CEE 498 Field Methods - Summer 2007

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CLASS DESIGN PROJECT

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SUMMARY AND AKNOWLEDGEMENTS

The present report is relative to the class design project for the CEE 498 Field Methods summer class 2007.

A data collection was organized in the period from June 11 to June 21 2007 in the Salt Fork watershed. The data collected, along with the existing, allowed for making some useful observation with the view to potential stream restoration projects, in terms of water quality, water supply, sediment transport, flood control and ecosystem restoration.

The instructors Dr. Arthur Schmidt and Dr. Robert Holmes and the technicians from USGS Illinois Water Science Center are gratefully acknowledged for the well organized and absolutely interesting class they offered.

DESCRIPTION OF THE PROJECT AREA

The Salt Fork River has its headwaters in Champaign County and flows through Champaign and Vermillion County before it joins with the North Fork of the Vermillion to form the Vermillion River at Danville, Illinois. Figure 1 shows an aerial photo of the project area.

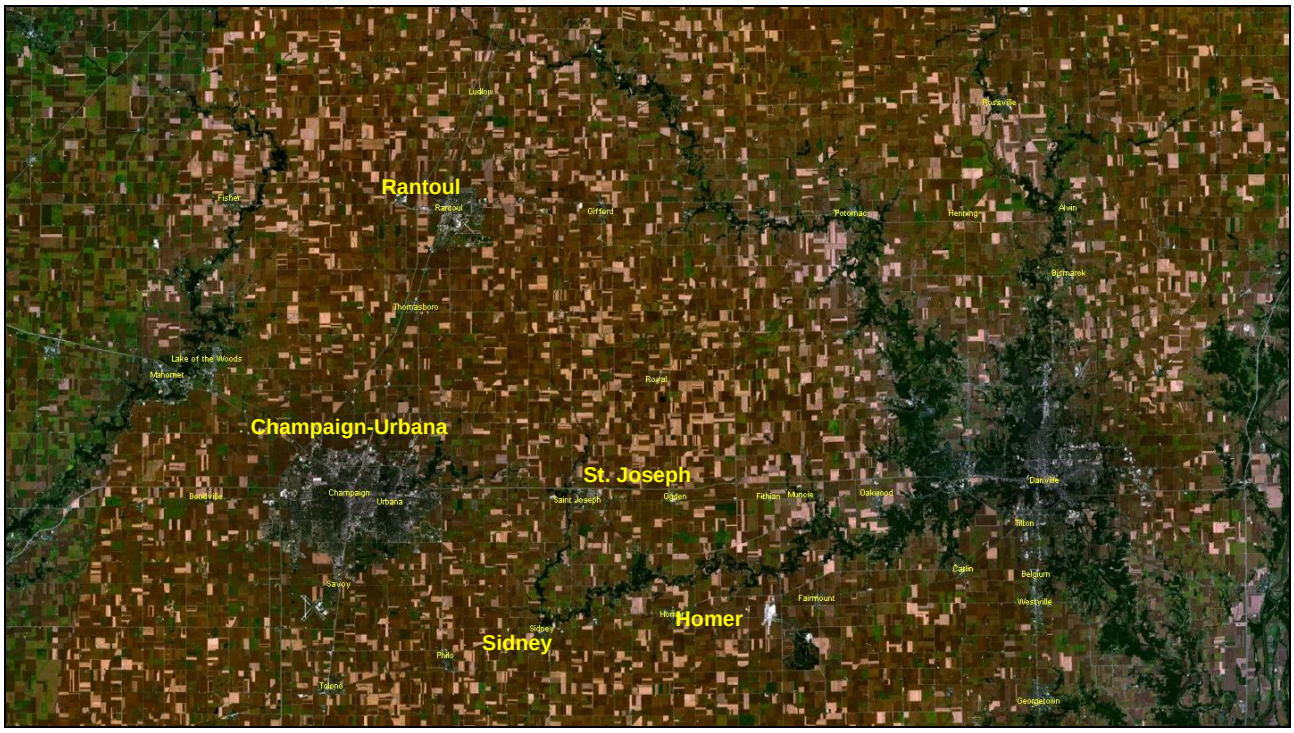


Figure 1. Aerial view of the project area.

The Salt Fork River basin has been anthropogenically altered, not only by the intensive row-crop agriculture, but also by the installation of tile drains and drainage ditches to allow for the increased drainage. As it can be observed from the Figure 2, prior to the mid to late 1800's, this land was poorly drained and considered un-inhabitable because of the swampy nature of the land. In the late 1800's and early 1900's channels were dredged and tile drains were installed in the fields as aids to drainage. This has allowed for intense agriculture use of the lands in the watershed. Periodic maintenance dredging continues today (as shown later for the Salt Fork reach of interest), albeit with increased controversy as environmental interests have tried to decrease the dredging activities.

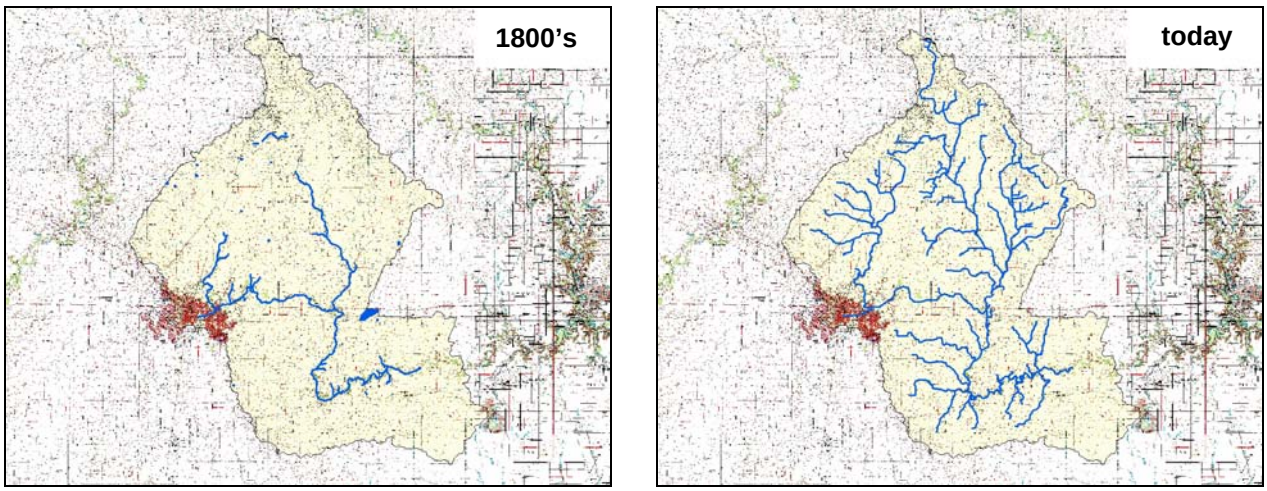


Figure 2. Waterways modification in the Salt Fork watershed from the 1800's to today.

Description of the watershed

Characteristics of the watershed

The Salt Fork watershed, closed at the section located right downstream from the confluence of the Olive Branch, downstream from the village of Homer, has the following characteristics:

- Area = 241337 acres;
- Perimeter = 180399 ft.

Land cover

Table 1 reports the land cover data for the watershed (the area considered is slightly lower than the whole watershed area).

Land cover	Area (acres)	Areal percentage (%)
barren	21.7	0.01
forestland	2873.0	1.33
grassland	22582.4	10.43
row crop	171742.8	79.30
small grain	3693.0	1.71
transportation	2379.1	1.10
urban	9654.8	4.46
water	2258.7	1.03
wetland	1376.0	0.63

Table 1. Land cover in the Salt Fork watershed.

The soil type is almost entirely B (areal percentage 86.2 %, shallow loess, sandy loam) or C (areal percentage 11.8 %, clay loams, shallow sandy loam, soils low in organic content and soils usually high in clay).

Rain gages

There are nine rain gages in the project area (see Figure 3):

- 5 of them are located in the Champaign-Urbana area;
- 1 of theme is located in the Rantoul area;
- 2 of them are located close to the USGS gaging station 03336900 (near St. Joseph);
- 1 of them is located close to the USGS gaging station 03337848 (near Sidney).

Gaging stations

In the watershed there are five active USGS gaging stations (see Figure 3):

1) Salt Fork near St. Joseph (ID 03336900);
2) Salt Fork below 2125 E above Sidney (ID 03337848);
3) Boneyard Creek at Urbana;
4) Boneyard Creek at Lincoln Avenue in Urbana;
5) Boneyard Creek at Race Street in Urbana.

There are also two inactive USGS gaging stations (see Figure 3):

6) Salt Fork near Homer (ID 03338000);
7) Saline Branch at Urbana (ID 03337500).

For three of the existing seven USGS gaging stations, the discharge data corresponding to the return periods (TR) 2, 5, 10, 25, 50 and 100 years are available, as reported by the Table 2.

Gaging station	Drainage area (mi^2)	Discharge (cfs) TR = 2 years	Discharge (cfs) TR = 5 years	Discharge (cfs) TR = 10 years	Discharge (cfs) TR = 25 years	Discharge (cfs) TR = 50 years	Discharge (cfs) TR = 100 years
Salt Fork near Homer	344	3790	5750	7050	8630	9770	10900
Salt Fork near St. Joseph	134	2520	3830	4760	6010	6980	7960
Saline Branch at Urbana	71	1270	2000	2480	3060	3480	3870

Table 2. Drainage areas and discharge values for different return periods for three of the seven USGS gaging stations in the Salt Fork watershed.

For the present analysis, the Salt Fork gaging station near St. Joseph (ID 03336900) and the Salt Fork gaging station below 2125 E above Sidney (ID 03337848) are considered. The following paragraphs describe the two stations in detail.

Salt Fork gaging station near St. Joseph

Sources

U.S. Geological Survey - Water Resources Data for Illinois ([1], [2]).

Characteristics

Code of the station
The code of the gaging station is 03336900.

