and the bottom EC. The bottom EC and the EC difference are dependent on the physical distribution of salt within the water column. These variables could be evaluated with a mathematical model, but such a model is beyond the scope of the analysis contemplated for this EIS. The average EC is based on averaging the EC over the length of the water column. This average could be estimated by calculating a flow-weighted average EC for the reservoir. However, such a flow-weighted average would represent a fully mixed condition for the reservoir. As is amply illustrated in Attachment 3, the EC of Brantley Reservoir is anything but evenly distributed through the water column on most occasions.

The final variable to be discussed of those in Table 8 is EC: O-I, the change in EC in Brantley Reservoir, which would be the difference between the data plotted on the left and right plots on Figure 9. Although most of the correlations in Table 8 are no better than those for the outflow EC, the correlation with the inflow EC is the best in the table, with an r of 0.8283. Based on that r, the inflow EC can explain 69 percent of the variation in the change in EC in the reservoir. The resulting regression relationship is shown on Figure 11. The change in EC can be used to back-calculate the outflow EC in accordance with the following equation:

$$EC_o = EC_i + (2757 - 0.67*EC_i).$$

The inflow EC (EC_i) can be calculated as was described in the section on the Sumner Dam releases. That value can then be used to evaluate the changes in the EC in Brantley Reservoir using the above relationship to estimate the outflow EC.

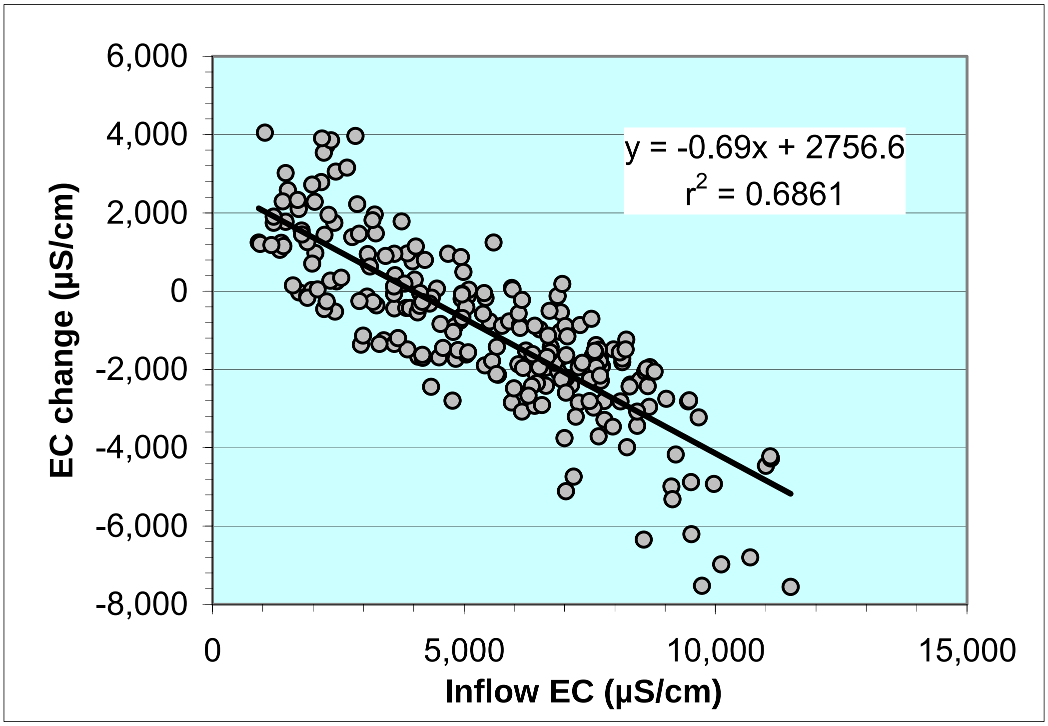


Figure 11: Regression of the change in EC in Brantley Reservoir on the inflow EC

Sumner Lake

Water quality data for Sumner Lake are rather sparse in comparison to Brantley Reservoir. The USGS operated a gage below Sumner Dam from September 1959 through August 1988. The specific conductance data from that record are plotted on Figure 12. There is a gap in the record from September 1966 until March 1972. For most of the period, the data consist of monthly readings, but the data are daily through much of the 1980's. The main purpose of Figure 12 is to illustrate the amount of variation in specific conductance that there is within and between years. In most of the years shown on Figure 12, the specific conductance of the Sumner Dam releases has a minimum between 500 and 1000 µmho/cm (=µS/cm) and a maximum between 2500 and 3000 µmho/cm.

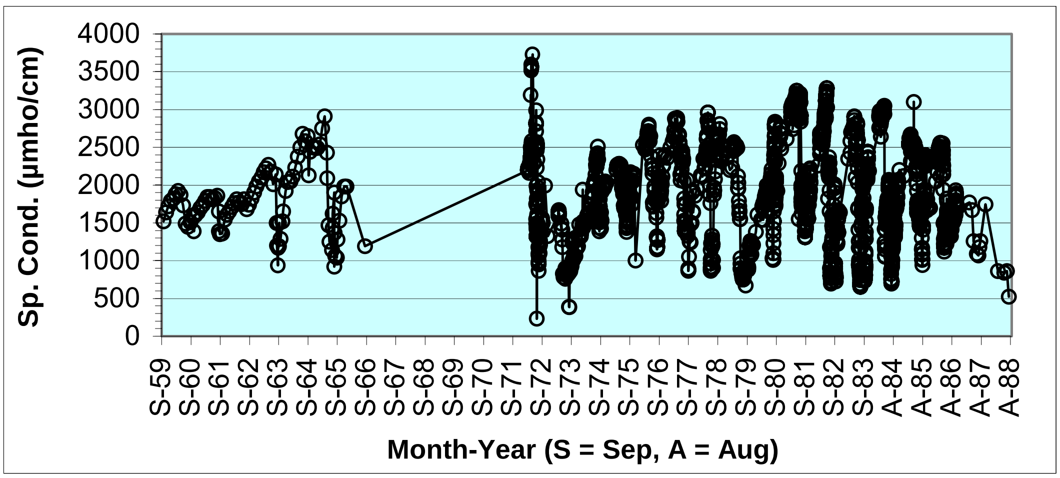


Figure 12: Specific conductance of the Pecos River downstream from Sumner Dam from 1959 through 1988

The New Mexico Department of Game and Fish measured surface temperature, specific conductance, D.O., and turbidity from May 2001 through May 2002 in conjunction with a study of reservoir fish. The data were provided by Shawn Denny (fisheries manager, Southeast Area, New Mexico Department of Game and Fish, Roswell, New Mexico; personal communication of January 30, 2003). The specific conductance data are summarized by month in Table 9. There were between 10 and 40 measurements in each set of data. The data in the early part of the study were collected at as many as 8 sites with 5 replicate measurements made distributed around each site. In the later part of the study, the goal was to get as much coverage of the lake as possible.

Based on the median EC data in Table 9, the lowest EC occurred in August, followed closely by the EC in April of the following year. The peak median EC occurred in May 2002, although the median EC in May 2001 ranked in the middle of the data set. The general pattern of the median EC data was to increase from May 2001 through July

2001, followed by a decrease through March 2001, with anther increase to the end of the data set in May 2002. This pattern is compared with the long-term average and confidence interval of the EC release data on Figure 13. The long-term average release EC shows a maximum in April and a minimum in August (Figure 13). There is not a great deal of difference in the months of occurrence of the extremes of the 2 data sets. There is only a 1 month difference in the time that the maximum occurred in the 2 data sets; the minimum EC in the 2 data sets occurred in the same month.

Table 9. Summary of New Mexico Department of Game and Fish data for Sumner Lake during 2001 and 2002

Date	No. of Obs.	Minimum	Median	Maximum
May 2001	40	880	1865	2100
Jun. 2001	40	2037	2110	2154
Jul. 2001	35	1670	2290	2630
Aug. 2001	25	1220	1250	2210
Oct. 2001	15	2090	2130	2290
Nov. 2001	30	1826	1856	2600
Dec. 2001	17	1826	1873	1879
Feb. 2002	20	1802	1851	1867
Mar. 2002	15	1260	1300	1870
Apr. 2002	10	2386	2450	2470
May 2002	10	2521	2714	2760

The above comparison is an attempt to evaluate whether there is a difference between the 2 data sets. Seven of the 11 median monthly EC's from the recent data are within the confidence intervals of the long-term monthly release data. This result would seem to indicate that there is not a great difference between the 2 data sets. However, a Mann-Whitney test comparing the 2 data sets did show a statistically significant difference, *i.e.* Mann-Whitney U of 2,665 and a probability of 0.0358.

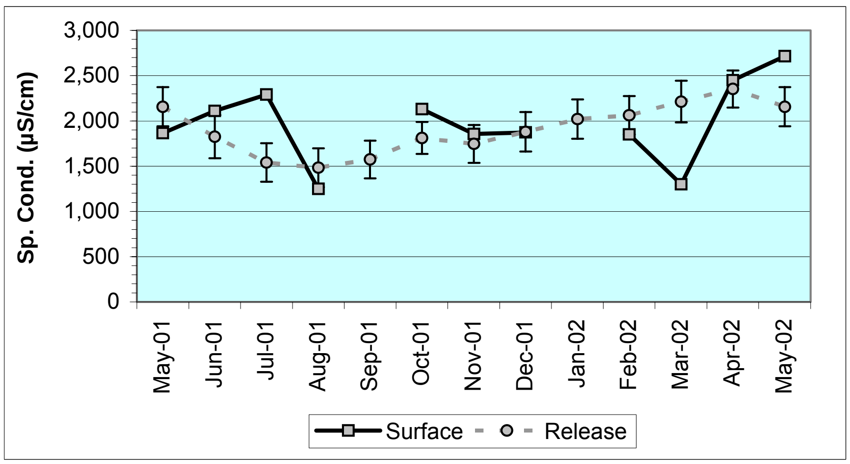


Figure 13: Median surface specific conductance of Sumner Lake during 2001 and 2002 along with the long-term confidence

Santa Rosa Lake

The Albuquerque District of the U.S. Army Corps of Engineers (CoE) monitors water quality in Santa Rosa Lake. Temperature and D.O. profiles are measured periodically at up to 3 sites in the reservoir. The flow from the outlet is also monitored. Data for Santa Rosa Lake were provided by the CoE covering the period 1980 through 2002. The data set also includes EC in mho/cm, pH and Secchi depth, all of which have only 1 reading per site. All of the EC readings were 0.3 mmho/cm, which is equivalent to 300 µmho/cm. All of the Secchi depths were 1 meter. The pH ranged from 7 to 8 and was measured to the nearest pH unit. Because there was little or no variation in these constituents, the description of Santa Rosa Lake will focus on the temperature and D.O. profiles.

Figure 14 shows monthly temperature and D.O. profiles from Santa Rosa Lake measured between June and December 1999. In June, there was weak thermal stratification between 5 and 7 meters, although there was a continuing significant drop in temperature to a depth of 15 meters. At the same time, the D.O. dropped off rapidly just below the depth of maximum temperature difference (Figure 14). In July, there was an even more distinctive thermocline present; this thermocline was located at a depth between 10 and 13 meters. There was a dramatic decline in D.O. at the depth of the thermocline (Figure 14). The September 1999 profile on Figure 14 also appears to show deep thermal stratification accompanied by a dramatic drop in D.O. However, the change in temperature is less than 0.5°C and is exaggerated by the scale of the *y*–axis, which total only 3°C. Alternatively, the decrease in D.O. between 17 and 18 in September is large and amounts to about 1.5 mg/L. The D.O. declined further to less than 0.1 mg/L near the reservoir sediments. In October 1999, there also appears to be a large decrease in

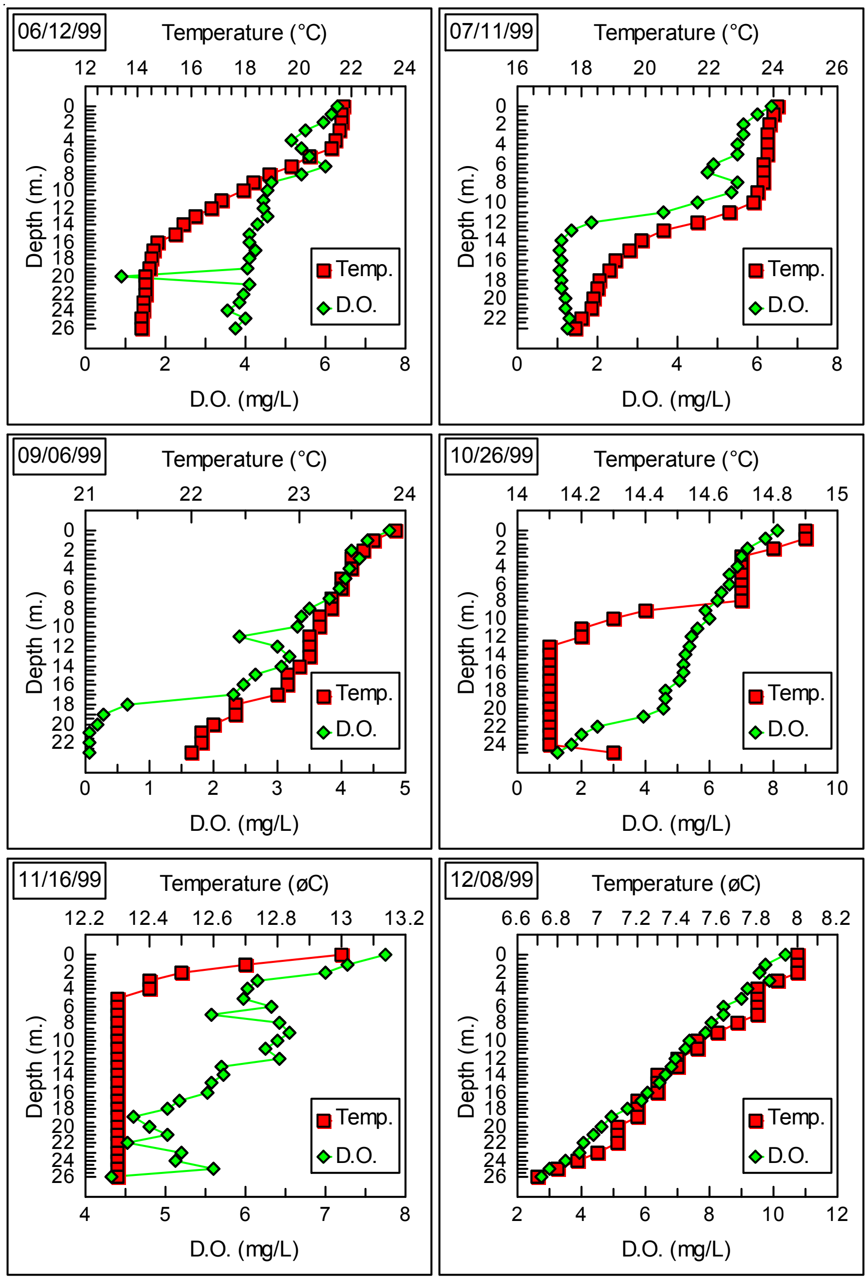


Figure 14: 1999 temperature and DO profiles from Santa Rosa Lake

temperature between 8 and 9 meters, but this decline appears more dramatic than it actually is because of the scale of the *y*-axis, which totals only 1°C. The D.O. shows a gradual decline throughout the water column in October with the greatest decrease near the sediments. In November 1999, the reservoir was essentially isothermal with a small amount of surface warming. At the same time, the D.O. profile shows an erratic pattern of increases and decreases through the length of the water column, but the general pattern is one of decreasing D.O. from surface to bottom. The last set of profiles on Figure 14 is for December 1999. There is an almost linear decrease in both temperature and D.O. throughout the length of their respective profiles. The decrease in temperature amounts to less than 1.5°C, while the D.O. decrease is from over 10 mg/L to less than 2 mg/L. There was an increase in the surface D.O. in December in comparison to November, but the bottom D.O. decreased in the intervening month (compare the D.O. axes in November and December). As a generality and on the basis of the 1999 profiles, the sediments appear to generate a large effect on the D.O. regime of Santa Rosa Lake, and any restriction of mixing due to thermal stratification drops the bottom D.O. to near 0.

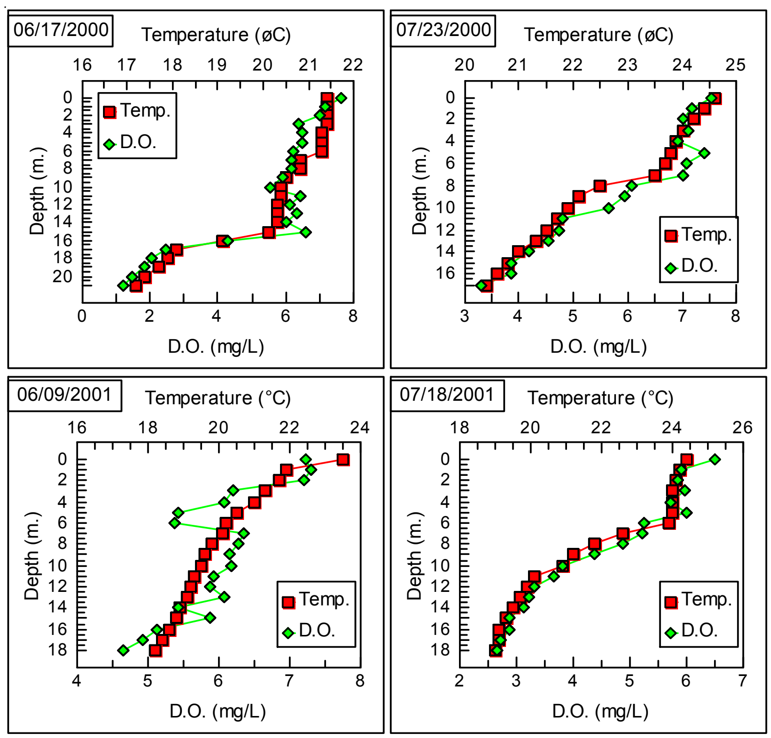


Figure 15: Temperature and DO profiles from June and July of 2000 and 2001 in Santa Rosa Lake

Figure 15 shows a similar set of June and July 2000 and 2001 temperature and D.O. profiles to those of Figure 14. Maximum thermal stratification develops in June and July and the remainder of this characterization will focus on those months.

In June 2000, there was a thermocline deep in the profile. There is a dramatic decline in D.O. right along the thermocline. There is a similar set of temperature and D.O. profiles in July. However, the July profiles are something of an anomaly in that the usually expected progression of thermal stratification is one of deepening; the July thermocline is shallower than that in June (Figure 15). The decline in D.O. in its profile still coincides with the depth of the thermocline. Consequently the 2000 profiles in Figure 15 support the conclusions based on the 1999 data in the previous figure.

The June 2001 temperature profile does not show a distinctive thermocline. There is surface warming that effects the greatest temperature change in the profile, but that change is restricted to the surface. Below the surface there is a gradual decrease in temperature throughout the profile. The temperature changes through the profile amount to only a tenth to a few tenths of a degree Celsius. The D.O. profile is somewhat erratic with both increases and decreases through the profile. The rather large increase in D.O. at the depth of around 7 meters probably reflects the influence of a higher D.O. interflow or a layer of actively photosynthesizing algae. The depth of the D.O. change does coincide with one of the larger temperature changes (0.3°C) in the profile.

The July 2001 temperature and D.O. profiles are nearly overlain on Figure 15. There is a distinctive thermocline in July located between 6 and 9 meters. The maximum decrease in temperature is 1.3°C between 6 and 7 meters. At the temperature of the water in this layer, the density change between the 2 layers of water is rather large and would represent very strong stratification. The D.O. concentration follows the plot of the temperature profile exactly with the mechanism of the oxygen decline almost certainly being decomposition of organic matter in the reservoir sediments that consumes the isolated hypolimnetic oxygen reserve. The July 2001 temperature and D.O. profiles are similar to those of 1999, but the D.O. decrease in July 2001 is somewhat less dramatic than in 1999.

There is one EC reading at each of the reservoir sites and the outflow from Santa Rosa Lake for each date in the database. As was noted above, all of the readings for all of the dates and all of the sites are the same, 0.3 mho/cm (or 300 μS/cm). This does not seem realistic. As is shown in Attachment 1, the inflow EC has ranged from 192 to 4,350 μS/cm, while the EC in the town of Santa Rosa about 9 miles downstream from the dam has ranged from 340 to 3710 μS/cm. The range in the outflow EC at Santa Rosa should approximate that of the outflow, but has never been that low. Consequently, the data do not seem usable for alternatives analysis. However, the operations of Santa Rosa Lake are not expected to change due to the water offset program. The above data are presented to simply characterize the historic water quality of the reservoir.

Ground Water Quality

Aquifers in the study area were described above. The ground water system in the Pecos River Valley is also described in Barroll and Shomaker (2003) and Robson and Banta (1995). Robson and Banta (1995) also includes a discussion of ground water quality in the basin. That discussion is reproduced below:

> Ground water in the western part of the carbonate aquifer in the Roswell Basin generally contains a preponderance of dissolved calcium, magnesium, and sulfate and is classified as either a calcium sulfate or a calcium magnesium sulfate type water. Calcium concentrations generally range from 100 to 500 milligrams per liter, magnesium concentrations generally range from 50 to 130 milligrams per liter, and sulfate concentrations generally range from 300 to 1,400 milligrams per liter. The water is of similar chemical composition to that in other carbonate-rock aquifers where active dissolution of limestone, dolomite, and gypsum is occurring. The water is classified as very hard. Dissolved-solids concentrations generally range from 700 to 2,600 milligrams per liter.
>
> Along the northeastern margin of the carbonate-rock aquifer, dissolved sodium and chloride concentrations in the water can be large; consequently, the water is classified as a sodium chloride type. Sodium concentrations in this area generally range from 1,500 to 3,000 milligrams per liter, and chloride concentrations range from 2,000 to 5,000 milligrams per liter (fig. 16). The water in this area is classified as very hard. Dissolved-solids concentrations range from 7,000 to 12,000 milligrams per liter.
>
> Water of large sodium chloride (salt) content is of particular concern in the Roswell Basin because most water is used for irrigation, and many crops can be damaged by excessive salt in the water and soil. The source of the large chloride concentrations in the carbonate-rock aquifer is uncertain but might be brine that moved across the relatively impermeable eastern boundary of the aquifer. Seasonal water-level declines in the carbonate-rock aquifer might temporarily reverse the direction of ground-water movement across the eastern boundary and enable brines in the deeper parts of the San Andres Limestone to move westward into the carbonate-rock aquifer. Chloride concentrations in water in the eastern part of the aquifer generally are larger near the end of the pumping season when water-level declines are large; concentrations decrease in the winter and early spring when water levels have returned to nonpumping levels. Large chloride concentrations in water samples from the bottom of some wells indicate that these concentrations are larger at greater depth in water in the eastern part of the carbonate-rock aquifer (fig. 17).
>
> When water with large chloride concentration is deep in the carbonate-rock aquifer (fig. 17A), it has little effect on the water quality in shallow parts of the aquifer, and water pumped from wells is of relatively uniform quality. However, if the water with large chloride concentration is drawn farther into the aquifer (fig. 17B), then wells close to the eastern boundary can be severely affected (well C), and more westerly wells might be unaffected or only moderately affected

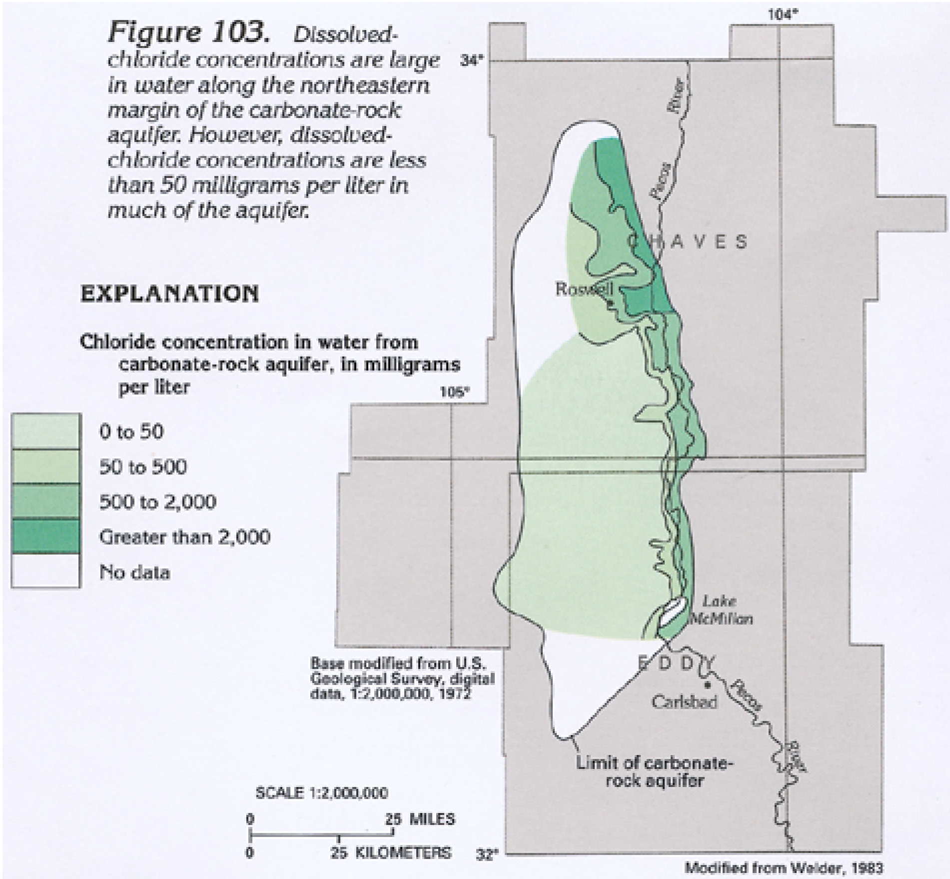


Figure 16: Reproduction of Figure 103 of Robson and Banta (1995)

(wells A and B), depending on well location and depth. Water in the carbonate-rock aquifer to the east of Roswell has undergone a marked increase in chloride concentration. Between 1959 and 1978, chloride concentrations increased by 1,000 to 2,000 milligrams per liter in water from some wells in this area. Increases in 1959-78 chloride concentrations generally have been less than 100 milligrams per liter along the southern one-half of the eastern margin of the aquifer.

Water in the southern one-half of the alluvial aquifer generally is a calcium sulfate type. In the northern one-half of the aquifer, and at a few points along the southeastern margin of the aquifer, the water generally is a mixed calcium sodium sulfate chloride type. The water is very hard throughout the aquifer; dissolved-solids concentrations range from about 500 to 5,000 milligrams per liter. Chloride concentrations range from about 50 milligrams per liter along the western margin of the aquifer to about 2,000 milligrams per liter in a few areas along the eastern margin of the aquifer (fig. 18).

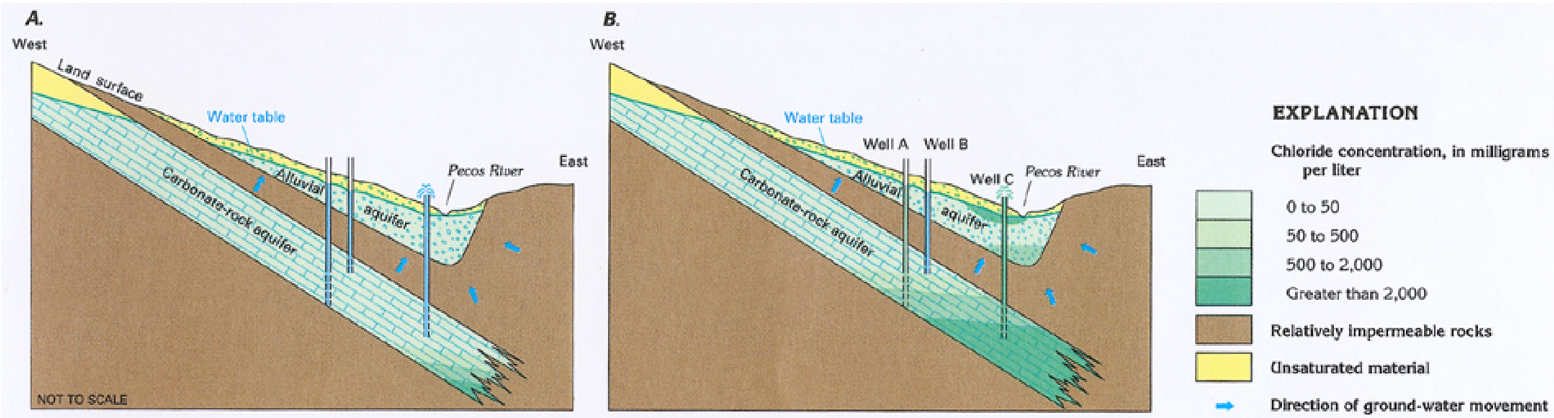


Figure 104. *A, During winter months when water levels in the aquifer are high, water with large chloride concentration can be present in the deep parts of the carbonate-rock aquifer. B, As water levels decline during the growing season, water with large chloride concentration can move upward and degrade the quality of water in some wells and in the alluvium.*

Figure 17: Reproduction of Figure 104 of Robson and Banta (1995)

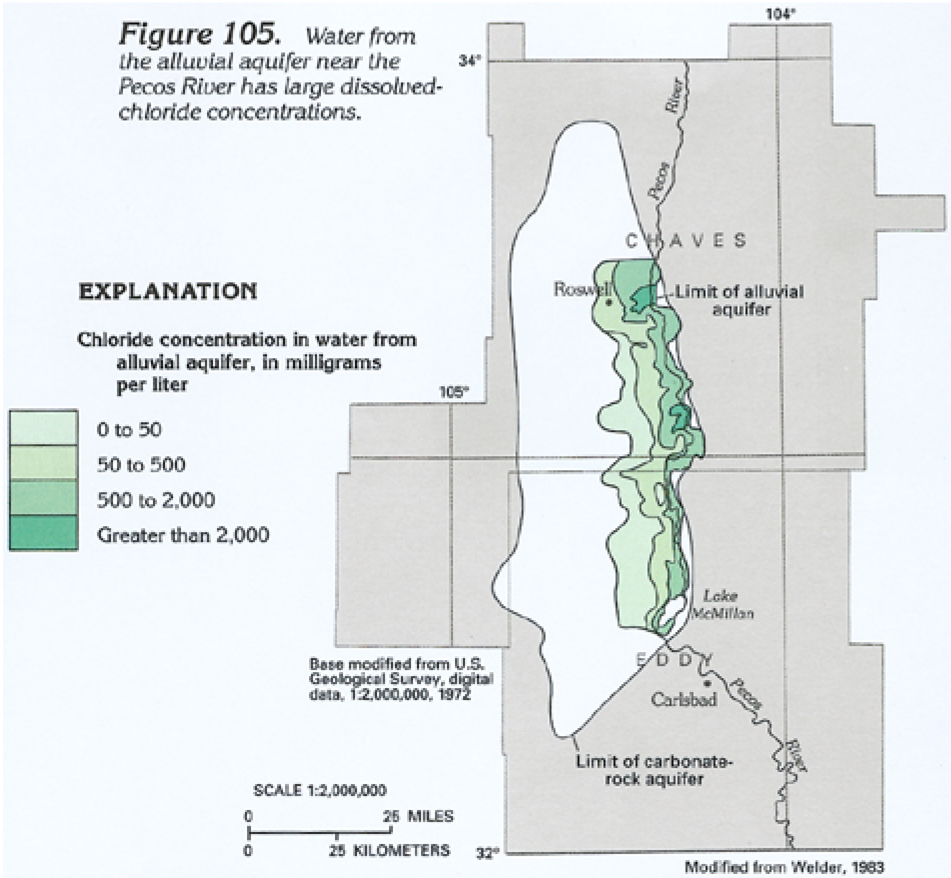


Figure 18: Reproduction of Figure 105 of Robson and Banta (1995)

> In the eastern part of the alluvial aquifer, chloride concentrations can be large in ground water near the upper or lower parts of the aquifer. Large concentrations in the upper part of the aquifer probably are caused by infiltration of water with large chloride concentration from local canals or from wells completed in more saline zones in the carbonate-rock aquifer (fig. 17B). Evapotranspiration by phreatophytes also concentrates dissolved minerals in the soil and shallow water table near the Pecos River. Water with large chloride concentration in the lower part of the alluvial aquifer likely is caused by upward movement of more saline water through the upper confining layer of the carbonate-rock aquifer. Both processes have caused water-quality degradation in the alluvial aquifer. Between about 1957 and 1978, chloride concentrations increased from 30 to 1,000 milligrams per liter in water from some wells.

The above described increase in chloride in the ground water was previously noted in the surface water description for the Pecos River. There is an increase in the percent chloride in the Pecos River beginning near Acme. The change to a high percentage is very evident at the Artesia gage on the Pecos River (see Figure 2 in the Basin-wide Water Quality section).

Ground water quality data from the 3 counties were inventoried and retrieved from the USGS NWIS database. The retrieval included a total of 42 observations from 20 sites. The data encompassed the period 1938 through 1972. Based on the assumption that these and other data were used by Robson and Banta (1995) and the fact that there were no recent data, they were not used further in this description.

Measured and Estimated Drain Quality

At the time that the data on Sumner Dam releases (see surface water quality section) were collected by Flo (1997), EC measurements were made at several drains adjacent to the Pecos River. The data for drains from Ft. Sumner Irrigation District (FSID) lands are shown on Figure 19. In the winter and spring of 1995, the EC of the 2 drains paralleled each other, but the EC of the lower drain is about 1,000 µS/cm higher. The EC of the drains remained fairly stable in the winter, but decreased in the spring. In June, the EC of the Fort Park drain increased, while that of the lower drain decreased. The net result was that the EC of the Fort Park Drain exceeded that of the Lower Drain by several hundred µS/cm. By August, the EC of the drains returned to the levels that had been present the preceding May. The EC of the drains appears to be unchanged most of the year, but decreases after the onset of the irrigation season. This type of response would be a reflection of dilution of the ground water feeding the drains by the applied irrigation water.

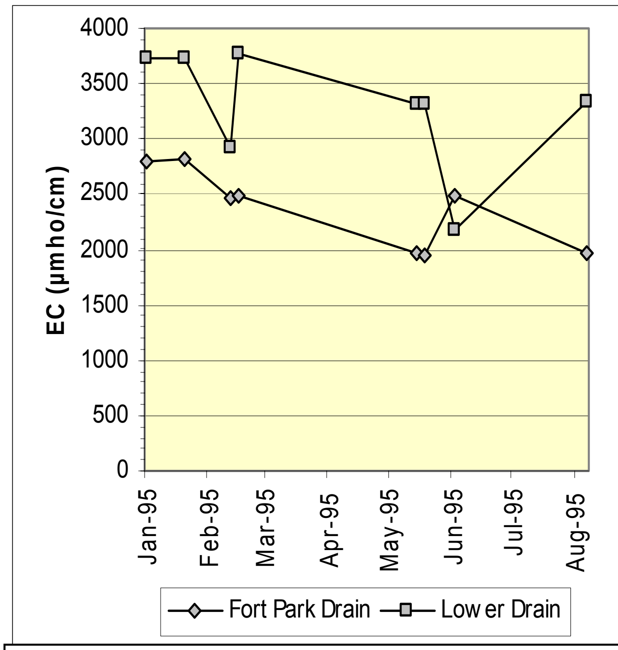


Figure 19: EC of the Fort Park and Lower drains

In general, the EC of the Fort Park Drain (Figure 19) are within the confidence interval of the Pecos River during low flow (see Figure 7 in the Sumner Dam Releases section under surface water). The EC of the Lower Drain was somewhat higher than that of the Fort Park Drain. However, although there is an increase in the EC of the Pecos River between stations ST-3 and TA-0.3 (see above referenced Figure 7), the upper limit of the EC confidence interval for the river at low flow remains below the EC of the Lower Drain. The lack of a change in the upper confidence interval between the above referenced sites indicates that the Lower Drain does not have a great effect on the EC of the river, even at low flow.

The drains discharge directly to the river. The Fort Park Drain is located about 25 miles downstream from Sumner Dam, while the Lower Drain is located about 35 miles downstream from the dam near Taiban. When there is no release from the dam, the gains in the river would be due to ground water accretions to the river. Based on this assumption, the alluvial ground water quality data were supplemented by calculating the EC of the unmeasured gains between sites when the river EC measurements were made in 1995-96. The EC's were calculated when the flow at the railroad bridge site, which is located about 18 miles downstream from the dam was less than 2 ft^3/s. The resulting EC data are shown on Figure 5. The EC's were calculated as the change between sites ST-2, the railroad bridge site, and ST-3, the Old Fort Park site, and between ST-3 and ST-4, the Taiban site. The drain data from Figure 19 are also plotted on Figure 20 as a basis for comparison to evaluate agreement between the calculated ungaged gains and measured drain data. The assumption is that the measured drain data are representative of all of the ground water from the area that enters the river. However, the drain data may be representative of only part of the ungaged gains, if ground water under the FSID is variable in quality.

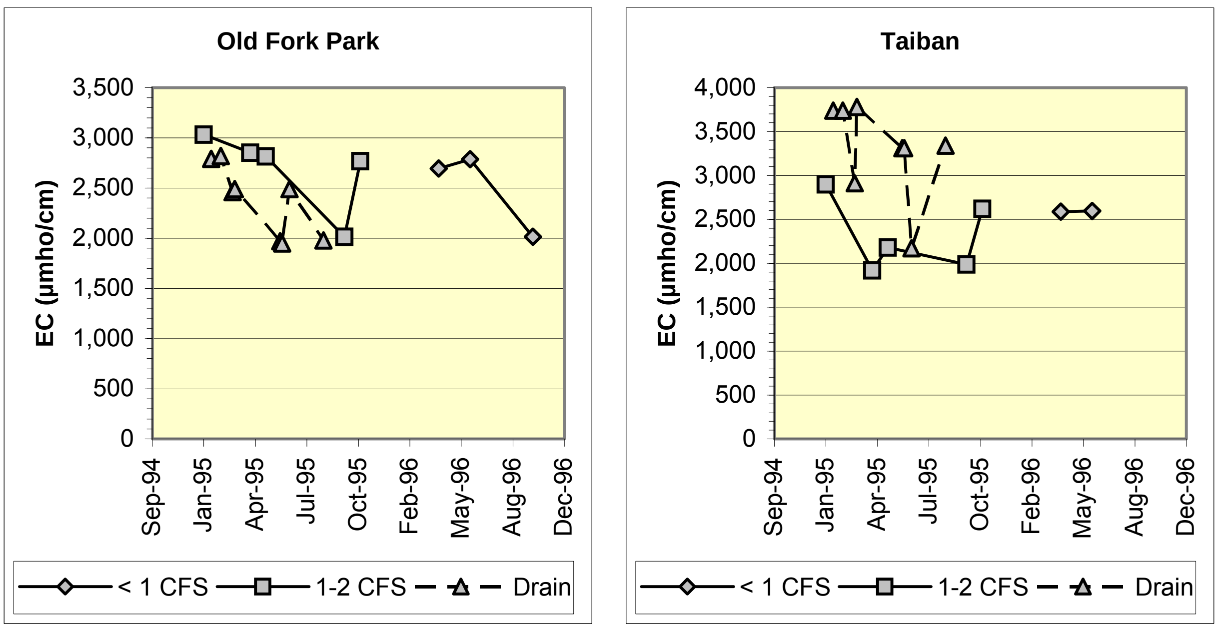


Figure 20: Comparison of the calculated EC of ungaged gains and measured drain EC

The flows shown on Figure 20 represent the flow of the Pecos River at site ST-2, which is located about 18 miles downstream from Sumner Dam. Since there was no release from Sumner Dam at the time when the measurements were made, the flows represent seepage gains between the dam and ST-2. As can be seen from Figure 20, all of the measured drain EC's are from 1995 and all of the calculated EC's from 1995 coincide with seepage of between 1 and 2 ft^3/s. Alternatively, all of the calculated data and the lowest seepage gains, *i.e.* < 1 ft^3/s, were from 1996, when there are no measured drain data.

The 2 sets of calculated EC's show a dichotomy in the comparisons with measured drain EC's. In the case of the data from the area of the Old Fort Park Drain, all of the calculated EC's are greater than the measured drain data, while in the case of the Lower Drain area, all of the calculated values except 1 are less than the measured drain data (Figure 20). The differences between the measured and calculated EC's in the area of the Old Fort Park Drain are smaller than those from the Lower Drain area. The calculated EC of the ungaged gains in the 2 river reaches show little difference, while the drains show a relatively large difference in EC. The calculated EC data indicate that the EC of the ground water in the area is much more uniform than the drain data show. In addition, the calculated EC data indicate that the ground water EC is much more like the river and the Old Fort Park drain on the average, than it is like the EC of the Lower Drain. It should be noted that, according to Flo (1997), both of the drains and Taiban Creek, along with diffuse irrigation return flows, enter the Pecos River between sites ST-3 and ST-4. Consequently, the calculated EC shown on the Lower Drain plot on Figure 5 represent a mix of all of these sources.

Bureau of Reclamation Samples

Additional drain and ground water EC measurements in the EIS study area were made during March and April 2003 (Brummer, 2003a & b). The March data included additional measurements of the EC of the FSID drains (Table 10). The March 2003 measurements are similar to those shown on Figure 4 from January 1995. In both 1995 and 2003, the EC of the Lower Drain is much higher than that of the main drain, but more so in 1995. The differences should reflect interannual variation.

Most of the data in Table 10 come from 3 general areas. The general areas include ones near Dexter, the McMillan Delta, and the CID salt cedar control demonstration area. The data from these areas can be used to demonstrate areal differences in EC in the shallow aquifers.

The EC of the ground water in the Dexter area is about twice that of the FSID area (Table 10). The 2 well samples have an EC of 6-7,000 µS/cm. However, the drain reading at over 16,000 µS/cm is over twice as high as the well readings. Unless there was an extreme amount of evaporative concentration of the drain water, the wells and the drain represent much different sources of water, but, if so, they do indicate that ground water EC in the area can vary greatly.

The only other area where there were gains such that an inflow EC could be calculated from the Flo (1997) flow and EC data were at sites in the Pecos Basin near Dexter. The EC of ungaged gains was calculated for the reaches between TA-4, located at the Acme gage, and AA-1, located at the Highway 380 crossing, and between AA-1 and AA-1.5, located near Dexter. Those data are plotted on Figure 21.

The calculated EC of the ungaged gains in the Highway 380 reach show a much larger degree of variation than those of the Dexter reach (Figure 21). In the Highway 380

Table 10. EC from wells and springs along the Pecos River in 2003					
Site	Date	Location	Specific Conductance (µS/cm)	Depth to water	Remarks
FSID main drain	March 2003	weir	2,720	—	5-10 ft^3/s flow
FSID lower drain	March 2003	Ditch	3,480	—	1-2 ft^3/s flow
Roswell municipal	March 2003	—	1,092	—	—
Well water	4/4/2003	Dexter - near river	7,100	—	Ag well
Well water	4/4/2003	Dexter	6,300	—	Ag well
Ag drain	4/4/2003	Dexter	16,100	—	Ag drain to Pecos river
m-37	4/5/2003	McMillan delta	4,110	35.5 feet bgs[1]	CID obs well
m-38	4/5/2003	McMillan delta	—	Dry at 28 feet	CID well
M35	4/5/2003	McMillan delta	11,400	28.0' bgs	CID well
m-33	4/5/2003	McMillan delta	4,500	15.5' bgs	CID well
M-32	4/5/2003	McMillan delta	8,200	32.7' bgs	CID well
m-30	4/5/2003	McMillan delta	9,100	28' bgs	CID well
m-29	4/5/2003	McMillan delta	6,600	29.0' bgs	CID well
m-28	4/5/2003	McMillan delta	2,300	30.5' bgs	CID well
m-25	4/5/2003	McMillan delta	1,100	23.0' bgs	CID well
m-26	4/5/2003	McMillan delta	4,550	28.5' bgs	CID well
m-24	4/5/2003	McMillan delta	2,550	25.0' bgs	CID well
m-36	4/5/2003	McMillan delta	4,960	30.0' bgs	CID well
Well 1 demo	4/7/2003	Demonstration area - SC control[2]	10,100	21.5' bgs	Obs well
Mc17	4/7/2003	Demo area	10,870	7.5' bgs	Old usbr obs well
Well 8	4/7/2003	Demo area	4,200	9.7' bgs	Obs well
Well 3	4/7/2003	Demo area	4,400	16.8' bgs	Obs well
Well 5	4/7/2003	Demo area	2,920	7.5' bgs	Obs well near river
Carlsbad springs	3/19/2003	Near flume	5,200	—	—
Carlsbad tap	3/19/2003	Municipal wells	770	—	—
Carlsbad tap	4/8/2003	Municipal wells	708	—	—
Supplemental well	4/8/2003	Irrigation well u986 north	1,429	—	—
Supplemental well	4/8/2003	Irrigation well u896 south	1,557	—	—

[1] bgs – below ground surface
[2] SC control – CID salt cedar (tamarisk) control demonstration area

reach, the EC of the gains range from about 10,000 µS/cm to over 28,000 µS/cm. However, 5 of the 6 calculated values are in the range of 10,000 to 20,000 µS/cm. On the other hand the EC values of the Dexter reach are much lower than those in the Highway 380 reach. All of the calculated EC's of the gains in the Dexter reach are between 6,000 and 8,000 µS/cm. In other words the maximum EC of the Dexter reach is lower than the minimum EC in the Highway 380 reach. This would mean that there would be a decrease in the river EC if it were lower than the gain EC. As is indicated

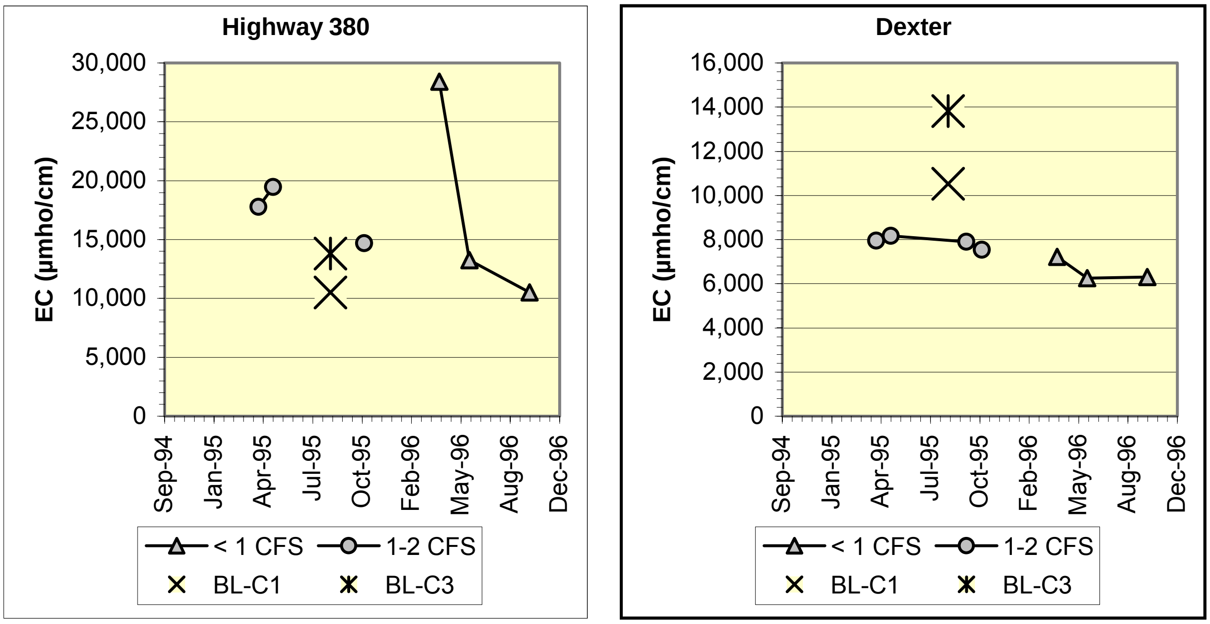


Figure 21: Calculated EC of gains in the Highway 380 and Dexter reaches of the Pecos River and measured EC of the Bitter Lakes drains

on the above reference Figure 7, there is a small decrease in EC between stations AA-1 and AA-1.5 at very low flow, but not at Sumner releases > 2 ft^3/s.

Figure 21 also shows an EC measurement of the Bitter Lakes drains. Those EC measurements were made in August and plot slightly below the EC of the gains at Highway 380, although the EC of BL-C3 is only slightly lower. Alternatively, the Bitter Lakes Drain EC measurements plot similar to the calculated EC of the drains from 1996 measurements. The drain EC measurements plot well above the calculated EC of the gains in the Dexter reach of the Pecos River (Figure 21). This result would indicate that the drain measurements are not particularly representative of the ground water quality in Dexter reach of the Pecos River.

The largest body of data in Table 10 is from the McMillan delta area at the upstream end of Brantley Reservoir. The EC's in that data set range from 1,100 to 11,400 µS/cm, indicating an extremely high degree of variation in the shallow (< 36 feet) ground water. The second largest EC data set in Table 10 is from the CID salt cedar demonstration control area. That data set also shows a high degree of variation in EC with a range from 2,920 to 10,870 µS/cm. Because of the high degree of variation within those data sets, there is no statistically significant difference between the 2 data sets, *i.e.* t = 0.66, probability of a greater t occurring by chance alone = 0.52, based on normalized (log-transformed) data. This leads to the somewhat ambiguous conclusion that the ground water in the lower Pecos Valley is uniformly variable.

All of the towns in the Pecos Basin below Sumner Dam obtain their municipal water from wells. Table 10 includes EC measurements of the treated water in Roswell and Carlsbad. While most of the other data in table 10 reflect the water quality of the Pecos alluvial aquifer, the City of Carlsbad obtains its water from the Capitan aquifer. There are 2 EC measurements of the Carlsbad municipal water in Table 10. Both of the EC measurements are between 700 and 800 µS/cm.

Barroll and Shomaker (2003) describe the Capitan aquifer and its relationship to the Carlsbad water supply. The following is summarized or quoted from that description.

As stated in Barroll and Shomaker (2003), the Capitan aquifer is an ancient reef which includes cavernous limestone from which high capacity wells can produce good quality water. The Capitan reef is a thick accumulation of Permian age massive limestone beds in which Carlsbad Caverns also formed. At Carlsbad, the Capitan aquifer is about 1,600 feet thick and immediately underlies the alluvium (*ibid*.).

An idealized stratigraphic column (aquifers) adapted from Land (2003) is shown in Table 11. Table 11 shows the variation in geologic formations from northwest to southeast and the relative position of the Capitan aquifer. The formations shown above the Capitan Reef are those that may be present, but are not present in all locations. As noted above, none of the formations shown in Table 11 overlie the Capitan Reef near Carlsbad.

There is an extremely transmissive segment of the Capitan aquifer extending from the Guadalupe Mountains to just east of the Pecos River. Water levels in all wells completed in this segment of the reef are at the same elevation and rise and fall in unison in response to recharge events (such as floods in Dark Canyon) and ground water withdrawals. Water quality in the Capitan aquifer is generally excellent southwest of Carlsbad with concentrations of total dissolved solid less than 700 mg/L (EC ~1075 µS/cm). West and north of Carlsbad, ground water mixes with poorer quality water from the bedrock aquifers in the Pecos Valley and lower quality river water seeping in from Lake

Table 11. Stratigraphy of southeast New Mexico (adapted from Land, 2003)

<table>
<tr><th rowspan="2">Era</th><th rowspan="2">Period</th><th colspan="4">NW ◄——► SE</th></tr>
<tr><th colspan="2">Northwest Shelf</th><th colspan="2">Delaware Basin</th></tr>
<tr><td rowspan="4">Cenozoic</td><td rowspan="2">Quaternary</td><td colspan="4">Pecos Valley alluvial fill</td></tr>
<tr><td colspan="4">Gatuna Formation</td></tr>
<tr><td rowspan="2">Tertiary</td><td colspan="4">Ogallala Formation</td></tr>
<tr><td colspan="4">Sierra Blanca Formation</td></tr>
<tr><td rowspan="3">Mesozoic</td><td>Cretaceous</td><td colspan="4"></td></tr>
<tr><td>Jurassic</td><td colspan="4"></td></tr>
<tr><td>Triassic</td><td colspan="4">Santa Rosa Fm./Dockum Group</td></tr>
<tr><td rowspan="11">Paleozoic</td><td rowspan="11">Permian</td><td colspan="2">Rustler Fm.</td><td colspan="2">Rustler Fm.</td></tr>
<tr><td colspan="2">Salado Fm.</td><td colspan="2">Salado Fm.</td></tr>
<tr><td colspan="2"></td><td colspan="2">Castille Fm.</td></tr>
<tr><td rowspan="5">Artesia Group</td><td>Tansil</td><td rowspan="5">Capitan Reef</td><td rowspan="5">Delaware Mountain Group</td></tr>
<tr><td>Yates</td></tr>
<tr><td>Seven Rivers</td></tr>
<tr><td>Queen</td></tr>
<tr><td>Grayburg</td></tr>
<tr><td colspan="2">San Andres/Glorieta</td><td colspan="2" rowspan="2">Bone Springs Formation</td></tr>
<tr><td colspan="2">Yeso/Victoria Peak</td></tr>
<tr><td colspan="2">Abo Fm.</td><td colspan="2">Hueco Group</td></tr>
</table>

Avalon. Originally Carlsbad diverted from the Capitan aquifer using a well field near the Pecos River. Degradation of water quality caused the city to drill a new well field closer to the Guadalupe Mountains, and thus closer to the source of natural recharge. Any increase in pumping from the Capitan aquifer may lead to farther decrease in water quality.

Table 10 also shows an EC reading from Carlsbad Springs. As can be seen, the EC of Carlsbad Springs is much greater than that of Carlsbad city water. The original discharge of the Capitan aquifer was Carlsbad Springs (Barroll and Shomaker, 2003). As noted in Barroll and Shomaker (2003), ground water pumping now intercepts much of that natural recharge. That pumping is reflected in depletions of spring flow and flow of the Pecos River. Artificial recharge associated with leakage from Lake Avalon enters the Capitan aquifer near the city of Carlsbad and is now a large component of the present flow of Carlsbad Springs (*ibid.*). Consequently the EC of Carlsbad Springs is more like that of the Pecos River than of the good quality water in the more westerly segment of the Capitan aquifer.

New Mexico State Engineer Ground Water Data

The Roswell District of the New Mexico Office of the State Engineer (OSE) periodically measures chloride (Cl) and specific electrical conductance (EC) from wells throughout the District. The complete data set was provided to Reclamation (Elisa Sims, OSE, personal communication to Jim Yahnke, Reclamation; letter of July 29, 2004). The Cl and EC data, along with the location, water temperature, and water-bearing formation (aquifer) for wells located within township-range locations along the mainstem of the Pecos River between Sumner Dam and the lower end of the CID were entered into a spreadsheet. The township-range combinations entered are shown in Table 12, which also includes a break down by county and irrigation district, if any. The data encompass measurements made from 1927 through 1999.

The main focus of the ground water analysis will be on the alluvial aquifer in the CID, which is located in Eddy County. However, data from De Baca and Chaves counties were also included in the database for the EIS because replacement water for the CID would likely originate from those areas. In addition, the data would provide a basis for comparison for the water quality estimates above, particular in the lower reach between Acme and Artesia, where the water quality is extremely poor on the basis of the estimates from the Bitter Lakes area.

Table 12. Alluvial areas between Fort Sumner Dam and the Southern end of the CID					
De Baca County		**Chaves County**		**Eddy County**	
FSID		South of FSID		CID	
Township	Range	Township	Range	Township	Range
T3N	R26E	T4S	R25E	T21S	R27E
T2N	R26E	T5S	R25E	T21S	R28E
		T6S	R25E	T22S	R27E
South of FSID		PVACD		T22S	R28E
Township	Range	Township	Range	T23S	R27E
T1N	R26E	T7S	R25E	T23S	R28E
T1S	R25E	T8S	R24E	T24S	R27E
T2S	R25E	T9S	R24E	T24S	R28E
T3S	R25E	T10S	R25E		
		T11S	R26E		
		T12S	R26E		
		T13S	R26E		
		T14S	R26E		
		T15S	R26E		
		T16S	R26E		
		T17S	R27E		

Carlsbad Irrigation District (CID)

Data from wells located in the CID are summarized by water-bearing formation in Table 13A. The alluvial aquifer shows the greatest range in EC of any of the aquifers, primarily because of the maximum value that is shown, *i.e.* over 200,000 µS/cm, which would be considered a brine. That measurement, which is nearly 10 times as high as the next highest EC value, was made in 1967 and was the only measurement made from that particular well; as noted in Table 13, the result is considered a statistical outlier and has been discarded from any of the other analyses.

More EC measurements were made in the CID in wells in the alluvial aquifer (212 - Table 13A) than in all of the other aquifers combined (157). The greatest median EC is also in the alluvial aquifer. As is noted in the footnote to Table 13, by far the highest maximum EC was also measured in a well from one of the unrecorded aquifers; the use noted for the well was that it was associated with the mining of ore, which may account for its extremely high EC. The median EC in wells from 4 of the aquifers, including the Capitan Reef and the Rustler, Castille, and Tansil formations, are similar and only differ by a little over 400 µS/cm, with a range between 3,223 and 3,660 µS/cm (Table 13A). By far the lowest median EC of any of the formations shown in Table 13 is in the Yates Formation. The next lowest EC is from wells where the aquifer is not recorded and, not surprisingly, appears to represent a mix of sources.

Table 13B presents a statistical comparison of the EC of wells in the various aquifers. Although the median EC of the alluvial wells is much higher than that of any of the other aquifers, the EC of the alluvial wells is not significantly different from that of wells in the Castille or Tansil formations, the wells of which are the 2nd and 3rd highest (Table 13A). In the case of wells in the Castille Formation, there are too few samples (3) to make a valid comparison. Although not shown in Table 13B, the results of the statistical comparison of the EC of wells from the Castille Formation show no significant differences from that of measurements from any of the other aquifers, including that from the Yates Formation. The EC of the wells in the Yates Formation is significantly lower than that of wells from any of the other aquifers.

Table 13. Summary of ground water EC data in various aquifers in the CID

A. Summary statistics by aquifer					
Aquifer	Samples	Minimum	Median	Maximum	
Alluvium	212	1,036	5,000	22,300	
Rustler	32	460	3,223	9,720	
Castille	3	3,490	3,591	3,830	
Capitan Reef	78	520	3,305	28,800	
Tansil	20	1,320	3,660	16,520	
Yates	12	420	653	5,000	
Not noted	12	720	2,315	203,120	
B. Kruskal-Wallis test of EC in ground water in different aquifers					
Aquifer 1	Aquifer 2	X^2	Prob. > X^2	Significant	
Alluvium	Capitan Reef	38.48	< 0.000001	Yes	
Alluvium	Rustler	17.39	0.000030	Yes	
Alluvium	Castille	2.55	0.109985	No	
Alluvium	Tansil	2.11	0.146118	No	
Alluvium	Yates	23.98	0.000001	Yes	
Alluvium	Not noted	4.91	0.026681	Yes	
Capitan Reef	Rustler	0.35	0.551411	No	
Capitan Reef	Castille	0.02	0.864612	No	
Capitan Reef	Tansil	1.25	0.262909	No	
Capitan Reef	Yates	13.11	0.000294	Yes	
Rustler	Tansil	0.01	0.925072	No	
Yates	Rustler	11.38	0.000743	Yes	
Yates	Tansil	14.26	0.000159	Yes	

As was noted above, the Capitan Reef (or Capitan Limestone) is an important aquifer in the Carlsbad area. The EC of wells in the Capitan Reef is similar to that of wells in the Rustler, Castille, and Tansil Formations. Ignoring the Castille Formation for reasons noted above, the comparisons of the EC in the Capitan with that of wells in the Rustler and Tansil formations show somewhat odd results. The median EC of the Capitan and Rustler wells show a difference of less than 100 µS/cm, but there is a significant difference between the 2 sets of EC data (Table 13B). Alternatively, there is a difference of over 350 µS/cm between the median EC of wells in the Capitan and Tansil Formations, yet there is no significant difference in those data sets (Table 13B). The median is only 1 point within the distribution of the data. The statistical test that is being used ranks the combined data sets and compares the resulting sum of the ranks of each against the proportion of each of the data sets that should be in each based on their number of observations. Because the medians are so similar, it is probably of little consequence whether the differences are significant or not. The important conclusions seem to be that ground water in the Carlsbad area from the Yates Formation is significantly lower in salt than other water, while water from the alluvium is generally higher in EC than other water.

Fort Sumner Irrigation District (FSID)

The FSID may also be affected by the Program in that water rights could be obtained for use farther downstream. However, the main consideration in the FSID is the returns from irrigation. The water quality of drains in the FSID was discussed above. The assumption there was that the drainage represented the ground water under the FSID. The OSE data set also includes data from wells within the FSID. A breakdown of the EC data by formation is included in Table 14A and a nonparametric comparison of the EC by aquifer is shown in Table 14B.

Table 14. Comparison of EC in ground water under the FSID

A. Summary statistics for EC by FSID aquifer (µS/cm)

Formation	Samples	Minimum	Median	Maximum
Alluvium	63	570	2286	7430
Chinle	8	990	1237	6920
Santa Rosa	25	650	1988	5177
Artesia Group	1	—	2290	—

B. Kruskal-Wallis test of EC in FSID aquifers

Aquifer 1	Aquifer 2	X^2	Prob. > X^2	Significant
Alluvium	Santa Rosa	0.345	0.556835	No
Alluvium	Chinle	4.527	0.033359	Yes
Chinle	Santa Rosa	2.824	0.092892	No

The FSID is primarily underlain by strata of Triassic age, while the CID was primarily underlain by Permian age strata, although in both cases Quaternary alluvium constitutes an important aquifer. The majority of EC measurements from the FSID are from alluvial wells (Table 14A). The total number of observations from wells in deeper strata combined is much less than the number from the alluvial wells alone.

Table 14 shows data from wells in the Chinle Formation. The Chinle Formation was not shown among the strata presented earlier in Table 11. According to Bachman (1981), the Chinle Formation constitutes the beds that overlie the Santa Rosa Formation in eastern New Mexico; both of those formations are included in the Triassic Dockum Group in eastern New Mexico. However, Bachman (1981) indicates that there is little justification for extending the formational names into southeastern New Mexico and prefers to call the Triassic rocks just that or call them the Dockum Group, undivided, as is shown in Table 11. In addition, Ken Fresquez, OSE, Roswell, New Mexico, who provided the data, indicates that the formational codes are preliminary and have not been verified and, in essence, are not to be trusted. The problem is that there are apparent differences in the EC of the ground water in the different formations, a factor that could be meaningful when offset water is obtained.

There is a statistically significant difference between the EC of the Quaternary alluvium and the Triassic Chinle Formation (Table 14B). There is no significant difference between the EC of the alluvium and the Santa Rosa Formation nor between that of the Santa Rosa and Chinle formations (Table 14B). The median EC of the Chinle Formation water is lower than the median EC of either the alluvium or the Santa Rosa Formation. Alternatively, the minimum EC of the Chinle Formation water is greater than the minima of either of the other formations, while its maximum EC is intermediate between the maxima of the other 2 formations. Another potential factor in the differences is that there are far fewer EC data points from the Chinle Formation than from either of the other formations. It may be that the Chinle Formation EC data are not truly representative of the EC of water in the formation, but there is no way to determine if that is the case based on the current data set.

Ground Water EC south of the FSID

The alluvial ground water in the river reach between the FSID and the PVACD may or may not be affected by the Carlsbad Water Supply Program. In the event that make up water is obtained from the area, the quality of water will be described. The wells from which there are EC measurements in the OSE data set are in the same water-bearing formations as was the case of the FSID. The majority of the measurements in both the FSID and the area to its south are from the alluvium, but the second greatest number are in wells from the Permian Artesia Group, undivided, while in the FSID the second most common aquifer from which measurements were made was the Triassic Santa Rosa Formation. Very few measurements were made in either area from other aquifers.

The EC data from the area south of the FSID, but north of the PVACD, are summarized in Table 15A. In this area of the Pecos Valley, the 3 most frequent data set for aquifers includes the data includes the data where the aquifer from which the water is drawn was not identified. There are also 2 sets of samples from surface springs; the aquifer from which the springs issue is similarly not identified. With the exception of the springs and water from the Santa Rosa Formation, where the median EC is approximately 1,500 and 11,000 μS/cm, the median EC of the ground water in the remaining aquifers is about 3,000 μS/cm (Table 15A). This is a bit higher than the EC of the FSID, which looks to be about 2,000 μS/cm based on the data in Table 14A.

Table 15. Summary of ground water EC data from the area between the FSID and the PVACD

A. Summary statistics of EC of ground water (μS/cm)

Formation	Samples	Minimum	Median	Maximum
Alluvium	40	956	2888	8200
Santa Rosa	4	1212	1454	1686
Chinle	5	2620	2872	3498
Artesia Group	37	813	3202	16580
Spring	2	3110	11030	18950
Not noted	6	2340	3186	4520

B. Kruskal-Wallis test of EC of ground water in different aquifers

Aquifer 1	Aquifer 2	X^2	Prob. > X^2	Significant
Artesia Group	Alluvium	0.019	0.890520	No
Alluvium	Not noted	0.345	0.557115	No
Alluvium	Santa Rosa	6.001	0.014299	Yes
Alluvium	Chinle	0.033	0.856689	No

Table 15B shows a statistical comparison between the EC of water in the alluvial aquifer with that in each of the other 4 sets of ground water data, including data from the 3 other aquifers and the data from identified aquifers. The only significant difference in EC from the alluvial aquifer is with the water from the Santa Rosa Formation. As with the Kruskal-Wallis tests on the EC of the FSID ground water, the statistical significance of the difference is not that great – both show probabilities between 0.01 and 0.05. In both instances, the amount of data from the data set that shows the difference from the alluvial aquifer is relatively small. There are 8 observations from the Chinle Formation in the FSID (Table 14A) and only 4 from the Santa Rosa Formation in the area to its south (Table 15A). Nevertheless, the median EC of the water from the wells in the Santa Rosa Formation is about ½ that of wells in the alluvium.

The inequity of the number of samples among aquifers was noted in the preceding discussion. There is also a large variation in sampling effort among areas along the river. Table 16 shows a summary of EC data by township in the FSID (T3N and T2N) and the area to the south (T1N through T6S). The townships selected for inclusion in the data set for the area between Sumner Dam and Brantley Reservoir, unlike that for the CID, are only those that encompass the river. The first 2 townships in Table 16 comprise the FSID and have the greatest number of measurements. The third township is immediately adjacent and probably receives some subsurface flow from the district. South of township 1N, the number of alluvial ground water EC measurements drops off dramatically from 22 to just 1 in township 1S. Each of the townships south of 1N and north of the PVACD has less than 10 EC measurements from the alluvial ground water (Table 16).

Table 16. Summary of alluvial ground water EC data by Township for wells in the FSID and to the south

Township	Samples	Minimum	Median	Maximum
03N	26	570	1661	2965
02N	37	910	2310	7430
01N	22	956	2160	8200
01S	1	—	2100	—
02S	3	3881	3945	4109
03S	7	3270	4170	5548
04S	2	1272	1991	2710
05S	5	3065	4429	6370
06S	0	—	—	—

The EC of the Pecos River shows an increase between Sumner Dam and Brantley Reservoir. Based on the median EC data in Table 16, the alluvial ground water appears to also show an increase in the same area. However, the small number of data points in the data set for the townships south of the FSID make any conclusions in that regard somewhat tentative, but such a conclusion is consistent with the fact that the increase is much more evident at the lower releases from Sumner Dam. The river in such a case consists mostly of base flow, *i.e.*, gains from ground water inflows.

Pecos Valley Artesian Conservancy District

The PVACD is a potential source of the water to offset the reduction in the CID supply due to the Carlsbad Project operational changes for the bluntnose shiner. In addition, land owners within the PVACD have offered to sell about 18,900 acres of land and associated water rights to the State of New Mexico for use in compliance with the settlement agreement with the State of Texas over the Pecos River Compact (OSE-ISC, 2003). Any such acquisition would be addressed in a separate EIS (*ibid.*), but would add water to the river. Water acquired from the PVACD for either of the above purposes would be expected to originate from the artesian aquifer. No matter what the purpose, the water quality of the river could be affected.

EC data for the various aquifers in the PVACD are summarized in Table 17A. Sampled wells in the PVACD represent a larger number and a somewhat different set of aquifers than the previous areas of the Pecos River upstream. The largest number of samples in the area north of the PVACD were from wells in the alluvium and the Artesia Group. Much of the increase in the number of aquifers is due to the samples from the Seven Rivers and Grayburg formations, both of which are members of the Artesia Group. The separation of the Artesia Group and 2 of its members adds names to the list.

Table 17. Comparison of EC in ground water in various aquifers in the PVACD

A. Summary statistics of EC (μS/cm) of ground water by aquifer

Formation	Samples	Minimum	Median	Maximum
Alluvium	872	890	5459	94400
Artesia Grp.	633	1750	5550	72400
Seven Rivers	11	4060	5849	6730
Grayburg	23	1291	1405	2383
San Andres	1923	561	3920	189900
Not noted	27	2832	6340	33000
Spring, seep	11	3310	4250	6820

B. Kruskal-Wallis test of EC of ground water in different aquifers

Aquifer 1	Aquifer 2	X^2	Prob. > X^2	Significant
Alluvium	San Andres	192.162	< 0.000001	Yes
Alluvium	Artesia Grp.	17.231	0.000033	Yes
Alluvium	Seven Rivers	0.238	0.625308	No
Alluvium	Grayburg	58.360	< 0.000001	Yes
Alluvium	Spring, seep	1.137	0.286197	No
Alluvium	Not noted	5.698	0.016984	Yes
Artesia Grp.	Seven Rivers	0.001	0.975223	No
Artesia Grp.	Grayburg	66.117	< 0.000001	Yes
Artesia Grp.	San Andres	221.970	< 0.000001	Yes

In the PVACD, the most commonly sampled aquifer was the San Andres Formation, which underlies the Artesia Group of aquifers (see Table 11). The alluvium and Artesia Group were the next most frequently sampled aquifers in that order in the PVACD (Table 17A).

Although the median EC of the Artesia Group and the alluvium in the PVACD are not greatly different (approximately 100 μS/cm - Table 17A), the 2 data sets show a statistically significant difference (Table 17B). In point of fact, the EC of the alluvium shows a significant difference from all of the other aquifers except the Seven Rivers Formation, which has the fewest EC measurements of any of the aquifers (Table 17).

There is also no significant difference between the EC of the alluvial wells and the surface seeps and springs (Table 17B). The springs and seeps, along with the Seven Rivers Formation, have the fewest observations of any of the water sources in Table 17. The surface seeps and springs do not represent a distinctive aquifer, but rather a surface discharge of ground water. The seeps and/or springs could be discharging alluvial ground water, as indicated by the lack of a significant difference in EC from the alluvial ground water, or water from any other formation that outcrops in the area, particularly from the San Andres which also has a similar EC (Table 17).

Valley-wide EC

It was shown above that the EC varies within the Pecos Valley. A breakdown of the EC in the areas encompassed by the various irrigation districts in the Pecos Valley is shown on Figure 22. The aquifers included on Figure 22 are the ones most often sampled in the OSE data base. The alluvial aquifer is present in all of the areas and sampled with the overall greatest frequency, although other aquifers may be sampled more frequently in individual areas (Figure 22B). The purpose of the inclusion of the category of "other" aquifers is to show the variation from north to south. The Artesia Group of aquifers is generally the second most commonly sampled, but there is only 1 measurement from that group in the FSID, while the Capitan Reef was the 2nd most commonly sampled aquifer in the CID (Figure 22B). The alluvial aquifer was the most commonly sampled in 3 of the 4 areas shown on Figure 20B, but the San Andres Formation was by far the most often sampled aquifer in the PVACD.

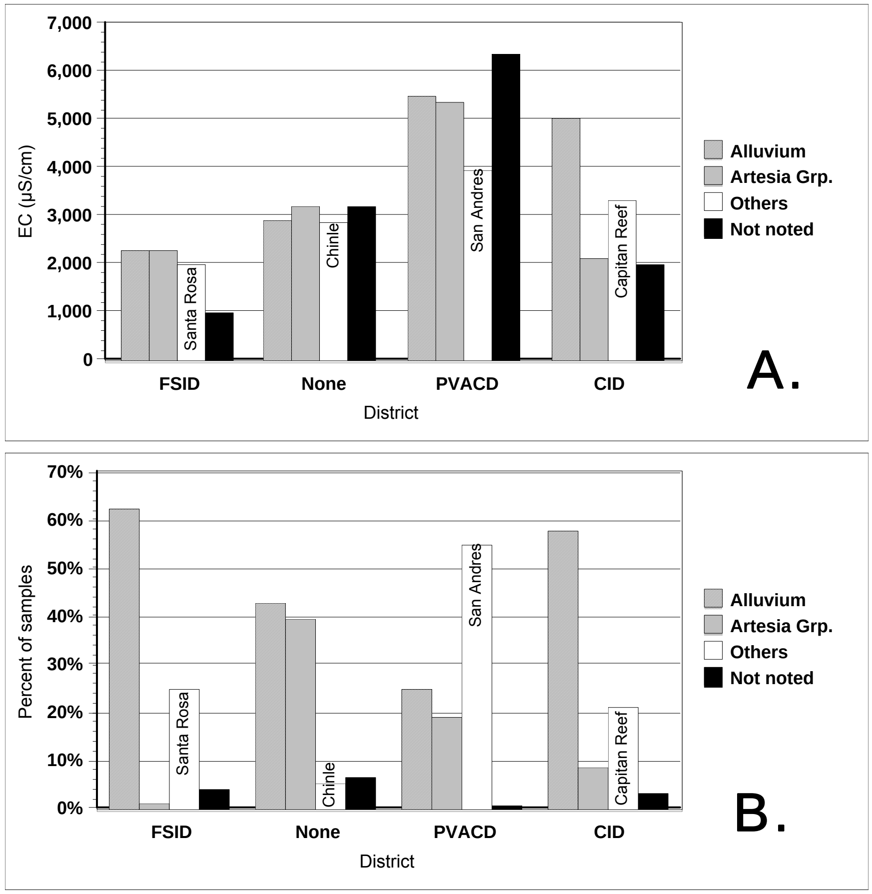
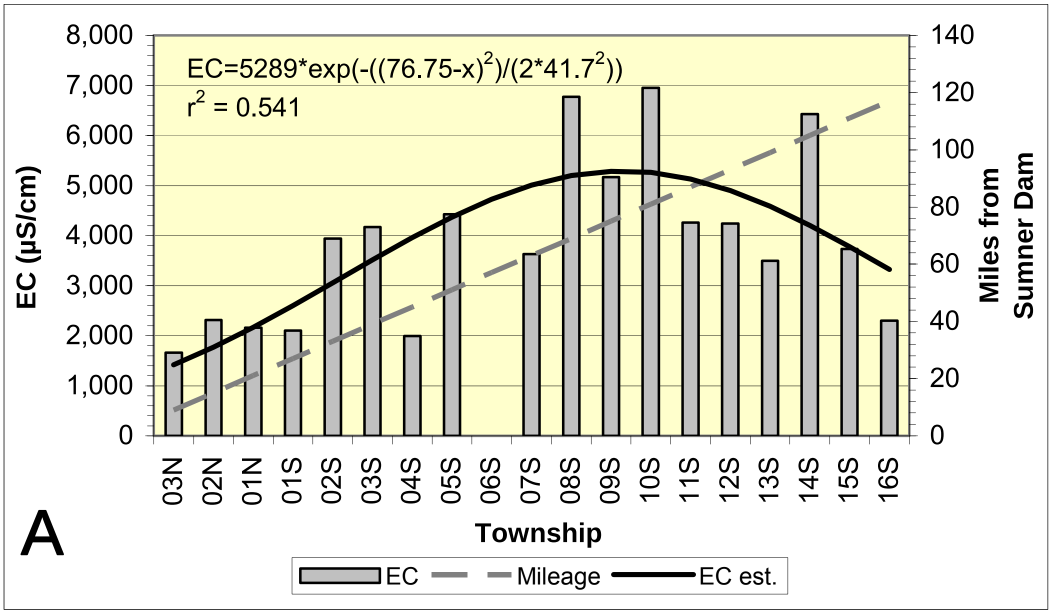


Figure 5: EC of ground water and breakdown of measurements by aquifer in the irrigation district areas on the Pecos Valley

In 3 of the 4 aquifers, the EC of the alluvium and that of the Artesia Group is not greatly different (Figure 22A). However, there is a large difference in the EC of the 2 aquifers in the CID, *i.e.* the EC of the Artesia Group is about 3,000 µS/cm lower. The main point of Figure 22 is to show that the quality of offset water for CID from ground water sources may be rather different from water currently in the District. In general ground water from the northern part of the valley nearer Sumner Dam has a lower EC than that nearer Brantley Reservoir, based on a breakdown by irrigation district and adjacent areas, but this is only generally true. There is actually much more variation in EC of the ground water than is shown by Figure 22.

There is also a large amount of variation in the median ground-water EC between townships in the river reach between Sumner Dam and Brantley Reservoir. Figure 23



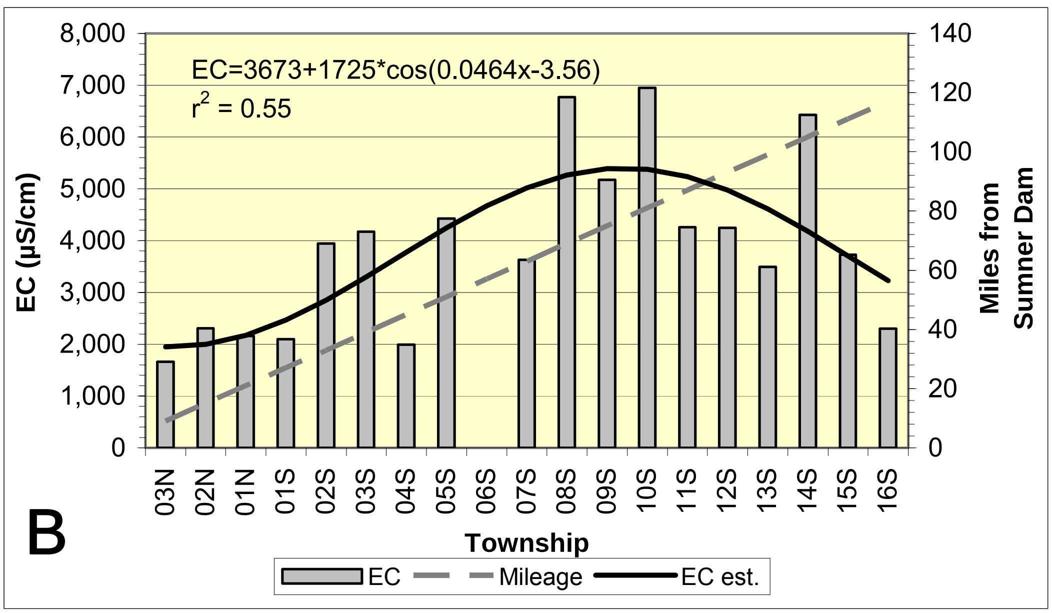


Figure 6: Median ground-water EC of the alluvial aquifer between Sumner Dam and Brantley Reservoir and two methods of showing trends

shows a plot of the median ground-water EC in each of the townships along the river in that reach. Figure 23 also shows a plot of the estimated mileage of the center of each township from Sumner Dam. Sumner Dam is located on the approximate line between townships 5N and 4N. The estimated distance plotted on Figure 23 would be the equivalent of air miles, rather than river miles. In the equations for the trend lines shown on Figure 23, the “x” is actually the mileage plotted against the 2nd *y*-axis, rather than the townships that are shown on the *x*-axis. The r^2-values for the trend lines are rather poor, but that is primarily a reflection of the variation in the median EC for the townships.

A possible reason for the high degree of variation is related to the large disparity in sampling effort in the townships. This is illustrated by Table 18, which shows the number of samples and the EC of wells in the 3 most heavily sampled aquifers in each of the townships between Sumner Dam and Brantley Reservoir.

Table 18. EC (µS/cm) and number of measurements in the ground water in the most heavily sampled aquifers in each township between Sumner Dam and Brantley Reservoir

Township	Estimated Mileage	Alluvium		Artesia Group		San Andres Fm.	
		Samples	EC	Samples	EC	Samples	EC
03N	9	26	1,661	0	—	0	—
02N	15	37	2,310	1	2,290	0	—
01N	21	22	2,160	0	—	0	—
01S	27	1	2,100	10	3,067	0	—
02S	33	3	3,945	2	1,310	0	—
03S	39	7	4,170	4	14,088	0	—
04S	45	2	1,991	6	2,480	0	—
05S	51	5	4,429	4	3,300	0	—
06S	57	0	—	11	3,202	0	—
07S	63	1	3,627	50	3,160	0	—
08S	69	66	6,773	98	5,057	632	5,475
09S	75	145	5,170	86	4,190	257	3,929
10S	81	219	6,950	320	10,500	79	9,840
11S	87	1	4,260	25	3,960	1	3,530
12S	93	30	4,246	18	3,070	147	3,767
13S	99	131	3,495	22	2,900	420	1,710
14S	105	150	6,425	0	—	63	1,457
15S	111	59	3,730	1	4,710	169	2,229
16S	117	66	2,300	6	2,915	154	1,659
17S	123	4	11,595	7	3,290	1	189,900

There are samples from the alluvium from each of the townships except 6S. However, the number of EC measurements between T1S and T7S is much smaller than form most of the townships to the north or the south, with the exception of T11S where there was only 1 measurement.

There are only 4 EC measurements in the alluvial aquifer of T17S. The combination of the large increase in EC in comparison with other wells in the alluvium and the small number of samples raises the question of the representativeness of the data. The township and range combination in which the wells are located is the same as the location of the USGS Artesia gage. As was noted above in the surface water section, the EC in the reach of the river upstream and at the Artesia gage shows a continual increase. Such an increase in the surface water is consistent with gains of saline inflows from ground water. On this basis, the high EC of the ground water in T17S is consistent with other data and should be considered to be a reflection of actual conditions.

There is only 1 EC measurement from the Artesia Group in T1N through T3N. The majority of EC measurements from wells in these townships were either from the alluvium or aquifers composed of the Triassic Santa Rosa and Chinle formations. The Artesia Group is of Permian age (Table 11). There are 10 or fewer EC measurements from the Artesia Group from T1S south through T5S, at which point the number of measurements increases considerably to a maximum of 320 in T10S. As was noted in Table 11, the geology of the valley changes from northeast to southwest. The increase in the number of wells in the Artesia Group from north to south is probably a reflection of that change in the aquifers as illustrated in Table 11.

The majority of EC measurements in the PVACD is from wells in the San Andres Formation. The artesian aquifer for which the PVACD was formed is located within the sequence of east-dipping carbonate rocks of the San Andres Formation (Barroll and Shomaker, 2003). Consequently, the PVACD should reflect the extent of San Andres outcrops near the Pecos River and the predominance of wells in the San Andres Formation in the PVACD should be expected. The EC in the San Andres shows a general decrease from north to south, although there is a dramatic increase shown in T17S (Table 18). However, the very high median EC, indicative of a brine, in the San Andres Formation reflects only 1 measurement; the well is an oil well and would not be representative of the general water quality of the aquifer. Most of the wells sampled in T17S were in the overlying Grayburg Formation of the Artesia Group, which has a much lower EC than that of the San Andres Formation (Table 17).

Water Quality Impacts

As discussed previously, the following indicators were selected to evaluate agricultural soil and land resources:

- Electrical conductivity (EC)
- Total dissolved solids (TDS, which in most cases needs to be computed from EC due to limited TDS data)

Summary of Impacts

Differences between the various action alternatives and the No Action Alternative are not at all straightforward. Depending on conditions, the action alternatives may show increases or decreases in the water quality indicator, specific electrical conductance. Consequently, this overview of the differences between the action alternatives and the No Action alternative will be based on a comparison of the overall average EC for the 60 years of hydrology from the RiverWare model.

Table 19 shows the average EC at the USGS gauge near Artesia and downstream from Brantley Dam for the pre-1991 baseline, No Action Alternative, No Action Alternative with a 6-week restriction on block releases, and the five action alternatives, the last of which includes three target levels of summer flows at the Taiban gauge. Table 19 also shows the rank of the mean EC from each of these alternatives. The last column of table 19 shows the difference between the mean EC for the No Action Alternative or the difference in EC between the two No Action Alternative formulations, or the difference in the mean EC between the No Action Alternative and each action alternative.

The greatest difference in EC is between the pre-1991 baseline and the No Action Alternative, which represents the existing condition. If the analysis is representative of conditions in the field, the greatest effects on water quality have already occurred. However, it should also be noted that the analysis summarized in table 19 does not include any attempt to offset depletions to the CID water supply.

Table 19 indicates that the overall average EC would be lower under the No Action Alternative with the 6-week restriction and the Acme Constant and Acme Variable Alternatives than the under No Action Alternative. Consequently, the average EC of the No Action Alternative ranks fifth overall among the alternatives. The overall average EC would be higher under the Critical Habitat Alternative and the four different formulations of the alternatives with target flows at the Taiban gauge than under the No Action Alternative. The addition of water offset options equally to the various alternatives would change the average EC, but may or may not change the rankings of the various alternatives. Changes in the rankings of the average EC due to the application of the water offset options would be primarily due to the need of more or less offset water by the various alternatives. The need for more or less offset water

Table 19. Water quality comparison of alternatives

Artesia EC (µS/cm)			
Alternative	Mean	Rank	Change
Pre-1991 baseline	5,217	1	—
No Action	5,710	5	493[1]
No Action w/6week	5,670	3	-40
Taiban Constant	5,760	7	50[2]
Taiban Variable (40 cfs)	5,756	6	46
Taiban Variable (45 cfs)	5,763	9	52
Taiban Variable (55 cfs)	5,765	10	55
Acme Constant	5,618	2	-92
Acme Variable	5,672	4	-38
Critical Habitat	5,762	8	52
EC downstream from Brantley Dam			
Alternative	Mean	Rank	Change
Pre-1991 baseline	4,432	1	—
No Action	4,619	5	187
No Action w/6week	4,605	3	-14
Taiban Constant	4,639	7	20
Taiban Variable (40 cfs)	4,635	6	16
Taiban Variable (45 cfs)	4,640	9	21
Taiban Variable (55 cfs)	4,640	10	21
Acme Constant	4,580	2	-39
Acme Variable	4,605	4	-15
Critical Habitat	4,640	8	21

[1] difference from the baseline
[2] difference from the No Action alternative

would make it impossible to apple offsets equally to all of the alternatives and the No Action Alternative.

Scope and Methods

The focus of the water quality impact analysis is on the Pecos River near Brantley Reservoir. The specific electrical conductance of water is related to total dissolved solids. Specifically, we compare the alternatives based on EC at two gages near Brantley: Artesia and Pecos River below Brantley. The EC at the Artesia gauge reflects the EC of the inflow to Brantley Reservoir. The inflow (Artesia) EC also was used to estimate the EC of the outflow from Brantley Reservoir, which is considered to represent the EC of the CID water supply. The estimated EC of the Brantley Reservoir releases was evaluated against the spring EC goal of CID for each of the alternatives.

Dry, Wet, and Average Conditions for Surface Water

Because surface water quality is intimately related to the amount of water in the system, the water quality impact analysis relies on the results of the RiverWare model. The reservoir contents from the RiverWare model were used to calculate the Effective Brantley Storage (EBS). The EBS was calculated for each by extracting the storage data for April 1 of each year and calculating the EBS using the following formula:

Avalon Storage + Brantley Storage + 0.75 x Sumner Storage + 0.65 x Santa Rosa Storage.

The EBS values were then used to determine whether April 1 of each year should be classified as being wet, normal, or dry. The breakdown of years in each of the groups is shown in table 20.

Table 20. Breakdown of dry, normal, and wet years by alternative based on EBS

Alternative	Dry Years	Normal Years	Wet Years
Pre-1991 baseline	19	21	20
No Action	22	24	14
No Action w/6week	23	23	14
Taiban Constant	24	19	17
Taiban Variable (40 cfs)	25	18	17
Taiban Variable (45 cfs)	25	17	18
Taiban Variable (55 cfs)	23	19	18
Acme Constant	25	24	11
Acme Variable	23	25	12
Critical Habitat	24	19	17

As shown in table 20, the number of years in each classification varies with alternative, and for most of the alternatives, there are more dry years than either normal or wet years. In other words, the number of dry years is greater among the action alternatives than under the No Action Alternative.

The low, median, and high flow years for each of the groupings in table 20 are shown in table 21. As might be expected from the variation in the number of years in each of the groupings, the median year also varies among the various alternatives with one notable exception. The driest year for all of the alternatives is the same, 1965 (Table 21). The driest year is likely to be the most critical and its use will put the alternatives on the

Table 21. Year between 1940 and 1999 that is representative of various water supply year types based on EBS				
Alternative	Extreme Driest year	Representative year by alternative		
		Dry Year	Normal Year	Wet Year
Pre-1991 baseline	1965	1952	1967	1943
No Action	1965	1952	1962	1943
No Action w/6week	1965	1978	1941	1956
Taiban Constant	1965	1981	1967	1985
Taiban Variable (40 cfs)	1965	1954	1967	1985
Taiban Variable (45 cfs)	1965	1954	1947	1959
Taiban Variable (55 cfs)	1965	1975	1997	1985
Acme Constant	1965	1990	1960	1951
Acme Variable	1965	1949	1960	1943
Critical Habitat	1965	1975	1967	1950

same basis for comparison. In other words, 1965 should represent something of a "worst case" scenario.

Each action alternative was compared to the No Action Alternative by plotting the daily estimated EC for each selected year for the gauge at Artesia, which represents the inflow to Brantley Reservoir, and the estimated EC of the Brantley Reservoir releases, which represents the EC of the water supply to CID. The plots, which appear in Attachment 4, show EC at the two sites for a wet year, a normal year, a dry year, and 1965, the driest year in the record. The impact assessment in this appendix shows tabular comparisons of the mean annual EC for each of the alternatives at Artesia and downstream from Brantley Dam for each of the above years.

Groundwater Quality Impact Assessment

The ground-water quality analysis focuses on changes in the quality of the recharge water in the CID. Most of the recharge to the CID ground water would not be affected by any of the alternatives. Any change in the quality (EC) of the recharge due to an alternative is compared to the quality of the No Action Alternative. The most affected sources of recharge would be the seepage from the Main Canal and the Southern Main Canal.

The effects of the water offset options vary greatly in their effects on water quality. The greatest differences depend more on the source of the offset water than the actual amount of water acquired. As was shown in chapter 3, there is a large difference in quality from north to south in both the river and the ground water between Fort Sumner Dam and Brantley Reservoir. The effects were evaluated based on various scenarios and mixes of source water for the offset supply. These sources were superimposed on the quality of water at the Artesia gauge that was estimated as described above.

No Action Alternative

The projected mean annual EC at Artesia for the No Action Alternative, which is equivalent to the present or current condition in terms of Carlsbad Project operations, is compared to an historic or pre-1991 operation in table 22. The table shows the projected average (geometric mean) EC for each site in each of the four years. The table also shows annual the difference between the two data sets with the different operations.

Table 22. Comparison of present condition with pre-1991 baseline

Site	Condition	Year	Year type	EC (μS/cm)	
				Average[1]	Difference
Artesia	Pre-1991 baseline	1943	Wet	4,707	—
		1967	Normal	5,861	—
		1952	Dry	5,592	—
		1965	Driest	6,213	—
	No Action (present)	1943	Wet	5,018	285
		1962	Normal	6,280	390
		1952	Dry	6,166	584
		1965	Driest	7,081	937
Brantley Dam	Pre-1991 baseline				
		1943	Wet	4,253	—
		1967	Normal	4,643	—
		1952	Dry	4,527	—
		1965	Driest	4,735	—
	No Action (present)	1943	Wet	4,361	106
		1962	Normal	4,772	125
		1952	Dry	4,750	204
		1965	Driest	5,043	323

[1] All of the averages presented here and in later tables are based on log-transformed data.

As should be expected, the highest average EC for each of the sites occurs in the driest year. However, the second highest EC does not occur in the dry year, but rather in the normal year (table 22). The dry year EC ranks third. More importantly, all of the comparisons show an increase in EC over the pre-1991 baseline operation; i.e. all of the differences are positive and illustrative of increases. This result indicates that the experimental operations over the last decade would increase the EC of Carlsbad Project water somewhat, although that increase is not as great as the one shown at the Artesia gauge.

To put the changes in EC into perspective, figure 24 shows the effect of increase in EC on the yield of alfalfa. The data to construct figure 24 were taken from Ayers and Westcot (1985). As shown on figure 22, there is a linear decrease in the percent yield of alfalfa in the EC range between 1,300 and 10,000 µS/cm. The decrease amounts to about a 10-percent decrease with each increase in EC of 900 µS/cm. On this basis, the effects of the greater EC at Brantley Dam would be less than 5 percent. However, the range in annual average EC for the pre-1991 baseline is between about 4,250 and 4,700µS/cm. With this range of EC, some yield reduction should already be occurring. On the basis of information presented in figure 24, the reduction would be on the order of 30 to 40 percent. However, it should be noted that the values plotted on figure 24 are considered a guide relative tolerances; absolute tolerances vary depending on climate, soil conditions, and climate (Ayers and Westcot, 1985). In the Pecos River area at the higher EC values, the presence of gypsum often reduces the actual yield reduction.