Location
Lat. 40°08'58", long. 88°02'03" (NAD of 1983), in SW1/4NE1/4 sec. 35, T.20 N., R.10 E., Champaign County, Hydrologic Unit 05120109, on left bank at upstream side of bridge on County Road 1850 N, 0.2 mi downstream from Spoon River, 2.5 mi north of St. Joseph, and at mile 46.8.

Drainage area
Drainage area = 134 mi^2

Surface water discharge and stage
Discharge measurements: October 1958 to September 1991, July 2004 to current year.
Stage measurements: July 2004 to current year. Datum of gage is 650.16 ft above NGVD of 1929 (650.00 ft NAVD 1988).
Extremes for period of record: maximum discharge = 6860 ft^3/s, gage height = 18.26 ft (May 16, 1968); maximum gage height = 18.99 ft, discharge = 6030 ft^3/s (February 10, 1959); minimum discharge = 1.7 ft^3/s (September 22, 1963).

Surface water quality
Chemical: water years 1978-91.
Water temperature: water years 1975-78.

Miscellaneous
Sediment concentration and particle size, water year 2005.

Remarks
Diurnal fluctuation at low flow caused by Rantoul sewage treatment plant.
Additional data for this station were found on the web or made available by USGS, as reported later in the report.

Salt Fork gaging station near Sidney

Here is a brief description of the data available for the new USGS gage 03337848 (Salt Fork below 2125 E near Sidney).
In the period from June 12 2006 to February 1 2007, observations and measurements are available for:

- gage height (ft);
- discharge (cfs);
- flow area (ft^2);
- top width (ft);
- maximum depth (ft);
- sediments (sampling);
- water temperature (°C);
- dissolved oxygen (mg/l);
- conductance (microsiemens/m^3);
- pH.

For the Salt Fork below 2125 E near Sidney are available also several suspended sediment data in the period from January 18 2006 to January 19 2007.

15-min data of stage, water temperature and turbidity are available in the period From September 22 2006 to June 22 2007. 5-min data of air temperature and precipitation are available for the same period.
Finally, additional discharge data were made available by USGS for the period from August 13 2006 to September 21 2006, as discussed later in the report.

Waste Water Treatment Plants (WWTP's)

There are three Waste Water Treatment Plants (WWTP's) in the area (see Figure 3):

a) Rantoul WWTP;
b) Urbana-Champaign WWTP;
c) St. Joseph WWTP.

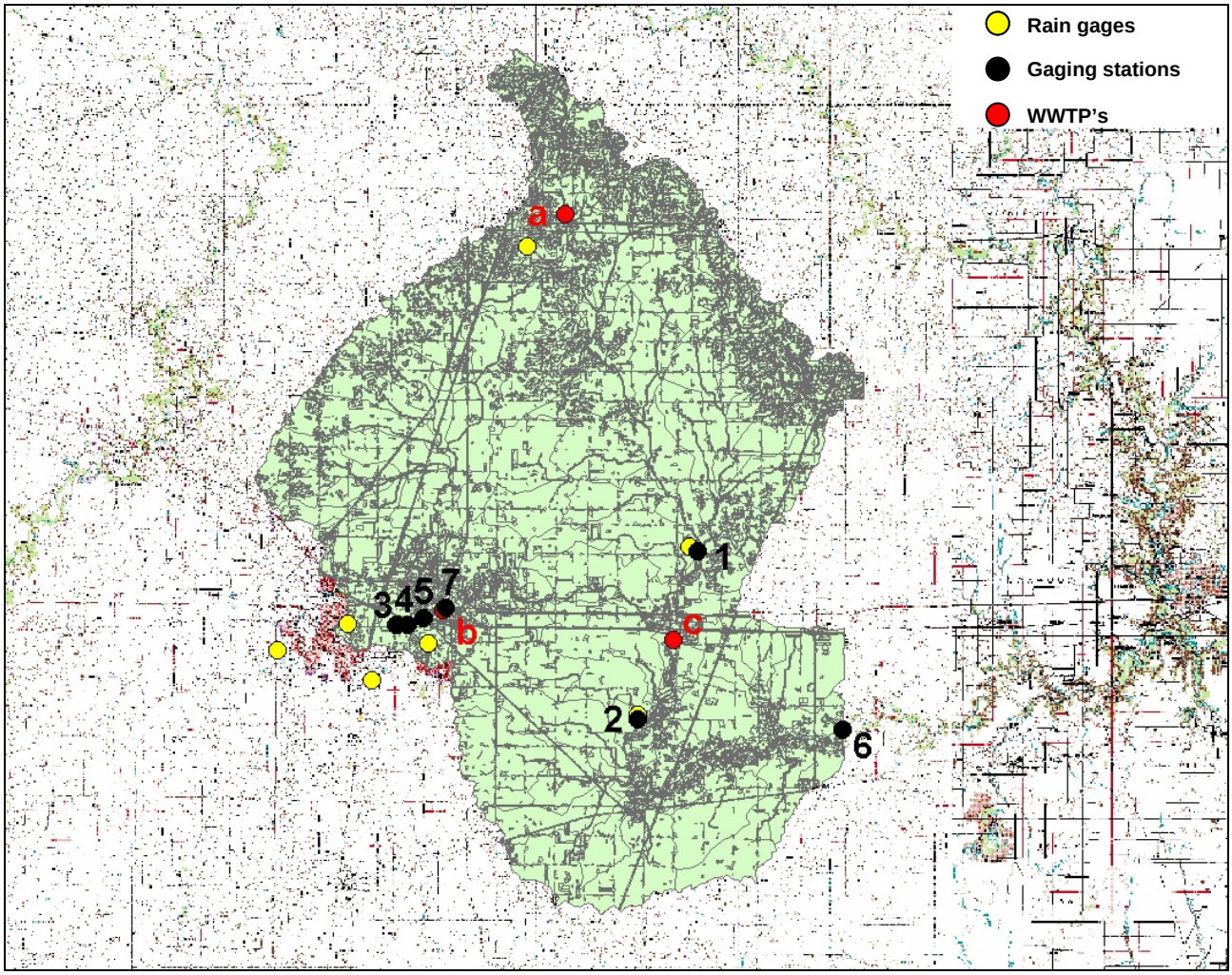


Figure 3. Location of the rain gages, gaging stations and waste water treatment plants in the Salt Fork watershed. Numbering is according to the text.

ISSUES

The following paragraphs describe briefly the main issues in the Salt Fork watershed.

Dredging

The latest dredging has stirred considerable controversy as phase 1 has been completed in 2005 with the wholesale removal of trees lining the river. Phase 2 is being scheduled for 2007-2008 time frame. See the Figure 16 later in the report to see the extension of the two dredging phases.

Waste water effluents

Urbanization plays an important role in the hydrology of the Salt Fork. The low flow for the upper reach is dominated by waste-water effluent from three waste water treatment plants. Urbana stormwater runoff from Champaign-Urbana is conveyed to the Salt Fork via the Saline Branch Ditch and the St. Joseph Drainage Ditch #3. Other municipalities serving as sources of urban stormwater are Rantoul, St. Joseph, Philo and Sidney.
In 2002, an ammonia spill at the University of Illinois Abbott Power plant resulted in a large fish kill along the Saline Branch Ditch and the Salt Fork.

Water quality impairment

A Total Maximum Daily Load (TMDL) study is ongoing in the Salt Fork as various reaches failed to meet designated uses because of water quality impairment. The most common water quality impairments in the Salt Fork River are elevated nutrients (nitrogen and phosphorus) and excessive sediment. In addition, due to the increased recreational use of the Salt Fork, the WWTP's in the upper basin will be soon required to disinfect summer-time effluent discharges.

Restoration projects

This reach of the Salt Fork is being investigated for potential stream restoration projects.

Water supply

The Salt Fork has been mentioned as a potential source of water supply for the Village of Sidney.

THE FIELD CAMPAIGN

The present chapter describes the field work activities done in the period from June 11 to June 21 2007 for the CEE 498 Field Methods summer class 2007.

Activities

Here is a brief description of the data collection campaign for each of the days of field/laboratory work. In particular, the activities the author took part in are listed. The results of each of the measurements made will be described later in the report.

Monday June 11 2007
Reconnaissance (Saline Branch Ditch, Salt Fork at the USGS gaging stations upstream near St. Joseph and near Sidney and St. Joseph Waste Water Treatment Plant).

Tuesday June 12 2007
Groundwater measurements close to the station near Sidney, support construction for ADV.

Wednesday June 13 2007
Cores inspection at the USGS laboratory.

Thursday June 14 2007
ADCP, ADV and Flow Tracker measurements plus survey at the Salt Fork station near Sidney.
Water quality measurements (St. Joseph Drainage Ditch #3 and Salt Fork at the gaging station near St. Joseph).

Friday June 15 2007
Flow measurements (Salt Fork at location 03337900 downstream from Sidney and St. Joseph Drainage Ditch #5).

Tuesday June 19 2007
Sediment transport and water quality demonstration and measurements at the Salt Fork station near Sidney, Saline Branch Ditch flow tracker and YSI water quality measurements, Salt Fork at Homer Lake Road (station code 03337810) YSI measurements, filtering for bacteria and water quality sample preparation at the USGS laboratory.

Wednesday June 20 2007
Bacteria counting at the USGS laboratory.

Thursday June 21 2007
YSI probe calibration demonstration at the USGS laboratory, inclined staff construction at the Salt Fork station near Sidney, total station survey, data logger demonstration, Flow Tracker measurements in the St. Joseph Drainage Ditch #3 and in Salt Fork near Sidney, YSI water quality measurements in the Salt Fork near Sidney, water quality probe removal, groundwater level measurements.

Figure 4. Field and laboratory activities during the period from June 11 to 21 2007.

Seepage, depth and discharge measurements

On June 14, 15, 19 and 21 2007, some seepage, depth and discharge measurements were done for 14 sections indicated in the Table 3. No measurements were done for the sections highlighted in italics (downstream from the station 03337900). See also the Figure 5.

Station ID	Stream	Description
03336900	Salt Fork	USGS gaging station 03336900
SSD	Stanton Special Ditch	Upstream from the confluence with the Salt Fork
SF1	Salt Fork	Downstream from the confluence of the Stanton Special Ditch
SBD	Saline Branch Ditch	Upstream from the confluence with the Salt Fork
SF2	Salt Fork	Downstream from the confluence of the Saline Branch Ditch
03337810	Salt Fork	Downstream from the St. Joseph WWTP
SJ#2	St. Joseph Drainage Ditch #2	Upstream from the confluence with the Salt Fork
03337845	Salt Fork	Downstream from the confluence of the St. Joseph Ditch #2
SJ#3	St. Joseph Drainage Ditch #3	Upstream from the confluence with the Salt Fork
03337848	Salt Fork	USGS gaging station 03337848, downstream from the confluence of the St. Joseph Ditch #3
SJ#4	St. Joseph Drainage Ditch #4	Upstream from the confluence with the Salt Fork
03337850	Salt Fork	Downstream from the confluence of the St. Joseph Ditch #4
SJ#5	St. Joseph Drainage Ditch #5	Upstream from the confluence with the Salt Fork
03337900	Salt Fork	Downstream from the confluence of the St. Joseph Ditch #5
Ditch 6	*Ditch 6*	*Upstream from the confluence with the Salt Fork*
Ditch 7	*Ditch 7*	*Upstream from the confluence with the Salt Fork*

Station ID	Stream	Description
SF4	*Salt Fork*	*Downstream from the confluence of the Ditch 6 and the Ditch 7*
Ditch 8	*Ditch 8*	*Upstream from the confluence with the Salt Fork*
SF5	*Salt Fork*	*Downstream from the confluence of the Ditch 8*
Ditch 9	*Ditch 9*	*Upstream from the confluence with the Salt Fork*
SF6	*Salt Fork*	*Downstream from the confluence of the Ditch 9*
Ditch 10	*Ditch 10*	*Upstream from the confluence with the Salt Fork*
Ditch 11	*Ditch 11*	*Upstream from the confluence with the Salt Fork*
Conkey BR	*Conkey Branch*	*Upstream from the confluence with the Salt Fork*
03338000	*Salt Fork*	*USGS gaging station 03338000, downstream from the confluence of the Ditch 10, the Ditch 11 and Conkey Branch*

Table 3. Seepage, depth and discharge measurements sites.

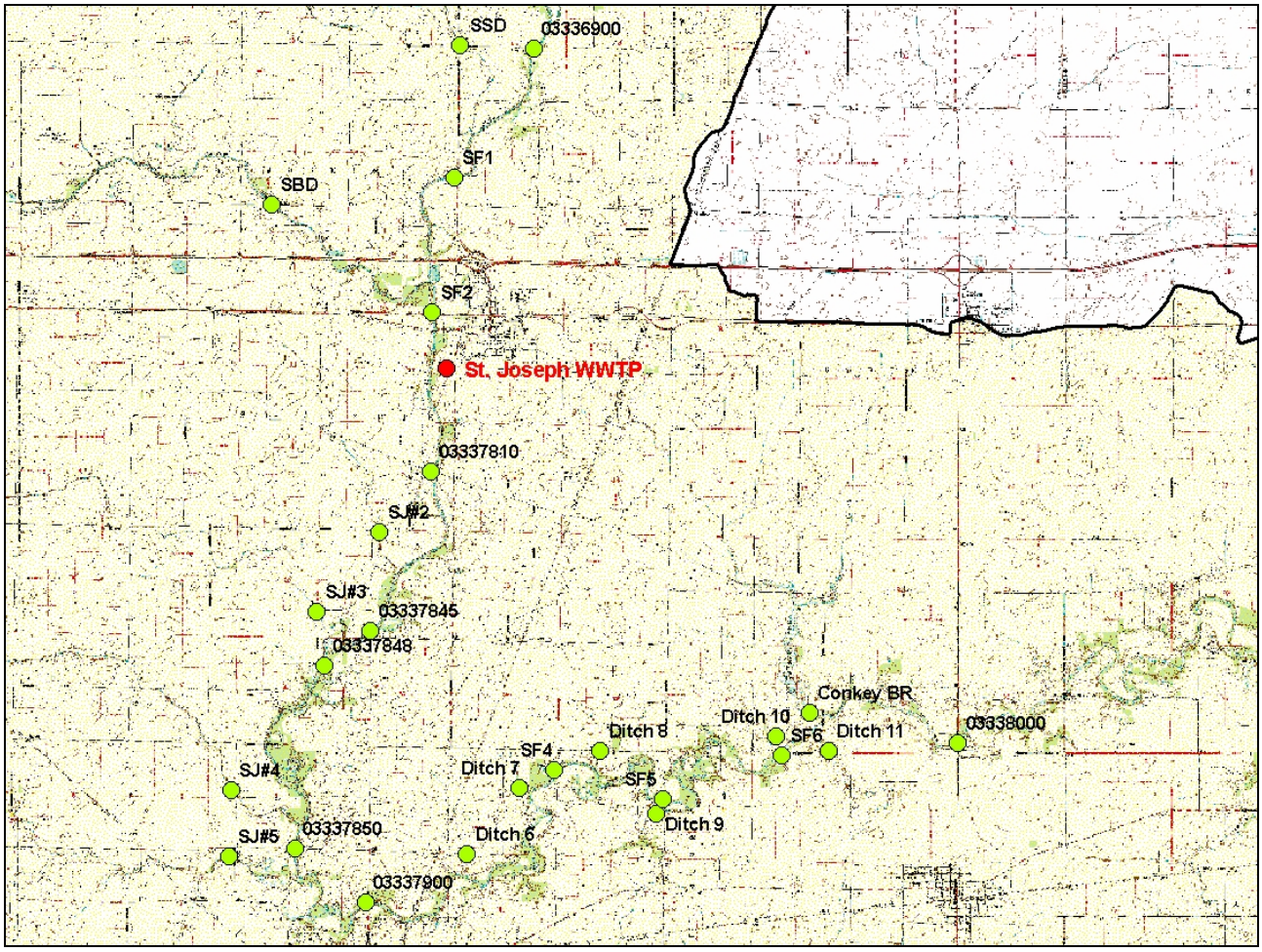
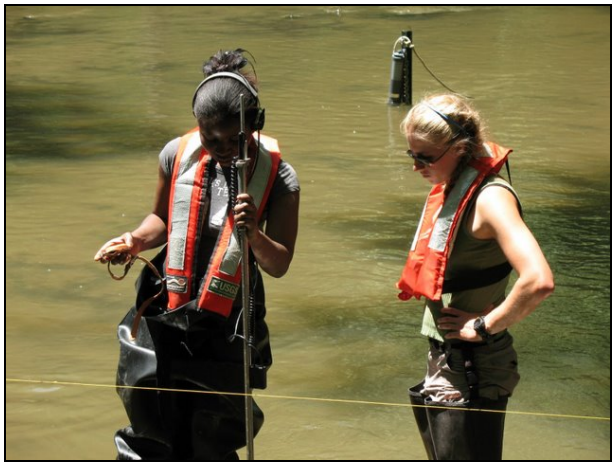


Figure 5. Seepage, depth and discharge measurements locations.



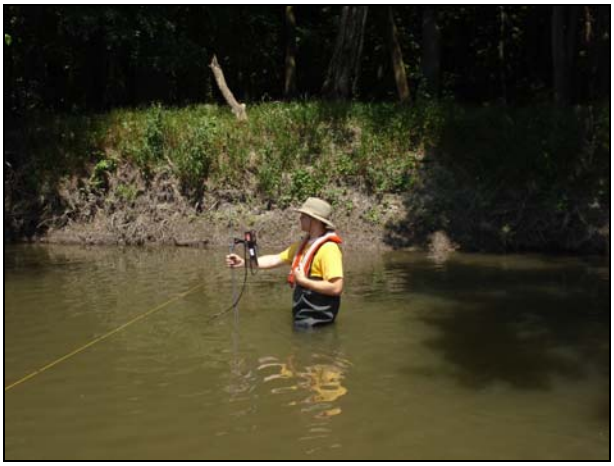


Figure 6. Discharge measurements with the pigmy meter (picture on the left) and the Flow Tracker (picture on the right).

Water quality measurements

On June 12, 14 and 19 2007, several water quality measurements with the handheld YSI probe were done for the 10 sections indicated in the Table 4. See also the Figure 7.

Station ID	Stream	Description
03336900	Salt Fork	USGS gaging station 03336900
SBD	Saline Branch Ditch	Upstream from the confluence with the Salt Fork
SF2	Salt Fork	Downstream from the confluence of the Saline Branch Ditch
SF3	Salt Fork	Right downstream from the St. Joseph WWTP
03337810	Salt Fork	Downstream from the St. Joseph WWTP
03337845	Salt Fork	Downstream from the confluence of the St. Joseph Drainage Ditch #2
SJ#3	St. Joseph Drainage Ditch #3	Upstream from the confluence with the Salt Fork
03337848	Salt Fork	USGS gaging station 03337848, downstream from the confluence of the St. Joseph Drainage Ditch #3
03337850	Salt Fork	Downstream from the confluence with the St. Joseph Drainage Ditch #4
03337900	Salt Fork	Downstream from the confluence with the St. Joseph Drainage Ditch #5

Table 4. Water quality measurements sites.