The EC data in table 22 are annual averages. Within the year, a range in EC would

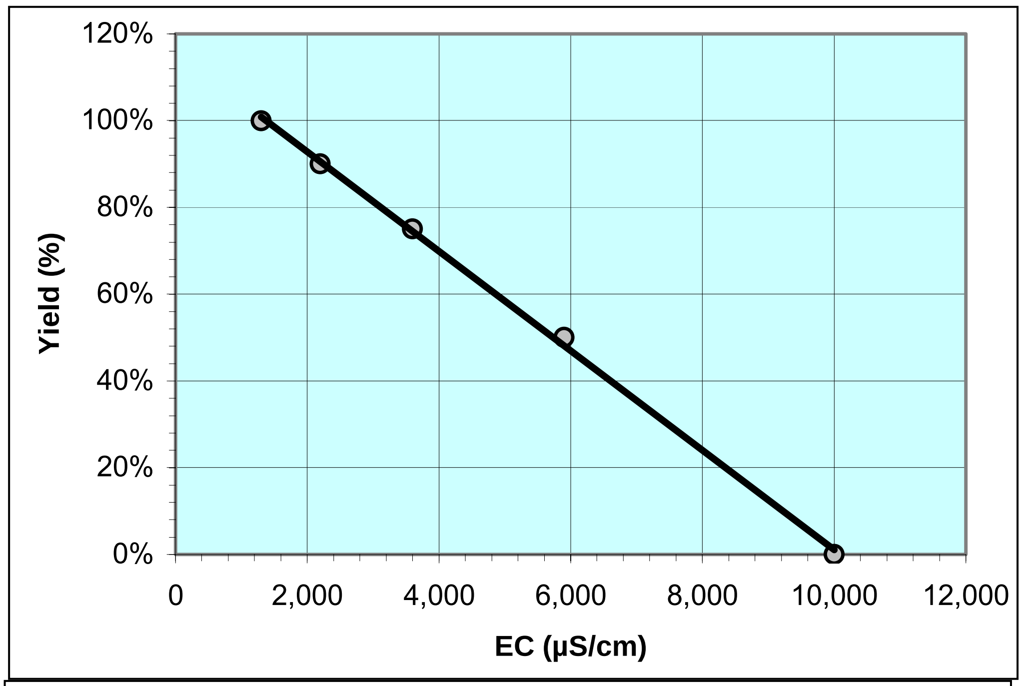


Figure 24: Effect of increased EC on alfalfa yields.

occur. The projected range in EC for the pre-1991 baseline and the No Action Alternative in a normal year are shown on figure 25. The remaining year-types are shown in the attachment, but the normal year is presented here as an example. As can be seen, while there is a net annual increase in EC under the current condition, the increase only occurs for part of the year.

- In the winter, there is little difference in EC, although the EC of the pre-1991 baseline is slightly higher.
- During April, the pre-1991 baseline EC is considerably higher
- Through most of May and June, the No Action Alternative EC is quite a bit higher than that of the pre-1991 baseline.
- During most of the summer, the pre-1991 baseline EC is generally higher.

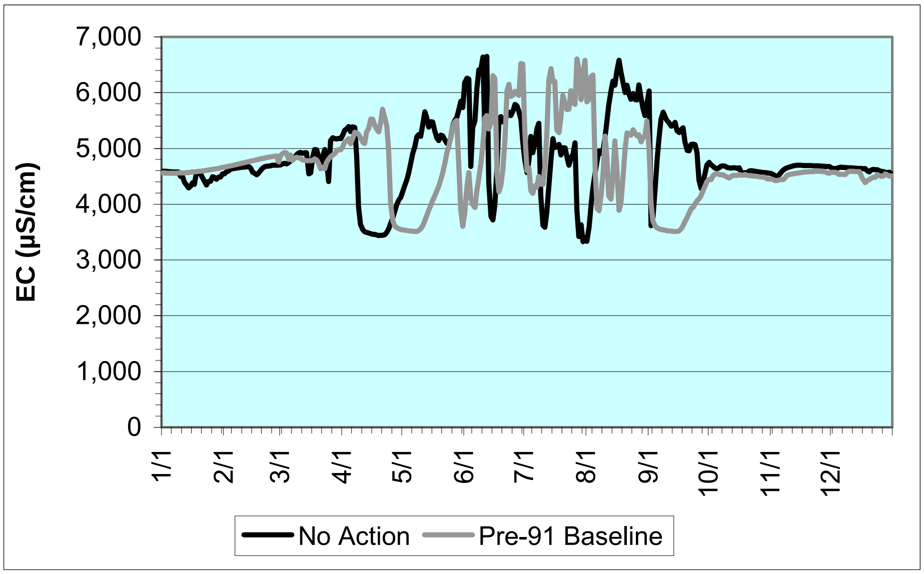


Figure 25: Daily EC at the Artesia gage in a normal year for the pre-1991 baseline and the No Action (present condition) Alternative

On figure 25, the range in EC for both conditions is from about 3,500 to about 6,500 µS/cm. From this perspective, there is probably little difference in the effects of changing from one operation to the other. Depending on the duration of the high EC, the yield reduction would be more a factor of the greatest EC, rather than the average.

Another important point is that the sensitivity of alfalfa to salt varies during the growing season. Alfalfa has been shown to be very sensitive to salinity during emergence Bauder et al. (1992). For example, the results of an experiment by Bauder et al. (1992) indicate that the loss of seedlings increased at TDS concentrations somewhere between 1,150 and 1,650 milligrams per liter (approximate EC of 1,770 and 2,540 µS/cm, respectively). The 100-percent yield level of alfalfa shown on figure 24 is at an EC of 1,300 µS/cm, with a 10-percent reduction in yield at 2,200 µS/cm. However, there is a large difference between seeding survival and a reduction in productivity in that the latter only involves growth, not survival.

The modification of the No Action Alternative that incorporates a 6-week restriction on block releases results in change in EC from that projected for the No Action alternative without the restriction, which is used as the No Action Alternative for purposes of the alternatives comparison. Table 23 presents a comparison of the projected EC for each of the two formulations of the No Action. The differences in EC in the various year-types among the alternatives are somewhat odd and unexpected. EC increases in three of the four year-types, but the increases are the reverse of what would be expected. The smallest increase at both the Artesia gauge and Brantley Dam is projected to occur during the driest year in the record, while the largest increase is projected to occur in the wet year. To further complicate matters, there is a large projected decrease in the normal year. The differences in EC are a reflection of the different operations necessitated by the block release restriction. The increases in EC that are shown in table 23 are a net annual change and are presented for alternatives comparison. For the timing of the differences, see Attachment D. Many of the resulting differences shown in table 23 can be attributed to differences in spills that are brought about when the operating criteria for the reservoirs in the system are dictated by factors that do not relate strictly to an optimal reservoir operation.

Table 23. Comparison of the No Action Alternative (present) with the No Action with the 6-week block release restriction alternative

Site	Condition	Year	Year type	EC (µS/cm)	
				Average	Difference
Artesia	No Action (present)	1943	Wet	5,018	—
		1962	Normal	6,280	—
		1952	Dry	6,166	—
		1965	Driest	7,081	—
	No Action w/6 week	1956	Wet	6,098	1,161
		1941	Normal	2,930	-3,095
		1978	Dry	6,858	850
		1965	Driest	7,119	32
Brantley Dam	No Action (present)	1943	Wet	4,361	—
		1962	Normal	4,772	—
		1952	Dry	4,750	—
		1965	Driest	5,043	—
	No Action w/6 week	1956	Wet	4,730	376
		1941	Normal	3,792	-957
		1978	Dry	4,978	270
		1965	Driest	5,052	9

Another factor affecting differences is that the same years are not necessarily compared. Only the driest year, 1965, is the same for all alternatives. The representative or median dry, normal and wet years often are different for the different alternatives. In the pre-1991 baseline comparison with the No Action Alternative, only the normal years differ (table 22). In the case of the two formulations of the No Action Alternative, the dry, normal, and wet year types are each represented by different years (table 23).

Another point to consider is that the relationship that generates the Brantley Dam EC is predicated on a certain degree of mixing or lack of mixing due to saline inflows that are denser than water in the reservoir. The relationship predicts a large decrease in EC when the EC is large because of mixing, but the resulting EC of the outflow is still relatively high. Alternatively, at lower EC, the relationship predicts an increase in EC because of mixing with the reservoir, but the outflow is still low because the EC of the reservoir should be low. The relationship is based on the way the reservoir reacted during the last decade. The future with the different operations may be different from the projections using the historic relationships. For example, the increase in releases from Fort Sumner Reservoir will dilute the inflows to Brantley Reservoir during what would otherwise be base inflow periods. This will dilute the Brantley Reservoir inflows. This may affect the degree of mixing that occurs during those lower flow periods. Consequently, the projected EC of the outflows from Brantley Dam may be based on a relationship that will change in the future. This is further explored in Attachment 5.

Another point to consider is that the simulated operation of Brantley Reservoir does not completely mimic the historic operation by CID. The higher EC underflow described above causes a buildup of high EC water in the bottom of the reservoir in front of the outlet. This buildup is most severe in winters where there is little inflow from local rainfall or snowmelt. The accumulation results because the normal saline winter inflows are around 60 ft^3/s, while the releases amount to about 20 ft^3/s. The excess is stored. Large inflows of lower EC water from rainfall or snowmelt can mix the saline bottom layer and dilute it. The saline water would be harmful if used to irrigate sensitive emergent alfalfa (or other crops as well). When there has not been enough winter inflow to mix the saline bottom water, CID has delivered a block release from Sumner Reservoir to effect the mixing prior to the initial delivery of irrigation water in the spring. These spring block releases for water quality improvement are not simulated in RiverWare. Consequently, the dilution that would be expected prior to the initial delivery of irrigation water (usually around April 1) is shown occurring in May in the pre-1991 baseline and in mid-April for the No Action alternative on figure 25. Because RiverWare does not simulate water quality, some other trigger would be needed for the early spring block release for water quality control. For purposes of the impact assessment, it was assumed that some means of water quality improvement will be made in the spring irrigation water deliveries even though the hydrologic model results do not necessarily show that happening.

Taiban Constant Alternative

The Taiban Constant alternative has a year-round target flow of 35 ft^3/s. Table 24 shows the projected average annual EC of the Taiban Constant alternative at the Artesia gauge and downstream from Brantley Dam for each of the 3 years types and the driest year in the record. The last column of the table shows the difference in EC from that of the No Action alternative. The EC of the No Action alternative for each of the year types were previously presented in tables 22 and 23 and are not repeated for the remaining alternatives.

The Taiban Constant Alternative is projected to show higher EC at the Artesia gauge in three of the four year types than under the No Action Alternative (table 24). In this case, the results are somewhat more in line with expectation, although the average increase in EC in the normal year is larger than that in either the dry year or the driest year in the record. The two dry-year average increases are essentially the same, at around 250 μS/cm, while the average increase in the normal year is much greater at over 600 μS/cm, or more than twice as large as the dry year increase. The wet year shows the only decrease relative to the No Action Alternative.

Table 24. Comparison of the No Action Alternative (present) and the Taiban Constant Alternative

Site	Year	Year type	EC (μS/cm)	
			Average	Difference
Artesia	1985	Wet	4,545	-352
	1967	Normal	6,771	660
	1981	Dry	6,349	245
	1965	Driest	7,250	261
Brantley Dam	1985	Wet	4,225	-123
	1967	Normal	4,976	227
	1981	Dry	4,820	95
	1965	Driest	5,107	77

Because the projected EC downstream from Brantley Dam is related to the inflow EC, the pattern of EC changes will be the same as the one shown for the Artesia gauge. Because of the buffering in the reservoir, the average EC will be lower than that at the gauge. It follows from the lower EC that the differences between an alternative and the No Action Alternative will generally be smaller as well. These latter two generalizations are shown in table 24, but the first is not exactly followed. At the Artesia gauge, the increase in the projected EC during the dry year is not as great as that in the driest year, but it is somewhat larger than that of the driest year downstream from Brantley Dam (table 24). However, the difference in the two increases is small and likely does not represent any real difference between the two.

Taiban Variable Alternative

The Taiban Variable alternative has the same winter target as the Taiban Constant alternative, but the Taiban Variable has three different formulations, each with a different summer target. Table 25 presents a comparison of the Taiban Variable Alternative at each of the three summer target levels.

Table 25. Comparison of the No Action Alternative (present) and the Taiban Variable Alternative at three summer target flow levels

Site	Year type	EC (µS/cm) – 55 cfs			EC (µS/cm) – 45 cfs			EC (µS/cm) – 40 cfs		
Artesia		Year	Average	Difference	Year	Average	Difference	Year	Average	Difference
	Wet	1985	4,621	-285	1959	5,342	444	1985	4,571	-300
	Normal	1997	5,126	-1,194	1947	5,861	-385	1967	6,770	659
	Dry	1975	7,004	923	1954	6,363	563	1954	6,376	571
	Driest	1965	7,197	190	1965	7,208	134	1965	7,178	114
Brantley Dam	Wet	1985	4,249	-100	1959	4,480	133	1985	4,235	-111
	Normal	1997	4,406	-371	1947	4,640	-132	1967	4,976	227
	Dry	1975	4,995	273	1954	4,862	173	1954	4,866	176
	Driest	1965	5,087	53	1965	5,083	40	1965	5,076	34

Table 25 illustrates the way in which the representative years can change just with the way in which an alternative is formulated. In table 4.36, the wet year is represented by 1985 for two of the alternative target levels, while the third alternative target level is represented by 1959. The dry year is similarly represented by 1954 for two of the alternative target levels, while the dry year is represented by 1975 for the third. The normal year is represented by a different year for each of the three alternative target levels. The years were previously shown in table 20, but the reason behind the difference is shown in table 25. Recall that the representative year is the one with the median EBS in each category. Because the number of years in each category changes among the alternatives (and target levels for alternatives with multiple formulations), as shown in table 20**,** the medians in the categories also change, which may further cause a change in average EC between the representative years even though the rankings of the years may not change. In other words, a possible factor in the differences is the number of years in the data base used to calculate the individual average EC.

The comparison of the EC of the various formulations of the Taiban Variable Alternative in table 25 also shows differences among the three that are more likely an actual factor in the operations than any artifact of the analysis, as described in the preceding paragraph. In the normal year, the average EC increases as the target flow decreases. This is the expected result, because the EC is inversely related to the flow at the Artesia gage. As the target flow and, thus, the flow itself increases, there is increasingly greater dilution of saline inflows in the lower reach of the river between Sumner Dam and Brantley Reservoir. However, the interrelationship among the EC of the three alternative target levels changes from the normal year when the dry and wet year are considered. In the dry year, the highest average EC is shown in the wet year. This is likely due to the fact that the target is so high that the available water is exhausted and no flow can be provided at which time there would be no dilution of the saline inflows for part of the year. The supply would be more adequate to meet the lower target flows than would be the case with the highest target flow. In the wet year, the highest average EC at about 5,300 μS/cm is shown for the intermediate target flow, while the EC of highest and lowest target flows are if around 4,600 μS/cm. The difference may be because of the difference in representative years, a difference in spills, or a combination of the 2 factors. The driest year in table 25 eliminates the effect of changing years, but also shows the EC of the intermediate flow target to be slightly greater than that of either the highest or lowest flow targets. However, the average EC for all three flow targets is within differences due to rounding, i.e. 7,200 μS/cm, and should be considered essentially equal.

Within each of the target flow levels, the projected average EC is lowest in the wet year (table 25). The EC in the normal, dry, and driest year is progressively higher within each set of target flow results.

The greatest difference in EC at the Artesia gauge between any of the three target flow levels of the Taiban Variable Alternative and that of the No Action Alternative is a decrease during the normal year at the highest flow target level (table 25). During the same year-type (normal) at Artesia, there is a somewhat smaller decrease in EC at the intermediate target flow level, but an increase in EC at the lowest target level. In all of the other year-types, there is projected to be an increase in EC at all of the target flow levels with the exception of a projected decrease in the wet year at the highest target flow (table 25). Interestingly, the largest average annual increase also involves the highest target flow; that increase occurs during the dry year. For all of the target flow levels, the increase in EC over that of the No Action alternative is larger in the dry year than the one for the driest year. This result may reflect a condition in the driest year when little can be done differently no matter what the intended operation may be – there is just no water available to provide any flexibility.

The results of the EC comparison downstream from Brantley Dam show the same pattern in the changes relative to the No Action Alternative as were shown at the Artesia gauge. This reflects the fact that the basis for the estimated EC at the site downstream from Brantley Dam is the EC at the Artesia gauge. The only thing to note is that the average EC downstream from Brantley Dam is lower than the one at the Artesia gauge. The overall differences in the EC at the two sites are larger during the dryer years than in the wetter years. In the wet year, the difference in the average EC between the Artesia gauge and Brantley Dam is about 600 μS/cm, but the same difference is over 2,000 μS/cm under dryer conditions.

Acme Constant Alternative

Table 26 presents the projected average EC for the Acme Constant Alternative at the two sites for each of the year-types. In the case of the Acme Constant Alternative, the lowest average EC (5,200 μS/cm at the Artesia gauge) occurs in the normal year. The EC in the wet and dry years is approximately the same (5,700 μS/cm) and about

500μS/cm higher than in the normal year. In the driest year, the projected average EC would be about 1,000 μS/cm higher yet. The EC downstream from Brantley Dam is much lower, and the differences among the EC of the different year-types are damped (table 26).

Table 26. Comparison of the No Action Alternative (present) and the Acme Constant Alternative

Site	Year	Year type	EC (μS/cm)	
			Average	Difference
Artesia	1951	Wet	5,657	713
	1960	Normal	5,199	-933
	1990	Dry	5,703	-526
	1965	Driest	6,659	-397
Brantley Dam	1951	Wet	4,577	222
	1960	Normal	4,464	-294
	1990	Dry	4,555	-183
	1965	Driest	4,901	-143

In three of the four year types, the EC of the Acme Constant Alternative is less than the respective EC of the No Action alternative. The lone increase in EC in comparison to the No Action Alternative is projected to occur in the wet year. Decreases in EC relative to the No Action Alternative are projected in the normal, dry, and driest years, with the largest decrease in the normal year and the smallest in the driest year (table 26).

Acme Variable Alternative

Table 27 presents the average EC of the Acme Variable Alternative for each of the four year types. The highest average EC of the four year types is shown in the driest year, which is no surprise. However, the lowest average annual EC of the four years is shown for the dry year. The average EC in the dry year is nearly 1,000 μS/cm lower than that of the normal year. The average EC of the wet and normal years are intermediate between those of the preceding year types, but despite the 1,000 μS/cm noted above, each is nearer the low average EC of the dry year rather than the high EC of the driest year.

All of the annual average ECs under the Acme Variable Alternative are negative (table 27), indicating a decrease in EC relative to the No Action Alternative. The greatest difference is shown for the dry year, and the smallest difference is for the driest year. To reinforce how inordinately low the dry year EC is, the difference from the No Action Alternative dry EC is by far the largest of the three year types at 1,606 μS/cm, which is more than twice as large a decrease as the next largest, which is shown in the normal

Table 27. Comparison of the No Action Alternative (present) and the Acme Variable Alternative

Site	Year	Year type	EC (µS/cm)	
			Average	Difference
Artesia	1943	Wet	4,900	-92
	1960	Normal	5,445	-782
	1949	Dry	4,591	-1,606
	1965	Driest	7,021	-83
Brantley Dam	1943	Wet	4,320	-39
	1960	Normal	4,531	-237
	1949	Dry	4,250	-486
	1965	Driest	5,020	-27

year. The differences from the EC of the No Action Alternative in the wet year and the driest year are comparatively small, both are less than 100 µS/cm.

The average annual ECs downstream from Brantley Dam are all in the range of EC that would show a reduction relative to that at the Artesia gage. The rankings of the annual average EC and the differences for the year-types are the same as those at the Artesia gage.

Critical Habitat Alternative

Table 28 presents the annual average EC of the four year types as projected for the Critical Habitat Alternative. The average annual EC rank inversely to the way the year types rank in terms of water supply, i.e. the lowest EC is in the wet year, while the average annual EC increases as water supply decreases. The lowest average annual EC is much lower than any of the other three in table 28.

The differences in EC from those of the No Action Alternative do not quite follow the pattern of the average EC. The smallest EC difference from that of the No Action Alternative occurs in the driest year. The sequence of increasing differences with decreasing water supply follows for the other three years, i.e. wet through dry (table 28). The differences from the No Action alternative show the same pattern as those at the Artesia gage.

Table 28. Comparison of the No Action Alternative (present) and the Critical Habitat Alternative

Site	Year	Year type	EC (µS/cm)	
			Average	Difference
Artesia	1950	Wet	5,096	241
	1967	Normal	6,723	617
	1975	Dry	7,060	985
	1965	Driest	7,209	134
Brantley Dam	1950	Wet	4,408	64
	1967	Normal	4,958	210
	1975	Dry	5,015	294
	1965	Driest	5,083	40

Actions Common to All Alternatives

Two sets of actions are common to all alternatives: (1) water offset options to address depletions and (2) additional water acquisition options to augment river flows. The impacts for the offset options are summarized in table 29. The augmentation options are essentially a subset of the offset options that are restricted to a location upstream from the critical habitat.

The analysis of the various offset options includes those that would be most effective and easy to implement in a timely manner. The first set of offset options relates to water acquisition, either by purchase or lease. From a practical perspective, the only difference between purchase and lease is that one is permanent and one is temporary. In terms of the effect on water quality, there is no other difference between the two activities.

The relationship between EC and flow is inverse. In other words, greater flow in the river provides greater dilution of diffuse saline inflows resulting in lower EC. The water acquisition offset options would leave water in the river rather than it being diverted for irrigation. The EC values presented in the preceding tables in can be adjusted to illustrate the EC if a set of offset such options are superimposed on the depleted flows evaluated previously. In the years that represent the year-types shown in those impact tables, the total offset can be supplied by the set of water acquisition options if the total amount of water that can be purchased or leased were available. On the possibly unwarranted assumption that this is true, resulting adjusted EC computed based on the correlation between flow rate and EC at the Artesia gage is presented in table 30. The problem is that in dry years, water may be short everywhere and acquired water rights

Table 29. Water offset options impacts on water quality

Option	Option category	Impact intensity (negligible, minor, moderate, or major)	Impact location (localized, or general)	Impact duration (short-term, long-term)	Impact summary
A	Onfarm conservation	Depends on the source of the water: FSID or CID – negligible, PVACD – moderate benefit	Sumner Dam to Roswell, negligible; with PVACD, moderate between Roswell and Brantley Res.	For the duration of the practices	Water from FSID would be essentially the same quality as water from Sumner Dam. In general, savings on CID would be used on CID and not enter the river. Water from PVACD, assumed from the artesian aquifer, would be slightly lower in EC (~4000 µS/cm) than the river near Artesia (~7000 µS/cm) and would have a moderate benefit to the river.
B	Drain construction/ renovation	Negligible	Sumner Dam to Brantley Res.	Indefinitely (as long as the drains remain)	Most of the time, the Pecos River consists of ground-water accretions. The EC of the river and its alluvial ground water in any given reach are essentially the same. Adding more to a reach would change nothing.
C	Hernandez Idea/Plan	Negligible	The water quality throughout the reach does not change greatly.	N/A	As long as the pump site remains north of Highway 380, there would be no effect on water quality if water from the lower end of the reach is returned.
D	Water right purchases	The effects are essentially the same as option A.	Depends on the location of the purchases	Long-term	See option A.
E	Water right leases	The effects are essentially the same as option A.	Depends on the location of the leases	Duration of the lease	See option A.
F	Riparian vegetation control	Minor to moderate improvement in ground- water quality	Localized	Short-term	Because of the salt concentrating nature of salt cedar, its removal could improve water quality. Removal of other high water-use vegetation could yield a minor decrease in the concentrating effects of evapotranspiration.
G	Acequia improvements	Negligible	From Puerto de Luna to Sumner Reservoir	Long-term	This is another form of water conservation. The water quality between Puerto de Luna and Sumner Lake does not change. Adding similar quality water would have no effect.
H	Pump supplemental wells	Negligible	Localized	Short-term	This would be an expansion of an existing use within the CID. Any effects would be those of the depletions themselves.
I	Import Canadian River water	Major	General	For the duration of the diversion	The EC of the water in the vicinity of Puerto de Luna is about 2,500 µS/cm. The median EC of the Canadian

Table 29. Water offset options impacts on water quality

Option	Option category	Impact intensity (negligible, minor, moderate, or major)	Impact location (localized, or general)	Impact duration (short-term, long-term)	Impact summary
					River downstream from Conchas Dam has been 7700 μS/cm during the last decade (1992-2003).
J	Reservoir entitlement storage	Negligible	General	Short-term	There could be a slight reduction in EC due to the reduction in the concentrating effect of evaporation.
K	Desalination	Negligible to minor	Localized	For the duration of any discharge	If the treated water is discharged to surface waters for delivery, the EC of the receiving stream could be raised or lowered depending on the volume and EC of the discharge relative to the EC and flow. The goal is to meet the irrigation standard, but there is none for EC (or TDS) in New Mexico.
L	Change cropping patterns	Negligible	Localized	Short-term	The analysis focused on CID. There may be no change or there may be reduced deliveries to Brantley Reservoir. In either case, there should be no measurable change in EC in the Pecos River.
M	Lower ground-water levels	Moderate	Localized	Long-term	Some of the seepage from the McMillan delta is highly saline. Lowering the water table would reduce seepage. If this seepage were reduced, under the assumption that areas with shallow ground water have higher EC, EC could be lowered in the vicinity of the seeps.
N	Range and watershed management	Negligible	Localized	For the duration of the activity	Additional base inflow would contribute additional ground water to the river. As noted before, the EC of the various river reaches generally reflects the EC of the adjacent ground water. This should not change.
O	Cloud seeding	Minor	Localized	Short-term	Effects would be confined to storm events. The increase in frequency or duration of storms could cause brief dilution of EC. The main effects would be increased erosion and TSS.
P	Ground-water recharge/ conjunctive use	See Q	Localized	For the duration of the activity	The WOOG team couldn't envision the option costing any less pumping water back into the ground (as opposed to just retiring pumpers and leaving it in the ground); so it became

Table 29. Water offset options impacts on water quality

Option	Option category	Impact intensity (negligible, minor, moderate, or major)	Impact location (localized, or general)	Impact duration (short-term, long-term)	Impact summary
					equivalent to Option Q.
Q	Well field development	Minor to moderate	Localized	For the duration of the activity	Seven Rivers: moderate decrease in EC when pumped water discharged to river. Buffalo Valley: minor decrease to moderate increase depending on source of water
R	Rio Hondo flood control	Minor	Localized	Short-term	Not an offset option; being built by the Corps.
S	Additional metering	Moderate	Localized	Long-term	Another form of water conservation that would focus on the area around Roswell. Should improve water quality somewhat.
T	Evaporation suppression	Negligible to major	Localized	Short-term	Evaporation-suppression would reduce EC slightly in the reservoirs. Toxicity of suppressants is unknown; could possibly have severe effects on biota.
U	Fort Sumner area gravel pit pumping	Negligible	Localized	Short-term	Ground water, which feeds the gravel pit, in the vicinity of the FSID is similar in EC to the river; adding ground water to the river in the area of the pit would have no noticeable effect.
V	Kaiser Channel lining	Minor	Localized	Short-term	Most of the recharge occurs from block releases and is apparently of good quality. The elimination of the better quality recharge could allow for poorer quality of ground water in the delta, but would probably have little effect on the river.
W	Import Salt Basin or Capitan Reef water	Minor	Localized	Short-term	According to the New Mexico Oil & Gas Commission's 2004 report, the water in the Salt Basin in of high quality. Importation of Salt Basin water would improve water quality to an undefined degree.
X	Flash distillation (desalination) cogeneration power plant	Minor	Localized	Long-term	Similar to Option K from a water quality perspective. Total volume of water is relatively small and could not greatly affect the quality of the Pecos River.
Y	Treat oil field waste water	Minor	Localized	For the duration of the activity	The option envisions treating oil field production waste to either of 2 levels of TDS: 5,000 mg/L – would degrade the river slightly

Table 29. Water offset options impacts on water quality

Option	Option category	Impact intensity (negligible, minor, moderate, or major)	Impact location (localized, or general)	Impact duration (short-term, long-term)	Impact summary
					500 mg/L – would improve the river slightly
Z	Renegotiate compact-forbearance	Negligible	General	Long-term	Similar in effect to option A, although the lands to be retired are downstream from the CID.

mg/L = milligrams per liter

may not yield the amount of offset water needed. The data presented in table 30 ignore that possibility and assume that the water needed up to the limit will be available.

Table 30. Difference in EC from that at the near Artesia gage from addition of offset water to the bypass flows shown in tables 23-28 for each of the individual alternatives

Alternative	Wet Year	Normal Year	Dry Year	Driest Year - 1965
No Action	-57	-420	-301	0
No Action w/6week	-44	-1	-365	0
Taiban Constant	-42	-840	-88	-29
Taiban Variable (40 cfs)	-42	-840	-1235	-441
Taiban Variable (45 cfs)	0	-81	-1113	-447
Taiban Variable (55 cfs)	-54	-31	-1257	-631
Acme Constant	-335	-136	-372	-230
Acme Variable	-40	-165	-452	-29
Critical Habitat	0	-23	-1290	0

The only time a value in table 30 is not negative is when no offset is needed. The condition is projected to occur in the wet year with the Critical Habitat and the Taiban Variable at the intermediate target flow alternatives. Interestingly, there is also no projected offset needed in the driest year for the No Action, its modification with the block release restriction, and, once again, the Critical Habitat alternative. In these cases, there would be no change relative to what was earlier shown for the individual alternatives in previous tables.

In general the largest projected decreases in EC in table 30 occur during the dry year. The No Action Alternative, for which the largest decrease is in the normal year, is the lone exception to this generalization. The decrease at the Artesia gauge shown in table

30 for the No Action Alternative is slightly larger than the increase that was shown in table 22, i.e. 390 µS/cm. The net effect would be essentially no change in EC in the representative normal year. Alternatively, in the wet and dry years, EC would be greater under the No Action Alternative than under the pre-1991 baseline; the offset option decreases would not be enough to completely offset the previously shown increases.

As another example, EC under the No Action Alternative with the block-release restriction is much lower than under No Action Alternative. Table 31 indicates that the offset options would cause a further decease of 1 µS/cm or essentially no additional change. It should be noted that the EC data on which the relationships are based were rounded to the nearest 10 µS/cm. Furthermore the regressions on which the EC projections are based have an even greater error. Consequently, changes of less than100µS/cm (or in some cases more than that) should be considered no change at all.

Table 31. Comparison of adjusted and unadjusted (previously shown in tables 23-28) for the EC (µS/cm) at the near Artesia gage

Alternative	Adjusted		Unadjusted	
	Normal year	Dry year	Normal year	Dry year
No Action	6,101	6,032	6,280	6,160
No Action with 6-week	2,930	6,702	2,930	6,858
Taiban Constant	6,479	6,345	6,771	6,349
Taiban Variable (40 cfs)	6,479	5,823	6,770	6,376
Taiban Variable (45 cfs)	5,823	5,865	5,861	6,363
Taiban Variable (55 cfs)	5,112	6,404	5,126	7,004
Acme Constant	5,135	5,499	5,199	5,703
Acme Variable	5,368	4,383	5,445	4,591
Critical Habitat	6,708	6,445	6,723	7,060

To put EC after application of the offset options into better perspective, the EC for the normal and dry years for each of the alternatives are shown in table 31 along with those after the offset options are included. The apparent inconsistencies related to the selection of years in comparison with the No Action Alternative that were discussed earlier are still shown in the adjusted EC data, but the decreases relative to the bypass flows alone are apparent. In all cases, the EC of the alternatives after adjusting for the additional flow due to the offset options is lower than that without the adjustment. This result indicates that the offsets, in addition to ameliorating the effects of depletions, ameliorate the effects on EC as well.

In addition to the offset options, there are additional water acquisition (AWA) options. The distinction between the two sets of options is that the purpose of the AWA options is to augment the flow to meet targets through the critical habitat. As a consequence, the AWA options must have a means of delivering water well upstream from the CID. In many cases, the AWA options are similar in their effects to the offset options shown above in table 29. For comparison, the effects of the AWA options are summarized in Table 32.

Table 32 Additional water acquisition option impacts on water quality

Option	Option category	Impact intensity (negligible, minor, moderate, or major)	Impact location (localized or general)	Impact duration (short-term, long-term)	Impact summary
A	Water right purchase	Depends on the source of the water: FSID or CID – negligible, PVACD – moderate benefit	Localized - Sumner Dam to Roswell, negligible; with PVACD, moderate between Roswell and Brantley Reservoir.	Long-term	See option D of preceding table.
B	Water right lease	Same as A	Same as A	Short-term – for the duration of the lease	See option E of preceding table
C	On-farm conservation	Same as A	Same as A	Short-term – for the duration of the practices	See option A of preceding table
D	Cropping pattern changes	Same as A	Same as A	Short-term – for the duration of the practices	See option L of preceding table – another form of conservation
E	Riparian vegetation control (upstream of Upper Critical Habitat)	Minor to moderate improvement in ground-water quality	Localized	Short-term – periodic with return of vegetation	See option F of preceding table
F	Import Canadian River water	Major	General	For the duration of the diversion	See option I of preceding table
G	Range and watershed management	Negligible	Localized	For the duration of the activity	See option N of preceding table
H	Evaporation suppression	Negligible to major	Localized	Short-term	See option T of preceding table
I	Fort Sumner area gravel pit pumping	Negligible	Localized	Short-term	See option U of preceding table
J	Fort Sumner well field	Negligible	Localized	Short-term	Ground water in the vicinity of Ft. Sumner is similar in quality to the river; adding the ground water to the river would have no effect on EC

Effects on Ground-Water EC

The differences in EC as forecast for the ground-water recharge are shown on figure 26. The figure shows the minimum, median, and maximum EC for each for the alternatives as a stacked bar graph. The median EC is the focus of the impacts analysis. For the most part, the median EC of the alternatives appear to rest on the 9,000 µS/cm gridline (figure 26). The EC pre-1991 baseline is well below that grid line at 8,700 µS/cm. The increase in EC of all of the alternatives relative to the baseline is consistent with the results of the river analysis presented previously.

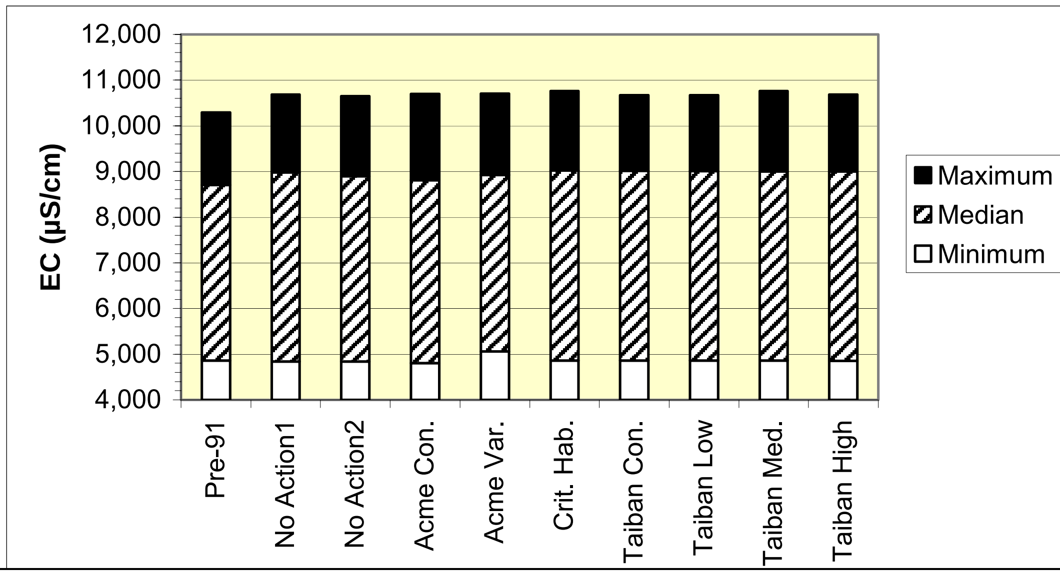


Figure 26: Minimum, median, and maximum EC (µS/cm) of the pre-1991 baseline, the No Action Alternative, and each of the action alternatives

Of the two formulations of the No Action Alternative, the No Action Alternative with the 6-week restriction on block releases (No Action 2 on figure 26) would each result in a slightly smaller increase in the recharge to ground water within the CID in comparison to the pre-1991 baseline than the No Action Alternative without the restriction. The only other alternatives that have a somewhat lower projected median EC than the No Action Alternative are the Acme Constant and the Acme Variable Alternative. The Acme Constant Alternative would have the lesser increase of the two Acme alternatives. The actual increases in the EC of the ground water relative to that of the recharge are assumed to be proportional to what has occurred historically.

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ATTACHMENT 1

SUMMARY WATER QUALITY DATA TABLES FOR STATIONS ON THE MAINSTEM OF THE PECOS RIVER

Table 1–1. USGS 08382650 Pecos River above Santa Rosa Lake, NM (1988-2001)									
Pollutant	Standard	Minimum	25th Pctile	Median	75th Pctile	Maximum	No. of Obs.	No. < D.L.[1]	No. > Std.
Temperature (°C)	32.2	3	11.5	15	19.5	28.7	55	N/A	0
Spec. Cond. (µS/cm)	None	192	390	791	895	4,350	53	N/A	N/A
Diss. Oxygen (mg/L)	None	6.0	8.0	8.8	9.8	12.8	52	N/A	N/A
pH, Standard Units	6.6-9	7.4	7.9	8.1	8.2	8.6	55	N/A	0
Calcium (mg/L as Ca)	None	34	66	140	158.5	200	50	N/A	N/A
Magnesium (mg/L as Mg)	None	3.8	8.3	17.4	19.1	25.9	50	N/A	N/A
Sodium (mg/L as Na)	None	4.7	8.8	11.0	11.0	20.5	50	N/A	N/A
Potassium (mg/L as K)	None	0.8	1.2	1.3	1.5	3.6	50	N/A	N/A
Chloride (mg/L as Cl)	400	0.9	4.7	6	7	12	49	N/A	0
Sulfate (mg/L as SO_4)	2,000	31	100	290	340	470	49	N/A	0
Aluminum (µg/L as Al)	87	2	< 10	10	30	7,400	29	7	5
Arsenic (µg/L as As)	150	< 1.0	< 1.0	1.00	< 2.0	2.00	23	17	0
Beryllium (µg/L as Be)	5.3	0.03	< 0.50	< 0.50	< 0.50	< 1.00	21	20	0
Boron (µg/L as B)	750	11	20	33	40	60	21	0	0
Cadmium (µg/L as Cd)	H[2]	< 0.04	< 1.00	< 1.00	< 1.00	< 1.00	23	23	0
Chromium (µg/L as Cr)	H	< 0.8	< 0.8	< 1.0	< 1.0	2.0	23	19	0
Cobalt (µg/L as Co)	50	0.1	< 1.00	< 3.00	< 3.00	< 3.00	29	25	0
Copper (µg/L as Cu)	H	< 1.0	1.0	1.5	2.0	6.0	23	2	0
Lead (µg/L as Pb)	H	< 0.08	< 1.00	< 1.00	1.0	2.0	23	16	0
Nickel (µg/L as Ni)	H	< 0.06	< 1.00	< 1.00	1.03	5.00	29	14	0
Selenium (µg/L as Se)	5	< 1.0	< 1.0	< 1.0	1.0	< 2.4	31	23	0
Silver (µg/L as Ag)	H	< 1.0	< 1.0	< 1.0	< 1.0	8.0	29	28	0
Vanadium (µg/L as V)	100	< 6.0	< 6.0	< 6.0	< 6.0	8.0	20	19	0
Zinc (µg/L as Zn)	H	< 1	2	4	9	19	23	4	0
Fecal Coliform .7 µm -mf (Col./100 mL)	400	0	< 1	8	110	> 6000	29	23	6
TDS (mg/L)	3,000	140	304	580	637	782	28	N/A	0

[1] D.L. - Detection Limit for trace elements (limit indicated by < in table). N/A - not applicable.
[2] H - indicates that the standard is based on water hardness and varies from sample to sample

Table 1–2. USGS 08383000 Pecos River at Santa Rosa, NM (downstream from the lake: 1988-98)									
Pollutant	Standard	Minimum	25th Pctile	Median	75th Pctile	Maximum	No. of Obs.	No. < D.L.[1]	No. > Std.
Temperature (°C)	32.2	4	9.5	15	19	31	45	N/A	0
Spec. Cond. (FµS/cm)	None	340	1855	2470	2635	3710	43	N/A	N/A
Diss. Oxygen (mg/L)	None	5.7	7.9	8.7	9.8	12	42	N/A	N/A
pH, Standard Units	6.6-9	7	7.7	7.8	8.1	8.4	44	N/A	0
Calcium (mg/L as Ca)	None	52	440	535	550	610	28	N/A	N/A
Magnesium (mg/L as Mg)	None	6.2	53	66	69	82	28	N/A	N/A
Sodium (mg/L as Na)	None	6.8	42.5	50	54	58	28	N/A	N/A
Potassium (mg/L as K)	None	1.6	2.0	2.2	2.3	3.1	28	N/A	N/A
Chloride (mg/L as Cl)	400	4.8	53	60	65	73	28	N/A	0
Sulfate (mg/L as SO_4)	2,000	67	1,200	1,450	1,500	1,800	28	N/A	0
Aluminum (µg/L as Al)	750	8	8	10	12	18	6	0	0
Arsenic (µg/L as As)	150	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	6	6	0
Beryllium (µg/L as Be)	5.3	< 2.00	< 2.00	< 2.00	< 2.00	< 2.00	6	6	0
Boron (µg/L as B)	750	30	88	100	110	120	28	0	0
Cadmium (µg/L as Cd)	H[2]	< 1.00	< 2.00	< 2.00	< 2.00	< 2.00	6	6	0
Chromium (µg/L as Cr)	H	< 1.00	< 2.00	< 2.00	< 2.00	< 2.00	6	6	0
Cobalt (µg/L as Co)	50	< 1.00	< 2.00	< 2.00	< 2.00	< 2.00	6	6	0
Copper (µg/L as Cu)	H	1.4	3.1	5.3	5.9	6.0	6	0	N/A[3]
Lead (µg/L as Pb)	H	< 1.00	< 2.00	< 2.00	< 2.00	< 2.00	6	6	0
Mercury (µg/L as Hg)	0.012	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	6	6	0
Nickel (µg/L as Ni)	H	1.22	4.43	5.25	6.62	16.00	6	0	N/A[3]
Selenium (µg/L as Se)	5	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	6	6	0
Silver (µg/L as Ag)	H	< 1.00	< 2.00	< 2.00	< 2.00	< 2.00	6	6	0
Zinc (µg/L as Zn)	H	2	5	6	8	10	6	0	N/A[3]

[1] D.L. - Detection Limit for trace elements (limit indicated by < in table). N/A - not applicable.
[2] H - indicates that the standard is based on water hardness and varies from sample to sample.
[3] N/A - Not available - hardness data do not coincide with trace element data; comparison not possible.