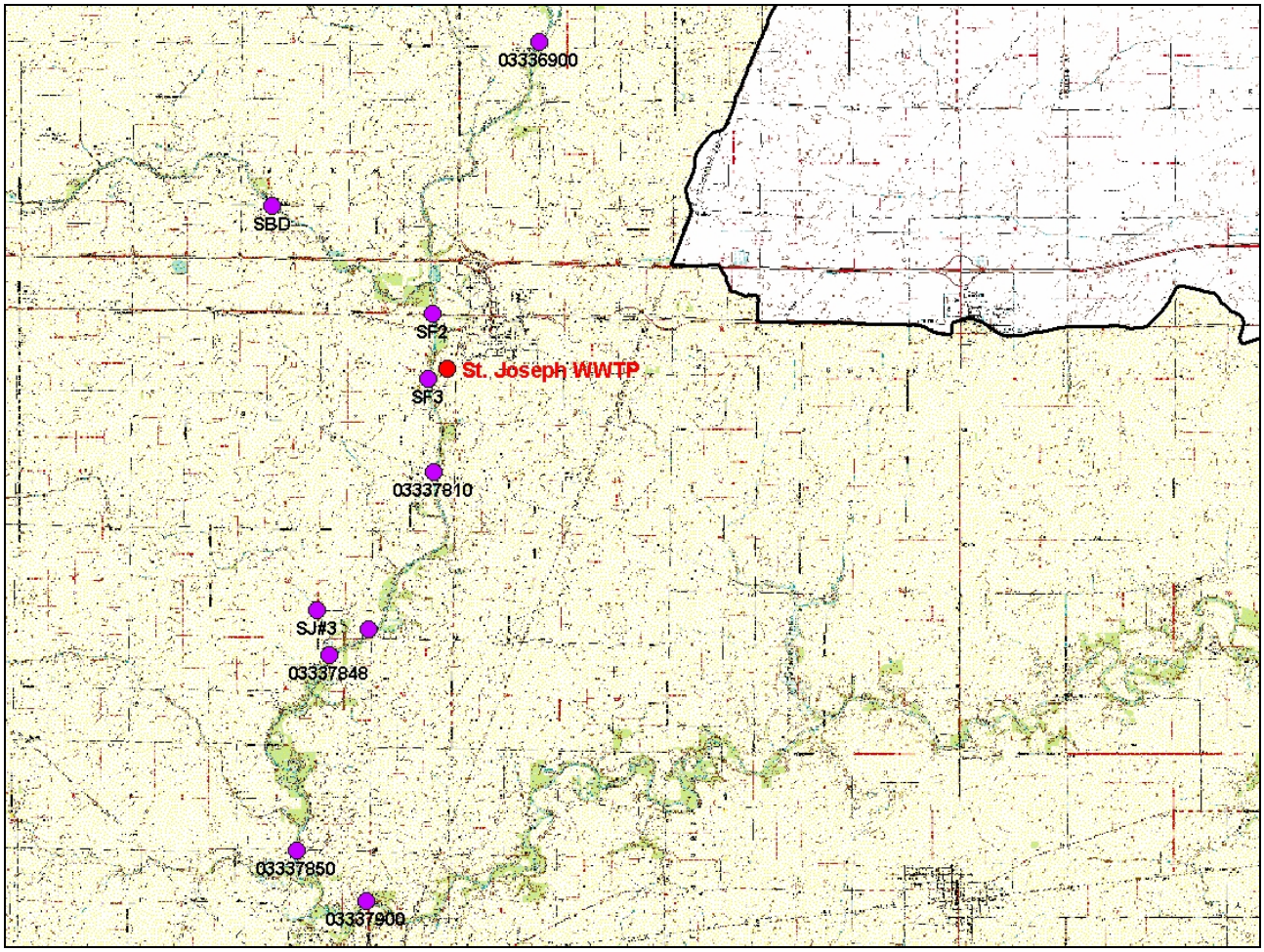


Figure 7. Water quality measurements locations.

A YSI water quality probe for continuous water quality monitoring was also installed in the Salt Fork at the USGS station near Sidney in the period from June 21 to July 7 2007. Its removal activities can be seen in the Figure 8 (lower left and right pictures).

Figure 8. YSI handheld probe calibration and measurements (pictures upper left and right) and continuous monitoring probe removal from water (pictures lower left and right).

Main remarks

On June 19 2007, a big difference in suspended sediment transport after a light rainfall event was observed between the Saline Branch Ditch (clear water) and the Salt Fork at the gaging station near Sidney (high turbidity) .

Another considerable observation is relative to the high bacteria level initially measured in Salt Fork at the gaging station near Sidney, suggesting the presence of an upstream "non environmental-friendly" landowner without a septic system. Later in the report, the complete results about the bacteria analysis will be presented.

Then 2 weeks of measurements with the continuous YSI probe were lost for a setting mistake. The probe was reinstalled in the Salt Fork in order to have data for the period from June 21 to July 7 2007.

LEVEL OF BACTERIA IMPAIRMENT

In this chapter, the level of bacteria impairment (*Escherichia Coli*) of the Salt Fork and Saline Branch Ditch is determined. The current Illinois EPA standards are compared to the results.

Bacteria colonies count

On June 19 2007, some water samples were collected to analyze for *E. Coli*.
In particular, the following stations were chosen:

- 03336900: Salt Fork at the USGS gaging station 03336900;
- SBD: Saline Branch Ditch, upstream from the confluence with the Salt Fork;
- SF2: Salt Fork, downstream from the confluence of the Saline Branch Ditch;
- 03337810: Salt Fork, downstream from the St. Joseph WWTP;
- 03337848: Salt Fork at the USGS gaging station 03337848;
- 03337900: Salt Fork, downstream from the confluence with the St. Joseph Drainage Ditch #5.

On June 20 2007, the *E. Coli* bacteria colonies were counted, through the membrane filtration procedure, using a filter pore size of 0.45 μm. Here are the characteristics of the media preparation:

- media type: mod mTEC: *E. coli* colonies are magenta;
- pre-poured plates;
- buffered water type: $PO_4/MgCl_2$.

On June 21, another sample was collected at the station 03337848 (Salt Fork at the USGS gaging station 03337848) given the surprisingly high number of colonies counted on June 20. The new sample colonies were counted on June 22.

The range of ideal colony counts differs depending on the fecal indicator group to be enumerated. Crowding and insufficient media to support full development of colonies can result if the bacterial concentration on the filter exceeds the upper limit of the ideal range. The lower limit of the ideal range is set as a number below which statistical validity becomes questionable.
In this case the ideal colony count range considered is from 20 to 80 (according to the standard procedure used for *E. coli* colonies). The computation is the sum of the colony counts for each sample volume, multiplied by 100, and divided by the sum of the sample volumes. Enumeration results for the membrane-filter method are expressed as a concentration in units of col/100 ml.

Table 5 and Table 6 report the counting results for the samples collected on June 19 and 21. The colony count that was considered for each case is the maximum between the initial count and the recount. The numbers considered in the computation are highlighted in bold in the table. The abbreviation “TNTC” means “Too Numerous To Count”.

	03336900: Salt Fork - USGS gaging station		SBD: Saline Branch Ditch - Upstream from the confluence with the Salt Fork		SF2: Salt Fork - Downstream from the confluence of the Saline Branch Ditch		03337810: Salt Fork - Downstream from the St. Joseph WWTP		03337848: Salt Fork - USGS gaging station		03337900: Salt Fork - Downstream from the confluence of the SJ#5	
Volume filtered (ml)	**Initial count**	**Recount**	**Initial count**	**Recount**	**Initial count**	**Recount**	**Initial count**	**Recount**	**Initial count**	**Recount**	**Initial count**	**Recount**
Filter blank (50 ml)	0	0	0	0	0	0	0	0	0	0	0	0
1	6	6	2	2	11	11	9	9	**48**	**46**	7	7
3	17	17	13	12	**24**	**24**	**40**	**39**	TNTC (1207)	TNTC	**52**	**52**
10	**63**	**63**	**31**	**31**	TNTC	TNTC	110	110	TNTC	TNTC	TNTC (180)	TNTC (165)
30	TNTC	TNTC	**85**	**83**	TNTC	TNTC	TNTC	TNTC	TNTC	TNTC	TNTC	TNTC
100	TNTC	TNTC	TNTC	TNTC	TNTC	TNTC	TNTC	TNTC	TNTC	TNTC	TNTC	TNTC
Filter blank 2 (100 ml)	0	0	0	0	0	0	0	0	5	5	0	0
Colony count	63		116		24		40		48		52	
Sample volume (ml)	10		40		3		3		1		3	
Col/ ml	6.3		2.9		8		13.3		48		17.3	
Col/100 ml	**630**		**290**		**800**		**1333**		**4800**		**1733**	

Table 5. Bacteria colony count for the samples collected on June 19.

	03337848: Salt Fork - USGS gaging station	
Volume filtered (ml)	**Initial count**	**Recount**
Filter blank (50 ml)	0	0
1	4	4
3	6	6
10	**30**	**29**
30	**87**	**87**
100	TNTC	TNTC
Filter blank 2 (100 ml)	0	0
Colony count	117	
Sample volume (ml)	40	
Col/ ml	2.9	
Col/100 ml	**293**	

Table 6. Bacteria colony count for the samples collected on June 21.

Figure 9 shows the comparison between the *E. Coli* counts at the different locations, providing an idea about the spatial variability of the bacteria impairment level in the Salt Fork watershed.