Table 1–3. USGS 08383500 Pecos River near Puerto De Luna, NM (1988-2001)										
Pollutant	Standard	Minimum	25th Pctile	Median	75th Pctile	Maximum	No. of Obs.	No. < D.L.[1]	No. > Std.
Temperature (°C)	32.2	0.5	9.5	16.5	24.0	29.0	51	N/A	0
Spec. Cond. (µS/cm)	None	297	1,680	2,740	2,910	3,350	51	N/A	N/A
Diss. Oxygen (mg/L)	None	6.4	7.9	9.4	10.7	15.1	50	N/A	N/A
pH, Standard Units	6.6-9	7.3	8.0	8.1	8.2	8.8	49	N/A	0
Calcium (mg/L as Ca)	None	69	393	545	560	610	50	N/A	N/A
Magnesium (mg/L as Mg)	None	8	50	68	71	90	51	N/A	N/A
Sodium (mg/L as Na)	None	11	69	99	100	120	51	N/A	N/A
Potassium (mg/L as K)	None	1.4	2.0	2.2	2.4	3.6	51	N/A	N/A
Chloride (mg/L as Cl)	400	6	99	140	146	180	51	N/A	0
Sulfate (mg/L as SO_4)	2,000	110	1,050	1,500	1,600	1,800	51	N/A	0
Aluminum (µg/L as Al)	87	< 1	2	6	7	19	18	5	0
Arsenic (µg/L as As)	150	< 1.0	< 1.0	< 1.0	< 2.0	3	33	27	0
Beryllium (µg/L as Be)	150	< 0.06	< 1.00	< 1.50	< 2.00	< 2.00	18	18	0
Boron (µg/L as B)	750	30	85	110	120	150	51	0	0
Cadmium (µg/L as Cd)	H[2]	< 0.04	< 1.00	< 1.00	< 2.00	6.00	33	28	0
Chromium (µg/L as Cr)	H	< 0.8	< 1.0	1.1	2.0	5.0	33	22	0
Cobalt (µg/L as Co)	50	0.11	1.06	< 1.50	< 2.00	< 2.00	18	14	0
Copper (µg/L as Cu)	H	< 1.0	1.0	3.0	5.2	14.0	33	5	0
Lead (µg/L as Pb)	H	0.05	< 1.00	< 1.00	< 2.00	1.00	33	30	0
Mercury (µg/L as Hg)	5	< 0.1	< 0.1	< 0.1	0.1	0.9	13	9	4
Nickel (µg/L as Ni)	H	< 0.10	1.65	3.82	5.89	15.00	18	4	0
Selenium (µg/L as Se)	5	< 1.0	< 1.0	< 1.0	< 2.0	4.9	33	32	0
Silver (µg/L as Ag)	H	< 1.0	< 1.0	< 2.0	< 2.0	< 2.0	18	18	0
Zinc (µg/L as Zn)	H	< 1	4	6	< 10	36	33	9	0
Fecal Coliform .7 µm -mf (Col./100 mL)	5	< 1	< 3	< 10	185	5,800	31	12	3
TDS (mg/L)	3,000	271	967	2,442	2,542	2,574	50	N/A	0

[1] D.L. - Detection Limit for trace elements (limit indicated by < in table). N/A - not applicable.
[2] H - indicates that the standard is based on water hardness and varies from sample to sample

Table 1–4. USGS 08386000 Pecos River near Acme, NM (1988-98)

Pollutant	Standard	Minimum	25th Pctile	Median	75th Pctile	Maximum	No. of Obs.	No. < D.L.[1]	No. > Std.
Temperature (°C)	32.2	3.0	6.3	15.5	20.6	29.0	41	N/A	0
Spec. Cond. (µS/cm)	N/A	875	1,880	2,680	3,748	5,500	41	N/A	N/A
Diss. Oxygen (mg/L)	N/A	5.3	8.6	9.5	11.2	13.0	38	N/A	N/A
pH, Standard Units	6.6-9	7.3	8.0	8.1	8.2	8.3	38	N/A	0
Calcium (mg/L as Ca)	None	140	280	370	453	580	41	N/A	N/A
Magnesium (mg/L as Mg)	None	22	50	76	93	140	41	N/A	N/A
Sodium (mg/L as Na)	None	30	92	160	320	560	41	N/A	N/A
Potassium (mg/L as K)	None	2.3	3.0	3.6	4.2	5.6	40	N/A	N/A
Chloride (mg/L as Cl)	4,000	27	115	200	425	860	41	N/A	0
Sulfate (mg/L as SO_4)	2,500	370	885	1,200	1,393	1,900	41	N/A	0
Aluminum (µg/L as Al)	87	5	6	8	107	293	7	0	2
Arsenic (µg/L as As)	150	< 1.0	< 1.0	< 1.0	1	2	22	13	0
Beryllium (µg/L as Be)	150	< 1.00	< 1.00	< 2.00	< 2.00	< 2.00	7	7	0
Cadmium (µg/L as Cd)	H[2]	< 1.00	< 1.00	< 1.00	< 1.00	4.00	22	21	0
Chromium (µg/L as Cr)	H	< 1.0	< 1.0	1.0	2.0	3.0	22	14	0
Cobalt (µg/L as Co)	50	< 1.00	< 1.00	< 2.00	< 2.00	< 2.00	7	6	0
Copper (µg/L as Cu)	H	< 1.0	1.0	1.0	3.3	14.0	22	5	0
Lead (µg/L as Pb)	H	< 1.00	< 1.00	< 1.00	< 2.00	< 5.00	22	21	0
Mercury (µg/L as Hg)	0.012	< 0.1	< 0.1	< 0.1	0.1	0.4	14	10	4
Nickel (µg/L as Ni)	H	2.1	3.5	4.0	10.0	12.0	7	0	0
Selenium (µg/L as Se)	5	< 1.0	< 1.0	< 1.0	< 1.0	1.0	22	19	0
Silver (µg/L as Ag)	H	< 1.0	< 1.0	< 2.0	< 2.0	< 2.0	7	7	0
Zinc (µg/L as Zn)	H	2	4	< 10	10	11	22	8	0
Fecal Coliform .7 µm -mf (Col./100 mL)	400	< 1	< 1	< 3	< 10	> 600	11	8	0
TDS (mg/L)	8,000	656	1,336	2,091	2,589	4,014	37	N/A	0

[1] D.L. - Detection Limit for trace elements (limit indicated by < in table). N/A - not applicable.
[2] H - indicates that the standard is based on water hardness and varies from sample to sample

Table 1–5. USGS 08396500 Pecos River near Artesia, NM (1988-2001)									
Pollutant	Standard	Minimum	25th Pctile	Median	75th Pctile	Maximum	No. of Obs.	No. < D.L.[1]	No. > Std.
Temperature (°C)	32.2	0.5	10.6	17.5	22.0	29.0	54	N/A	0
Spec. Cond. (µS/cm)	None	1,390	3,863	7,100	8,335	13,900	52	N/A	N/A
Diss. Oxygen (mg/L)	None	6.2	8.0	10.1	11.0	14.8	50	N/A	N/A
pH, Standard Units	6.6-9	7.1	8.0	8.1	8.3	8.6	49	N/A	0
Calcium (mg/L as Ca)	None	200	380	510	560	700	52	N/A	N/A
Magnesium (mg/L as Mg)	None	32	99	170	190	290	52	N/A	N/A
Sodium (mg/L as Na)	None	55	415	910	1,100	2,000	51	N/A	N/A
Potassium (mg/L as K)	None	1.7	4.7	6.4	8.5	19.0	52	N/A	N/A
Chloride (mg/L as Cl)	6,000	82	680	1,600	1,890	4,000	51	N/A	0
Sulfate (mg/L as SO_4)	3,000	73	1,100	1,625	1,800	2,500	52	N/A	0
Aluminum (µg/L as Al)	87	< 1	< 4	12	0	0	19	9	0
Arsenic (µg/L as As)	150	< 1.0	< 1.0	1.4	2.0	3.0	34	14	0
Beryllium (µg/L as Be)	150	< 0.06	< 1.00	< 3.00	< 4.00	< 4.00	19	19	0
Boron (µg/L as B)	750	76	225	355	435	900	52	0	1
Cadmium (µg/L as Cd)	H[2]	< 0.10	< 1.00	< 1.00	< 4.00	6.0	34	30	0
Chromium (µg/L as Cr)	H	< 0.8	< 1.0	2.0	< 4.0	< 10.0	33	21	0
Cobalt (µg/L as Co)	50	0.75	< 1.00	< 3.00	< 4.00	4.58	19	14	0
Copper (µg/L as Cu)	H	< 1.0	1.0	< 4.0	6.8	28.0	34	2	0
Lead (µg/L as Pb)	H	0.11	< 1.00	< 1.00	< 4.00	8.0	34	29	0
Mercury (µg/L as Hg)	5	< 0.1	< 0.1	< 0.1	0.1	0.5	14	9	5
Nickel (µg/L as Ni)	H	< 0.2	3.3	5.0	7.4	21.0	19	3	0
Selenium (µg/L as Se)	5	< 1.0	1.7	1.4	< 2.4	3.7	34	11	0
Silver (µg/L as Ag)	H	< 1.0	< 1.0	< 3.0	< 4.0	< 4.0	19	19	0
Zinc (µg/L as Zn)	H	< 4	6	< 10	12	27	34	7	0
TDS (mg/L)	14,000	762	2,440	4,478	5,080	8,874	49	N/A	0

[1] D.L. - Detection Limit for trace elements (limit indicated by < in table). N/A - not applicable.
[2] H - indicates that the standard is based on water hardness and varies from sample to sample

Table 1–6. USGS 08401500 Pecos River below Brantley Dam near Carlsbad, NM (1988-1997)								
Pollutant	Standard	Minimum	25th Pctile	Median	75th Pctile	Maximum	No. of Obs.	No. > Std.
Temperature (°C)	32.2	3.5	10.5	16.0	23.0	28.5	45	0
Spec. Cond. (µS/cm)	None	1,490	3,020	4,430	6,405	8,100	42	N/A
Diss. Oxygen (mg/L)	None	6.6	8.6	9.9	11.2	13.5	43	N/A
pH, Standard Units	6.6-9	7.1	7.8	8.0	8.2	8.7	43	0
Calcium (mg/L as Ca)	None	200	345	425	470	560	36	N/A
Magnesium (mg/L as Mg)	None	38	81	110	153	200	36	N/A
Sodium (mg/L as Na)	None	93	318	475	745	1,000	36	N/A
Potassium (mg/L as K)	None	3.0	5.0	6.1	6.8	11.0	36	N/A
Chloride (mg/L as Cl)	None	130	520	750	1,250	1,900	35	N/A
Sulfate (mg/L as SO_4)	None	580	1,100	1,200	1,500	2,100	35	N/A
Boron (µg/L as B)	750	90	189	245	313	440	36	0

Table 1–7 USGS 08405200 Pecos River below Dark Canyon at Carlsbad, NM (1988-2001)								
Pollutant	Standard	Minimum	25th Pctile	Median	75th Pctile	Maximum	No. of Obs.	No. > Std.
Temperature (°C)	34	3.0	14.0	21.0	26.5	32.0	79	0
Spec. Cond. (µS/cm)	None	1,870	3,133	3,735	4,270	5,500	76	N/A
Diss. Oxygen (mg/L)	None	5.2	7.8	9.0	10.3	13.9	76	N/A
pH, Standard Units	6.6-9	7.0	7.7	7.8	8.0	8.9	76	0
Calcium (mg/L as Ca)	None	200	300	330	370	441	79	N/A
Magnesium (mg/L as Mg)	None	42	93	110	128	162	79	N/A
Sodium (mg/L as Na)	None	120	300	350	408	601	79	N/A
Potassium (mg/L as K)	None	2.24	4.34	4.90	5.44	27.90	79	N/A
Chloride (mg/L as Cl)	3,500	180	484	590	686	991	79	0
Sulfate (mg/L as SO_4)	2,500	650	940	1,060	1,200	1,400	79	0
Boron (µg/L as B)	750	110	198	226	263	591	68	0

Table 1–8. USGS 08406500 Pecos River near Malaga, NM (1988-2001)								
Pollutant	Standard	Minimum	25th Pctile	Median	75th Pctile	Maximum	No. of Obs.	No. > Std.
Temperature (°C)	32.2	5.5	13.3	19.5	26.3	37.0	79	1
Spec. Cond. (µS/cm)	None	3,160	5,900	6,400	7,000	12,000	78	N/A
Diss. Oxygen (mg/L)	None	5	8	9	11	16	74	N/A
pH, Standard Units	6.6-9	7.0	7.8	8.0	8.1	9.3	75	1
Calcium (mg/L as Ca)	None	270	460	492	525	650	79	N/A
Magnesium (mg/L as Mg)	None	86	170	190	212	280	79	N/A
Sodium (mg/L as Na)	None	290	670	740	838	1,900	79	N/A
Potassium (mg/L as K)	None	4.2	9.2	10.8	12.0	51.0	79	N/A
Chloride (mg/L as Cl)	10,000	440	1,100	1,290	1,453	3,300	78	0
Sulfate (mg/L as SO_4)	3,000	630	1,500	1,670	1,800	2,700	78	0
Boron (µg/L as B)	750	200	358	395	450	1,000	68	2

Table 1–9. USGS 08407000 Pecos River at Pierce Canyon Crossing, NM (1988-2001)								
Pollutant	Standard	Minimum	25th Pctile	Median	75th Pctile	Maximum	No. of Obs.	No. > Std.
Temperature (°C)	32.2	5.5	14.5	21.0	26.0	31.0	79	0
Spec. Cond. (µS/cm)	None	2,910	7,940	9,030	10,200	32,500	78	N/A
Diss. Oxygen (mg/L)	None	5	8	10	11	17	74	N/A
pH, Standard Units	6.6-9	7.0	7.9	8.0	8.2	8.7	75	0
Calcium (mg/L as Ca)	None	260	462	500	541	700	78	N/A
Magnesium (mg/L as Mg)	None	86	180	210	230	360	78	N/A
Sodium (mg/L as Na)	None	300	1,100	1,305	1,573	6,600	78	N/A
Potassium (mg/L as K)	None	7	30	37	47	250	78	N/A
Chloride (mg/L as Cl)	10,000	500	1,853	2,205	2,675	11,000	78	0
Sulfate (mg/L as SO_4)	3,000	670	1,543	1,705	1,970	2,800	78	0
Boron (µg/L as B)	750	71	428	505	597	1,640	68	8

Table 1–10. USGS 08407500 Pecos River at Red Bluff, NM (1988-1994)									
Pollutant	Standard	Minimum	25th Pctile	Median	75th Pctile	Maximum	No. of Obs.	No. < D.L.[1]	No. > Std.
Temperature (°C)	32.2	5.0	11.3	16.3	25.4	30.0	36	N/A	0
Spec. Cond. (µS/cm)	None	3,820	9,000	10,500	12,200	31,200	35	N/A	N/A
Diss. Oxygen (mg/L)	None	5.3	8.1	9.3	10.6	14.7	34	N/A	N/A
pH, Standard Units	6.6-9	7.9	8.1	8.1	8.2	8.8	36	N/A	0
Calcium (mg/L as Ca)	None	300	450	475	572.5	860	34	N/A	N/A
Magnesium (mg/L as Mg)	None	98	190	205	255	440	34	N/A	N/A
Sodium (mg/L as Na)	None	410	1,200	1,600	2,000	6,300	34	N/A	N/A
Potassium (mg/L as K)	None	3.3	30	44	57	230	33	N/A	N/A
Chloride (mg/L as Cl)	10,000	620	2,100	2,700	3,350	11,000	33	N/A	0
Sulfate (mg/L as SO_4)	3,000	990	1,650	2,000	2,200	3,200	33	N/A	0
Aluminum (µg/L as Al)	87	< 10	< 10	20	30	750	23	8	3
Arsenic (µg/L as As)	150	< 1.0	1.0	1.0	2.0	3.0	12	2	0
Beryllium (µg/L as Be)	5.3	< 10.0	< 10.0	< 10.0	< 10.0	< 10.0	12	12	0
Cadmium (µg/L as Cd)	H[2]	< 1	< 1	< 2	< 2	11	12	9	0
Chromium (µg/L as Cr)	H	< 1	< 2	< 2	3	7	12	5	0
Cobalt (µg/L as Co)	50	< 1	< 1	< 1	1	4	24	19	0
Copper (µg/L as Cu)	H	< 1	1	2	3	8	12	2	0
Lead (µg/L as Pb)	H	< 1	< 2	< 2	< 3	31	12	11	1
Mercury (µg/L as Hg)	0.012	< 0.1	0.1	0.1	0.3	0.7	12	3	9
Nickel (µg/L as Ni)	H	< 1	< 1	< 1	2	11	24	18	0
Selenium (µg/L as Se)	5	< 1	1	1	2	< 4	25	8	0
Silver (µg/L as Ag)	H	< 1.0	< 1.0	< 1.0	< 1.0	< 4.0	24	24	0
Vanadium (µg/L as V)	100	14	< 25	45	59	170	25	2	2
Zinc (µg/L as Zn)	H	< 10	10	20	30	40	12	3	0
TDS (mg/L)	20,000	2,560	5,801	6,736	8,275	21,775	36	N/A	0

[1] D.L. - Detection Limit for trace elements (limit indicated by < in table). N/A - not applicable.
[2] H - indicates that the standard is based on water hardness and varies from sample to sample

Table 1–11. USGS 08412500 Pecos River near Orla, TX (1992-2001)								
Pollutant	Standard	Minimum	25^{th} Pctile	Median	75^{th} Pctile	Maximum	No. of Obs.	No. > Std.
Temperature (°C)	32.2	3.0	16.6	23.0	25.0	38.0	55	1
Spec. Cond. (µS/cm)	None	6,120	8,933	9,415	10,475	19,500	54	N/A
Diss. Oxygen (mg/L)	5	5.3	7.2	8.4	10.0	13.4	44	0
pH, Standard Units	6.5-9	7.1	7.7	7.8	7.9	8.1	50	0
Bicarbonate (mg/L) as HCO_3)	None	54	91	101	125	172	46	N/A
Calcium (mg/L as Ca)	None	472	544	586	650	940	55	N/A
Magnesium (mg/L as Mg)	None	179	204	223	238	340	55	N/A
Sodium (mg/L as Na)	None	938	1,203	1,300	1,473	4,600	55	N/A
Potassium (mg/L as K)	None	2	28	31	33	43	55	N/A
Chloride (mg/L as Cl)	7,000	1,580	2,035	2,155	2,535	6,400	55	0
Sulfate (mg/L as SO_4)	3,500	1,680	1,985	2,035	2,238	3,000	55	0
TDS (mg/L)	15,000	4,938	6,130	6,302	7,296	15,385	46	1

ATTACHMENT 2

PLOTS OF SPECIFIC CONDUCTANCE AT VARIOUS SUMNER DAM RELEASE LEVELS AT STATIONS ON THE MAINSTEM OF THE PECOS RIVER

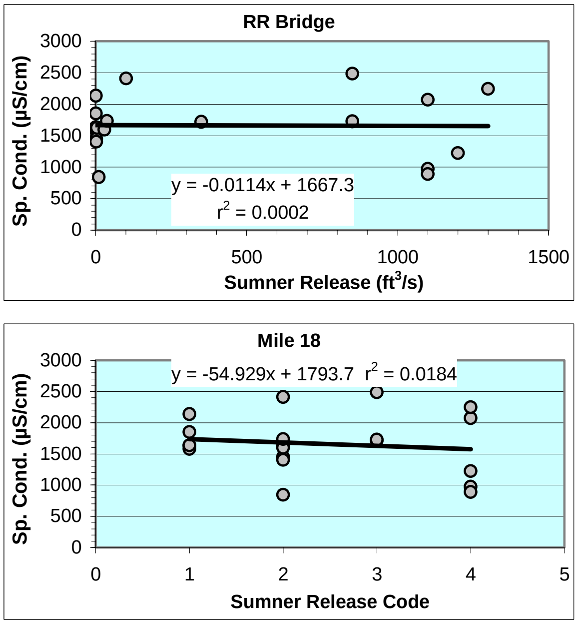


Figure 1: Relationship between the Sumner release and the specific conductance at site ST-2

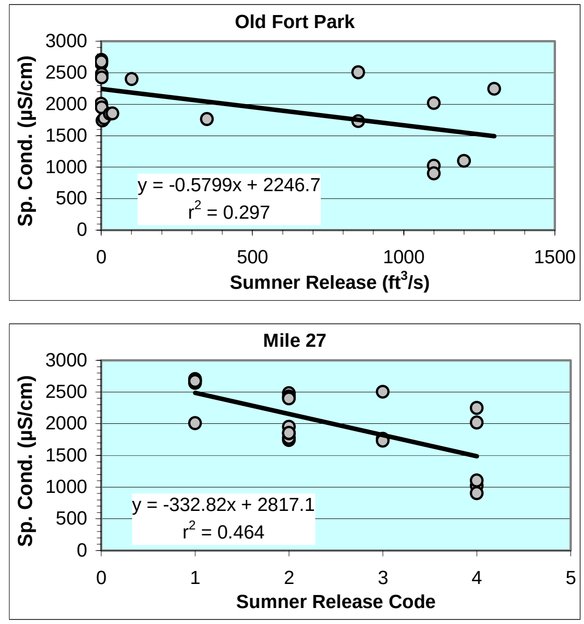


Figure 2: Relationship between the Sumner release and the specific conductance at site ST-3

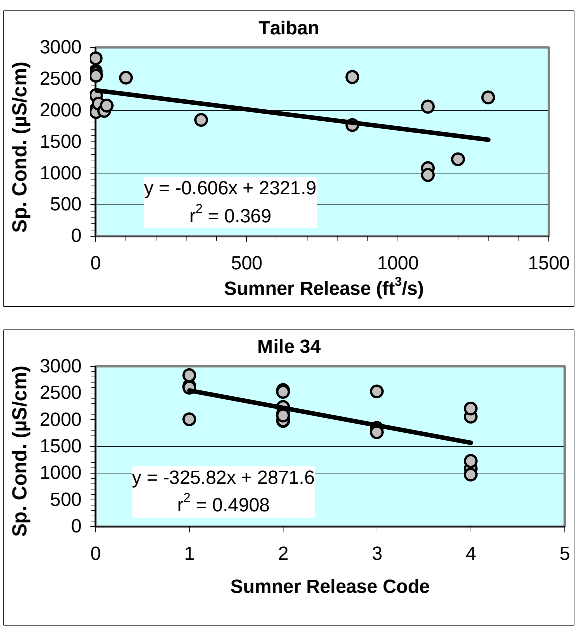


Figure 3: Relationship between the Sumner release and the specific conductance at site ST-4

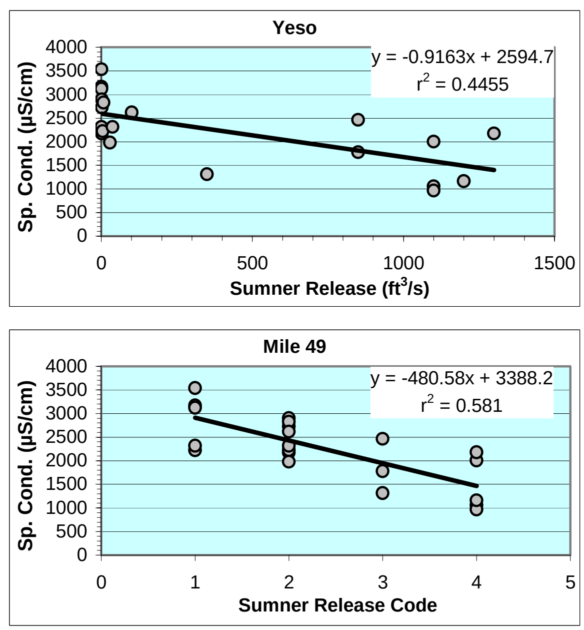


Figure 4: Relationship between the Sumner release and the specific conductance at site TA-0.3

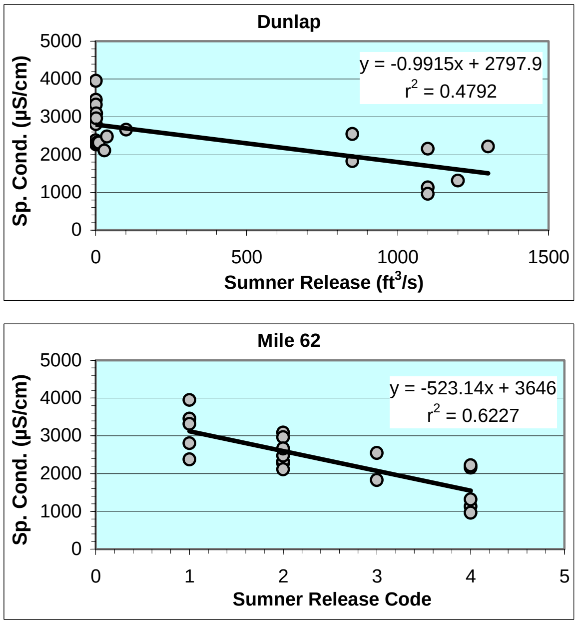


Figure 5: Relationship between the Sumner release and the specific conductance at site TA-0.5

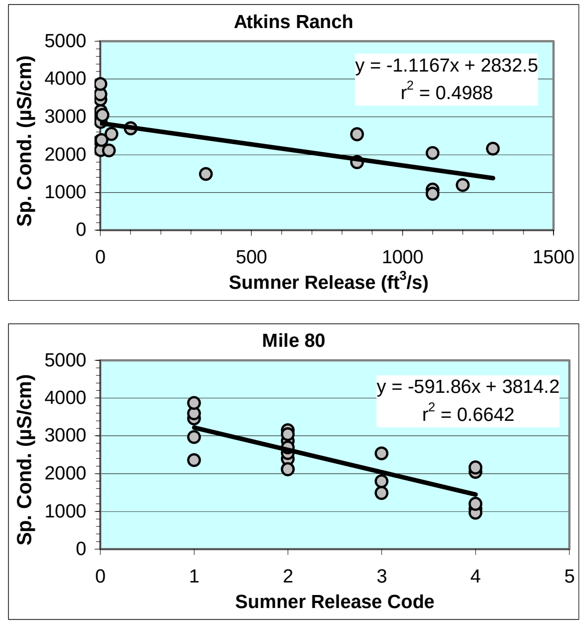


Figure 6: Relationship between the Sumner release and the specific conductance at site TA-1

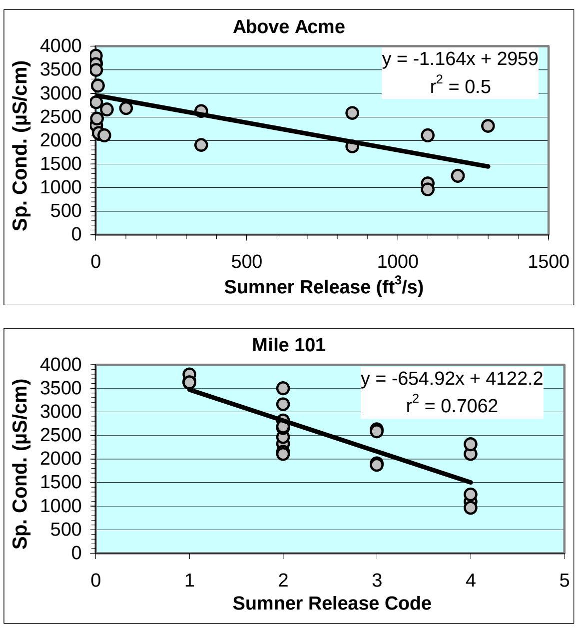


Figure 7: Relationship between the Sumner release and the specific conductance at site TA-2

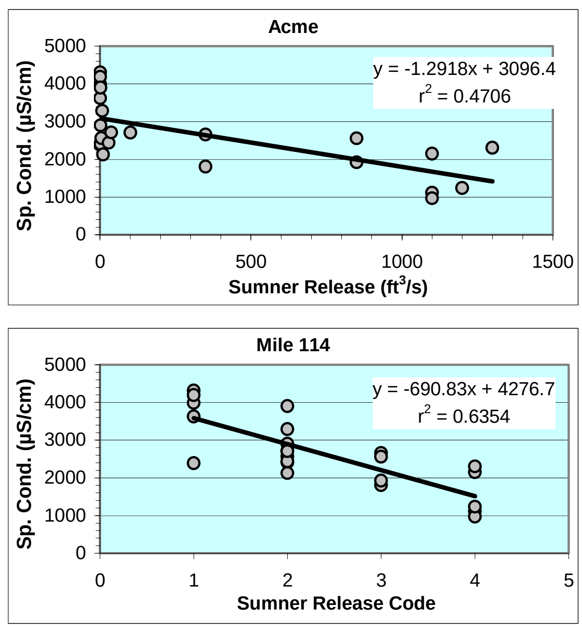


Figure 8: Relationship between the Sumner release and the specific conductance at site TA-4

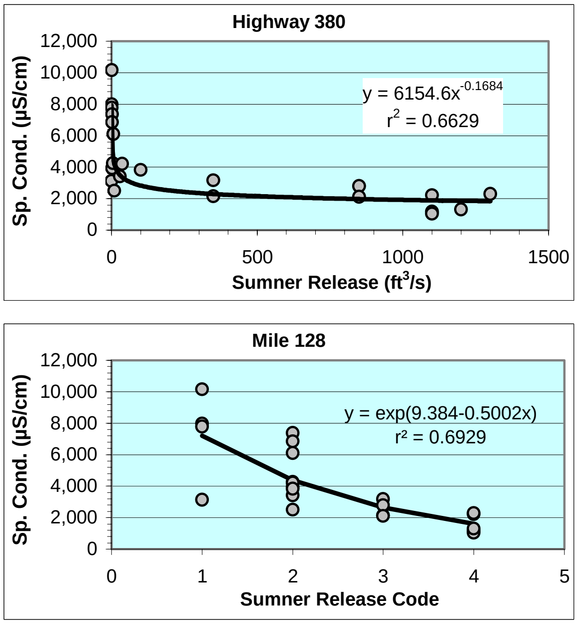


Figure 9: Relationship between the Sumner release and the specific conductance at site AA-1

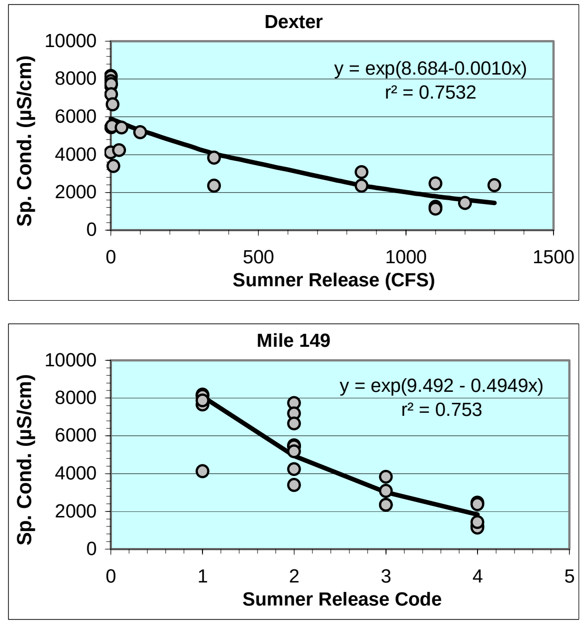


Figure 10: Relationship between the Sumner release and the specific conductance at site AA-1.5

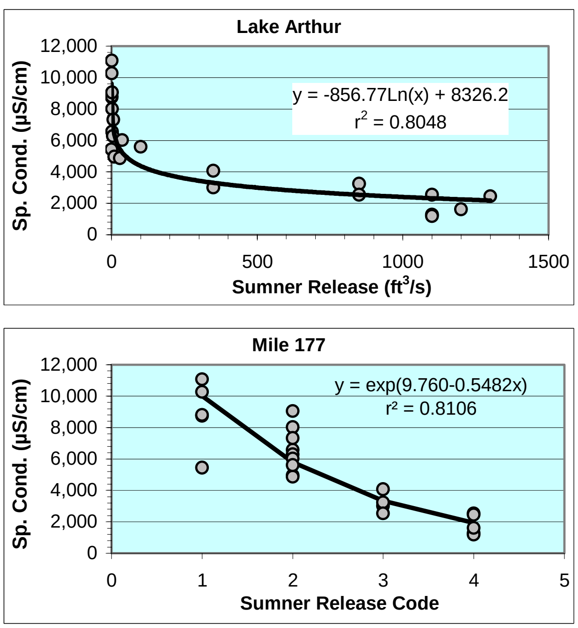


Figure 11: Relationship between the Sumner release and the specific conductance at site AA-3

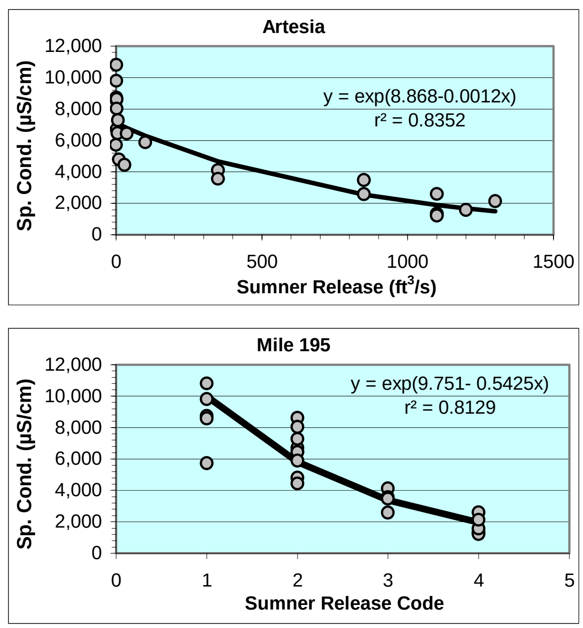


Figure 12: Relationship between the Sumner release and the specific conductance at site AA-4

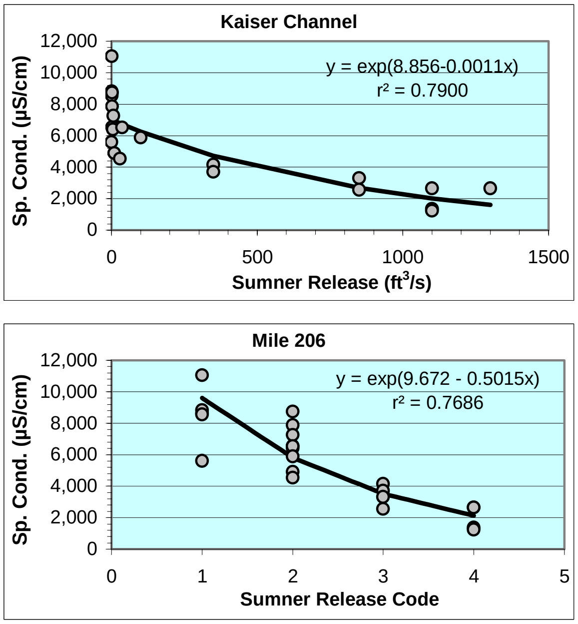


Figure 11: Relationship between the Sumner release and the specific conductance at site AK-1

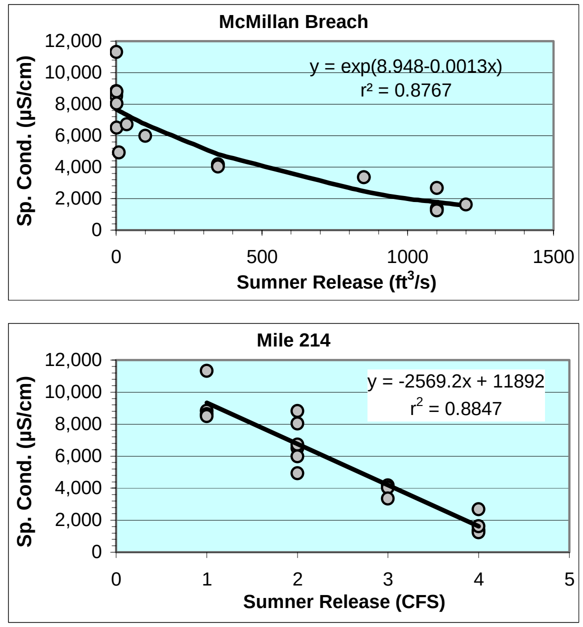
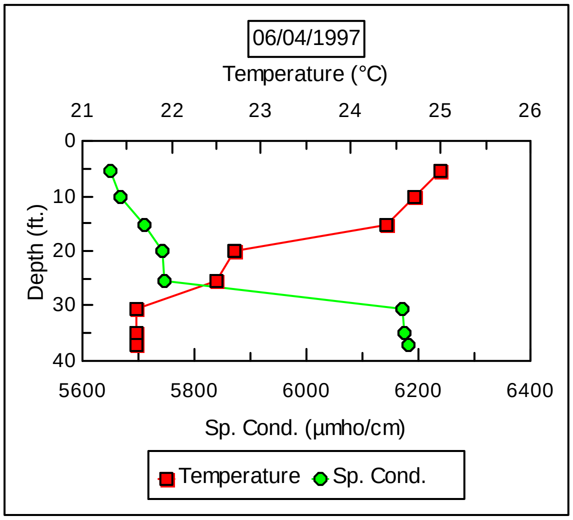
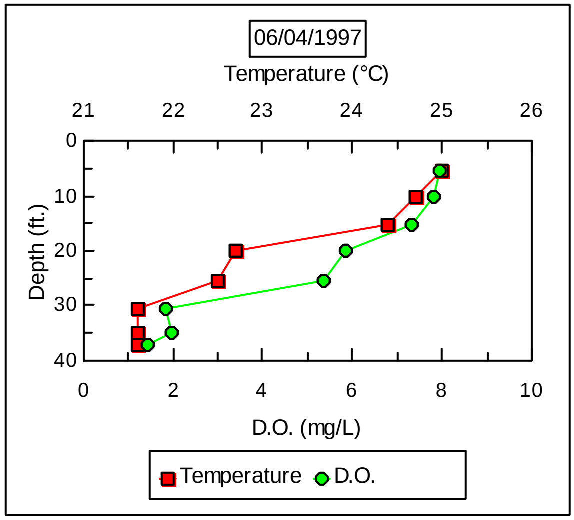


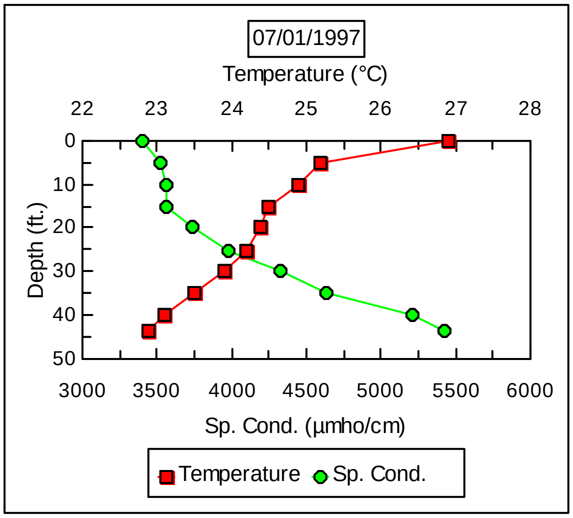
Figure 12: Relationship between the Sumner release and the specific conductance at site AK-2

ATTACHMENT 3

TEMPERATURE AND DISSOLVED OXYGEN PROFILES IN BRANTLEY RESERVOIR 1997 – 2001


06/04/1997
Temperature (°C)
21
22
23
24
25
26
0
10
20
30
40
Depth (ft.)
5600
5800
6000
6200
6400
Sp. Cond. (µmho/cm)
Temperature
Sp. Cond.


06/04/1997
Temperature (°C)
21
22
23
24
25
26
0
10
20
30
40
Depth (ft.)
0
2
4
6
8
10
D.O. (mg/L)
Temperature
D.O.


07/01/1997
Temperature (°C)
22
23
24
25
26
27
28
0
10
20
30
40
50
Depth (ft.)
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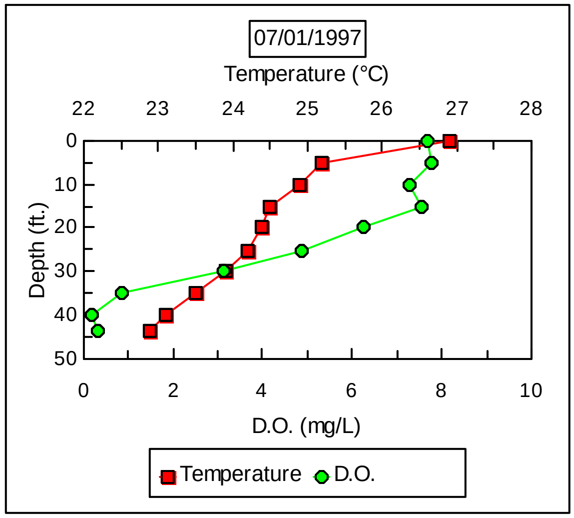
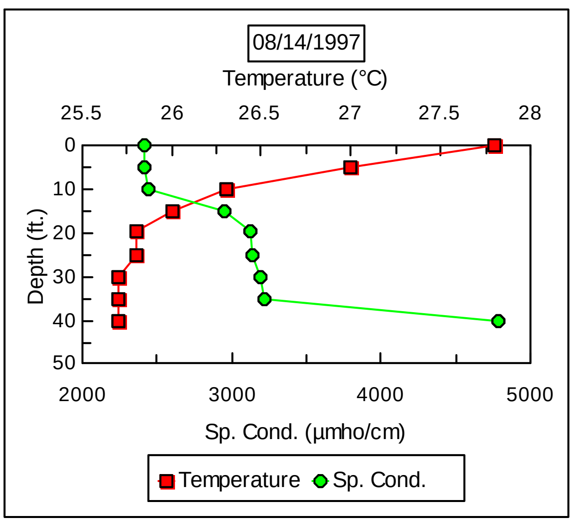
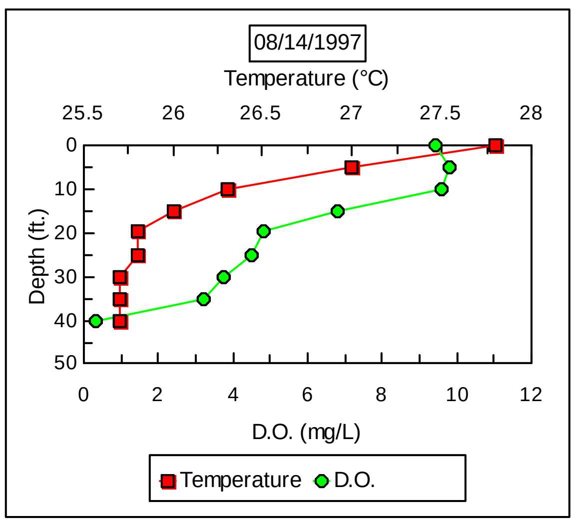
3500
4000
4500
5000
5500
6000
Sp. Cond. (µmho/cm)
Temperature
Sp. Cond.


07/01/1997
Temperature (°C)
22
23
24
25
26
27
28
0
10
20
30
40
50
Depth (ft.)
0
2
4
6
8
10
D.O. (mg/L)
Temperature
D.O.


08/14/1997
Temperature (°C)
25.5
26
26.5
27
27.5
28
0
10
20
30
40
50
Depth (ft.)
2000
3000
4000
5000
Sp. Cond. (µmho/cm)
Temperature
Sp. Cond.


08/14/1997
Temperature (°C)
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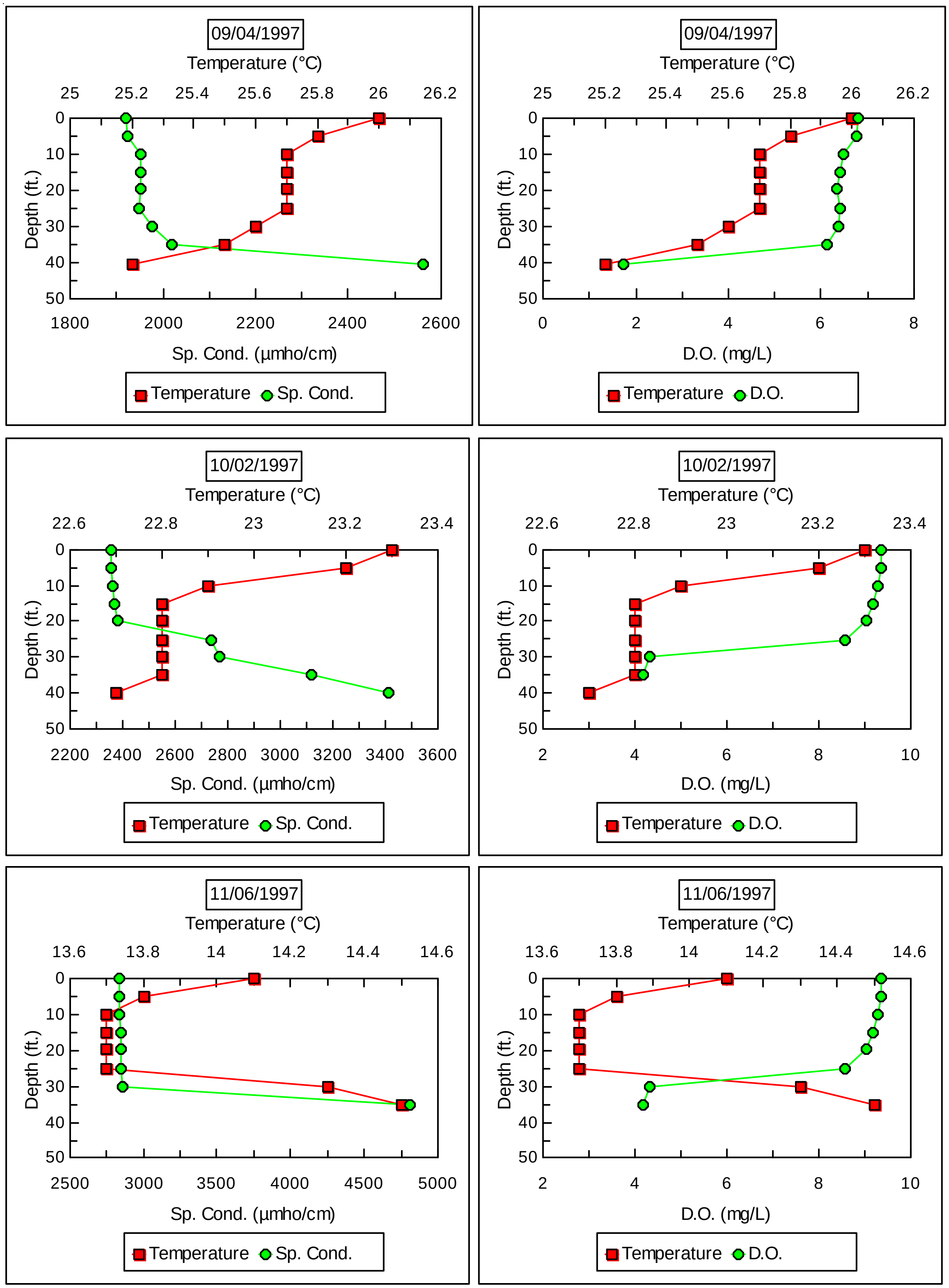
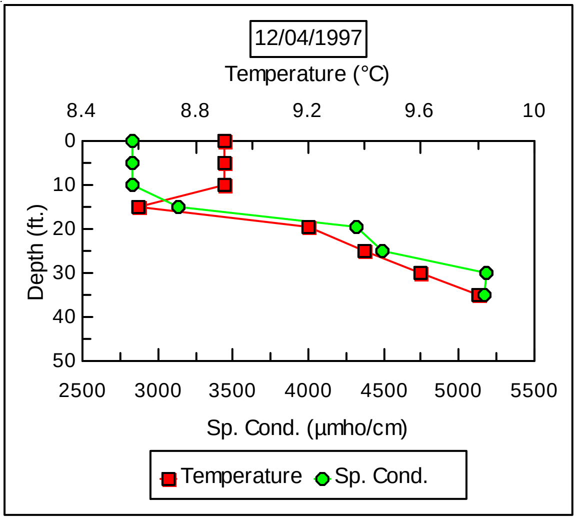
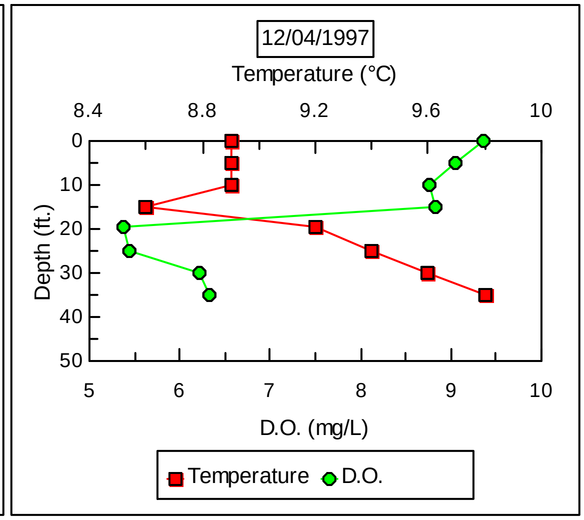
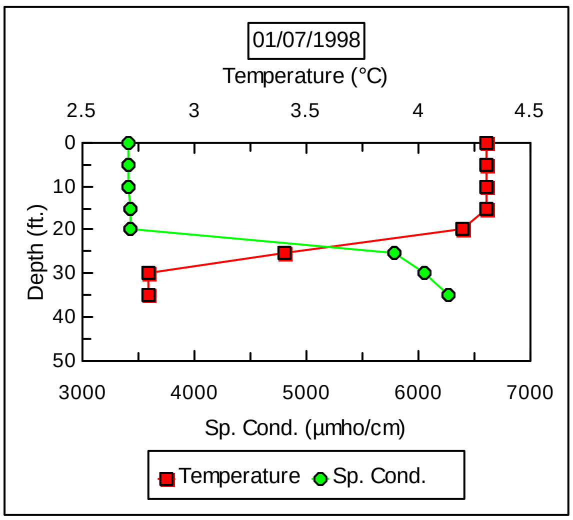
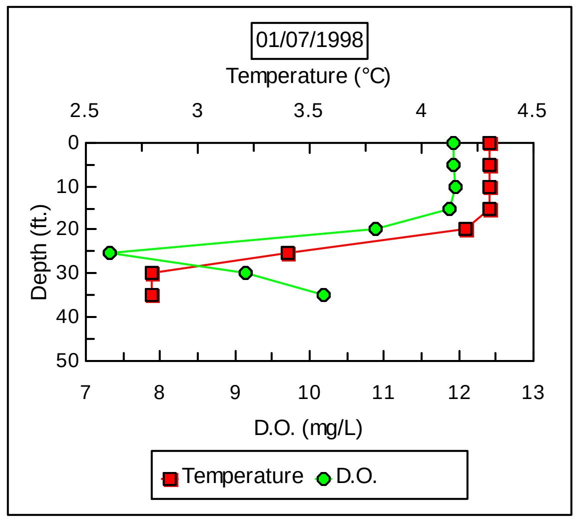
26
26.5
27
27.5
28
0
10
20
30
40
50
Depth (ft.)
0
2
4
6
8
10
12
D.O. (mg/L)
Temperature
D.O.