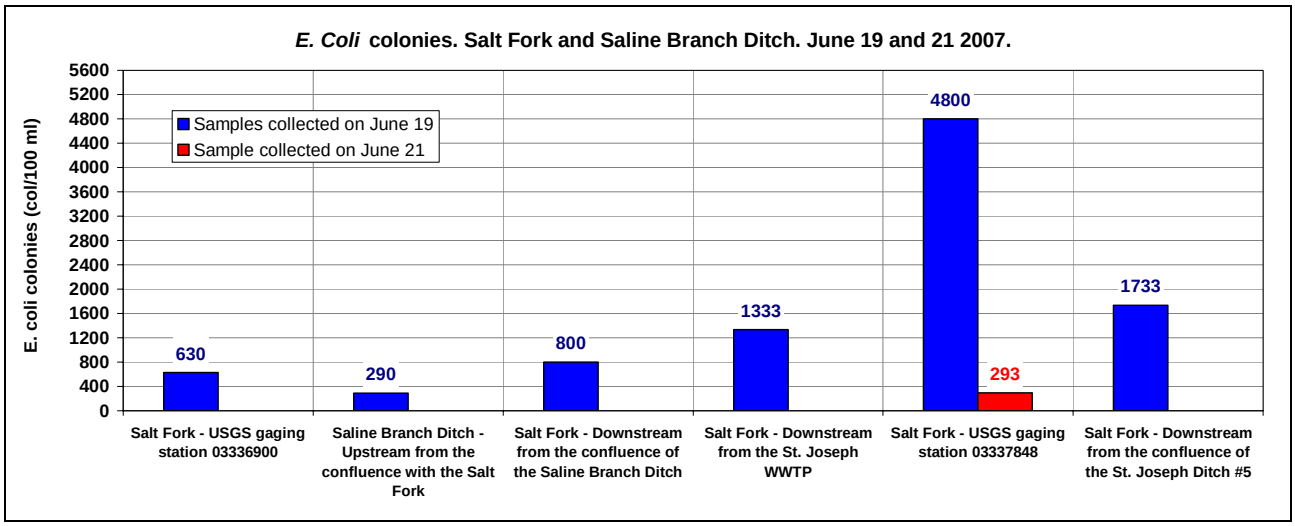


Figure 9. Bacteria colony count for the samples collected on June 19 and 21 2007.

Here are the main observation which can be made about the spatial variability of the level of bacteria impairment:

- along the Salt Fork, there are three factors which contribute to increase the number of bacteria: the confluence of the Saline Branch Ditch (carrying the Urbana-Champaign WWTP effluents), the St. Joseph WWTP and, probably, a bacteria source located upstream from the USGS gaging station 03337848 near Sidney;
- the St. Joseph WWTP surely represents a cause of bacteria impairment, since there are no big Salt Fork tributaries between the station SF2 (Salt Fork downstream from the confluence of the Saline Branch Ditch) and the station 03337810 (Salt Fork downstream from the St. Joseph WWTP);
- the big increment observed at the station 03337848 (Salt Fork - USGS gaging station) on June 19 was not confirmed by the new sample collected on June 21 (see Figure 9). On the other hand, as already reported above, there might be a "non environmental friendly" landowner, who is located upstream from this station and does not have a septic system for waste water treatment, so future water quality monitoring would be recommended. The St. Joseph Drainage Ditch #2 should not be responsible for bacteria impairment, whereas the St. Joseph Drainage Ditch #3 should be investigated in the future, since Urbana stormwater runoff is conveyed by this ditch;
- downstream from the station 03337848, the level of bacteria impairment increases again, and it would be interesting to find out the causes of this in the future. The reach upstream from the USGS gaging station 03336900 should be investigated in the future, in order to analyze the effect of the Rantoul WWTP on the bacteria impairment level.

The data collected on June 2007 are not enough to make an evaluation about the die-off temporal rates of the bacteria impairment levels and the couple of data at the gaging station near Sidney is not reliable for this scope. However, this kind of analysis is desirable for the future campaigns.

Current Illinois EPA standards and former studies

Regarding the current Illinois EPA standards, the IPCB (Illinois Pollution Control Board) sets the Environmental Regulations for the State of Illinois [3]. The Part 302 is relative to the Water Quality Standards.

In particular, the Section 302.209 states that *"during the months May through October, based on a minimum of five samples taken over not more than a 30 day period, fecal coliform (STORET number 31616) shall not exceed a geometric mean of 200 per 100 ml, nor shall more than 10% of the samples during any 30 day period exceed 400 per 100 ml in protected waters. Protected waters are defined as waters which, due to natural characteristics, aesthetic value or environmental significance are deserving of protection from pathogenic organisms.*" (effective July 11, 1988).

The USEPA produced a National Criteria for *E. Coli* for recreational waters in 1986 and the criteria vary depending upon the type of water body [4]. The state of Illinois has not adopted the national criteria for *E. Coli* because they are not convinced it is beneficial over the fecal coliform standard and because new methods and indicators are likely to replace *E. Coli* in a few years.

USEPA promulgated the *E. Coli* standard for the Great Lakes and the marine coastal beaches. The Illinois Department of Health is responsible for water quality standards at Great Lakes shoreline and beach areas and it has adopted the *E. Coli* standard of 126 colonies/100 ml for these areas.

For the present *E. Coli* analysis, the 126 col/100 ml standard was considered. According to the June 19 and 21 measurements, all the stations do not comply with this water quality standard.

On the other hand, according to a recent study by Tetra Tech, Inc., 2007 [5], there are no particular issues on fecal coliform impairment in the Salt Fork watershed (at least in the reaches analyzed in this study). Tetra Tech analyzed the Saline Branch (stations BPJC-08, BPJC-UC-A2) and the Spoon Branch (stations BPJD-01 and BPJD-02) without observing any violation of the fecal coliform water quality standard, whereas there is no analysis on the *E. Coli* impairment levels.

Given the contradictory results of the present study, other measurements should be done in the future. It is a fact that the WWTP's in the upper Salt Fork basin will be soon required to disinfect summer-time effluent discharges, for the increased waterway recreational use.

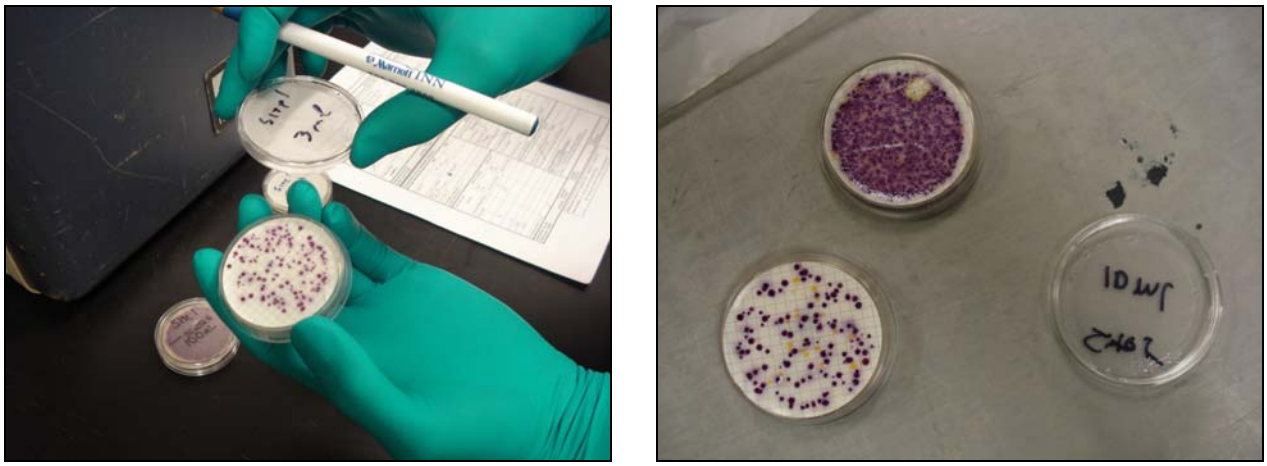


Figure 10. Bacteria colony count at the USGS Urbana laboratory.

TEMPERATURE DATA

In this chapter, as part of the Total Maximum Daily Load (TMDL) investigation, the spatial and temporal variation of the water temperature data from the St. Joseph to the Sidney USGS gage are investigated. The temperature plays an important role in the dissolved oxygen dynamics, as explained in the next chapter.

Available temperature data

For the USGS gaging station 03336900 near St. Joseph, the temperature data are available on line from the USGS' National Water Information System Web Interface [6]. The page is updated daily and reports the water temperature data every 15 minutes, along with the gage height, the discharge, the turbidity, the precipitation, the relative humidity and the air temperature. Here the data in the period from June 2 to July 2 2007 are considered.
Moreover, the USGS National Water Information System [7] made available the 15-min water temperature data from August 1 2006 to July 11 2007.
For the USGS gaging station 03337848 near Sidney, two sets of data are available: the first contains 15-min data from September 22 2006 to June 23 2007 (continuous monitoring station, see Figure 11); the second one contains 15-min data from June 2 to July 2 2007 (continuous water quality monitoring YSI probe).

Figure 11. Continuous temperature monitoring station and data logger at the USGS gaging station near Sidney.

Spatial and temporal variation of the water temperature from St. Joseph to Sidney

Figure 12 shows the comparison between the water temperature at the gages near St. Joseph and near Sidney in the period from June 21 to July 2 2007.
Both the data sets show a diurnal variability with a progressive increase of the temperature due to the solar irradiation until the sunset. During the night the water temperature decreases. The range of variation is greater near St. Joseph, since there is no vegetation along the banks because of the dredging activities (see Figure 15 and Figure 16). This fact has a consequence on the dissolved oxygen levels, as will be explained in the following chapter.

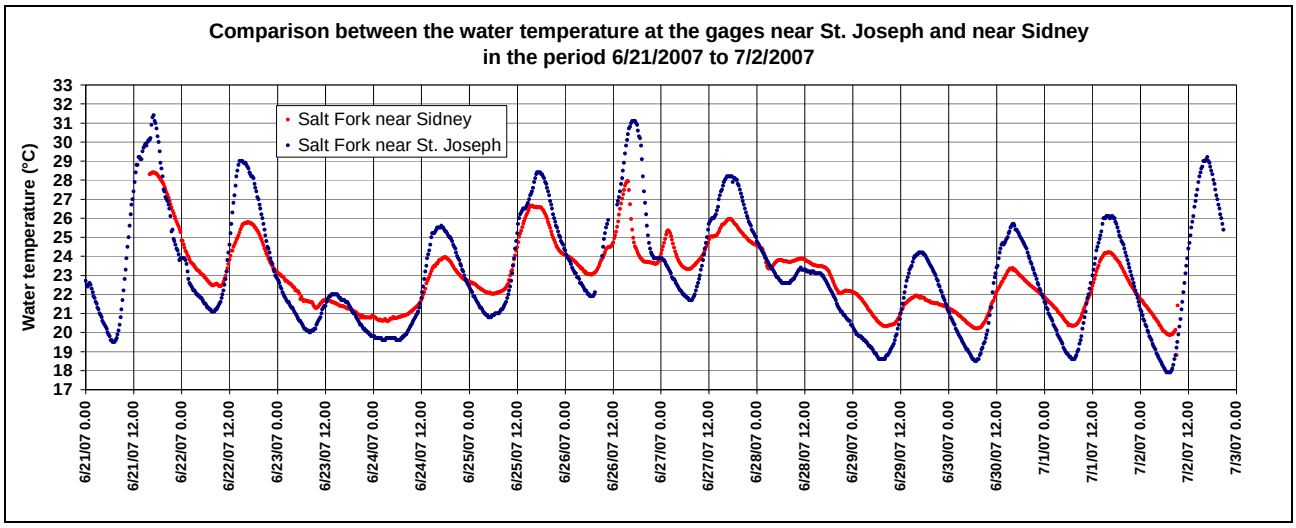


Figure 12. Comparison between the water temperature at the gages near St. Joseph and near Sidney in the period from June 21 to July 2 2007.