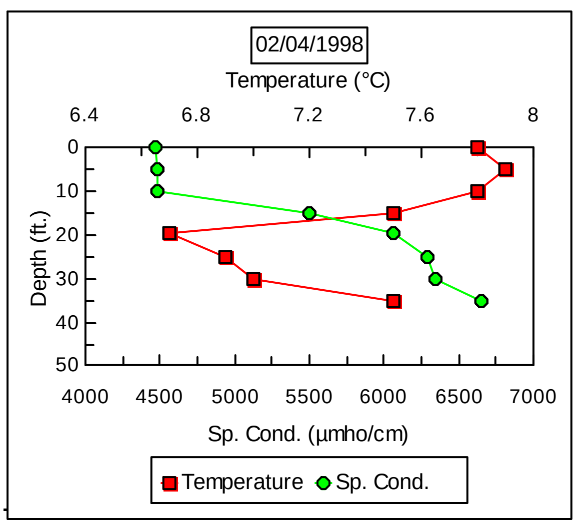

09/04/1997
Temperature (°C)
25 25.2 25.4 25.6 25.8 26 26.2
Depth (ft.)
0 10 20 30 40 50
1800 2000 2200 2400 2600
Sp. Cond. (µmho/cm)
Temperature Sp. Cond.
09/04/1997
Temperature (°C)
25 25.2 25.4 25.6 25.8 26 26.2
Depth (ft.)
0 10 20 30 40 50
0 2 4 6 8
D.O. (mg/L)
Temperature D.O.
10/02/1997
Temperature (°C)
22.6 22.8 23 23.2 23.4
Depth (ft.)
0 10 20 30 40 50
2200 2400 2600 2800 3000 3200 3400 3600
Sp. Cond. (µmho/cm)
Temperature Sp. Cond.
10/02/1997
Temperature (°C)
22.6 22.8 23 23.2 23.4
Depth (ft.)
0 10 20 30 40 50
2 4 6 8 10
D.O. (mg/L)
Temperature D.O.
11/06/1997
Temperature (°C)
13.6 13.8 14 14.2 14.4 14.6
Depth (ft.)
0 10 20 30 40 50
2500 3000 3500 4000 4500 5000
Sp. Cond. (µmho/cm)
Temperature Sp. Cond.
11/06/1997
Temperature (°C)
13.6 13.8 14 14.2 14.4 14.6
Depth (ft.)
0 10 20 30 40 50
2 4 6 8 10
D.O. (mg/L)
Temperature D.O.

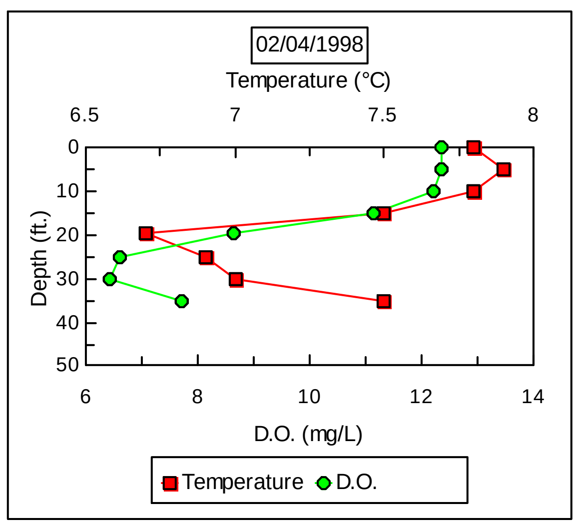

12/04/1997
Temperature (°C)
8.4 8.8 9.2 9.6 10
Depth (ft.)
0 10 20 30 40 50
2500 3000 3500 4000 4500 5000 5500
Sp. Cond. (µmho/cm)
Temperature Sp. Cond.

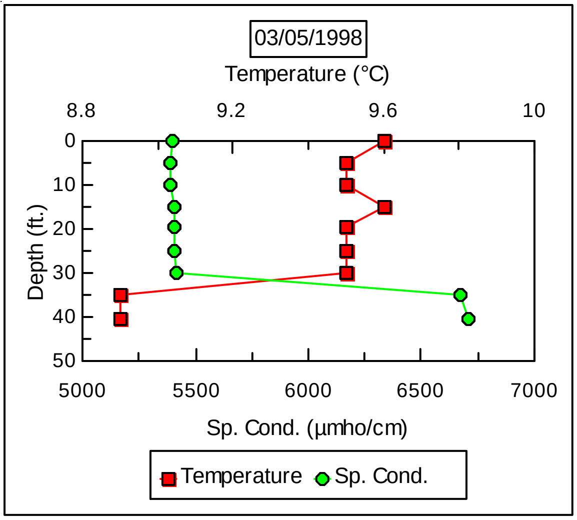

12/04/1997
Temperature (°C)
8.4 8.8 9.2 9.6 10
Depth (ft.)
0 10 20 30 40 50
5 6 7 8 9 10
D.O. (mg/L)
Temperature D.O.


01/07/1998
Temperature (°C)
2.5 3 3.5 4 4.5
Depth (ft.)
0 10 20 30 40 50
3000 4000 5000 6000 7000
Sp. Cond. (µmho/cm)
Temperature Sp. Cond.

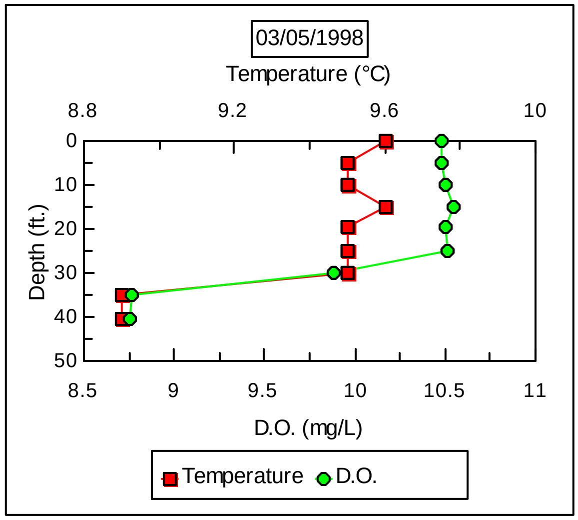

01/07/1998
Temperature (°C)
2.5 3 3.5 4 4.5
Depth (ft.)
0 10 20 30 40 50
7 8 9 10 11 12 13
D.O. (mg/L)
Temperature D.O.


02/04/1998
Temperature (°C)
6.4 6.8 7.2 7.6 8
Depth (ft.)
0 10 20 30 40 50
4000 4500 5000 5500 6000 6500 7000
Sp. Cond. (µmho/cm)
Temperature Sp. Cond.

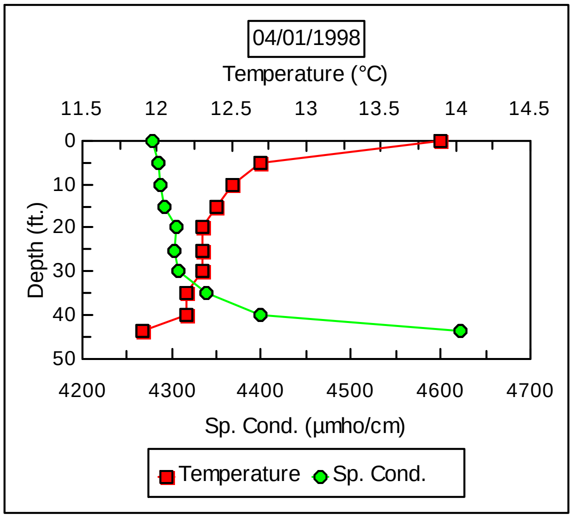

02/04/1998
Temperature (°C)
6.5 7 7.5 8
Depth (ft.)
0 10 20 30 40 50
6 8 10 12 14
D.O. (mg/L)
Temperature D.O.



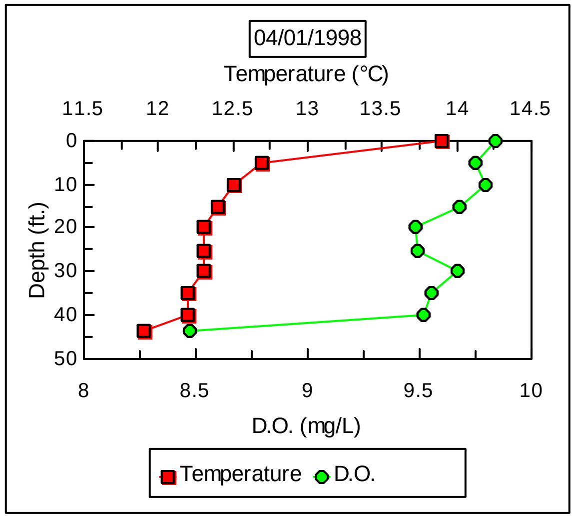
03/05/1998
Temperature (°C)
8.8
9.2
9.6
10
Depth (ft.)
Sp. Cond. (µmho/cm)
5000
5500
6000
6500
7000
Temperature
Sp. Cond.



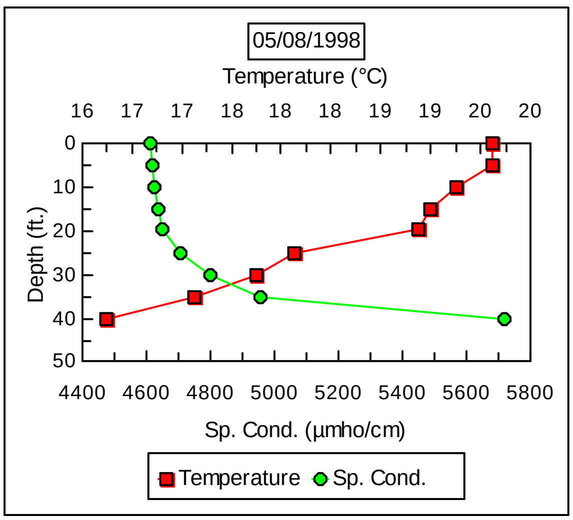
03/05/1998
Temperature (°C)
Depth (ft.)
D.O. (mg/L)
Temperature
D.O.



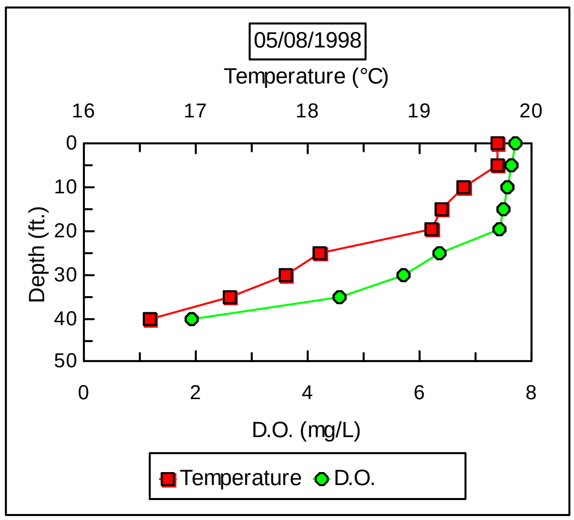
04/01/1998
Temperature (°C)
Depth (ft.)
Sp. Cond. (µmho/cm)
Temperature
Sp. Cond.



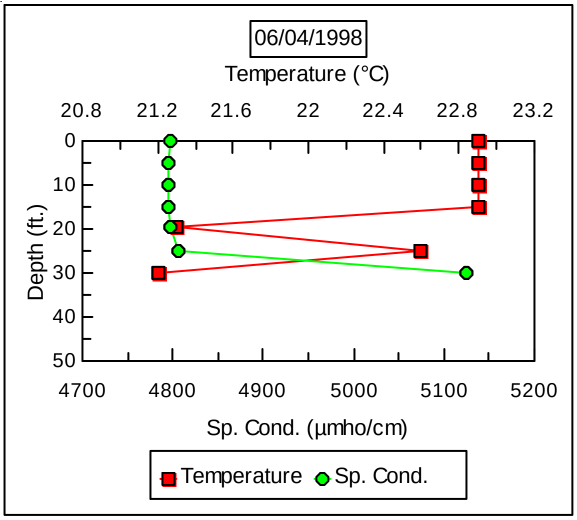
04/01/1998
Temperature (°C)
Depth (ft.)
D.O. (mg/L)
Temperature
D.O.

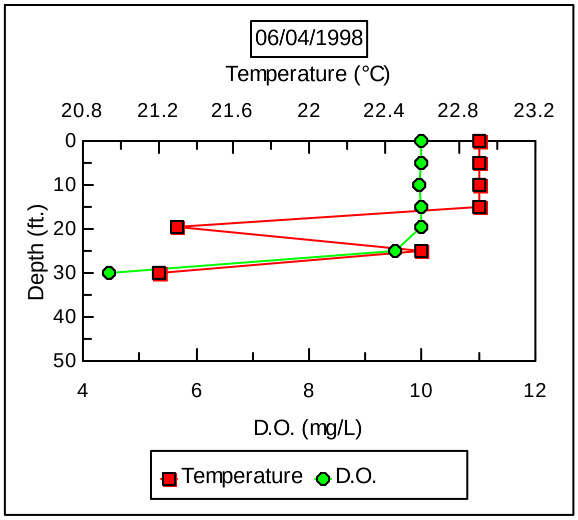


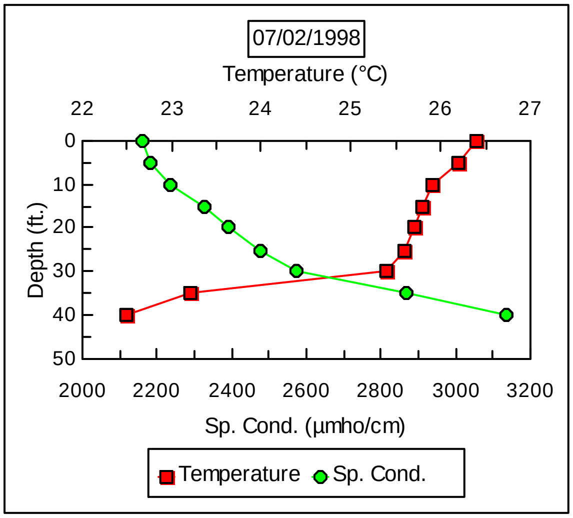
05/08/1998
Temperature (°C)
Depth (ft.)
Sp. Cond. (µmho/cm)
Temperature
Sp. Cond.

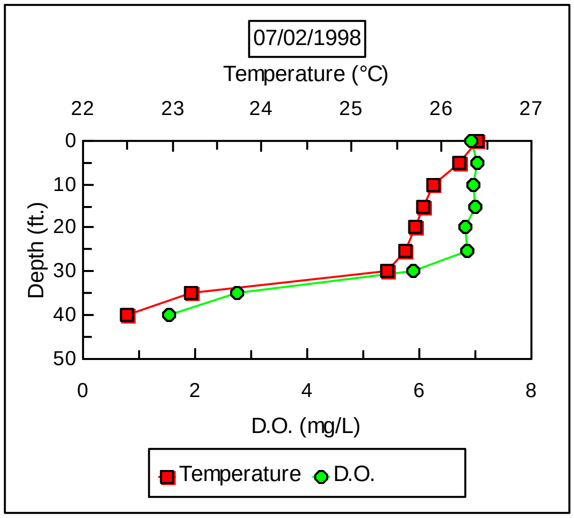


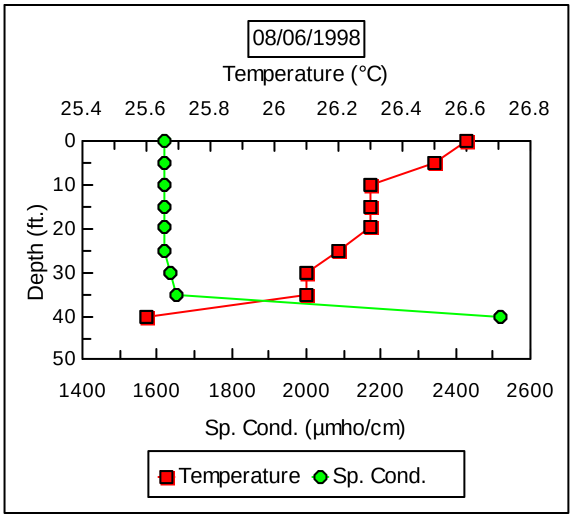
05/08/1998
Temperature (°C)
Depth (ft.)
D.O. (mg/L)
Temperature
D.O.

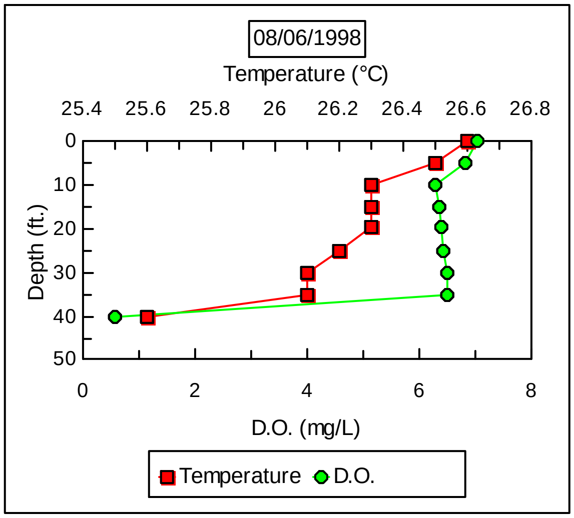

06/04/1998
Temperature (°C)
20.8 21.2 21.6 22 22.4 22.8 23.2
Depth (ft.)
0 10 20 30 40 50
4700 4800 4900 5000 5100 5200
Sp. Cond. (µmho/cm)
Temperature Sp. Cond.

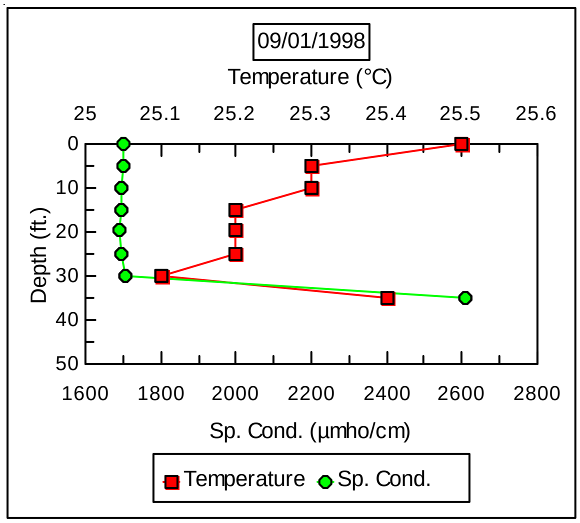

06/04/1998
Temperature (°C)
20.8 21.2 21.6 22 22.4 22.8 23.2
Depth (ft.)
0 10 20 30 40 50
4 6 8 10 12
D.O. (mg/L)
Temperature D.O.

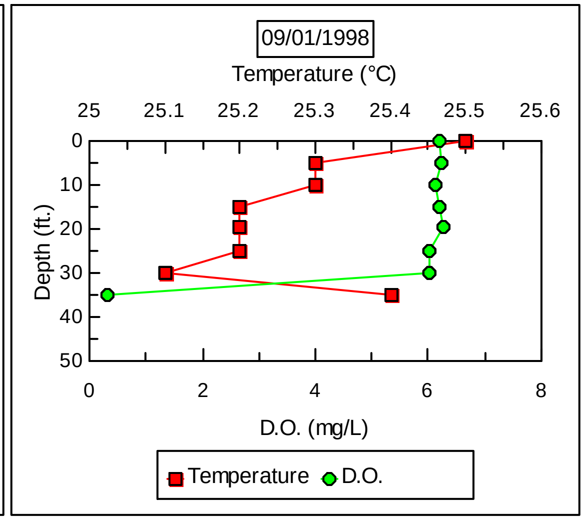

07/02/1998
Temperature (°C)
22 23 24 25 26 27
Depth (ft.)
0 10 20 30 40 50
2000 2200 2400 2600 2800 3000 3200
Sp. Cond. (µmho/cm)
Temperature Sp. Cond.

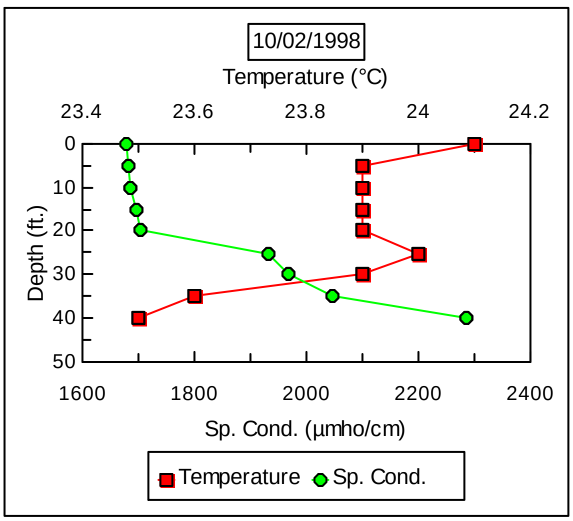

07/02/1998
Temperature (°C)
22 23 24 25 26 27
Depth (ft.)
0 10 20 30 40 50
0 2 4 6 8
D.O. (mg/L)
Temperature D.O.

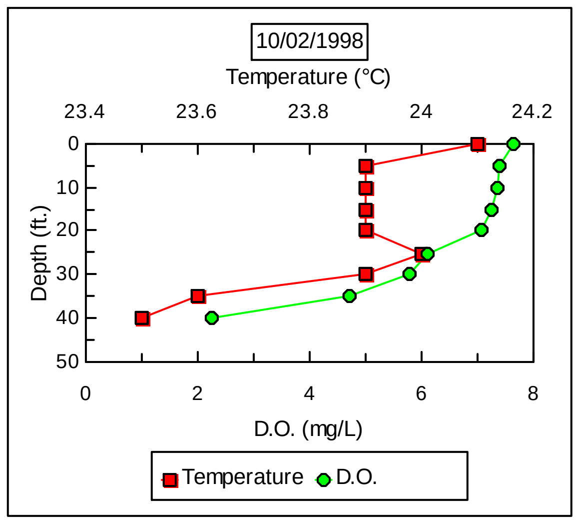

08/06/1998
Temperature (°C)
25.4 25.6 25.8 26 26.2 26.4 26.6 26.8
Depth (ft.)
0 10 20 30 40 50
1400 1600 1800 2000 2200 2400 2600
Sp. Cond. (µmho/cm)
Temperature Sp. Cond.

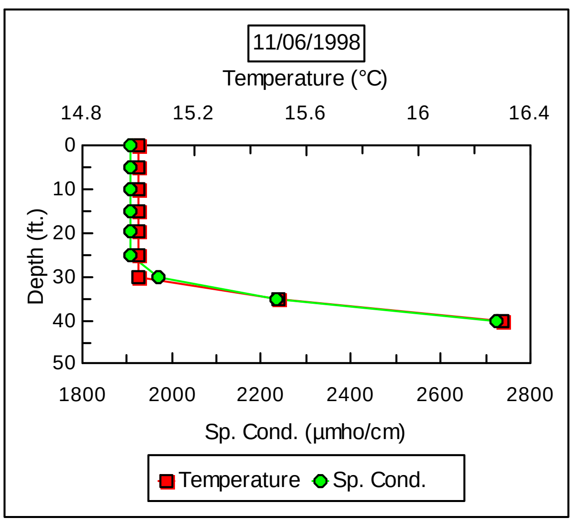

08/06/1998
Temperature (°C)
25.4 25.6 25.8 26 26.2 26.4 26.6 26.8
Depth (ft.)
0 10 20 30 40 50
0 2 4 6 8
D.O. (mg/L)
Temperature D.O.

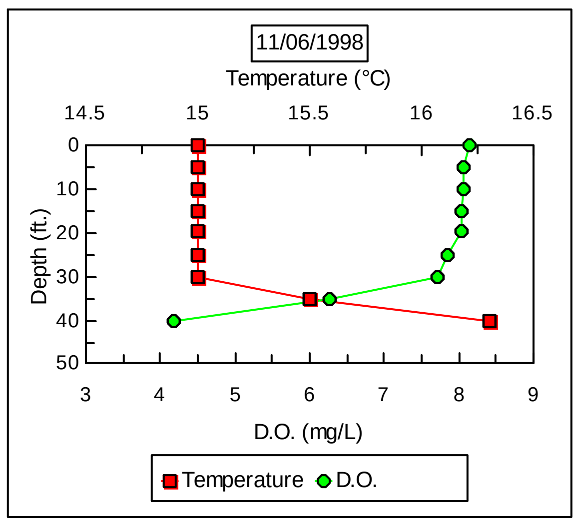

09/01/1998
Temperature (°C)
25 25.1 25.2 25.3 25.4 25.5 25.6
Depth (ft.)
0 10 20 30 40 50
1600 1800 2000 2200 2400 2600 2800
Sp. Cond. (µmho/cm)
Temperature Sp. Cond.

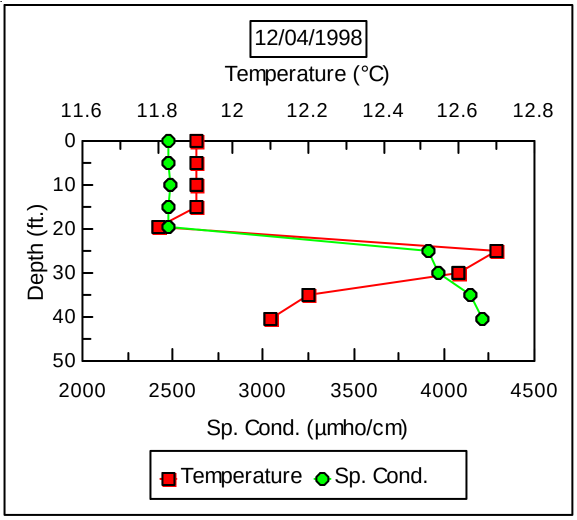

09/01/1998
Temperature (°C)
25 25.1 25.2 25.3 25.4 25.5 25.6
Depth (ft.)
0 10 20 30 40 50
0 2 4 6 8
D.O. (mg/L)
Temperature D.O.

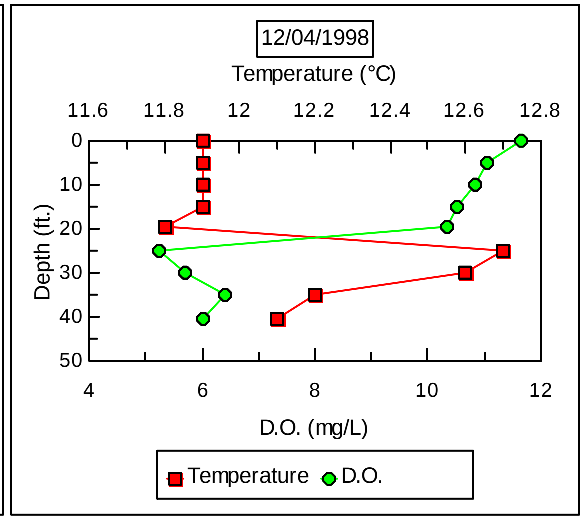

10/02/1998
Temperature (°C)
23.4 23.6 23.8 24 24.2
Depth (ft.)
0 10 20 30 40 50
1600 1800 2000 2200 2400
Sp. Cond. (µmho/cm)
Temperature Sp. Cond.

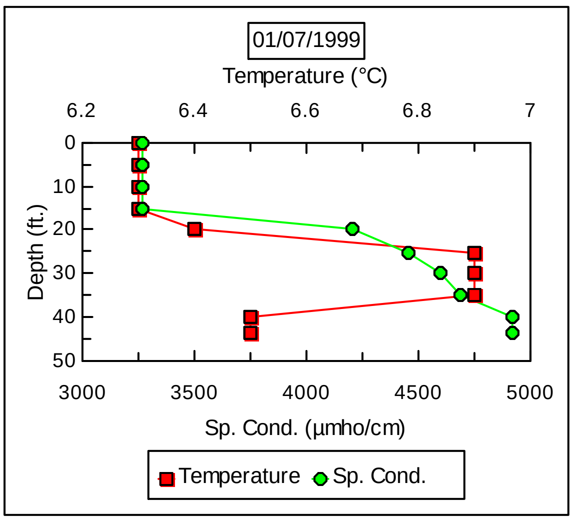

10/02/1998
Temperature (°C)
23.4 23.6 23.8 24 24.2
Depth (ft.)
0 10 20 30 40 50
0 2 4 6 8
D.O. (mg/L)
Temperature D.O.

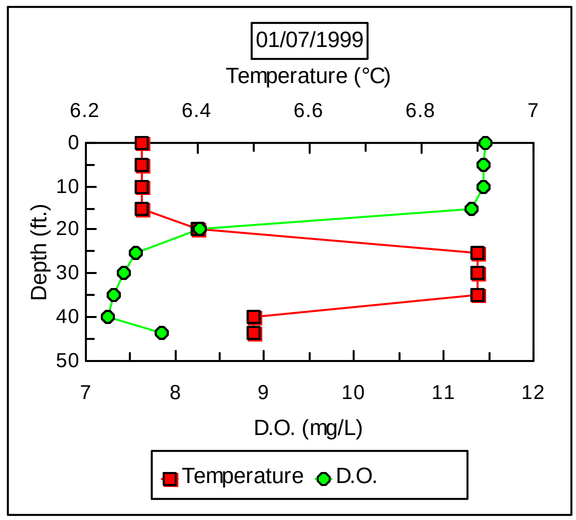

11/06/1998
Temperature (°C)
14.8 15.2 15.6 16 16.4
Depth (ft.)
0 10 20 30 40 50
1800 2000 2200 2400 2600 2800
Sp. Cond. (µmho/cm)
Temperature Sp. Cond.

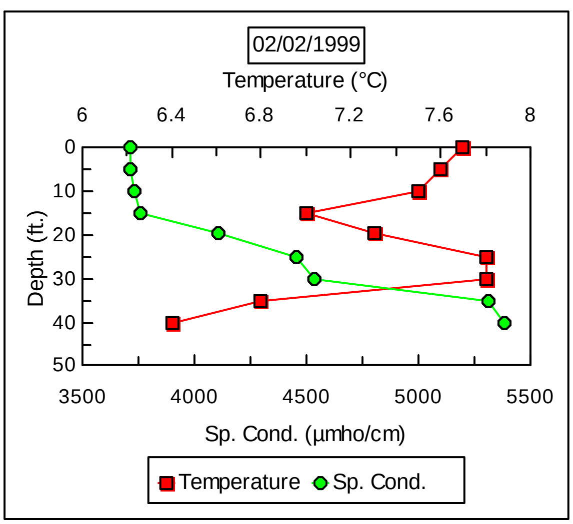

11/06/1998
Temperature (°C)
14.5 15 15.5 16 16.5
Depth (ft.)
0 10 20 30 40 50
3 4 5 6 7 8 9
D.O. (mg/L)
Temperature D.O.

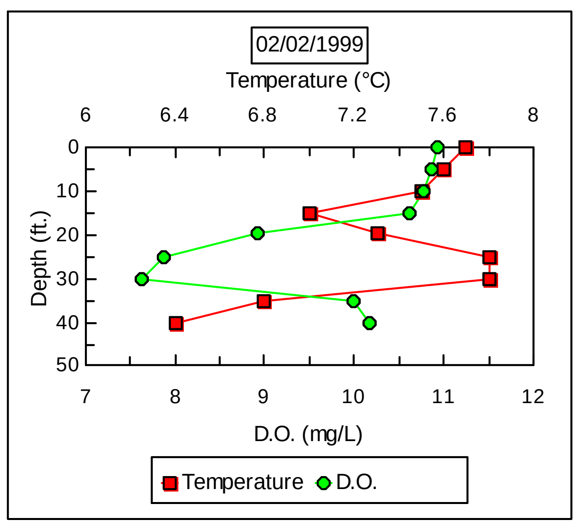

12/04/1998
Temperature (°C)
11.6 11.8 12 12.2 12.4 12.6 12.8
Depth (ft.)
0 10 20 30 40 50
2000 2500 3000 3500 4000 4500
Sp. Cond. (µmho/cm)
Temperature Sp. Cond.

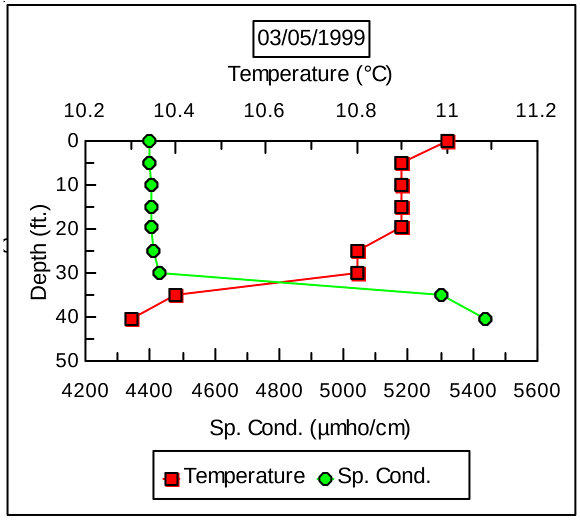

12/04/1998
Temperature (°C)
11.6 11.8 12 12.2 12.4 12.6 12.8
Depth (ft.)
0 10 20 30 40 50
4 6 8 10 12
D.O. (mg/L)
Temperature D.O.

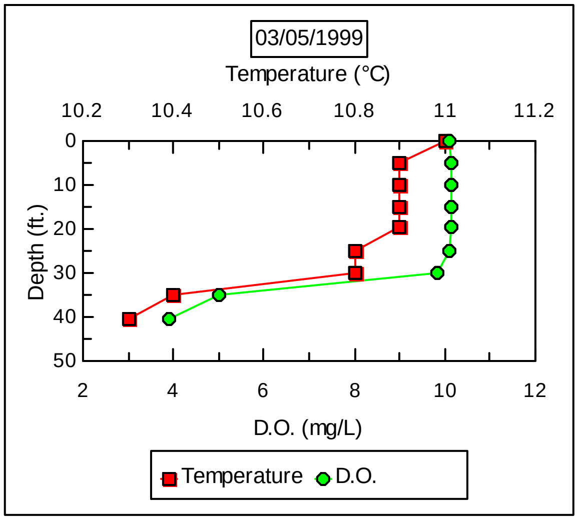

01/07/1999
Temperature (°C)
6.2 6.4 6.6 6.8 7
Depth (ft.)
0 10 20 30 40 50
3000 3500 4000 4500 5000
Sp. Cond. (µmho/cm)
Temperature Sp. Cond.

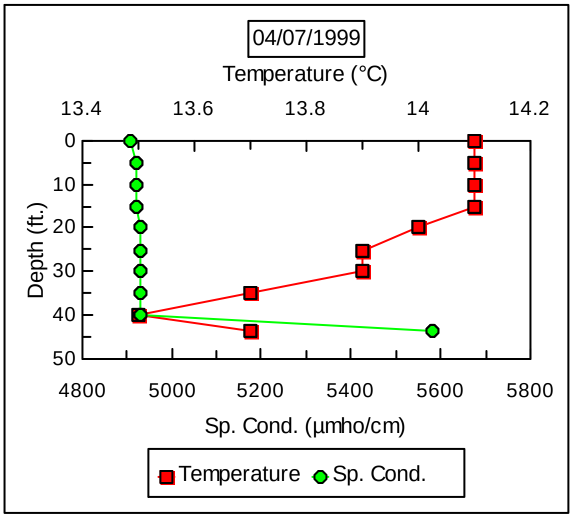

01/07/1999
Temperature (°C)
6.2 6.4 6.6 6.8 7
Depth (ft.)
0 10 20 30 40 50
7 8 9 10 11 12
D.O. (mg/L)
Temperature D.O.

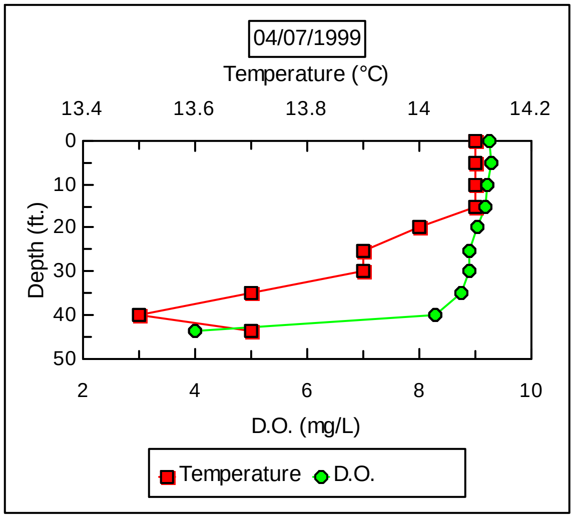

02/02/1999
Temperature (°C)
6 6.4 6.8 7.2 7.6 8
Depth (ft.)
0 10 20 30 40 50
3500 4000 4500 5000 5500
Sp. Cond. (µmho/cm)
Temperature Sp. Cond.

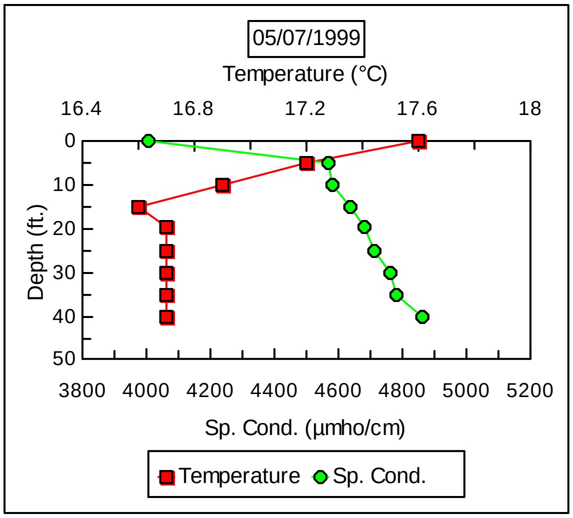

02/02/1999
Temperature (°C)
6 6.4 6.8 7.2 7.6 8
Depth (ft.)
0 10 20 30 40 50
7 8 9 10 11 12
D.O. (mg/L)
Temperature D.O.

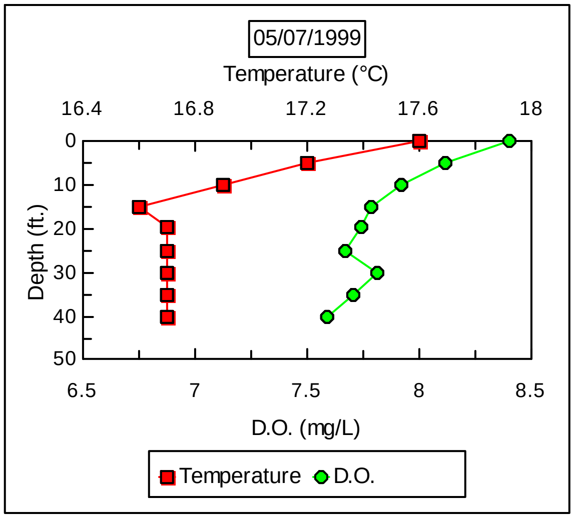

03/05/1999
Temperature (°C)
Depth (ft.)
Sp. Cond. (µmho/cm)
Temperature
Sp. Cond.

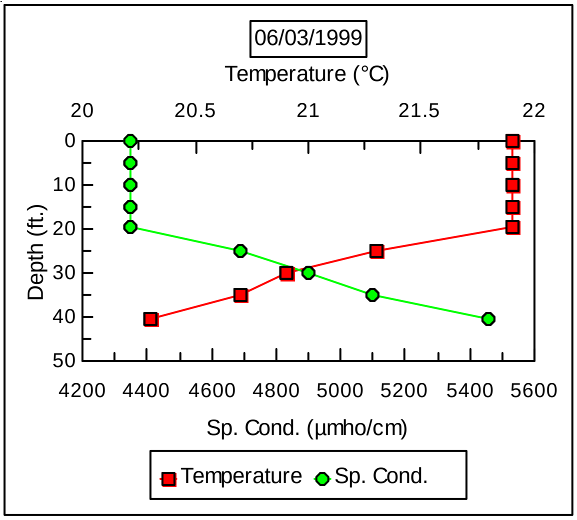

03/05/1999
Temperature (°C)
Depth (ft.)
D.O. (mg/L)
Temperature
D.O.

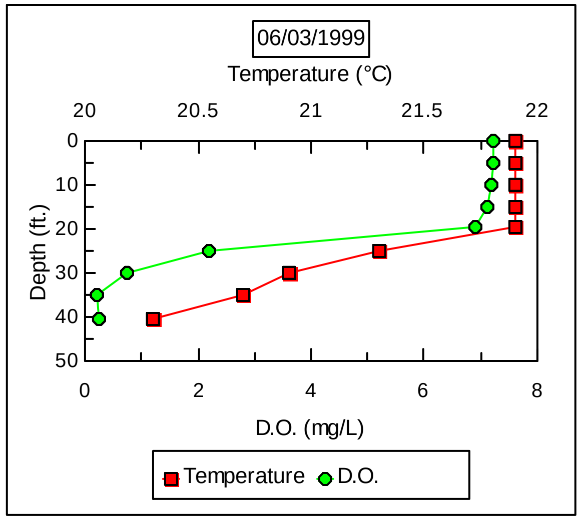

04/07/1999
Temperature (°C)
Depth (ft.)
Sp. Cond. (µmho/cm)
Temperature
Sp. Cond.

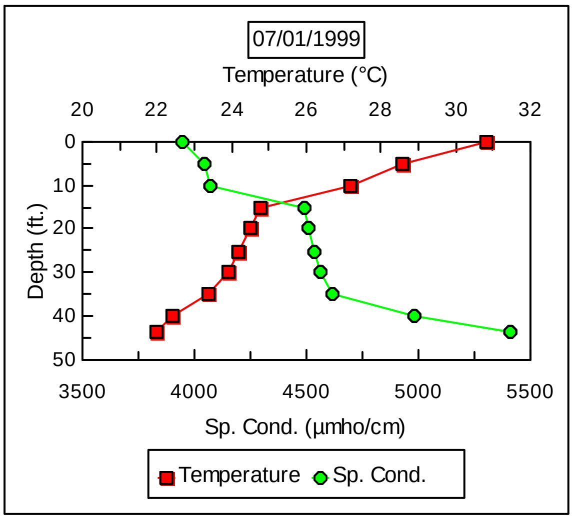

04/07/1999
Temperature (°C)
Depth (ft.)
D.O. (mg/L)
Temperature
D.O.

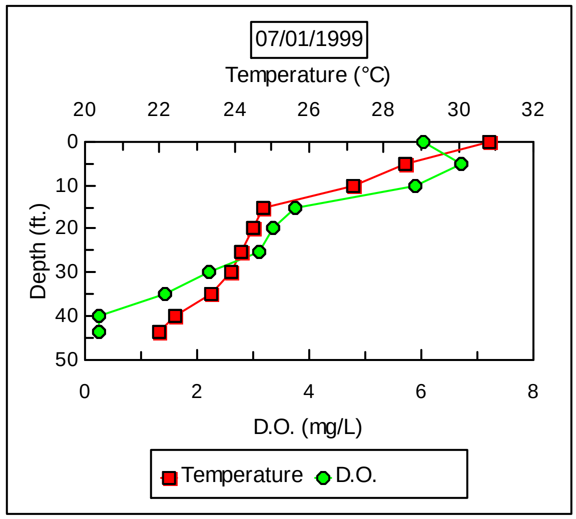

05/07/1999
Temperature (°C)
Depth (ft.)
Sp. Cond. (µmho/cm)
Temperature
Sp. Cond.

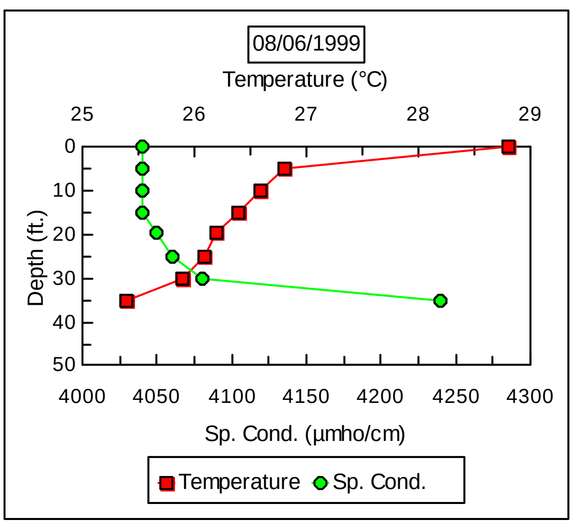

05/07/1999
Temperature (°C)
Depth (ft.)
D.O. (mg/L)
Temperature
D.O.

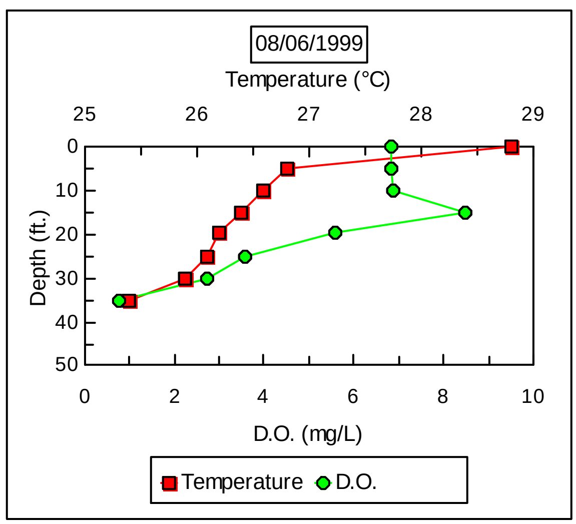

06/03/1999
Temperature (°C)
20
20.5
21
21.5
22
0
10
20
30
40
50
Depth (ft.)
4200
4400
4600
4800
5000
5200
5400
5600
Sp. Cond. (µmho/cm)
Temperature
Sp. Cond.

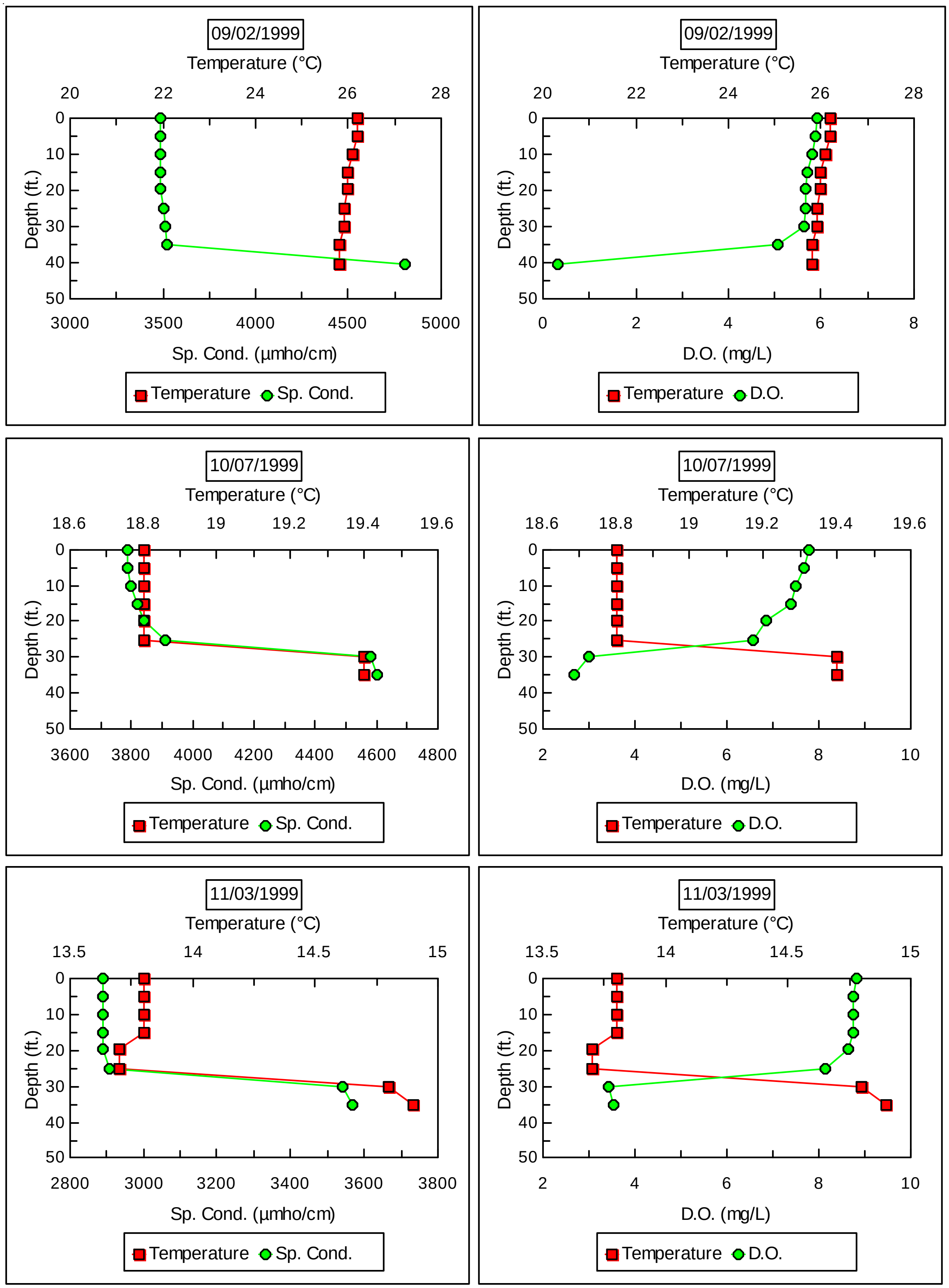

06/03/1999
Temperature (°C)
20
20.5
21
21.5
22
0
10
20
30
40
50
Depth (ft.)
0
2
4
6
8
D.O. (mg/L)
Temperature
D.O.