In order to get a more general understanding on the spatial and temporal variation of the water temperature from St. Joseph to Sidney, a comparison was made between the water temperature series in the period from September 22 2006 to July 2 2007 (in the periods when the water temperature data were considered reliable).

The following figures shows the period from September 22 to October 8 2006 (during the Fall season) and the period from November 27 2006 to January 31 2007 (last Fall period and first Winter period). The water temperature in the Salt Fork near St. Joseph is generally lower than the corresponding one near Sidney, since the warming effect of the riparian vegetation is absent.

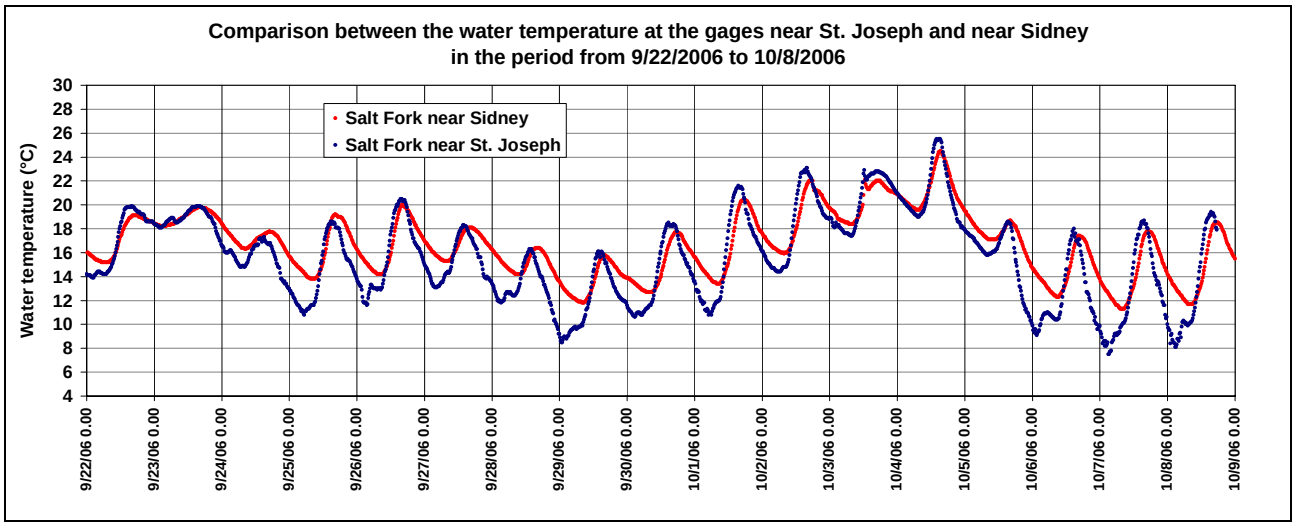


Figure 13. Comparison between the water temperature at the gages near St. Joseph and near Sidney in the period from September 22 to October 8 2006.

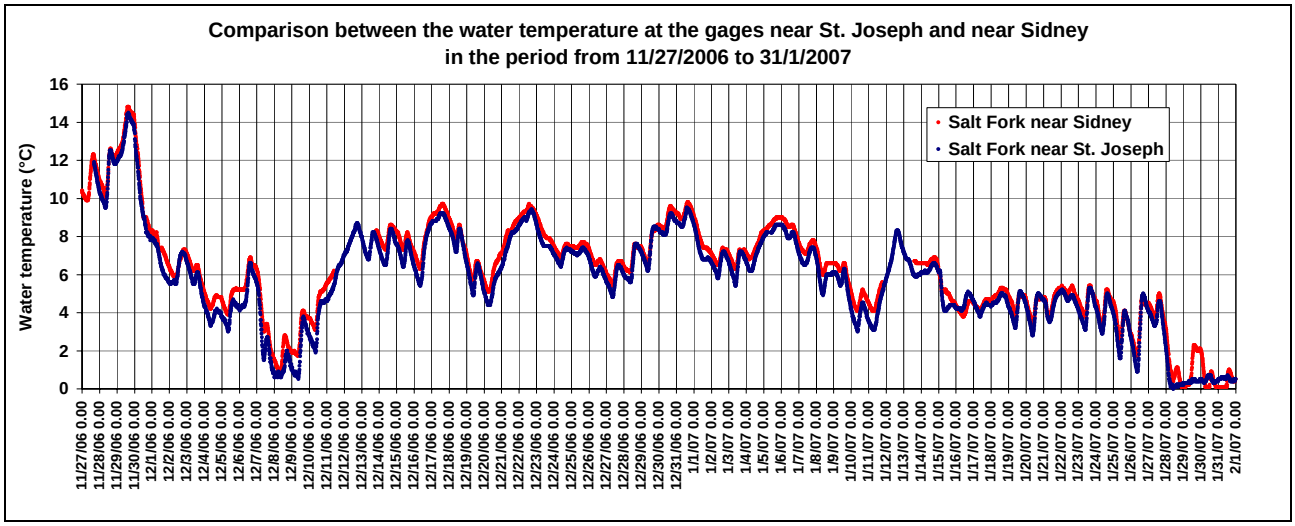


Figure 14. Comparison between the water temperature at the gages near St. Joseph and near Sidney in the period from November 27 2006 to January 31 2007.

Figure 15. Comparison between the riparian vegetation for the Salt Fork at the USGS gaging station near St. Joseph (picture on the left, looking upstream) and near Sidney (picture on the right, looking downstream).

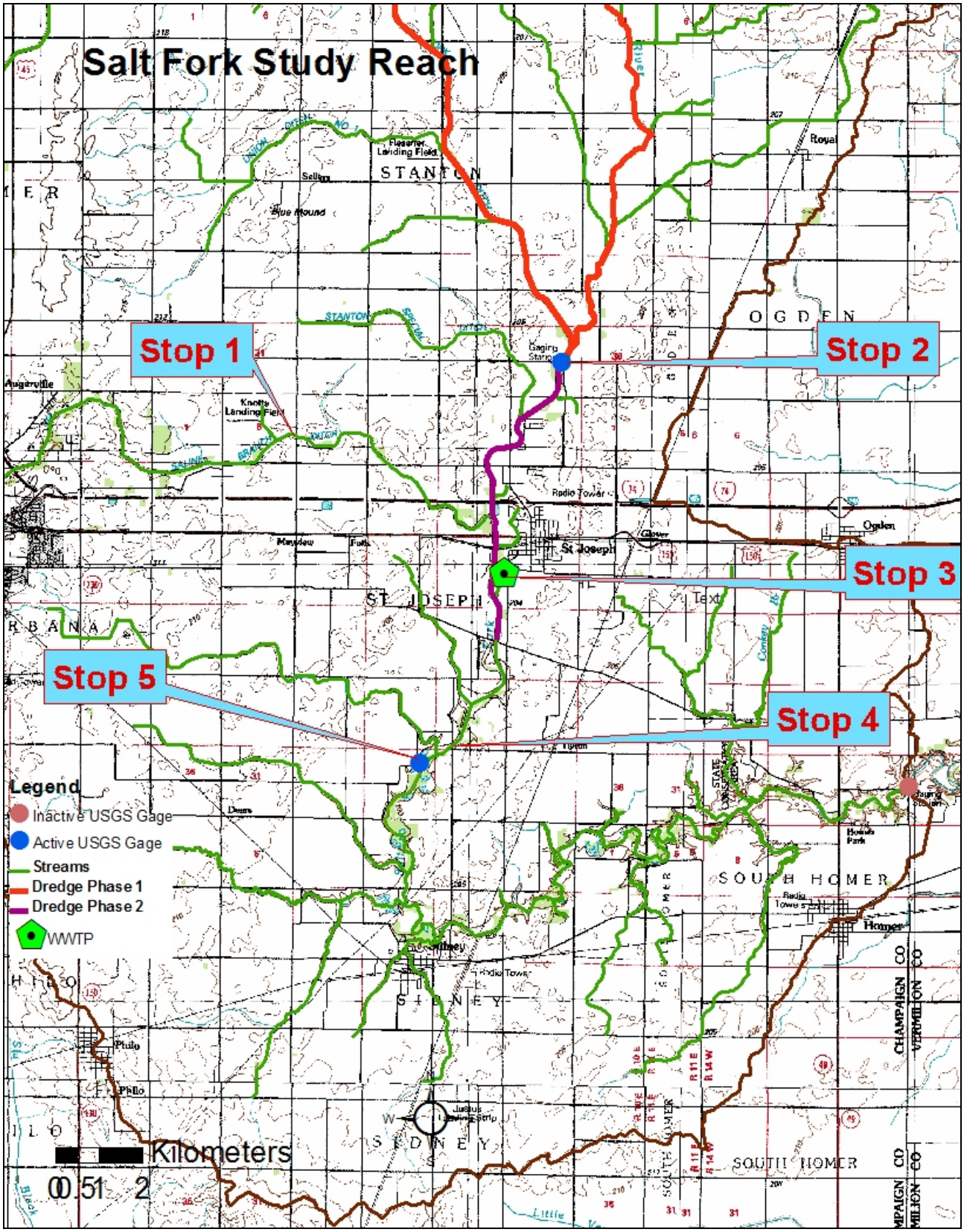


Figure 16. Dredging phases on the recognition map.