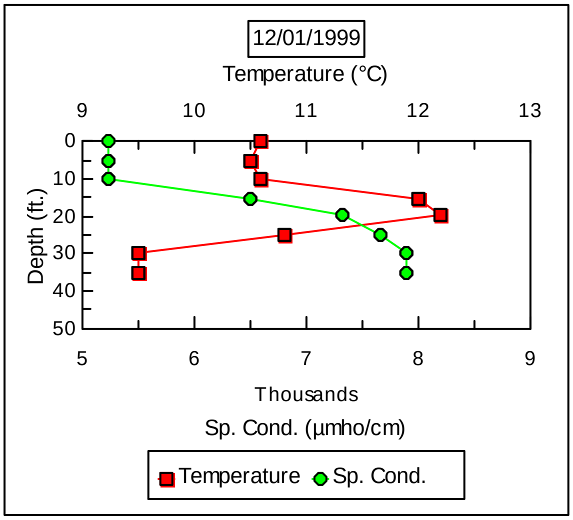

07/01/1999
Temperature (°C)
20
22
24
26
28
30
32
0
10
20
30
40
50
Depth (ft.)
3500
4000
4500
5000
5500
Sp. Cond. (µmho/cm)
Temperature
Sp. Cond.

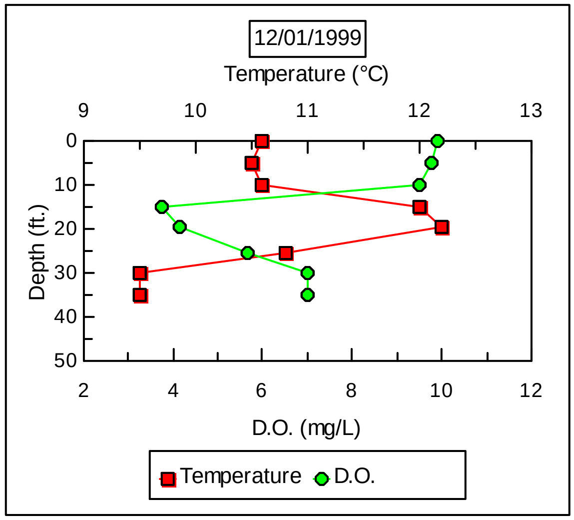

07/01/1999
Temperature (°C)
20
22
24
26
28
30
32
0
10
20
30
40
50
Depth (ft.)
0
2
4
6
8
D.O. (mg/L)
Temperature
D.O.

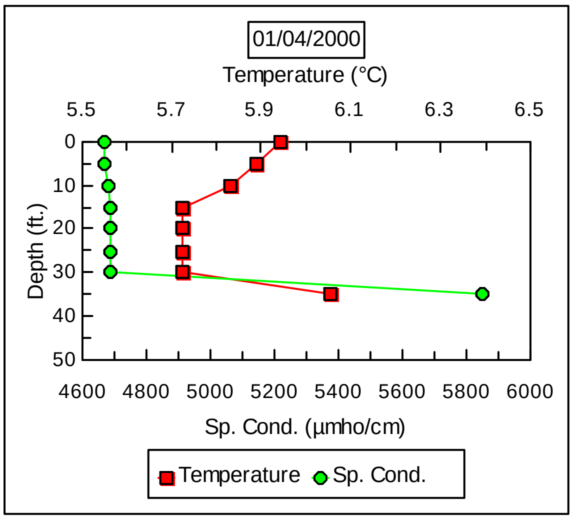

08/06/1999
Temperature (°C)
25
26
27
28
29
0
10
20
30
40
50
Depth (ft.)
4000
4050
4100
4150
4200
4250
4300
Sp. Cond. (µmho/cm)
Temperature
Sp. Cond.

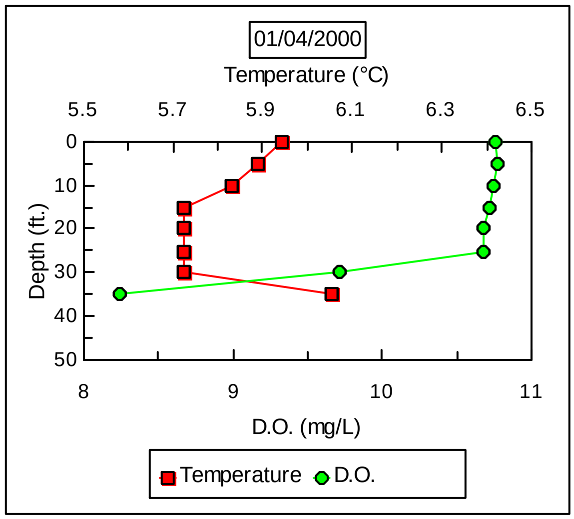

08/06/1999
Temperature (°C)
25
26
27
28
29
0
10
20
30
40
50
Depth (ft.)
0
2
4
6
8
10
D.O. (mg/L)
Temperature
D.O.

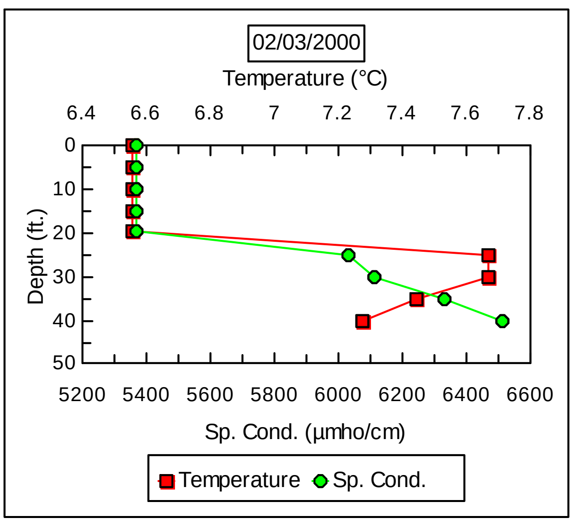

09/02/1999
Temperature (°C)
Depth (ft.)
Sp. Cond. (µmho/cm)
Temperature
Sp. Cond.
09/02/1999
Temperature (°C)
Depth (ft.)
D.O. (mg/L)
Temperature
D.O.
10/07/1999
Temperature (°C)
Depth (ft.)
Sp. Cond. (µmho/cm)
Temperature
Sp. Cond.
10/07/1999
Temperature (°C)
Depth (ft.)
D.O. (mg/L)
Temperature
D.O.
11/03/1999
Temperature (°C)
Depth (ft.)
Sp. Cond. (µmho/cm)
Temperature
Sp. Cond.
11/03/1999
Temperature (°C)
Depth (ft.)
D.O. (mg/L)
Temperature
D.O.

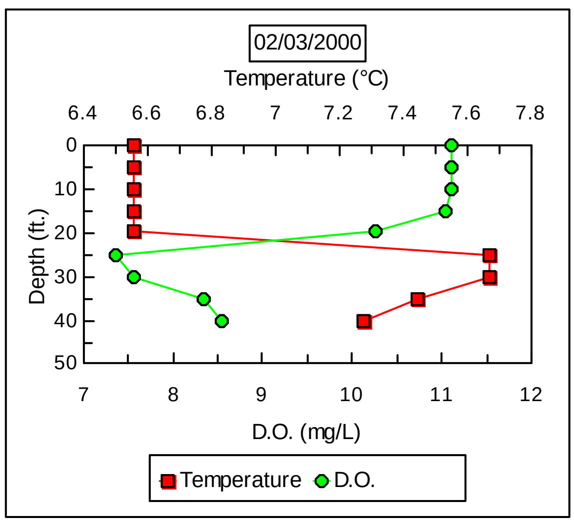

12/01/1999
Temperature (°C)
9
10
11
12
13
0
10
20
30
40
50
Depth (ft.)
5
6
7
8
9
Thousands
Sp. Cond. (µmho/cm)
Temperature
Sp. Cond.

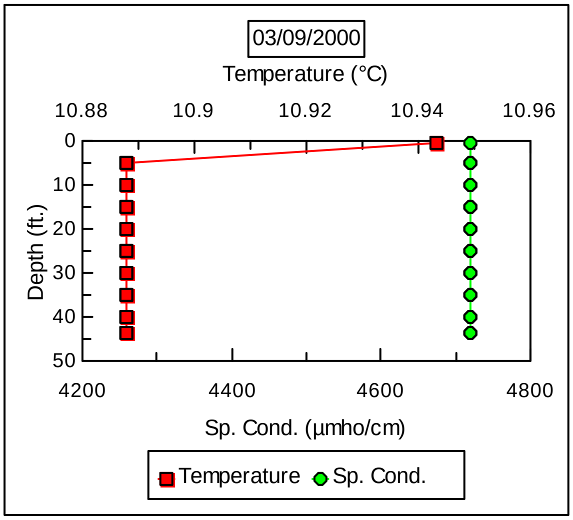

12/01/1999
Temperature (°C)
9
10
11
12
13
0
10
20
30
40
50
Depth (ft.)
2
4
6
8
10
12
D.O. (mg/L)
Temperature
D.O.

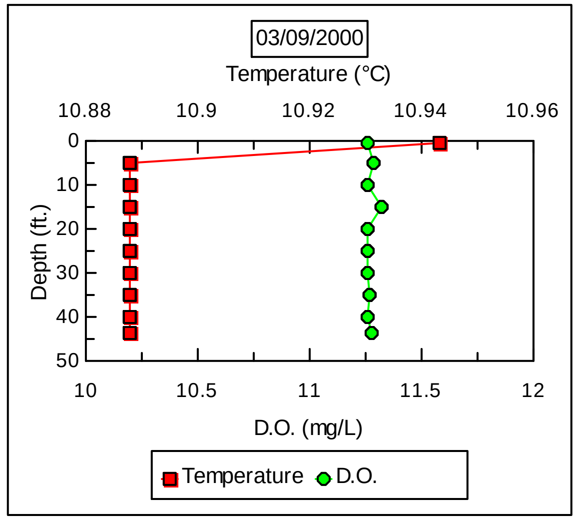

01/04/2000
Temperature (°C)
5.5
5.7
5.9
6.1
6.3
6.5
0
10
20
30
40
50
Depth (ft.)
4600
4800
5000
5200
5400
5600
5800
6000
Sp. Cond. (µmho/cm)
Temperature
Sp. Cond.

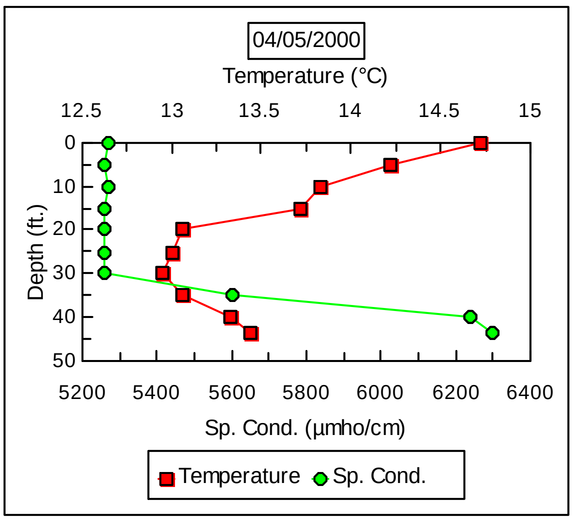

01/04/2000
Temperature (°C)
5.5
5.7
5.9
6.1
6.3
6.5
0
10
20
30
40
50
Depth (ft.)
8
9
10
11
D.O. (mg/L)
Temperature
D.O.

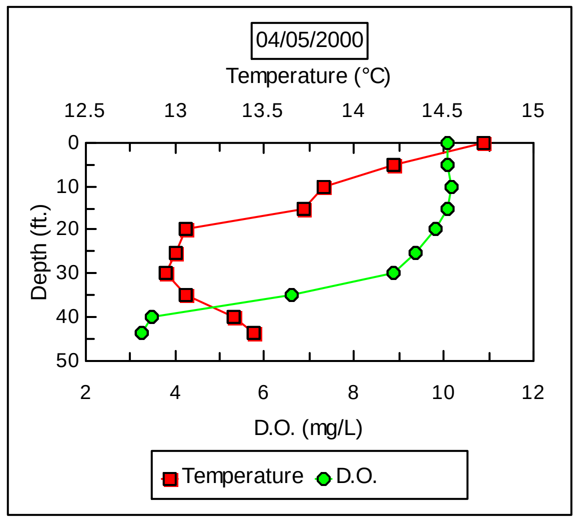

02/03/2000
Temperature (°C)
6.4
6.6
6.8
7
7.2
7.4
7.6
7.8
0
10
20
30
40
50
Depth (ft.)
5200
5400
5600
5800
6000
6200
6400
6600
Sp. Cond. (µmho/cm)
Temperature
Sp. Cond.

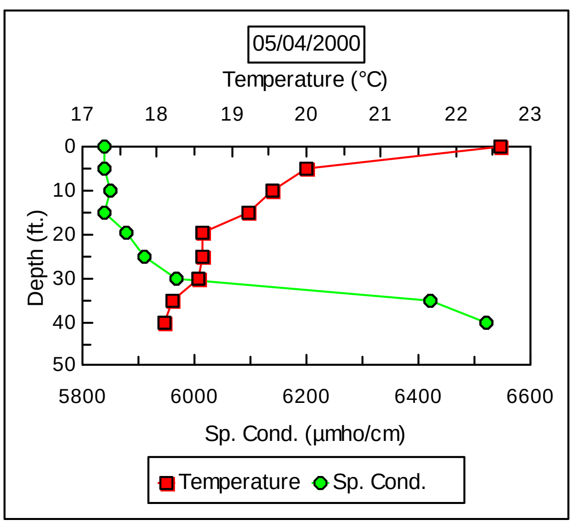

02/03/2000
Temperature (°C)
6.4
6.6
6.8
7
7.2
7.4
7.6
7.8
0
10
20
30
40
50
Depth (ft.)
7
8
9
10
11
12
D.O. (mg/L)
Temperature
D.O.

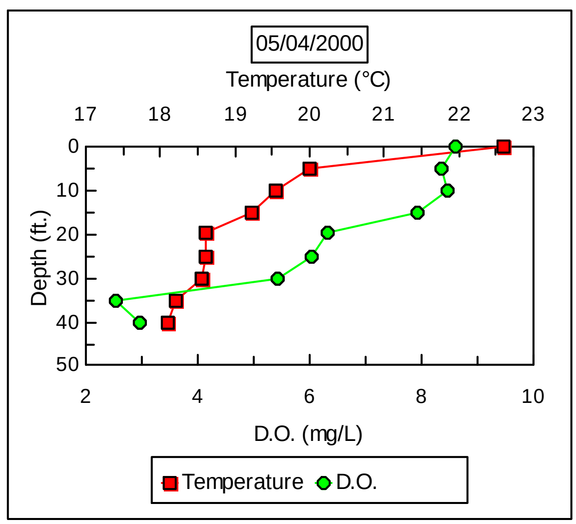

03/09/2000
Temperature (°C)
10.88 10.9 10.92 10.94 10.96
Depth (ft.)
0 10 20 30 40 50
4200 4400 4600 4800
Sp. Cond. (µmho/cm)
Temperature Sp. Cond.

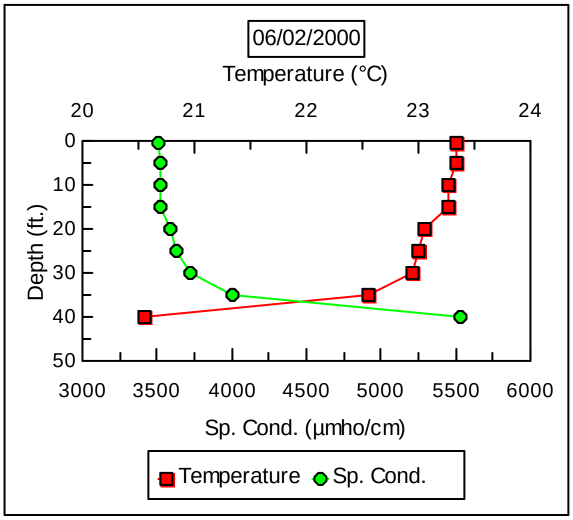

03/09/2000
Temperature (°C)
10.88 10.9 10.92 10.94 10.96
Depth (ft.)
0 10 20 30 40 50
10 10.5 11 11.5 12
D.O. (mg/L)
Temperature D.O.

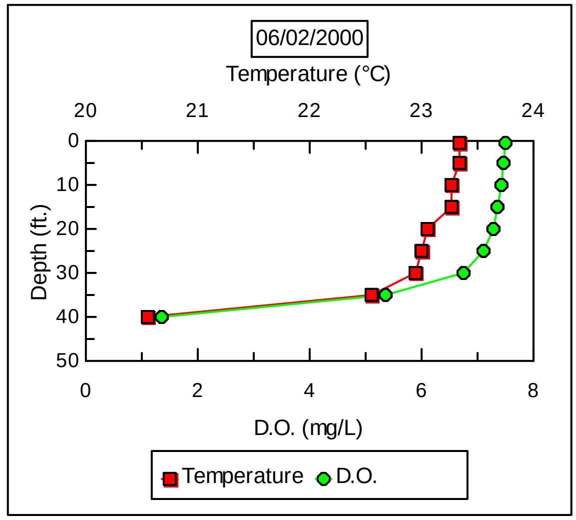

04/05/2000
Temperature (°C)
12.5 13 13.5 14 14.5 15
Depth (ft.)
0 10 20 30 40 50
5200 5400 5600 5800 6000 6200 6400
Sp. Cond. (µmho/cm)
Temperature Sp. Cond.

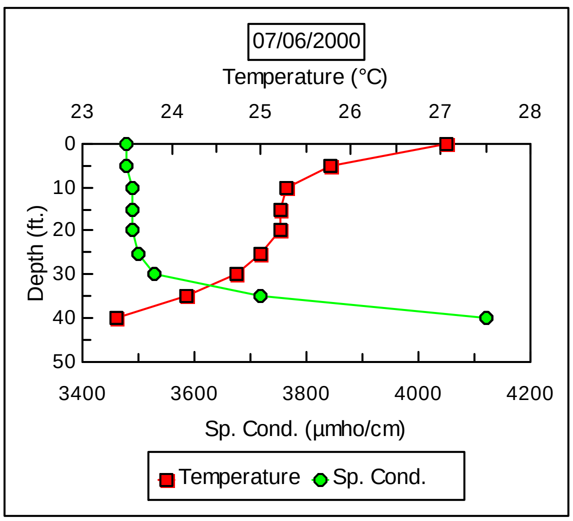

04/05/2000
Temperature (°C)
12.5 13 13.5 14 14.5 15
Depth (ft.)
0 10 20 30 40 50
2 4 6 8 10 12
D.O. (mg/L)
Temperature D.O.

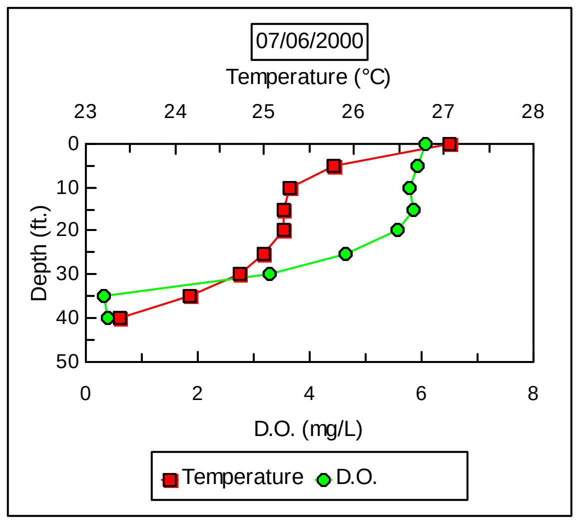

05/04/2000
Temperature (°C)
17 18 19 20 21 22 23
Depth (ft.)
0 10 20 30 40 50
5800 6000 6200 6400 6600
Sp. Cond. (µmho/cm)
Temperature Sp. Cond.

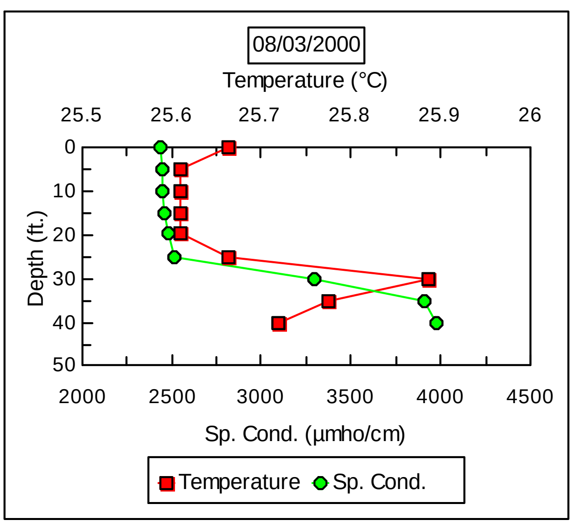

05/04/2000
Temperature (°C)
17 18 19 20 21 22 23
Depth (ft.)
0 10 20 30 40 50
2 4 6 8 10
D.O. (mg/L)
Temperature D.O.

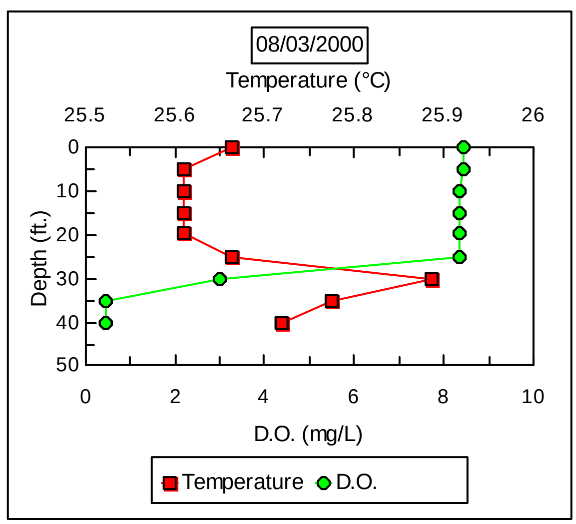

06/02/2000
Temperature (°C)
20 21 22 23 24
0 10 20 30 40 50
Depth (ft.)
3000 3500 4000 4500 5000 5500 6000
Sp. Cond. (µmho/cm)
Temperature
Sp. Cond.

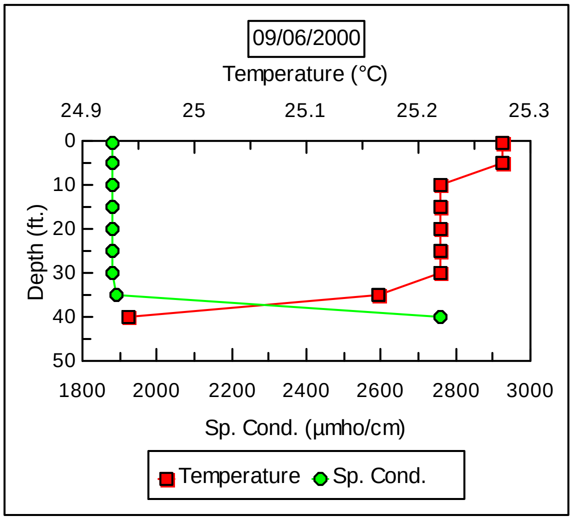

06/02/2000
Temperature (°C)
20 21 22 23 24
0 10 20 30 40 50
Depth (ft.)
0 2 4 6 8
D.O. (mg/L)
Temperature
D.O.

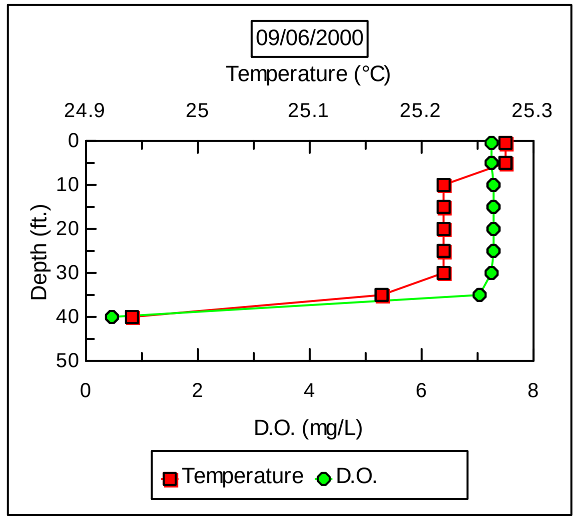

07/06/2000
Temperature (°C)
23 24 25 26 27 28
0 10 20 30 40 50
Depth (ft.)
3400 3600 3800 4000 4200
Sp. Cond. (µmho/cm)
Temperature
Sp. Cond.

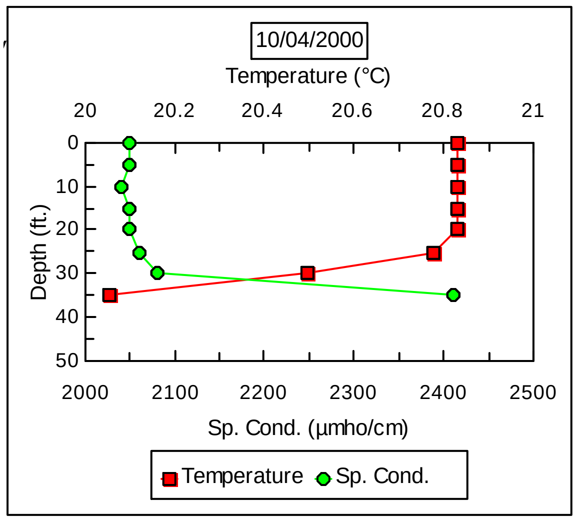

07/06/2000
Temperature (°C)
23 24 25 26 27 28
0 10 20 30 40 50
Depth (ft.)
0 2 4 6 8
D.O. (mg/L)
Temperature
D.O.

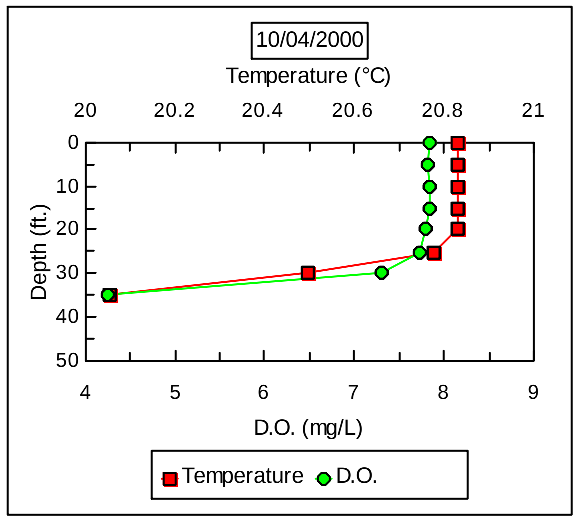

08/03/2000
Temperature (°C)
25.5 25.6 25.7 25.8 25.9 26
0 10 20 30 40 50
Depth (ft.)
2000 2500 3000 3500 4000 4500
Sp. Cond. (µmho/cm)
Temperature
Sp. Cond.

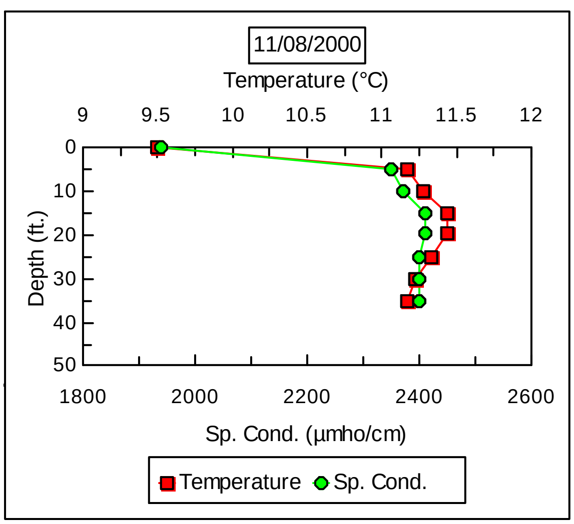

08/03/2000
Temperature (°C)
25.5 25.6 25.7 25.8 25.9 26
0 10 20 30 40 50
Depth (ft.)
0 2 4 6 8 10
D.O. (mg/L)
Temperature
D.O.

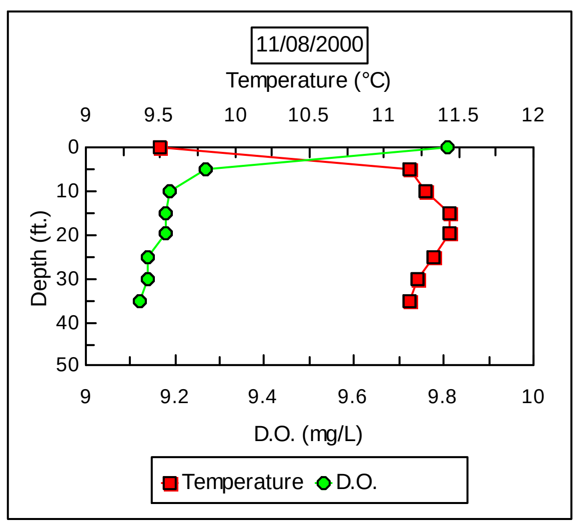

09/06/2000
Temperature (°C)
24.9 25 25.1 25.2 25.3
Depth (ft.)
0 10 20 30 40 50
1800 2000 2200 2400 2600 2800 3000
Sp. Cond. (µmho/cm)
Temperature Sp. Cond.

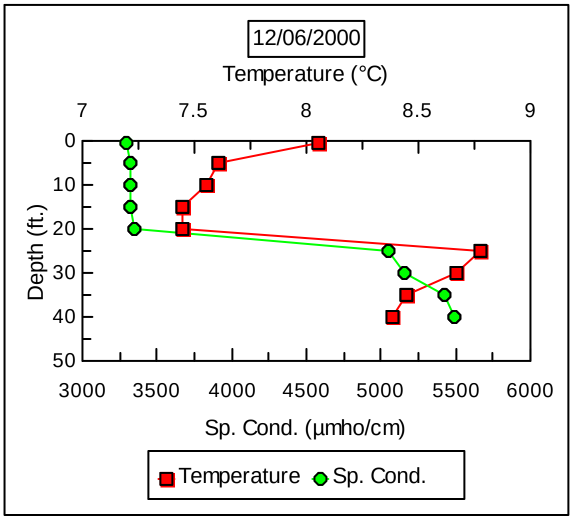

09/06/2000
Temperature (°C)
24.9 25 25.1 25.2 25.3
Depth (ft.)
0 10 20 30 40 50
0 2 4 6 8
D.O. (mg/L)
Temperature D.O.

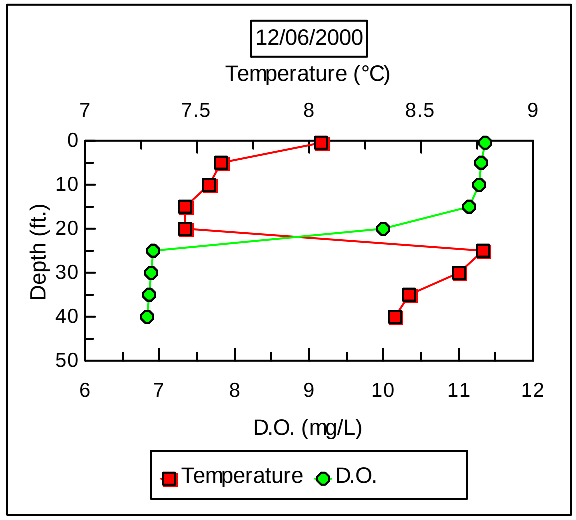

10/04/2000
Temperature (°C)
20 20.2 20.4 20.6 20.8 21
Depth (ft.)
0 10 20 30 40 50
2000 2100 2200 2300 2400 2500
Sp. Cond. (µmho/cm)
Temperature Sp. Cond.

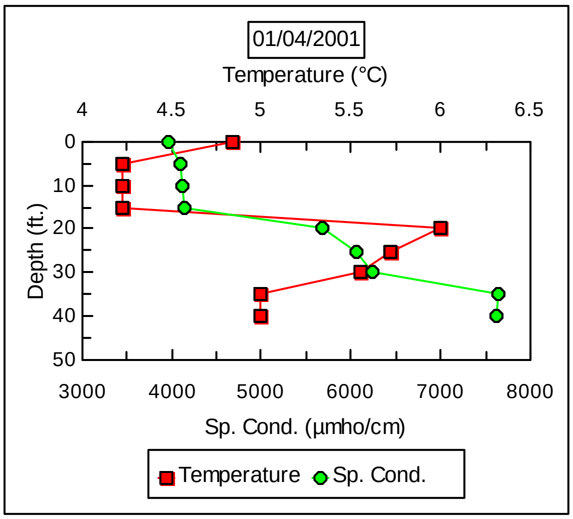

10/04/2000
Temperature (°C)
20 20.2 20.4 20.6 20.8 21
Depth (ft.)
0 10 20 30 40 50
4 5 6 7 8 9
D.O. (mg/L)
Temperature D.O.

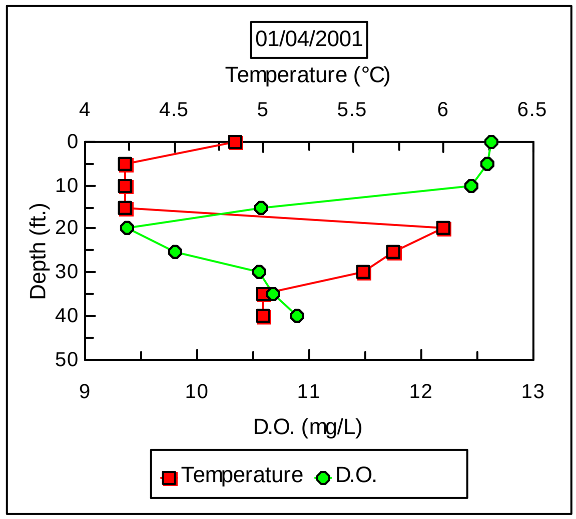

11/08/2000
Temperature (°C)
9 9.5 10 10.5 11 11.5 12
Depth (ft.)
0 10 20 30 40 50
1800 2000 2200 2400 2600
Sp. Cond. (µmho/cm)
Temperature Sp. Cond.

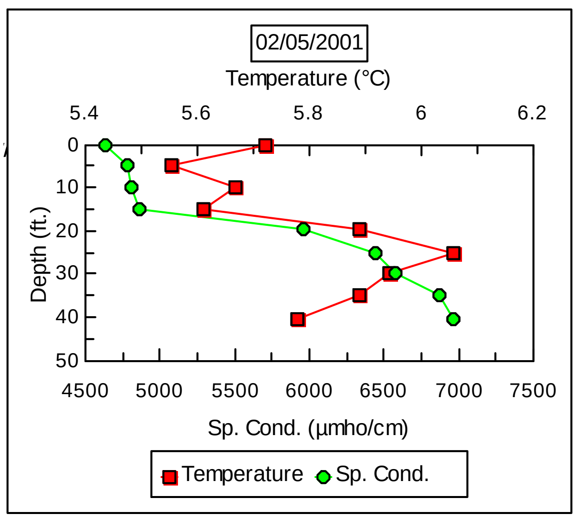

11/08/2000
Temperature (°C)
9 9.5 10 10.5 11 11.5 12
Depth (ft.)
0 10 20 30 40 50
9 9.2 9.4 9.6 9.8 10
D.O. (mg/L)
Temperature D.O.

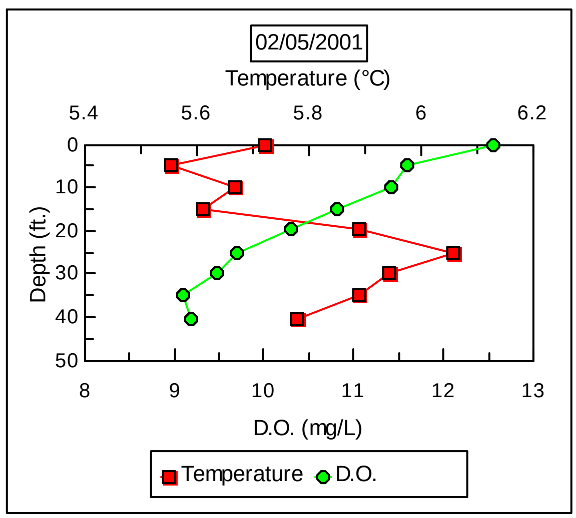

12/06/2000
Temperature (°C)
7
7.5
8
8.5
9
0
10
20
30
40
50
Depth (ft.)
3000
3500
4000
4500
5000
5500
6000
Sp. Cond. (µmho/cm)
Temperature
Sp. Cond.

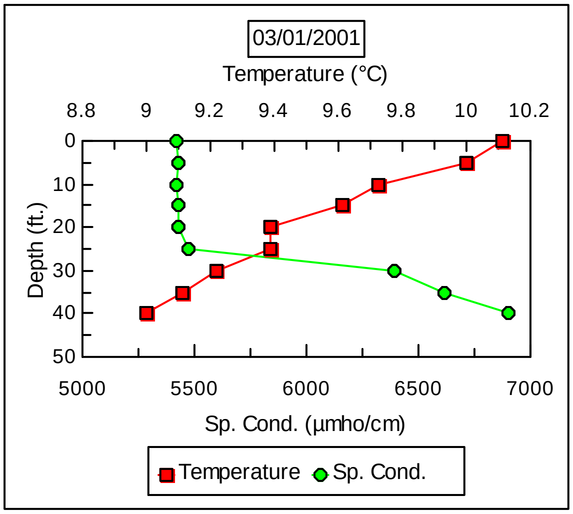

12/06/2000
Temperature (°C)
7
7.5
8
8.5
9
0
10
20
30
40
50
Depth (ft.)
6
7
8
9
10
11
12
D.O. (mg/L)
Temperature
D.O.

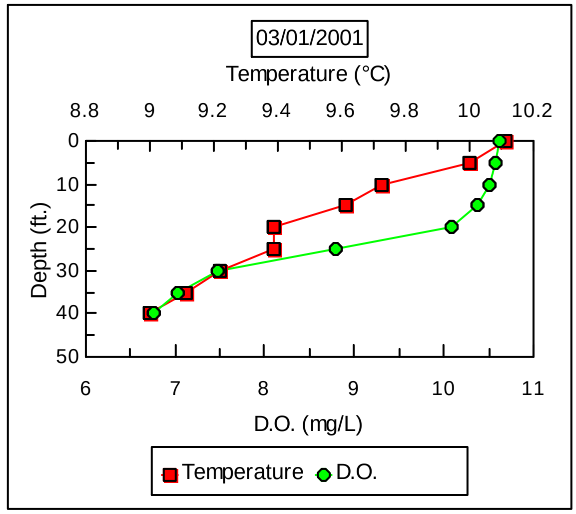

01/04/2001
Temperature (°C)
4
4.5
5
5.5
6
6.5
0
10
20
30
40
50
Depth (ft.)
3000
4000
5000
6000
7000
8000
Sp. Cond. (µmho/cm)
Temperature
Sp. Cond.

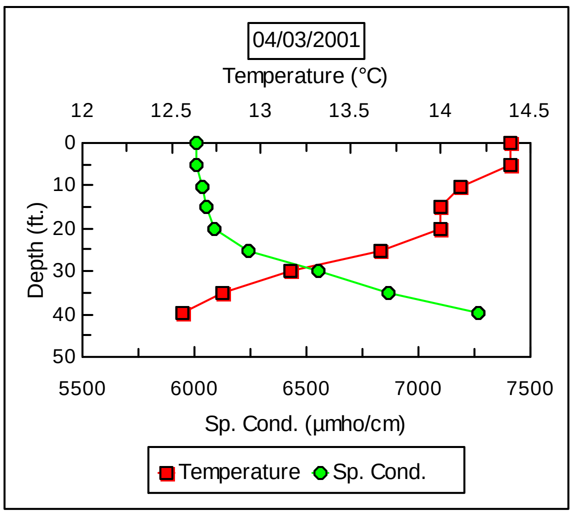

01/04/2001
Temperature (°C)
4
4.5
5
5.5
6
6.5
0
10
20
30
40
50
Depth (ft.)
9
10
11
12
13
D.O. (mg/L)
Temperature
D.O.

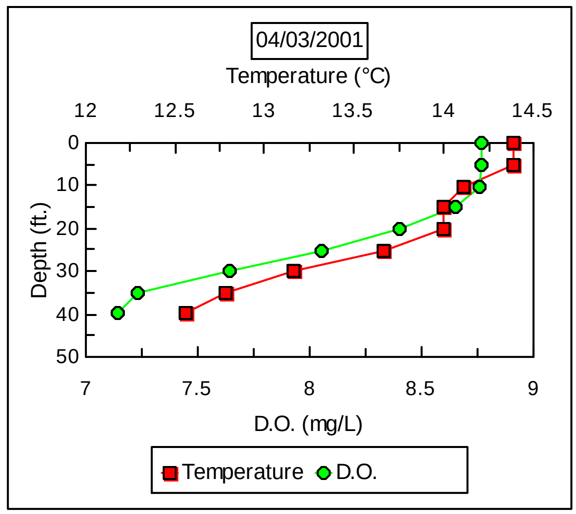

02/05/2001
Temperature (°C)
5.4
5.6
5.8
6
6.2
0
10
20
30
40
50
Depth (ft.)
4500
5000
5500
6000
6500
7000
7500
Sp. Cond. (µmho/cm)
Temperature
Sp. Cond.

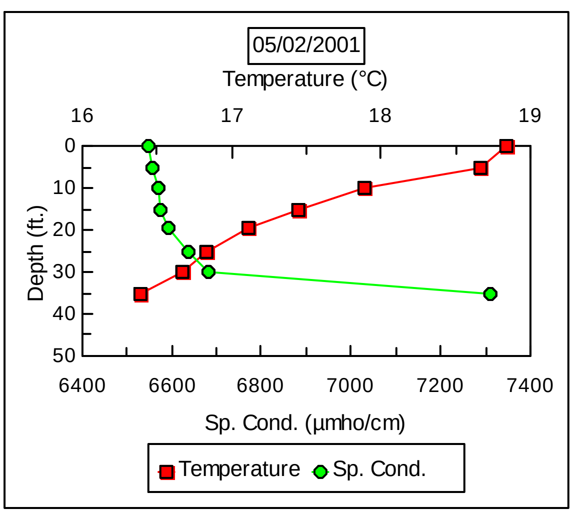

02/05/2001
Temperature (°C)
5.4
5.6
5.8
6
6.2
0
10
20
30
40
50
Depth (ft.)
8
9
10
11
12
13
D.O. (mg/L)
Temperature
D.O.

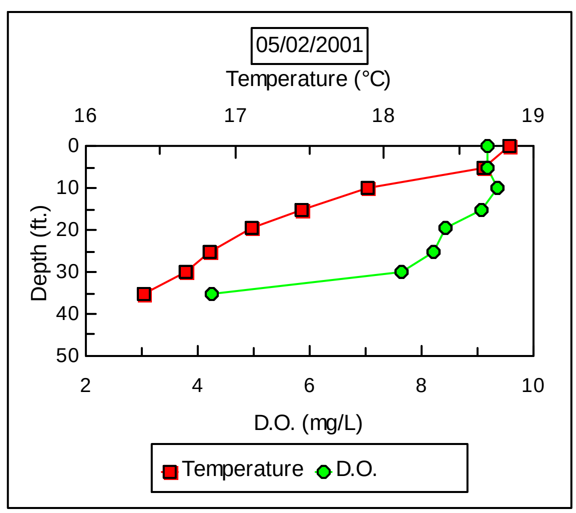

03/01/2001
Temperature (°C)
8.8 9 9.2 9.4 9.6 9.8 10 10.2
Depth (ft.)
0 10 20 30 40 50
5000 5500 6000 6500 7000
Sp. Cond. (µmho/cm)
Temperature
Sp. Cond.

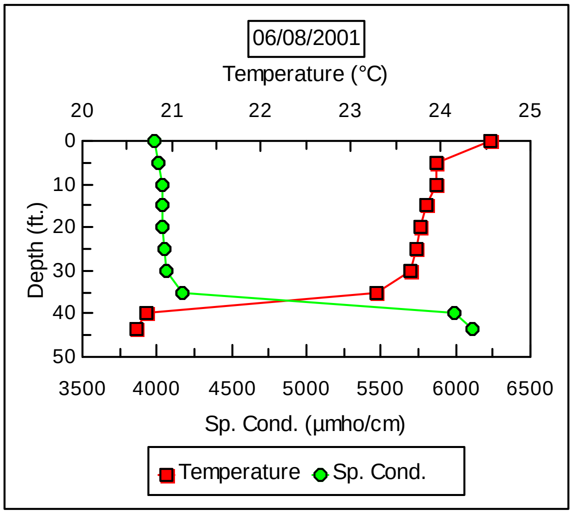

03/01/2001
Temperature (°C)
8.8 9 9.2 9.4 9.6 9.8 10 10.2
Depth (ft.)
0 10 20 30 40 50
6 7 8 9 10 11
D.O. (mg/L)
Temperature
D.O.

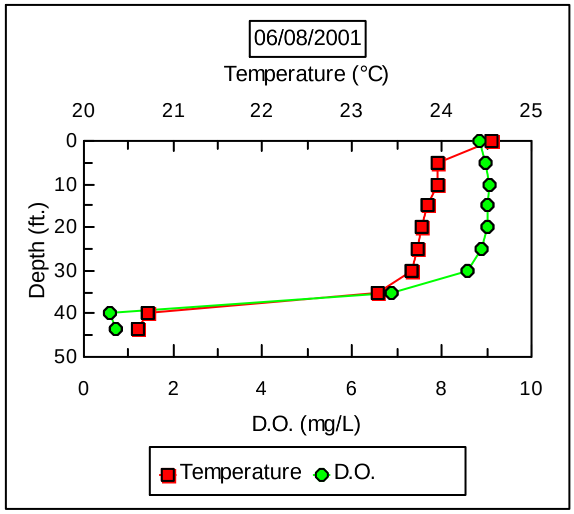

04/03/2001
Temperature (°C)
12 12.5 13 13.5 14 14.5
Depth (ft.)
0 10 20 30 40 50
5500 6000 6500 7000 7500
Sp. Cond. (µmho/cm)
Temperature
Sp. Cond.

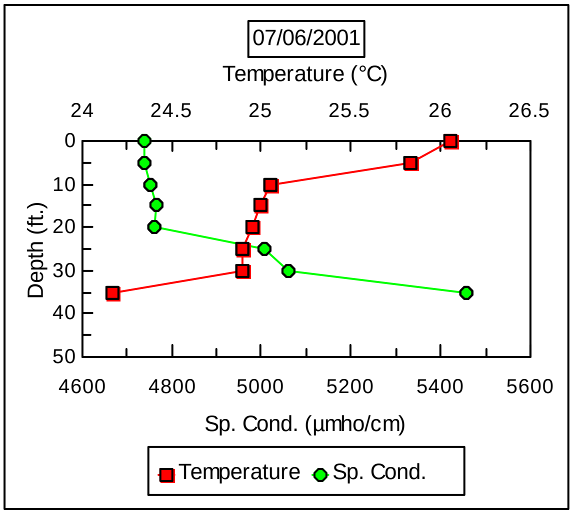

04/03/2001
Temperature (°C)
12 12.5 13 13.5 14 14.5
Depth (ft.)
0 10 20 30 40 50
7 7.5 8 8.5 9
D.O. (mg/L)
Temperature
D.O.

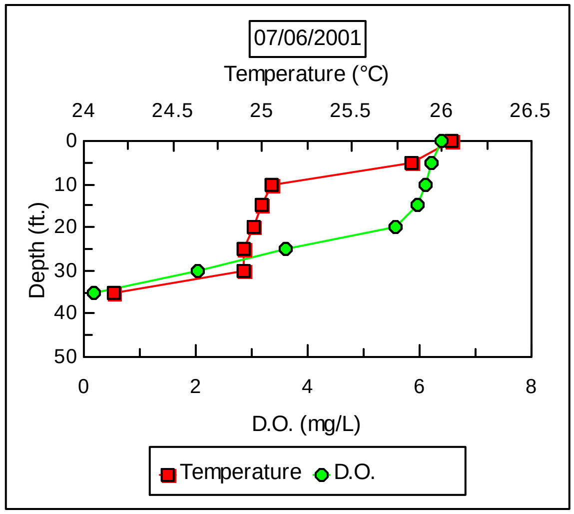

05/02/2001
Temperature (°C)
16 17 18 19
Depth (ft.)
0 10 20 30 40 50
6400 6600 6800 7000 7200 7400
Sp. Cond. (µmho/cm)
Temperature
Sp. Cond.

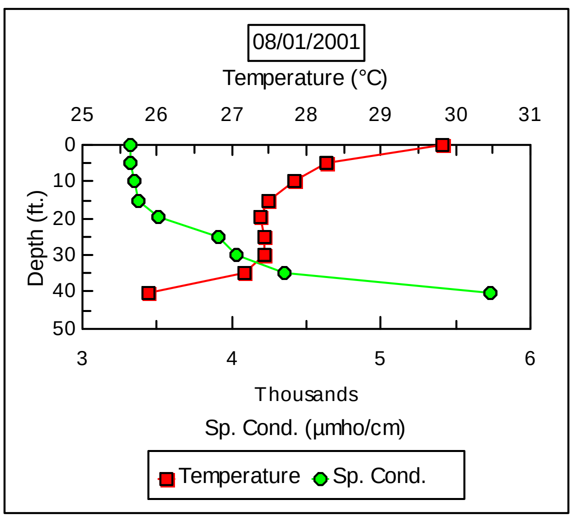

05/02/2001
Temperature (°C)
16 17 18 19
Depth (ft.)
0 10 20 30 40 50
2 4 6 8 10
D.O. (mg/L)
Temperature
D.O.

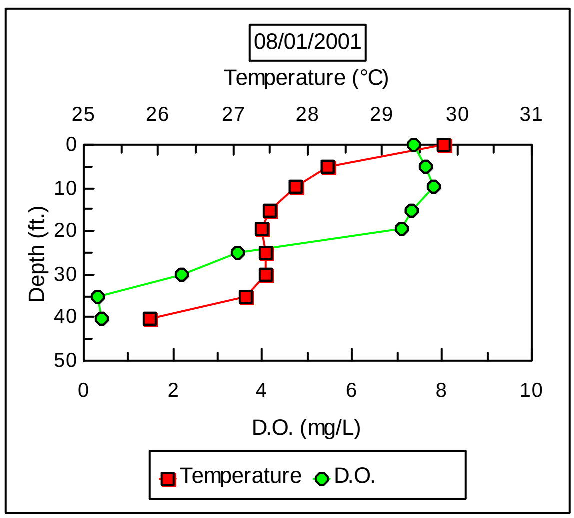

06/08/2001
Temperature (°C)
20 21 22 23 24 25
0 10 20 30 40 50
Depth (ft.)
3500 4000 4500 5000 5500 6000 6500
Sp. Cond. (µmho/cm)
Temperature Sp. Cond.

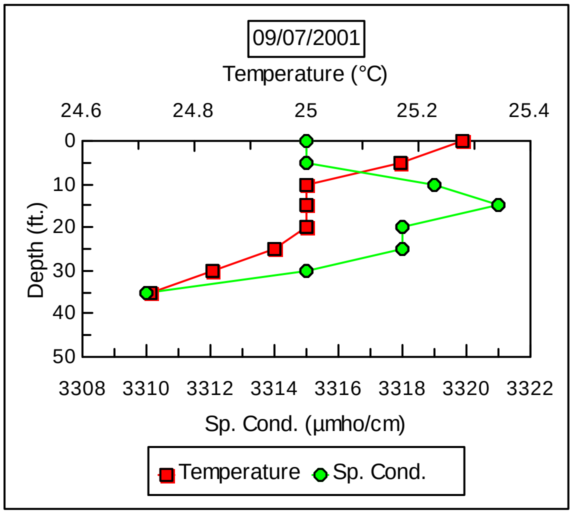

06/08/2001
Temperature (°C)
20 21 22 23 24 25
0 10 20 30 40 50
Depth (ft.)
0 2 4 6 8 10
D.O. (mg/L)
Temperature D.O.

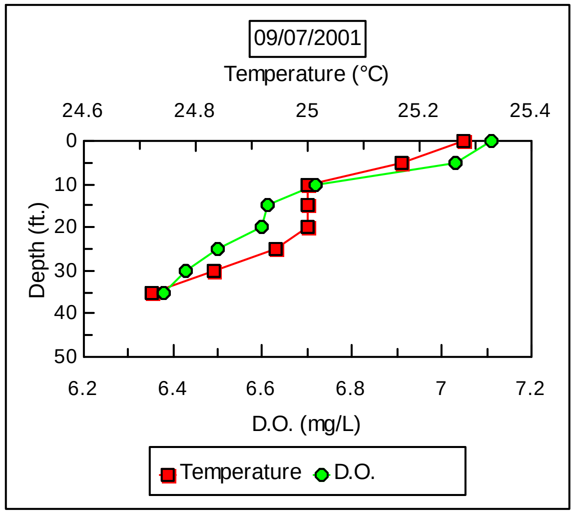

07/06/2001
Temperature (°C)
24 24.5 25 25.5 26 26.5
0 10 20 30 40 50
Depth (ft.)
4600 4800 5000 5200 5400 5600
Sp. Cond. (µmho/cm)
Temperature Sp. Cond.

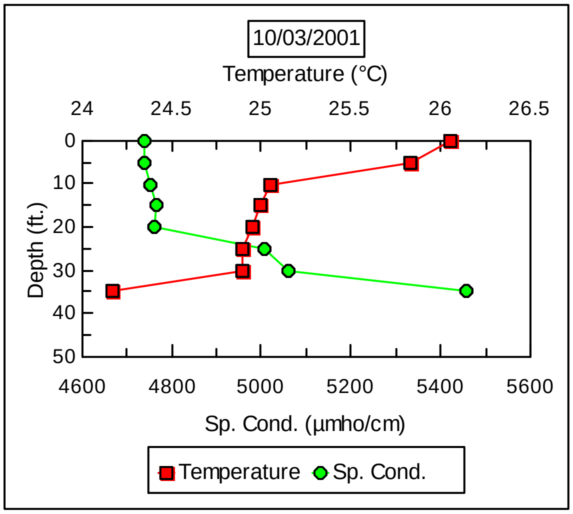

07/06/2001
Temperature (°C)
24 24.5 25 25.5 26 26.5
0 10 20 30 40 50
Depth (ft.)
0 2 4 6 8
D.O. (mg/L)
Temperature D.O.

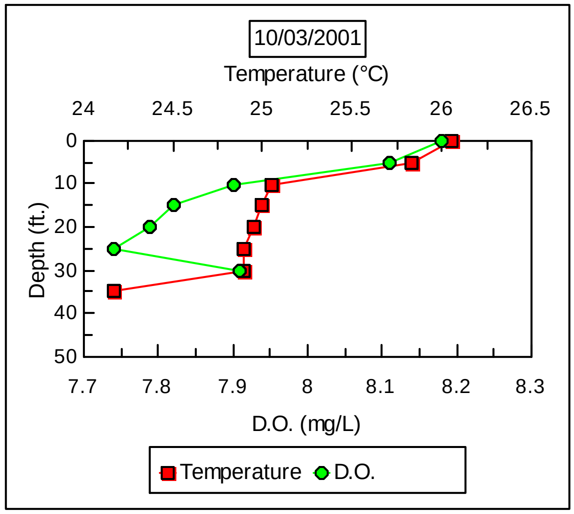

08/01/2001
Temperature (°C)
25 26 27 28 29 30 31
0 10 20 30 40 50
Depth (ft.)
3 4 5 6
Thousands
Sp. Cond. (µmho/cm)
Temperature Sp. Cond.


08/01/2001
Temperature (°C)
25 26 27 28 29 30 31
0 10 20 30 40 50
Depth (ft.)
0 2 4 6 8 10
D.O. (mg/L)
Temperature D.O.


09/07/2001
Temperature (°C)
24.6
24.8
25
25.2
25.4
Depth (ft.)
0
10
20
30
40
50
3308
3310
3312
3314
3316
3318
3320
3322
Sp. Cond. (µmho/cm)
Temperature
Sp. Cond.


09/07/2001
Temperature (°C)
24.6
24.8
25
25.2
25.4
Depth (ft.)
0
10
20
30
40
50
6.2
6.4
6.6
6.8
7
7.2
D.O. (mg/L)
Temperature
D.O.


10/03/2001
Temperature (°C)
24
24.5
25
25.5
26
26.5
Depth (ft.)
0
10
20
30
40
50
4600
4800
5000
5200
5400
5600
Sp. Cond. (µmho/cm)
Temperature
Sp. Cond.


10/03/2001
Temperature (°C)
24
24.5
25
25.5
26
26.5
Depth (ft.)
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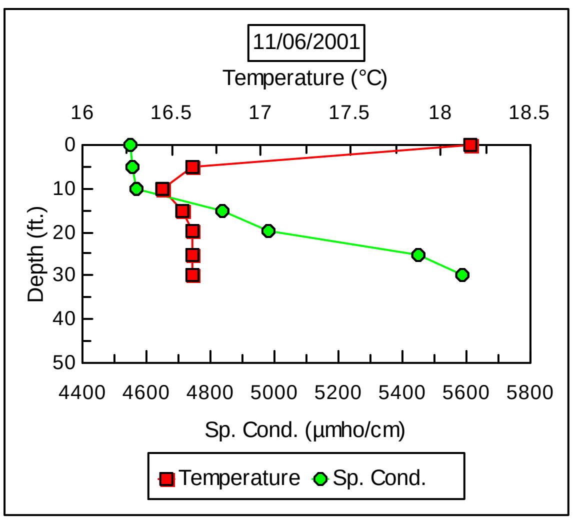
10
20
30
40
50
7.7
7.8
7.9
8
8.1
8.2
8.3
D.O. (mg/L)
Temperature
D.O.


11/06/2001
Temperature (°C)
16
16.5
17
17.5
18
18.5
Depth (ft.)
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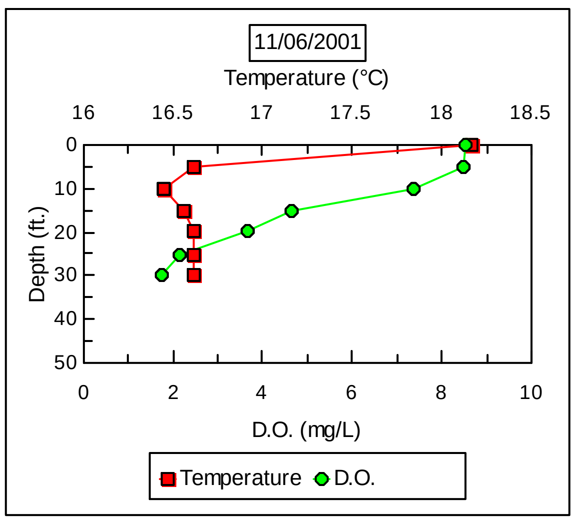
10
20
30
40
50
4400
4600
4800
5000
5200
5400
5600
5800
Sp. Cond. (µmho/cm)
Temperature
Sp. Cond.


11/06/2001
Temperature (°C)
16
16.5
17
17.5
18
18.5
Depth (ft.)
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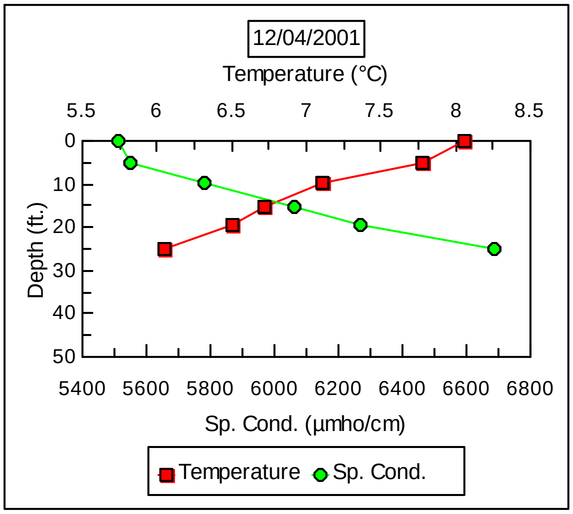
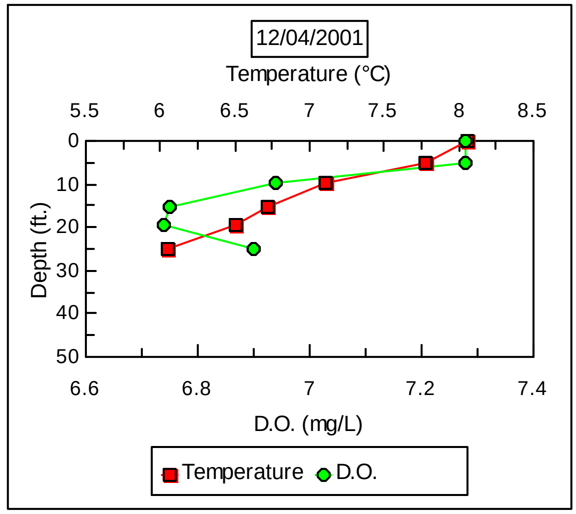
10
20
30
40
50
0
2
4
6
8
10
D.O. (mg/L)
Temperature
D.O.


12/04/2001
Temperature (°C)
5.5 6 6.5 7 7.5 8 8.5
Depth (ft.)
0 10 20 30 40 50
5400 5600 5800 6000 6200 6400 6600 6800
Sp. Cond. (µmho/cm)
Temperature
Sp. Cond.


12/04/2001
Temperature (°C)
5.5 6 6.5 7 7.5 8 8.5
Depth (ft.)
0 10 20 30 40 50
6.6 6.8 7 7.2 7.4
D.O. (mg/L)
Temperature
D.O.

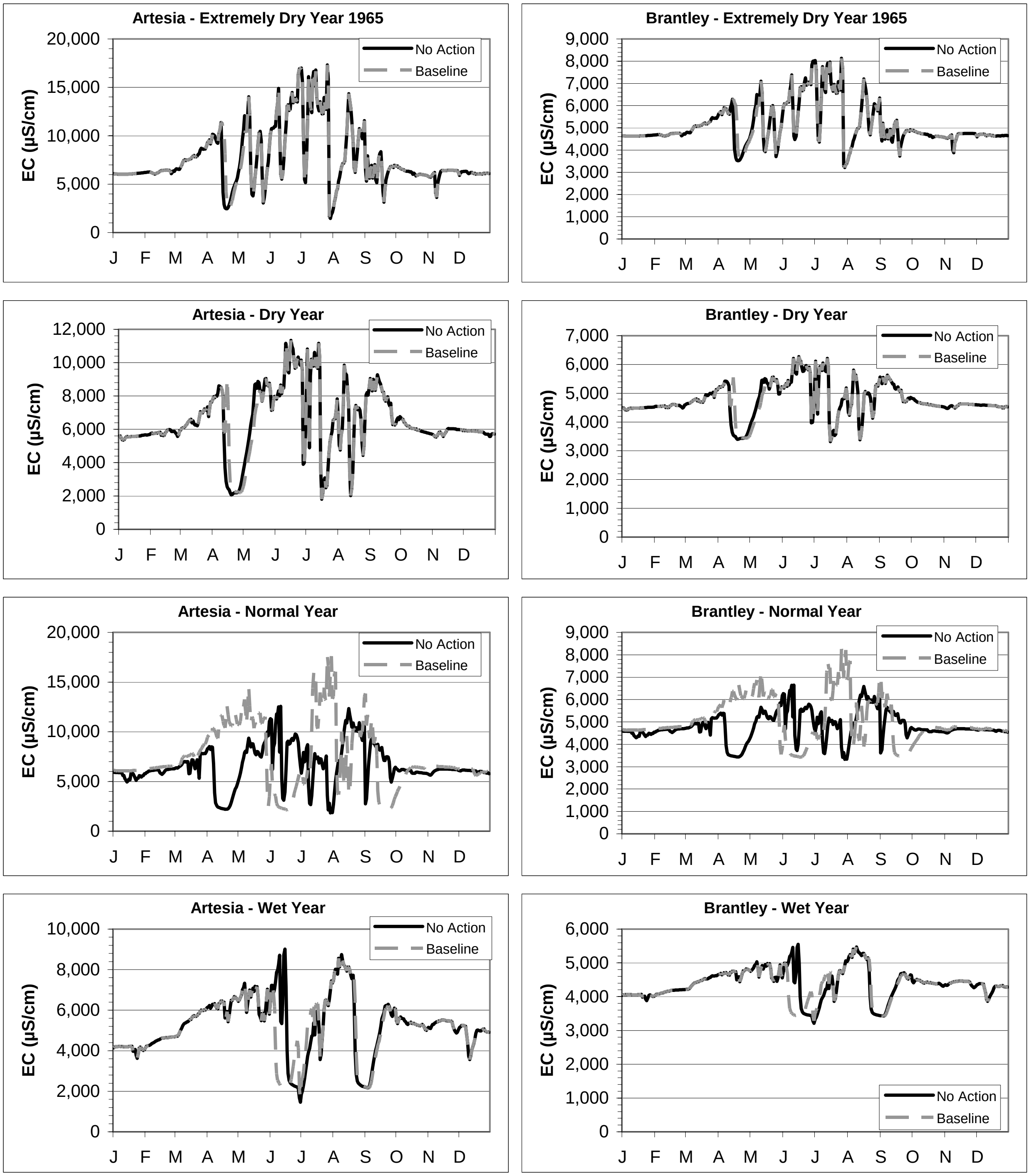
Attachment 4

Dry, Normal, and Wet Year EC Plots

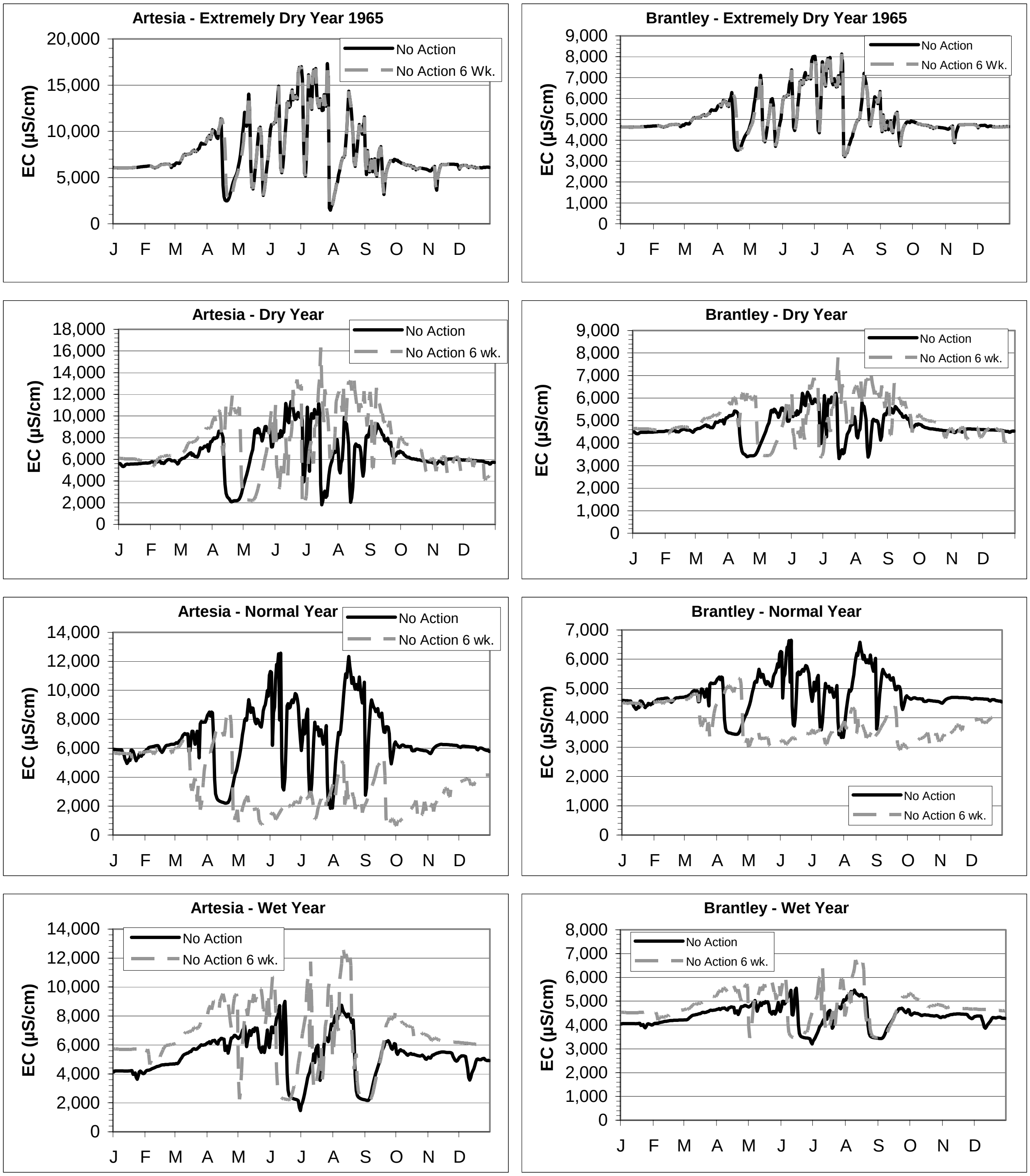
Breakdown of dry, normal, and wet years by alternative based on Effective Brantley Storage (EBS)			
Alternative	Dry Years	Normal Years	Wet Years
Pre-1991 baseline	19	21	20
No Action	22	24	14
No Action w/6week	23	23	14
Taiban Constant	24	19	17
Taiban Variable (40 cfs)	25	18	17
Taiban Variable (45 cfs)	25	17	18
Taiban Variable (55 cfs)	23	19	18
Acme Constant	25	24	11
Acme Variable	23	25	12
Critical Habitat	24	19	17

EBS = Avalon storage + Brantley storage + (0.75 x Sumner storage) + (0.65 x Santa Rosa storage)

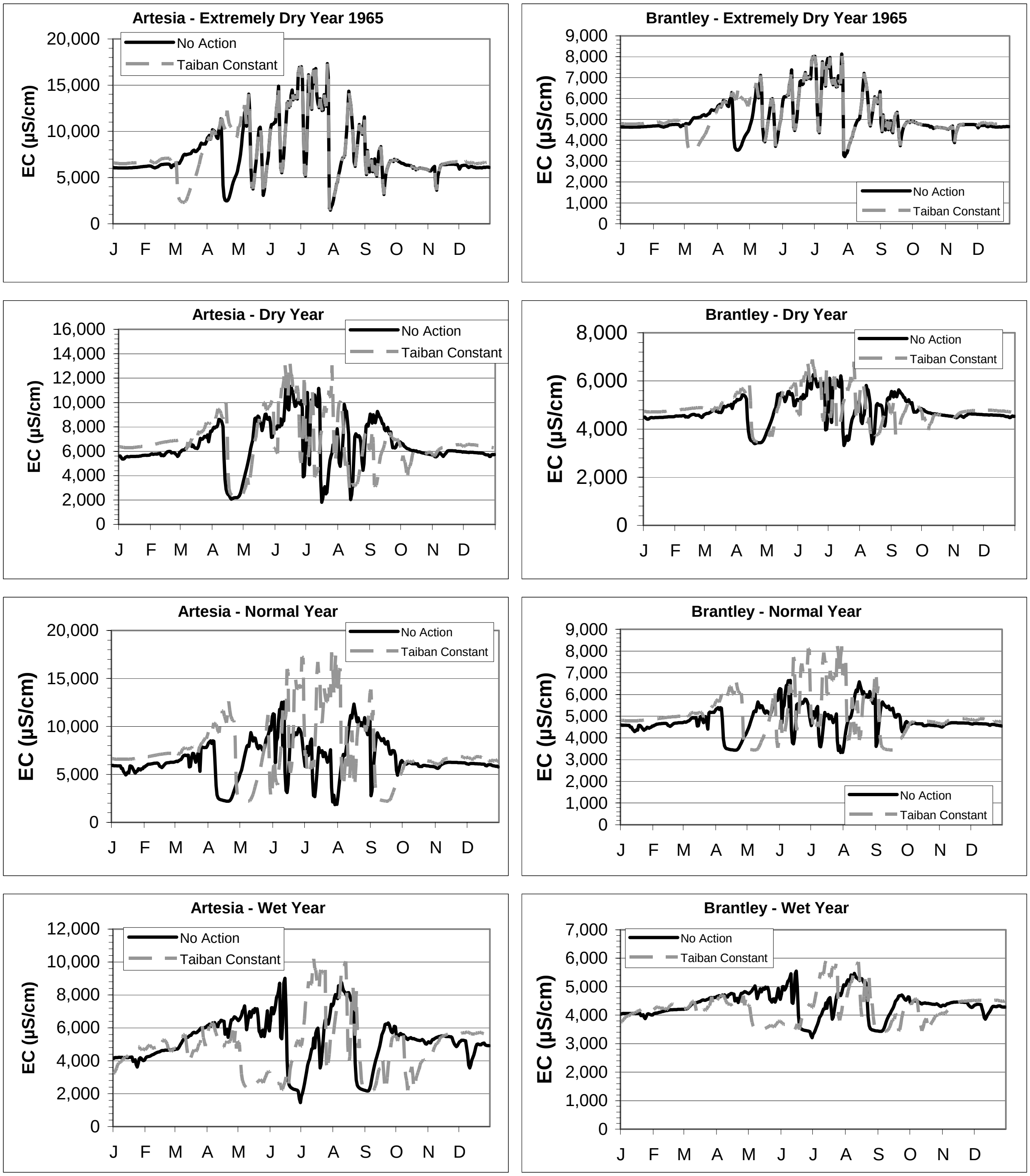
Classification:
Dry Hydrologic Condition – EBS < 75,000 acre-feet
Average (Normal) Hydrologic Condition – EBS > 75,000 & < 110,000 acre-feet
Wet Hydrologic Condition – EBS > 110,000 acre-feet



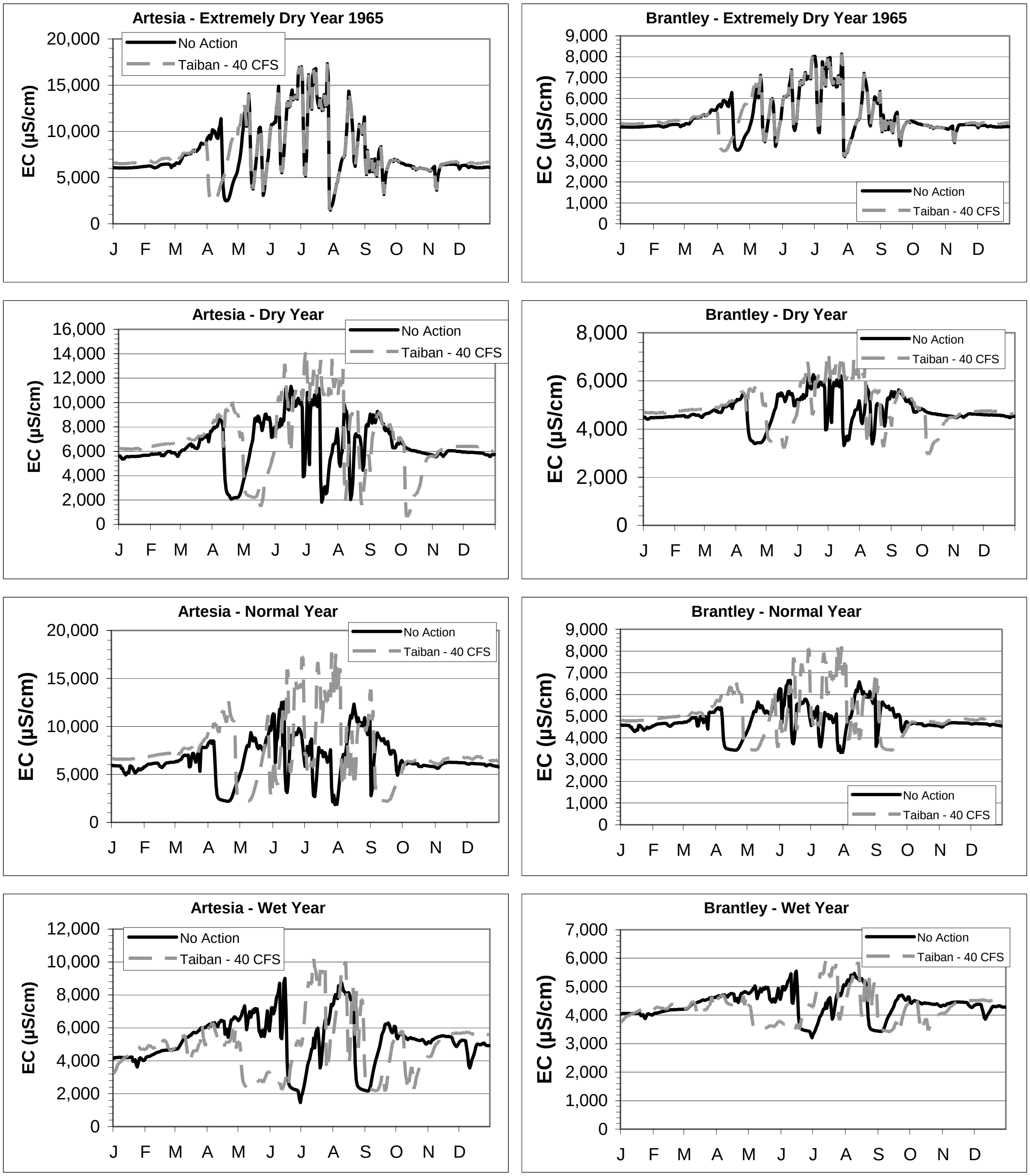
Comparison of the projected daily EC for the pre-1991 Baseline and the No Action Alternative (present condition) at the near Artesia and below Brantley gages in each of 4 EBS year-types



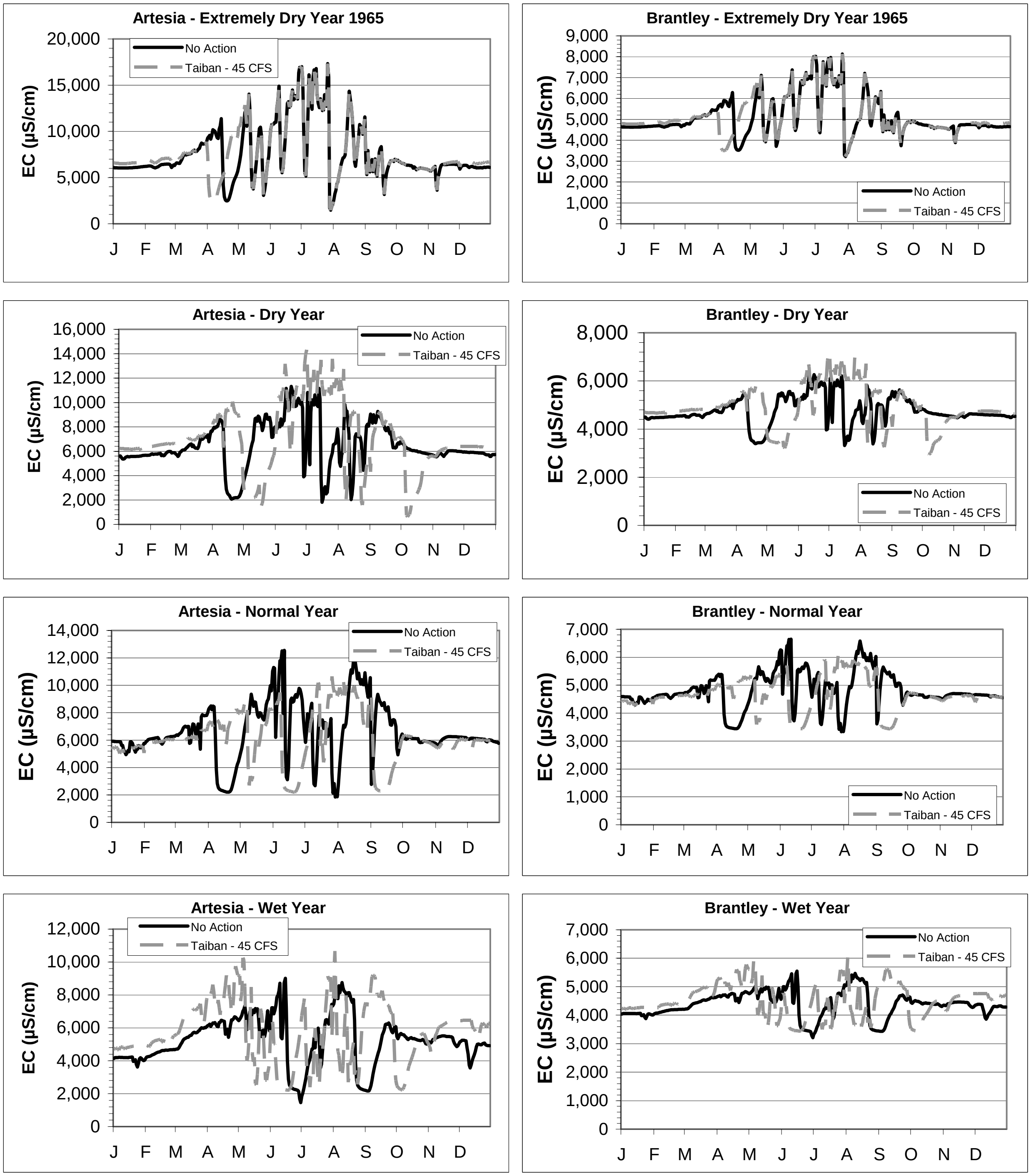
Comparison of the projected daily EC for No Action Alternative (present condition) with that of the No Action with the 6-week limitation on block releases at the near Artesia and below Brantley gages in each of 4 EBS year-types



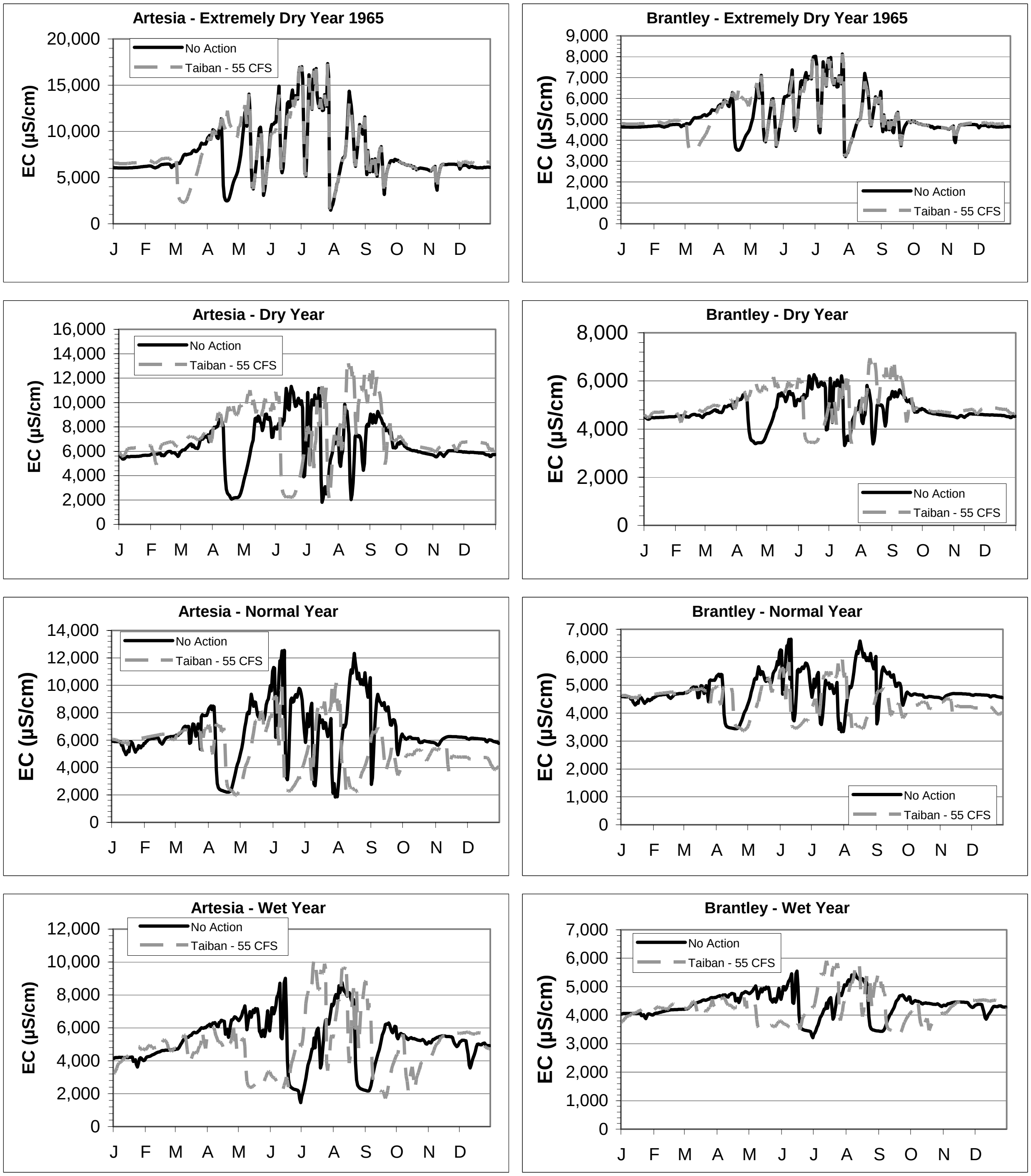
Comparison of the projected daily EC for No Action Alternative (present condition) with that of the Taiban Constant Alternative at the near Artesia and below Brantley gages in each of 4 EBS year-types



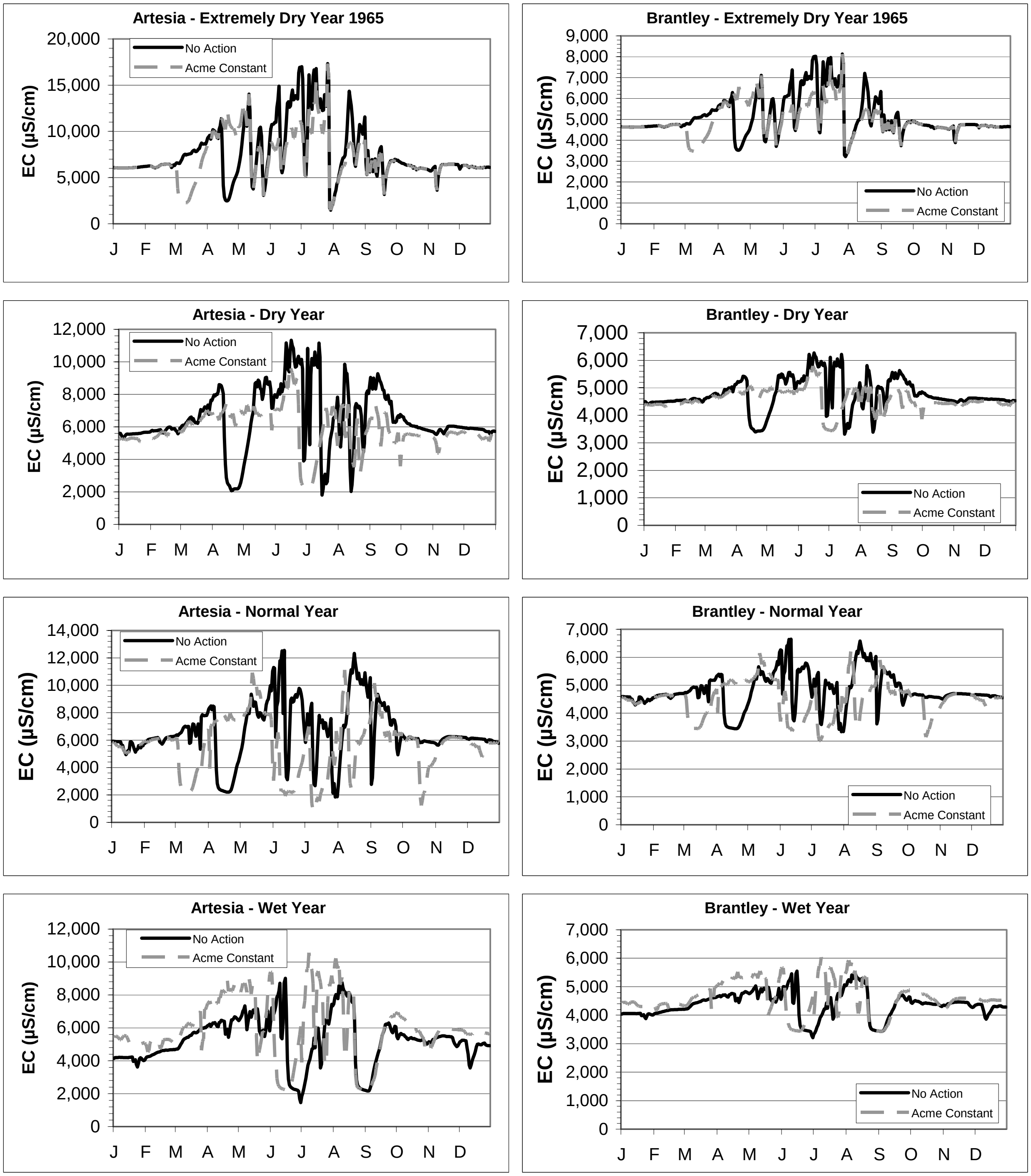
Comparison of the projected daily EC for No Action Alternative (present condition) with that of the Taiban Variable Low Target Flow (40 ft^3/s) Alternative at the near Artesia and below Brantley gages in each of 4 EBS year-types



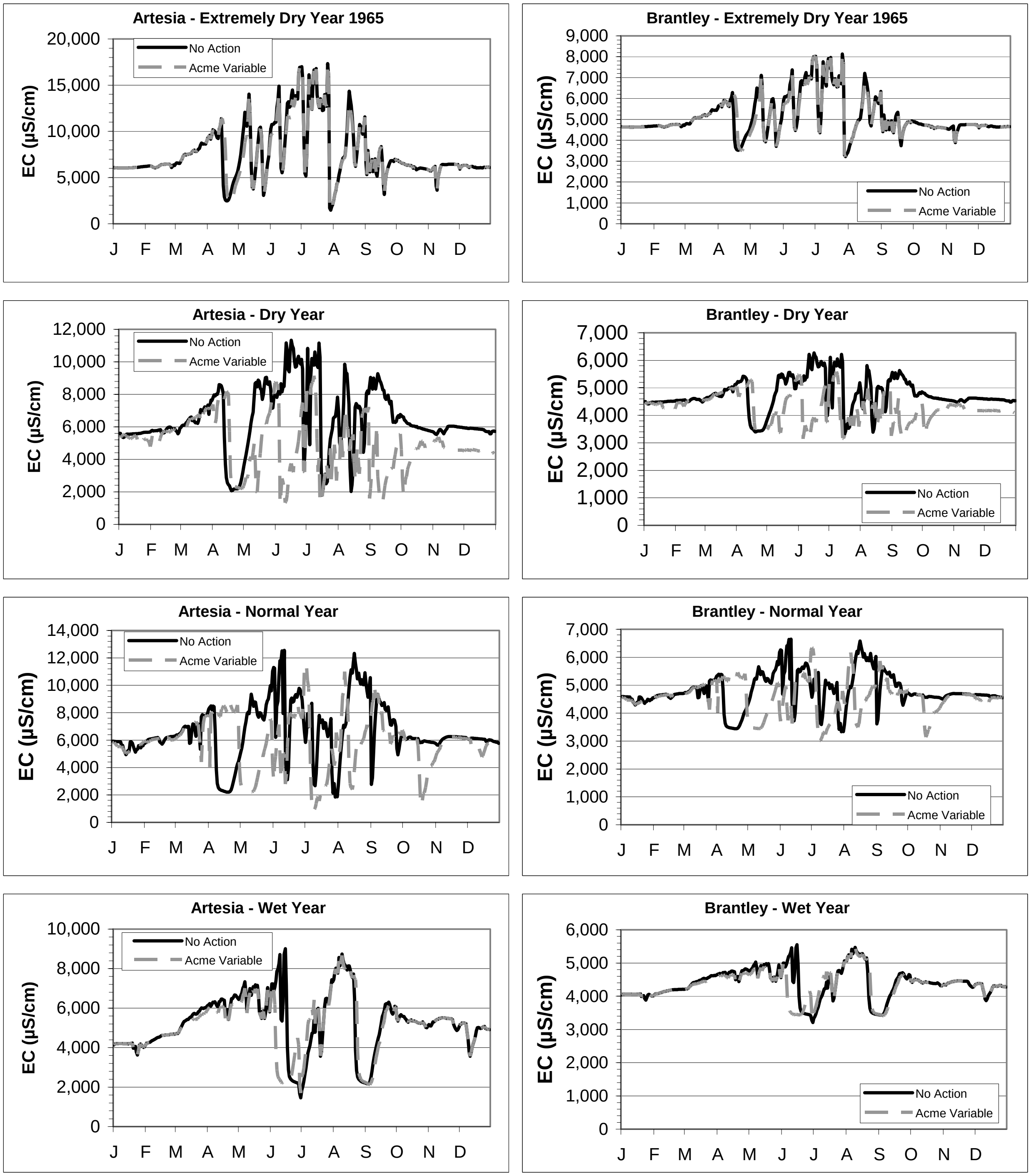
Comparison of the projected daily EC for No Action Alternative (present condition) with that of the Taiban Variable Medium Target Flow (45 ft^3/s) Alternative at the near Artesia and below Brantley gages in each of 4 EBS year-types



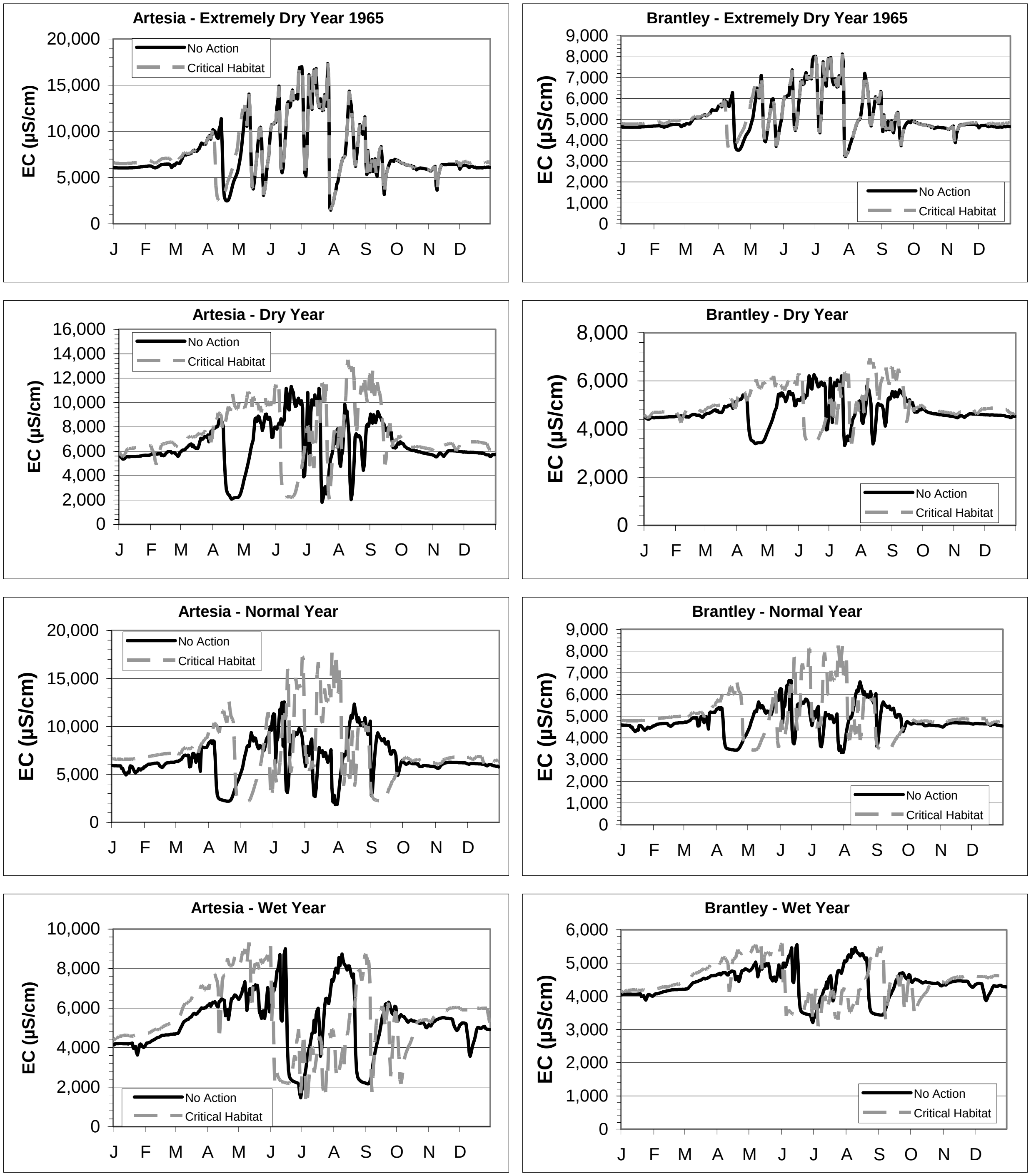
Comparison of the projected daily EC for No Action Alternative (present condition) with that of the Taiban Variable High Target Flow (55 ft^3/s) Alternative at the near Artesia and below Brantley gages in each of 4 EBS year-types



Comparison of the projected daily EC for No Action Alternative (present condition) with that of the Acme Constant Alternative at the near Artesia and below Brantley gages in each of 4 EBS year-types



Comparison of the projected daily EC for No Action Alternative (present condition) with that of the Acme Variable Alternative at the near Artesia and below Brantley gages in each of 4 EBS year-types



Comparison of the projected daily EC for No Action Alternative (present condition) with that of the Critical Habitat Alternative at the near Artesia and below Brantley gages in each of 4 EBS year-types

ATTACHMENT 5

BRANTLEY SALINITY ISSUE PAPER

HYDROSPHERE
Resource Consultants

Date: 03 December 2004

To: Jim Yahnke, Miguel Rocha, US Bureau of Reclamation
Tomas Stockton, Tetra Tech
John Carron, Hydrosphere

Cc: Sara Rhoton, Peter Burck, Elisa Sims, NMISC
Marsha Carra, US Bureau of Reclamation
David Batts, Kevin Doyle, Tetra Tech

From: Jim McCord, Ph.D., P.E., Jodi Clark

Subject: Brantley Salinity Issues: Investigation of Winter Season Salinity Stratification from Impact Analysis Results

Introduction

The purpose for doing the analyses presented in this memo was to evaluate late-winter salinity stratification from impact analysis results in an attempt to answer the following question:

> Will winter bypasses lead to development of an excessively thick "fresh water" upper layer that will adversely affect CID's ability to mechanically mix a deep "saline" layer, thus forcing CID to "waste" saline water prior to the beginning of the irrigation season?