DISSOLVED OXYGEN

In this chapter, the dissolved oxygen concentration data, collected using the YSI probe at different locations in the Salt Fork watershed (see Table 4) and every 15 minutes at the station 03337848 near Sidney in the period from June 21 2007 to July 2 2007 are analyzed.

Dissolved oxygen concentration measurements at several locations

Dissolved oxygen concentration measurements were done using the handheld YSI water quality probe on the following days and location:

- June 12 2007 (around 14:00 CST)
  03336900 (USGS gaging station 03336900)
  SF2 (downstream from the confluence of the Saline Branch Ditch)
  SF3 (right downstream from the St. Joseph WWTP)
  03337810 (downstream from the St. Joseph WWTP)
  03337845 (downstream from the confluence of the SJ#2)
  03337848 (USGS gaging station 03337848)
  03387850 (downstream from the confluence of the SJ#4)
  03337900 (downstream from the confluence of the SJ#5)

- June 14 2007 (morning, between 8:52 and 11:31 CST)
  03336900 (USGS gaging station 03336900)
  SF2 (downstream from the confluence of the Saline Branch Ditch)
  SF3 (right downstream from the St. Joseph WWTP)
  03337810 (downstream from the St. Joseph WWTP)
  03337845 (downstream from the confluence of the SJ#2)
  03337848 (USGS gaging station 03337848)
  03387850 (downstream from the confluence of the SJ#4)
  03337900 (downstream from the confluence of the SJ#5)

- June 14 2007 (afternoon, at 15:42 CST)
  03336900 (USGS gaging station 03336900)

- June 19 2007 (between 9:40 and 14:07 CST)
  03336900 (USGS gaging station 03336900)
  SF2 (downstream from the confluence of the Saline Branch Ditch)
  03337810 (downstream from the St. Joseph WWTP)
  03337848 (USGS gaging station 03337848)
  03387850 (downstream from the confluence of the SJ#4)
  03337900 (downstream from the confluence of the SJ#5)

The following figures help to understand the spatial variability of the dissolved oxygen along the Salt Fork. June 12 and June 14 were sunny days, preceded by dry periods of at least one week. On the contrary, the June 19 measurements were done after a rainfall event (1.10 and 0.20 inches of rain were measured on June 18 and 19 at the St. Joseph WWTP).
Usually, for each location, three measurements were done in three different points. The values reported in the following graphs are the mean values.

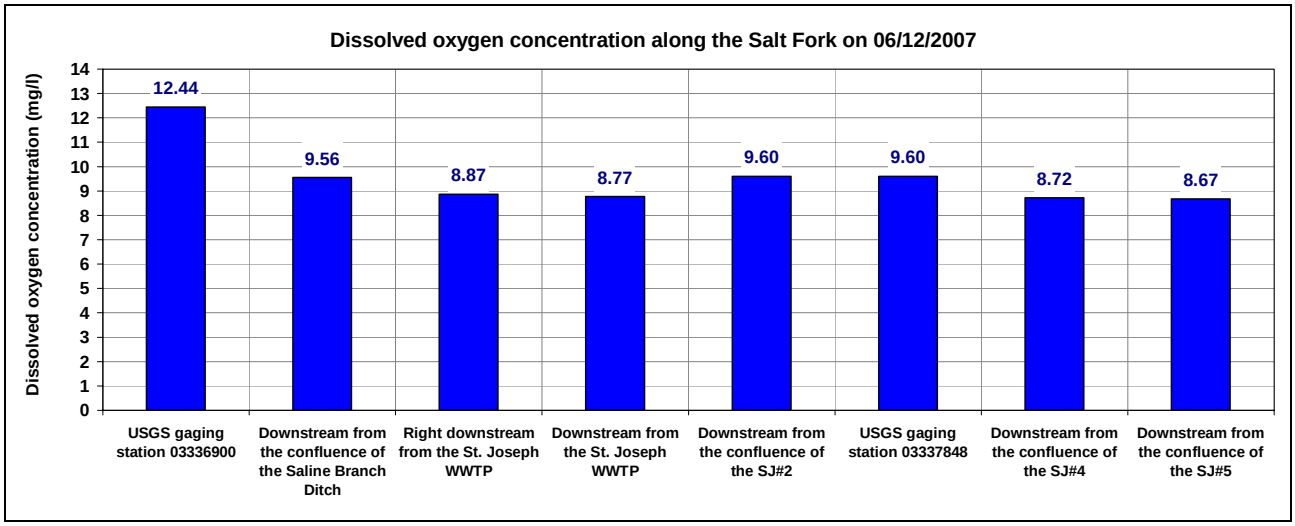


Figure 17. Dissolved oxygen concentration along the Salt Fork on June 12 2007.

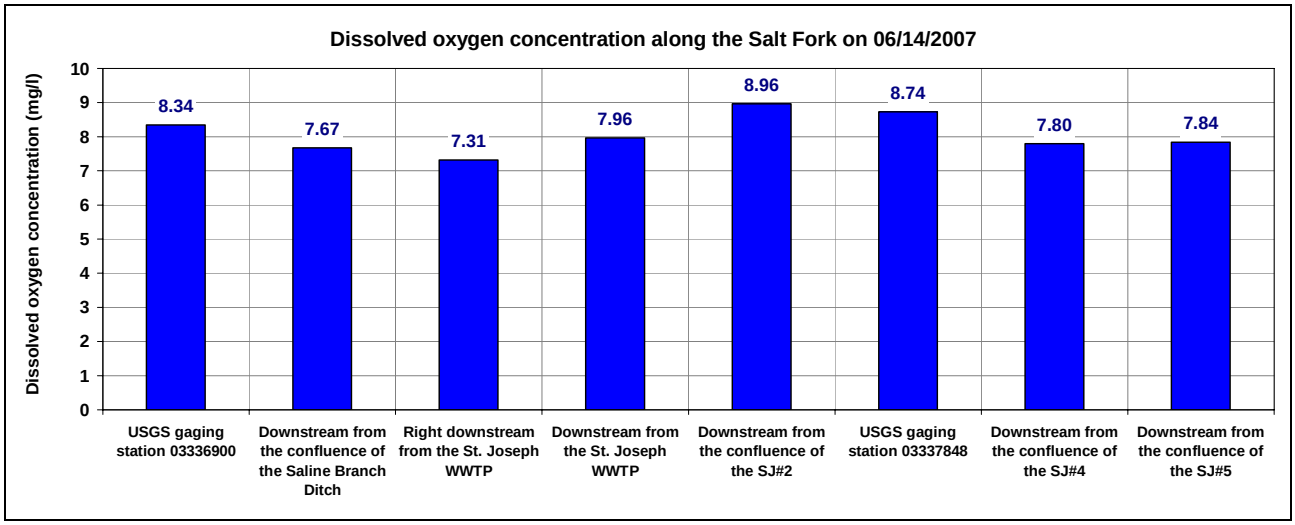


Figure 18. Dissolved oxygen concentration along the Salt Fork on June 14 2007.

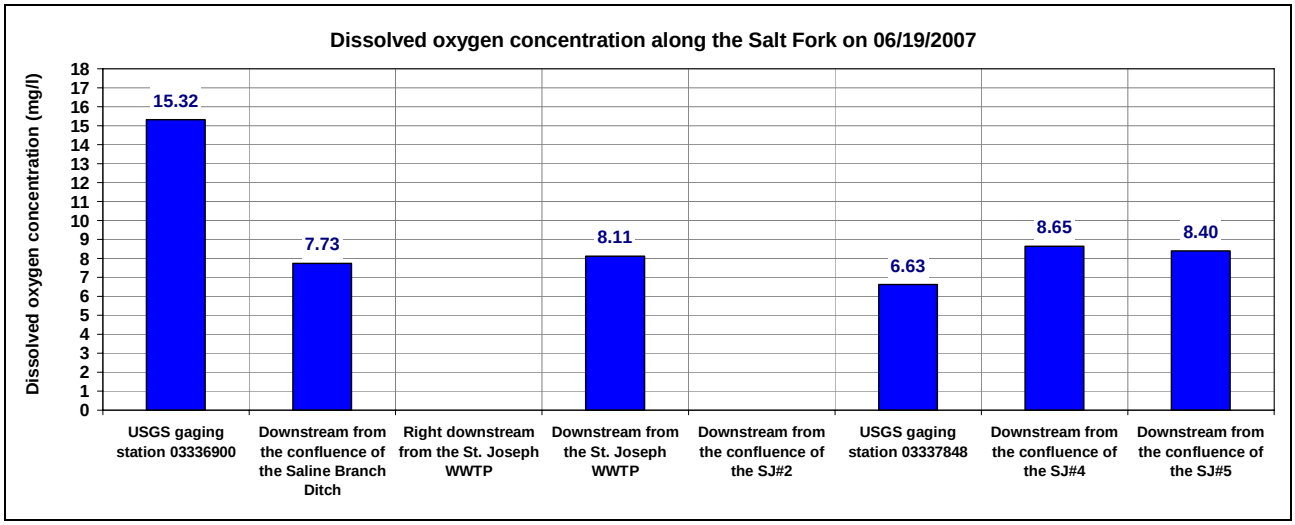


Figure 19. Dissolved oxygen concentration along the Salt Fork on June 19 2007.

From the figures above, it is evident that the confluence of the Saline Branch Ditch (carrying the Urbana-Champaign WWTP effluents) and the effluents coming out from the St. Joseph WWTP (where the dissolved oxygen right downstream was 7.57 mg/l) cause a decrease of the dissolved oxygen levels, which is then recovered downstream, as expected according to the typical dynamics patterns for dissolved oxygen (see for example the Streeter-Phelps equations).
The data collected also help give some information about the diurnal variability of the dissolved oxygen concentration. Figure 20 compares the measurements done in the morning (8:52 CST) and in the afternoon (15:42 CST) of June 14 at the USGS gaging station 03336900 near St. Joseph. The graph reports the values of water temperature too.