The motivation for looking into this issue stems from the observation by Jim Yahnke (WQ Workgroup) that impact analysis model results showed fewer early Spring block releases than the historical data. Historically, Tom Davis (CID) called for an early block release to "freshen up" poor water quality in Brantley. Figures 1 and 2 show typical profiles of total dissolved solids (TDS) in Brantley in Summer and late Winter respectively.

Lake Salinity Stratification

We began by performing a mass balance on Brantley. We focused on the November 1 to March 1 time period for each water year and calculated the cumulative daily change in volume for 11/01/n – 03/01/n+1 from Brantley daily storage values for each scenario. We also calculated the volume from components.

$$V_{iw} = \int_{11/1/n}^{3/1/n+1} Q_{\inf low} dt \cong \int_{11/1/n}^{3/1/n+1} (Q_{Kaiser} + BrantleyUL - Q_{PRbelowBrantley} - Evaporation)dt$$

where

V_{iw} = Winter volume inflow to Brantley (11/01/n and 03/01/n+1)

$Q_{\inf low}$ = Daily inflows to Brantley

Q_{Kaiser} = Daily flows Pecos River at Kaiser

$BrantleyUL$ = Brantley Unidentified Losses

$Q_{PRbelowBrantley}$ = Daily flows Pecos River below Brantley

$Evaporation$ = Daily Brantley Evaporation

The daily value for each component was directly calculated from model results for each scenario including Brantley elevation used in the Brantley UL calculations. The Brantley UL was based on correlation to change in Brantley elevation (Fig. 3). Figure 4 shows a check of component volume calculations against modeled Brantley volume for each alternative. The component data was then used to evaluate the salinity stratification. The saline layer top elevation was calculated first using the elevation storage correlation shown in Fig 5. The storage used was the minimum of the initial November 1 storage or 3,500 AF plus the Brantley UL value. Total Brantley volume was calculated next as the initial November 1 Volume + Kaiser – Pecos River below Brantley + Brantley UL. The fresher layer (also reservoir) top elevation was then calculated using this volume and the elevation-storage rating curve (Fig. 5). The thickness of the fresher layer was then calculated by subtracting the top elevation of the more saline layer from the top of the fresher layer. A plot showing the exceedance curve of fresh layer thickness for each scenario is shown in Figure 6.

Outflow Salinity

We also looked at the correlation of specific electrical conductance (EC) inflow and change in EC Outflow-Inflow (O-I) from data that was representative of times when there was an early spring block release (Fig. 7). This yielded a higher correlation than the model developed by Jim Yahnke using year round data (Fig. 8). We also developed a correlation between Brantley storage at the beginning of the early spring block release and the average outflow EC during the block release (Fig. 9). Using this correlation, we developed an exceedance curve for Brantley outflow EC based on March 1 storage as shown in Figure 10. Table 1 shows the ranking of the scenarios based on mean Brantley outflow EC derived from March 1 Brantley Storage. This ranking is quite different from the average annual Brantley outflow EC ranking reported by Jim Yahnke in magnitude, ordering, and range of variability (Table 1). The narrow range for the predicted average annual EC indicates that it is not strongly impacted by the variation in operations among the alternatives. The predicted early spring EC results, on the other hand, suggest a greater impact by the variation in operations among the alternatives.

Ayers and Westcott (1985) provided data that shows a linear decrease in percent yield of alfalfa in the EC range between 1,300 and 10,000 µS/cm (Fig. 11). This relationship was used in conjunction with our computed early spring EC to develop an exceedance curve of alfalfa yield reduction for each scenario (Fig. 12).

Summary

These results show that

- The alternatives with higher winter bypass flows are more likely to develop a thicker fresh layer (Figure 6).
- There is a higher correlation between inflow EC and change in EC (O-I) for data during early spring block releases that for year round data (Figures 7 and 8).
- There may be a relationship between average outflow EC during an early spring block release and Brantley volume at the beginning of the block release (Figure 9).
- Seasonal variations in operations affect outflow EC (Table 1).
- The more alternatives with higher winter bypass flows result in a higher mean early spring outflow EC (Figure 10) and thus have a higher likelihood of adverse impacts to crops (Figure 12).

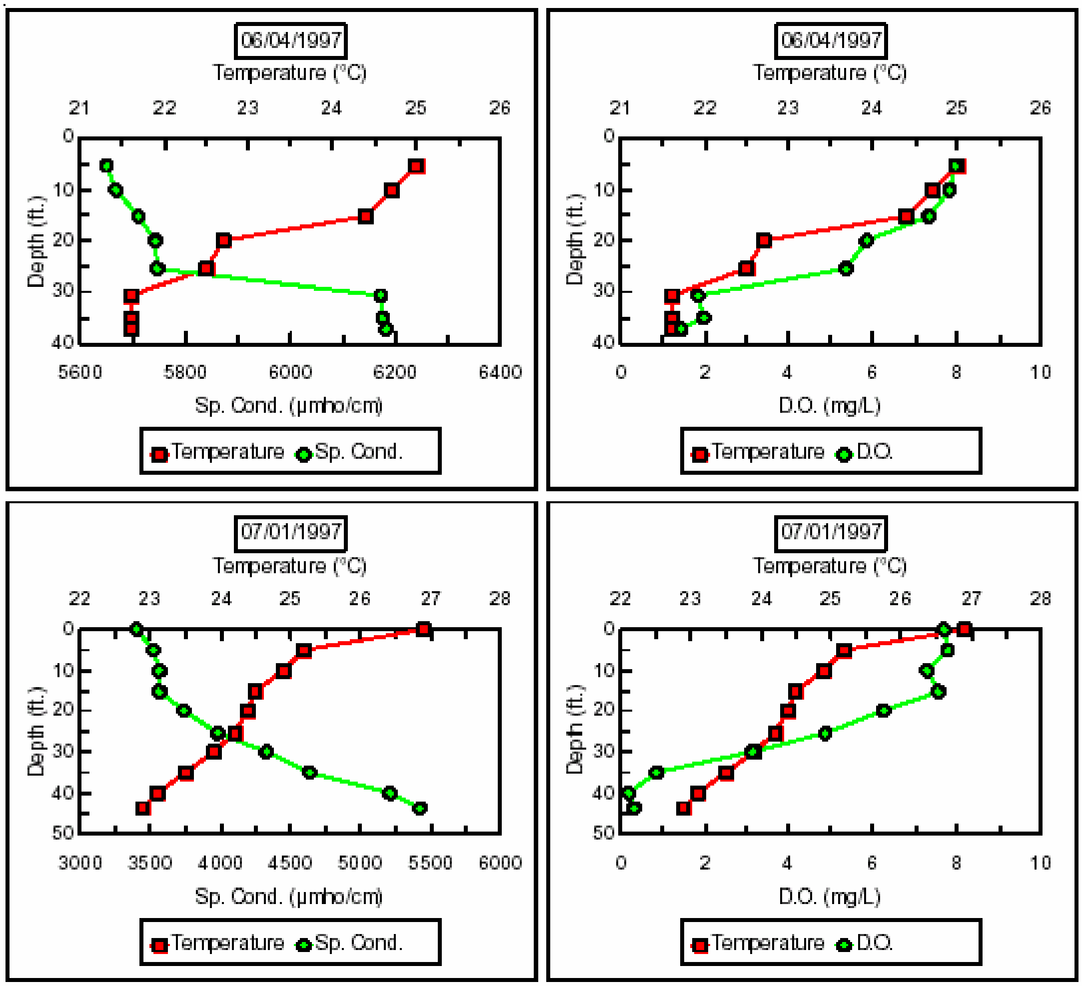


Figure 1. Summertime TDS (Sp. Cond.) profiles in Brantley Reservoir.

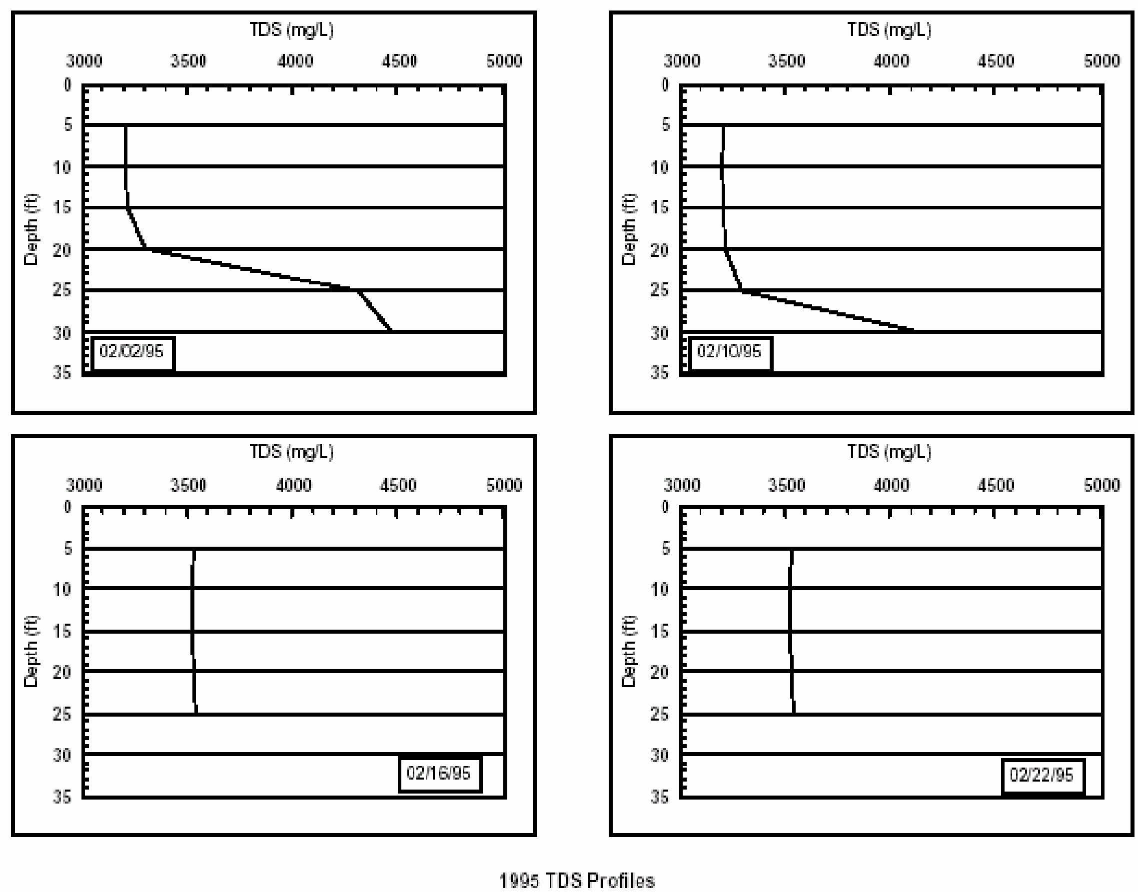


Figure 2. Late Winter TDS profiles for Brantley Reservoir.

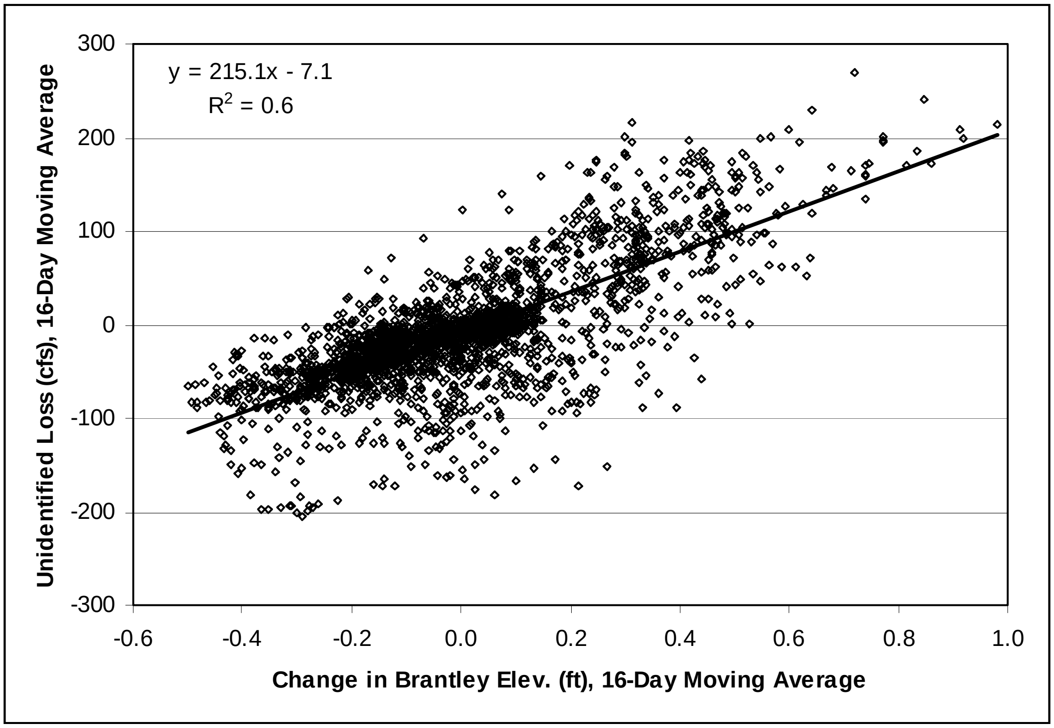


Figure 3. Scatter plot and best fit linear model for ULs versus change in reservoir elevation. 16-day moving average of equation components.

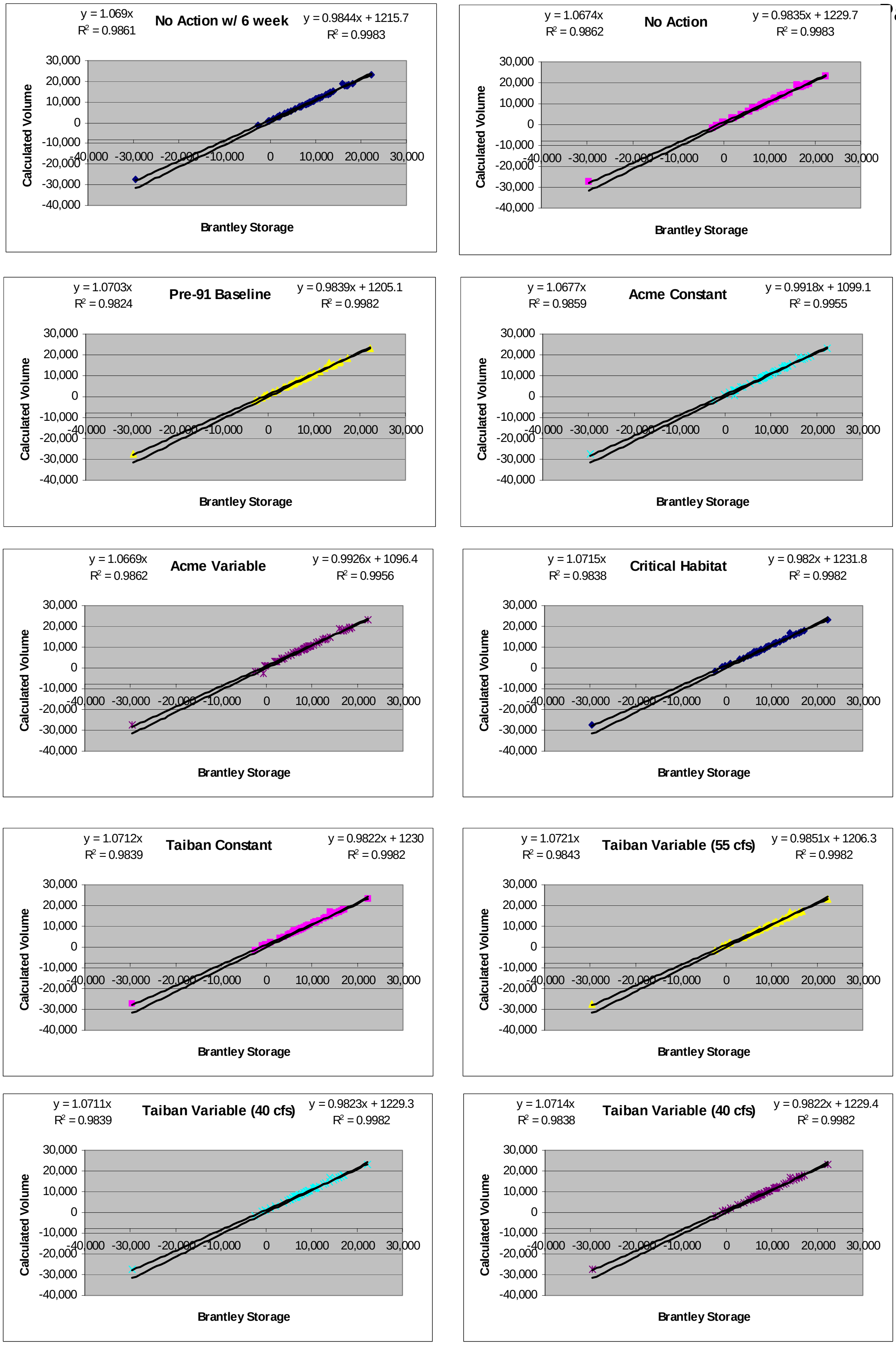


Figure 4. Mass Balance check of modeled Brantley Storage and calculated Volume from model components.

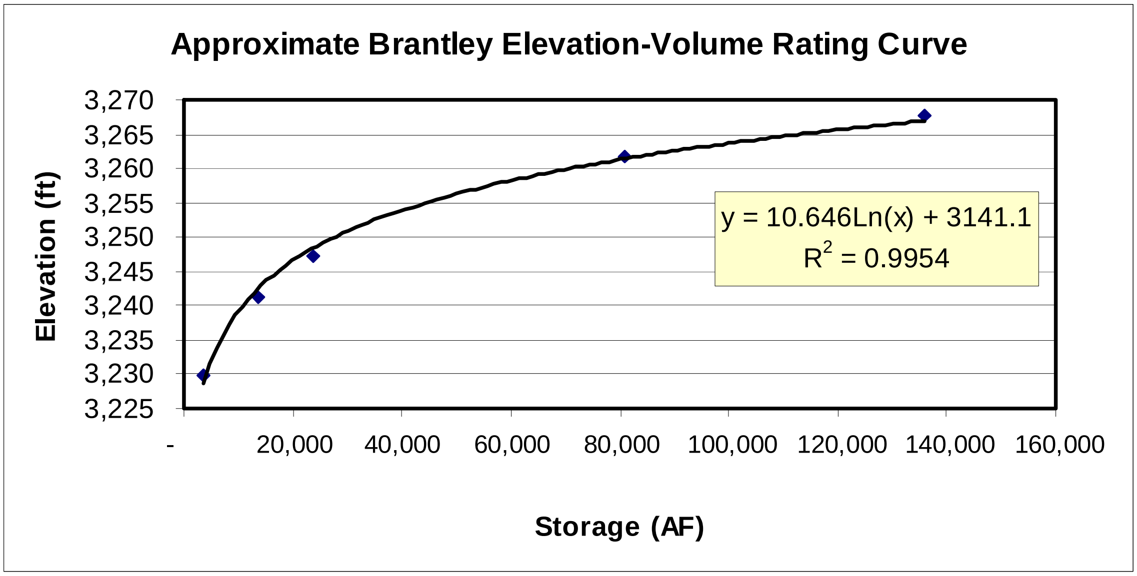


Figure 5. Approximate Brantley elevation – volume rating curve.

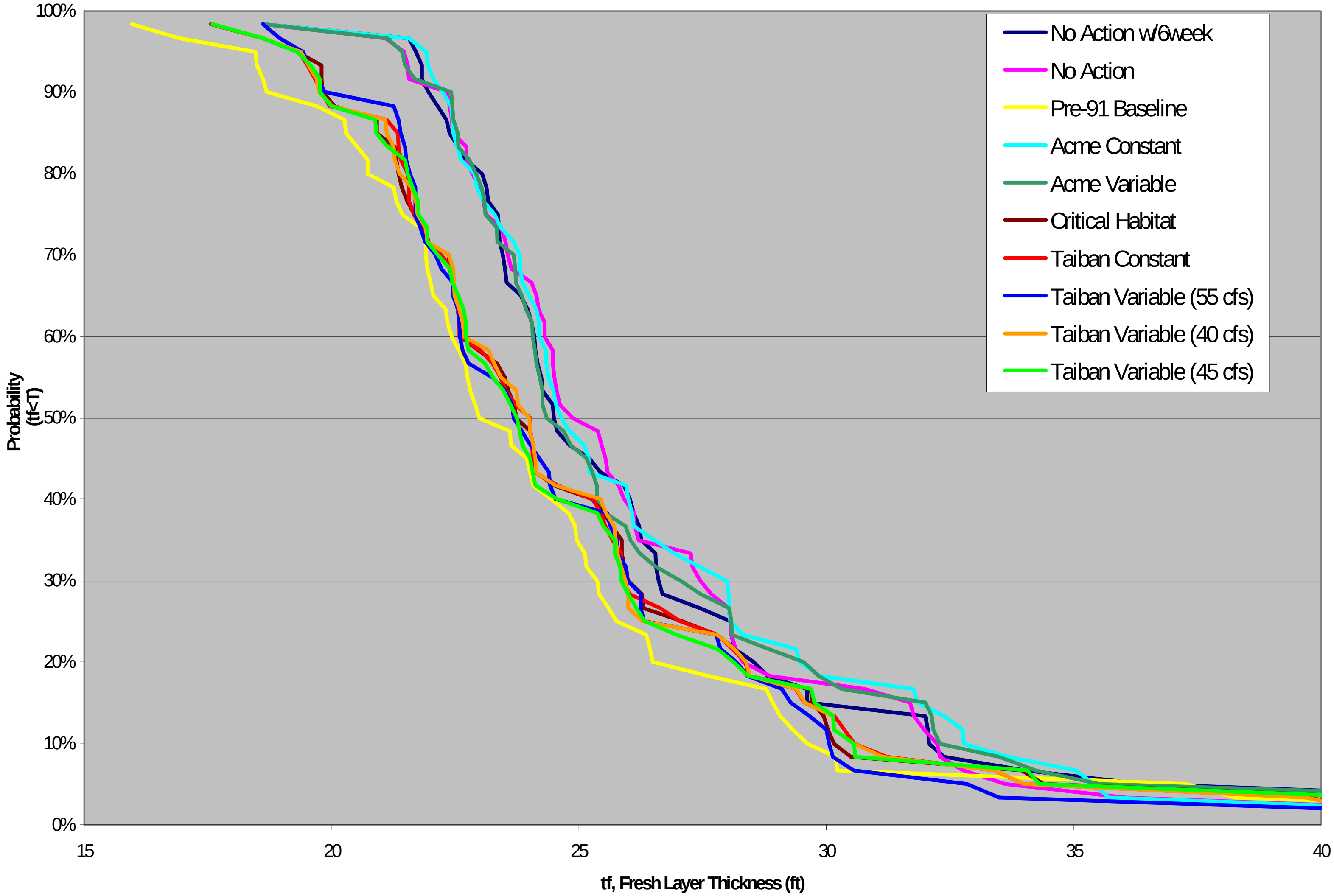


Figure 6. Exceedance curve of fresh layer thickness for each scenario.

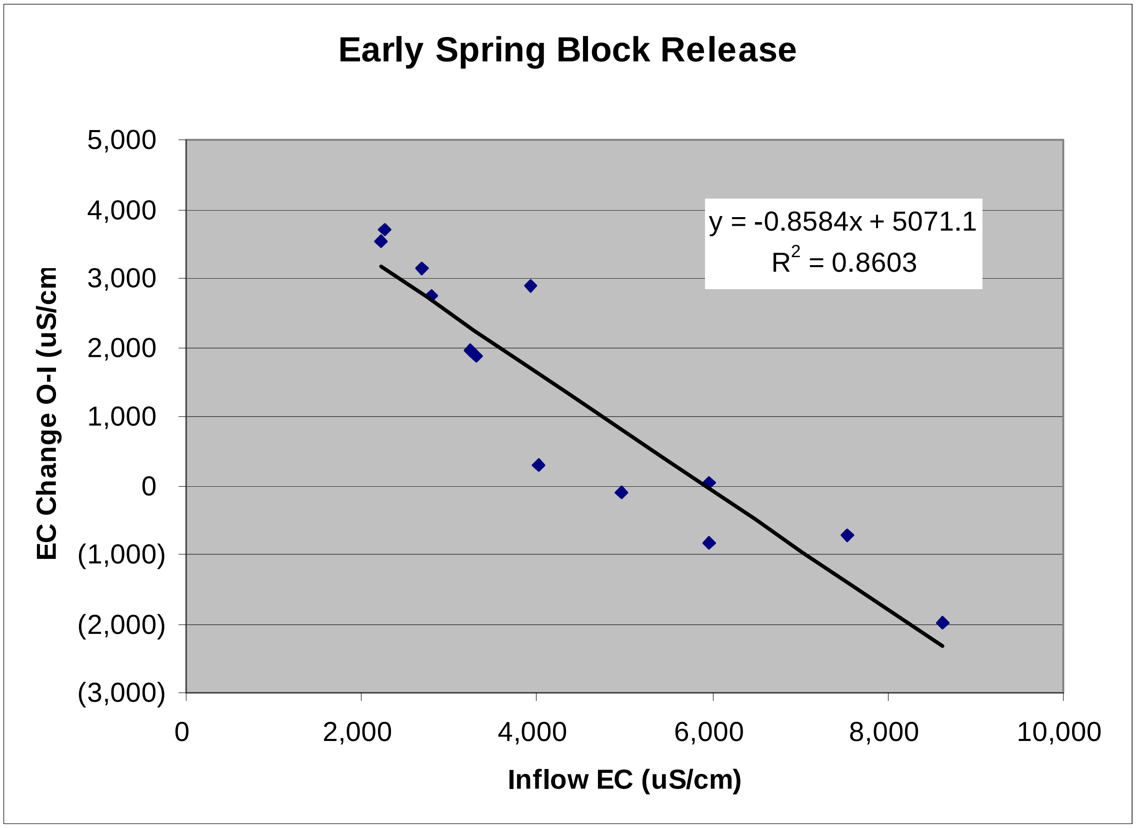


Figure 7. Plot of inflow EC versus change in EC (Outflow – Inflow) for dates when there were early spring block releases between February 1 and April 15.

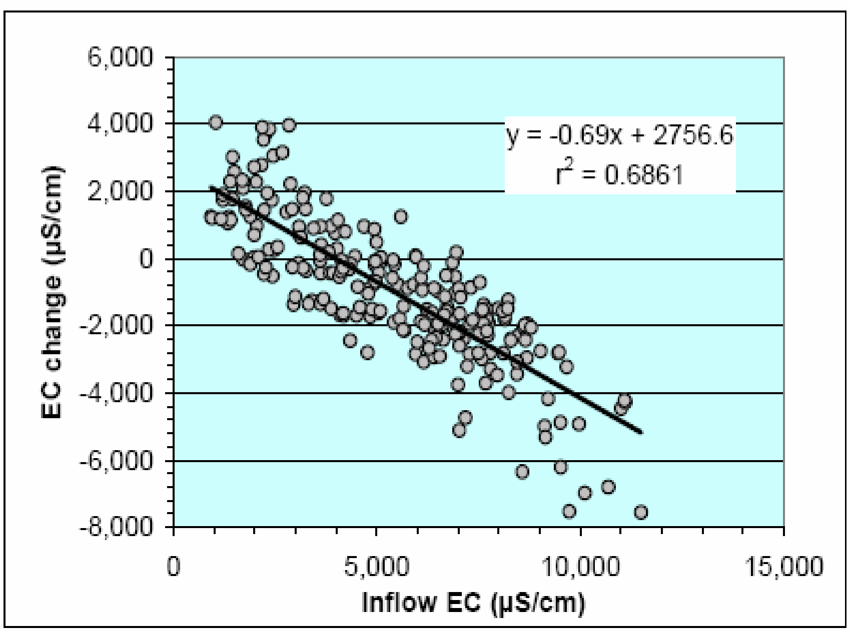


Figure 8. Regression of the change in EC in Brantley Reservoir on the Inflow EC (Yahnke, 2004).

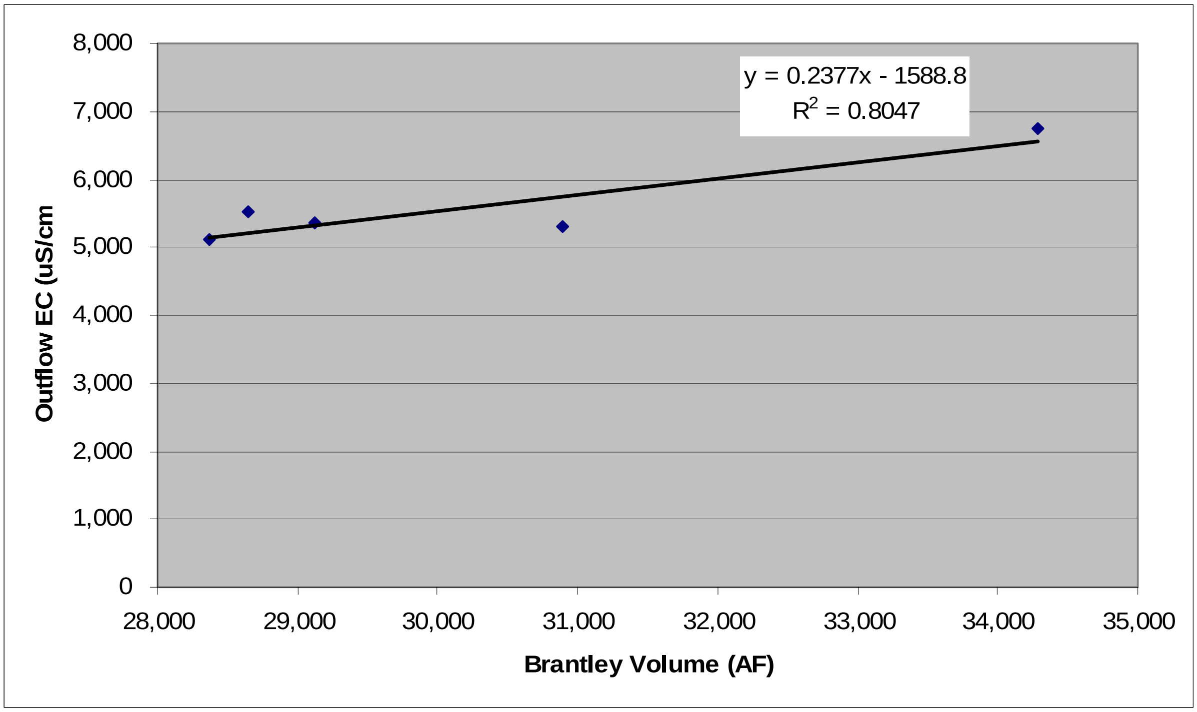


Figure 9. Plot of average outflow EC during block release versus Brantley volume at beginning of block release for early spring block releases.

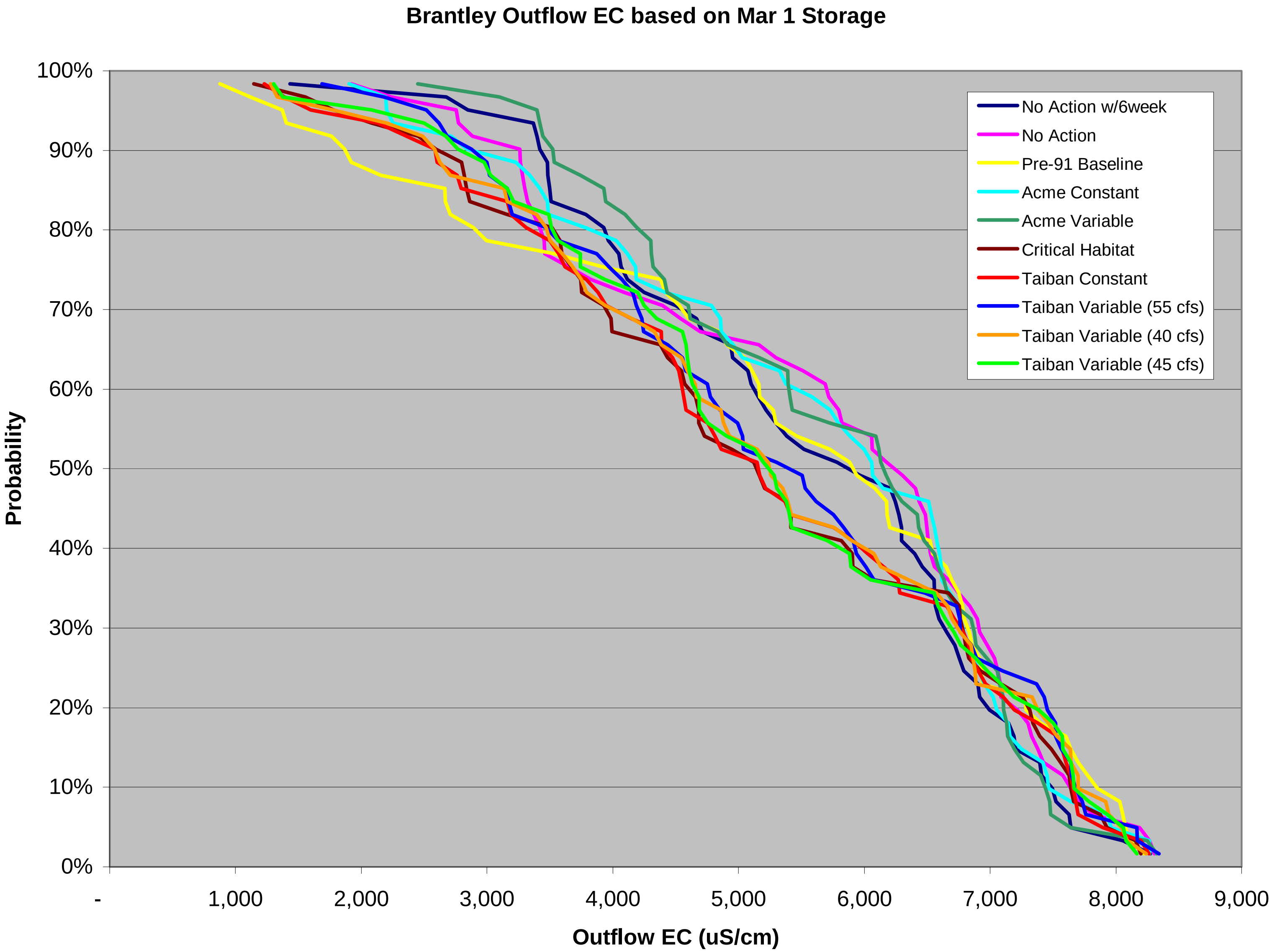


Figure 10. Exceedance curve of Brantley outflow EC based on March 1 storage.

Table 1. Mean early spring and average annual outflow EC with ranking for all scenarios.

Alternative	Mean Early Spring Outflow EC	Rank	Mean Average Annual Outflow EC	Rank
Critical Habitat	5,251	1	4,640	8
Taiban Constant	5,256	2	4,639	7
Taiban Variable (40 cfs)	5,321	3	4,640	9
Taiban Variable (45 cfs)	5,350	4	4,640	10
Taiban Variable (55 cfs)	5,428	5	4,635	6
Pre-91 Baseline	5,451	6	4,432	1
No Action w/6week	5,545	7	4,605	3
Acme Constant	5,676	8	4,580	2
No Action	5,703	9	4,619	5
Acme Variable	5,793	10	4,605	4
Range	541		208	

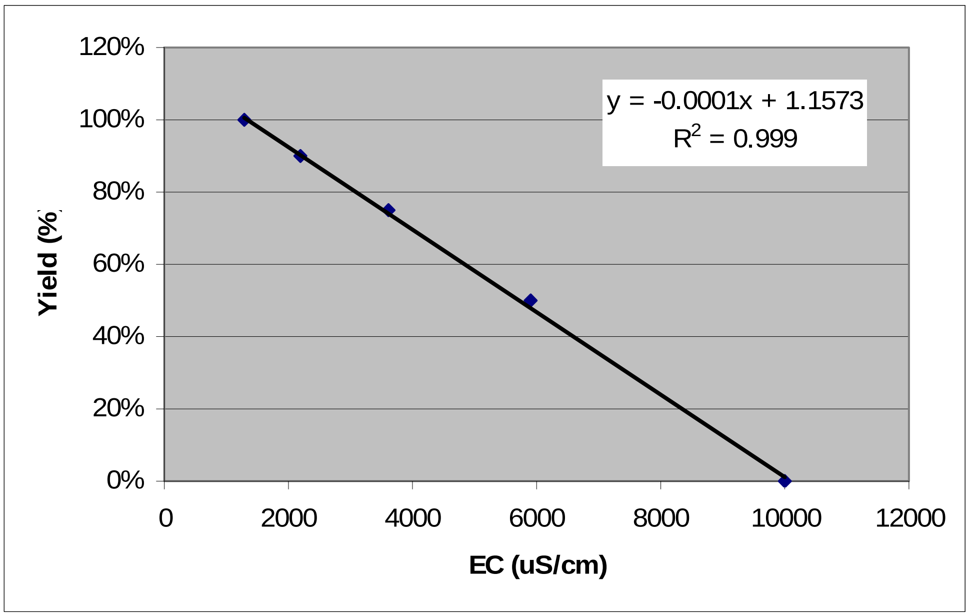


Figure 11. Effect of increased EC on alfalfa yield.

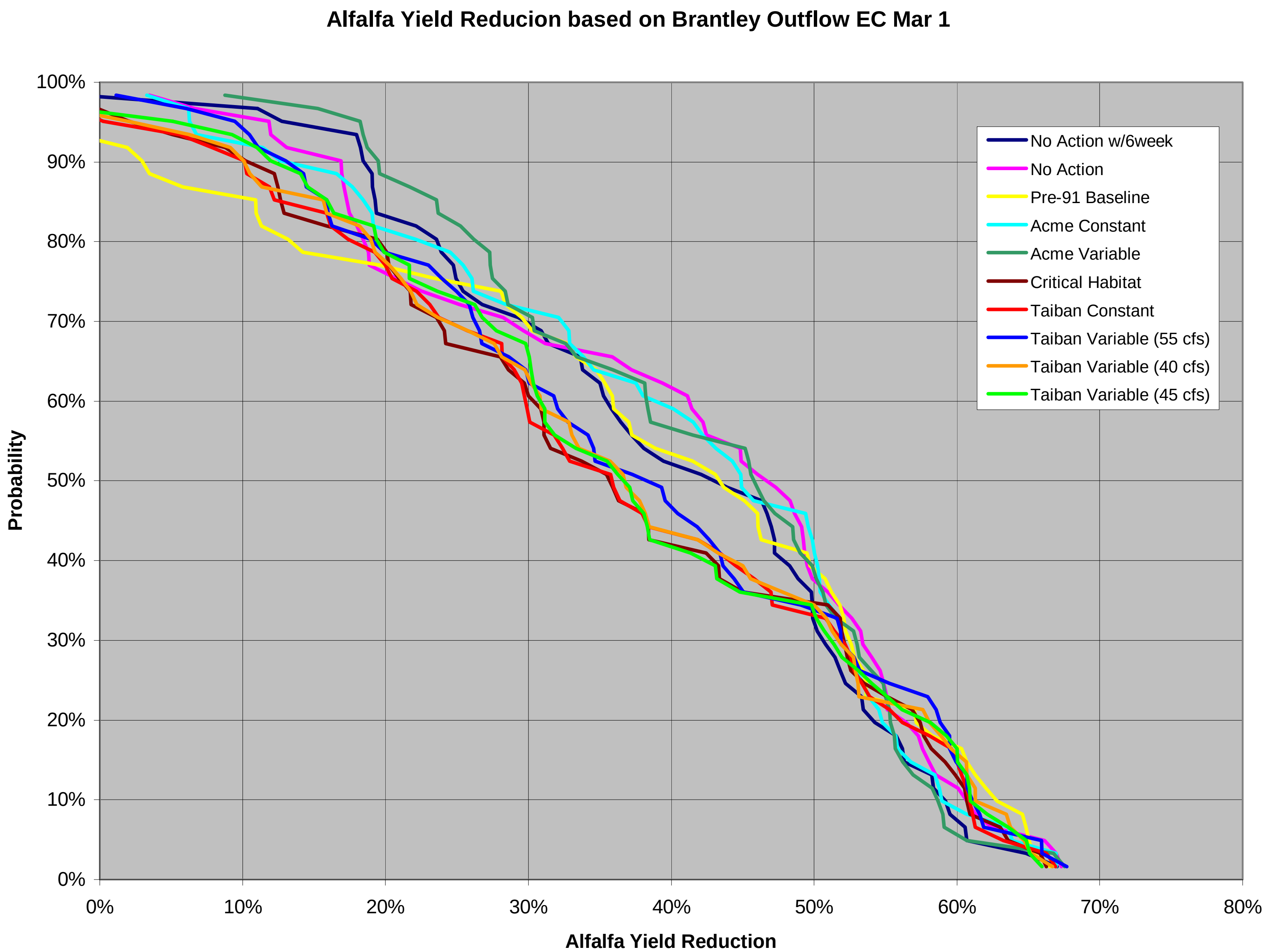


Figure 12. Exceedance curve of alfalfa yield reduction.