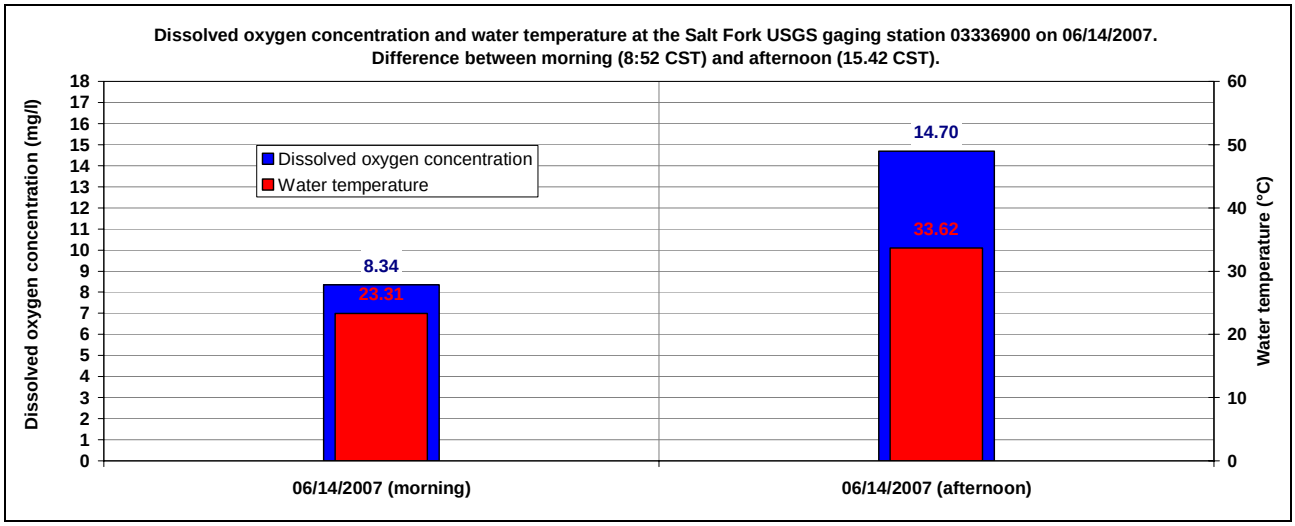


Figure 20. Diurnal variation of the dissolved oxygen concentration and water temperature at the USGS gaging station 03336900 near St. Joseph on June 14 2007.

From the figure above, a diurnal pattern can be seen. In the afternoon, when the temperature is higher, the photosynthesis by plants and algae produces more oxygen. The conditions in the afternoon are probably supersaturated (the dissolved oxygen concentration is greater than the value at saturation, which decreases if the temperature increases). A decrease of the value of dissolved oxygen concentration has to be expected as the sun sets. The increase of the water temperature in the afternoon is here due also to the lack of the vegetation on the banks, since the vegetation buffer was removed by the dredging operations, as already reported above in the report.

Dissolved oxygen measurements were made also for the Saline Branch Ditch on June 12, June 14 (morning) and June 19 and for the Saint Joseph Drainage Ditch #3 on June 12, June 14 (morning and afternoon) and June 19.
The comparison between the dissolved oxygen concentration in the Salt Fork upstream and downstream from the confluence of the Saline Branch Ditch and the Saline Branch Ditch dissolved oxygen concentration itself (see Figure 21) shows, especially on June 19, the impact of the Saline Branch Ditch (which is the recipient of the Urbana-Champaign WWTP effluents) on the Salt Fork dissolved oxygen levels, confirming what already introduced above.

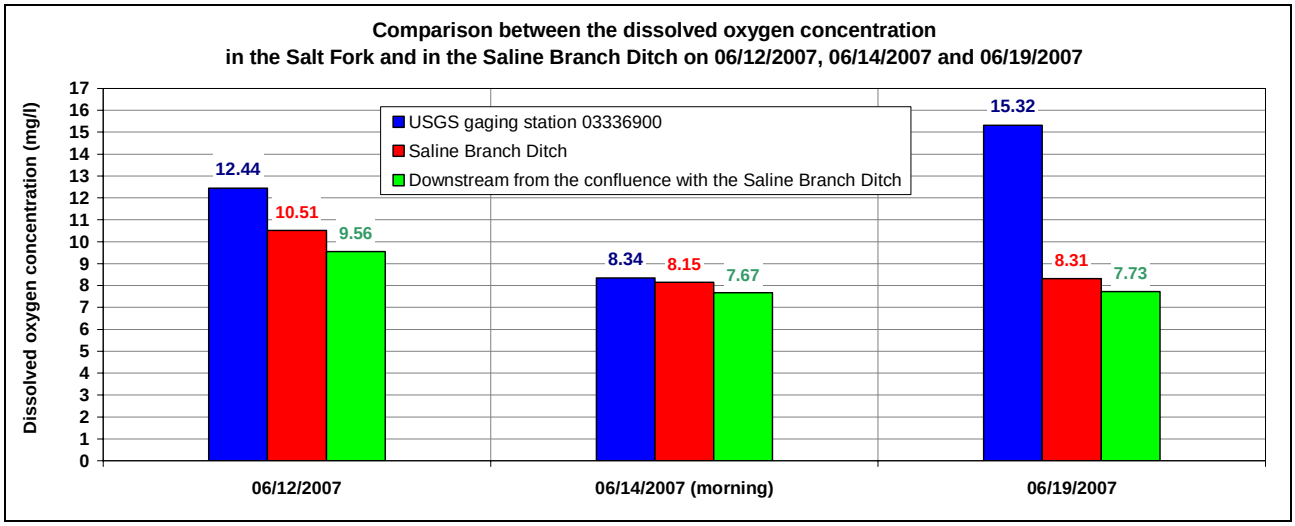


Figure 21. Comparison between the dissolved oxygen concentration in the Salt Fork and in the Saline Branch Ditch on June 12, 14 and 19 2007.

The comparison between the dissolved oxygen concentration in the Salt Fork upstream and downstream from the confluence of the Saint Joseph Drainage Ditch #3 and the Saint Joseph Drainage Ditch #3 dissolved oxygen concentration itself (see the Figure 22) suggests that this ditch does not represent an issue in terms of dissolved oxygen level (even if more measurement should be made in order to be more confident about this conclusion).

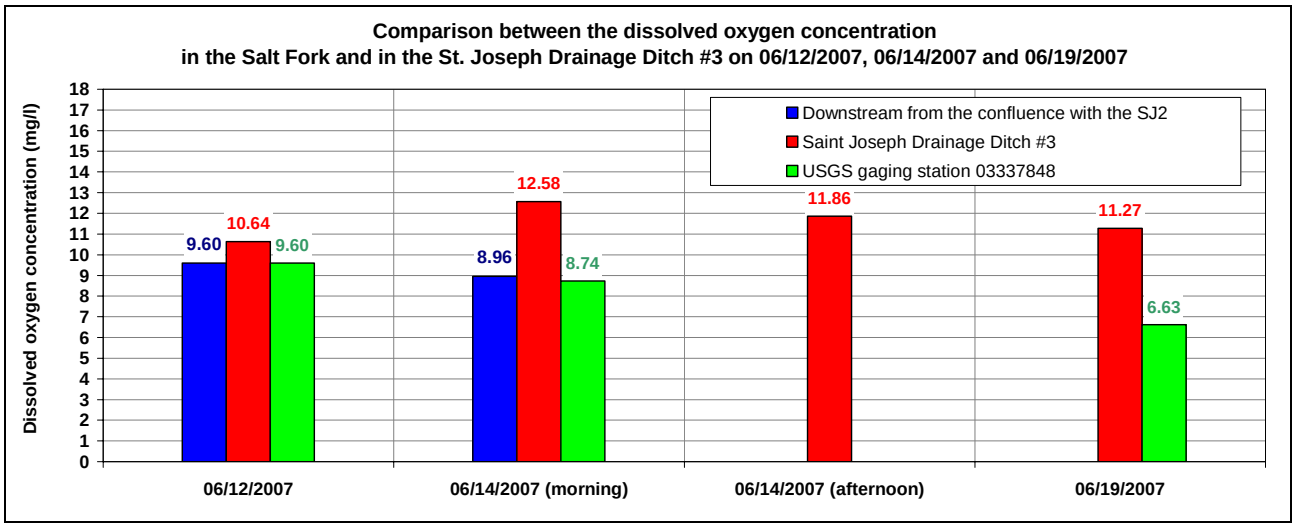


Figure 22. Comparison between the dissolved oxygen concentration in the Salt Fork and in the St. Joseph Drainage Ditch #3 on June 12, 14 and 19 2007.

Continuous dissolved oxygen concentration measurements for the Salt Fork near Sidney

Continuous water quality observations are available from June 21 to July 2 2007 for the station 03337848 near Sidney (1030 observation every 15 minutes).

Figure 23 shows the variation of the dissolved oxygen concentration through this period, along with the percentage ratio of the actual concentration to the saturation concentration at the given temperature and pressure. Note that this can be greater than 100% because other sources of oxygen (most notably photosynthesis by plants and algae) result in supersaturated conditions.

Despite of the fact that the continuous data were collected during a period dominated by runoff (conditions different from the ones which characterized the previous two dry weeks, when the YSI handheld probe measurements were done), it is still possible to observe a diurnal pattern of the dissolved oxygen concentration, especially on June 22, 24, 25 and 26. During these days, the dissolved oxygen pattern follows pretty well the water temperature pattern, as shown in the Figure 24. Moreover, the strong decrease of dissolved oxygen concentration which can be observed in the afternoon of June 26 could be due to the organic matter delivered to the river by the rain events on June 21, 22, 23 and 24 (1.30, 1.20, 1.90 and 0.20 inches of rain respectively measured at the St. Joseph WWTP).

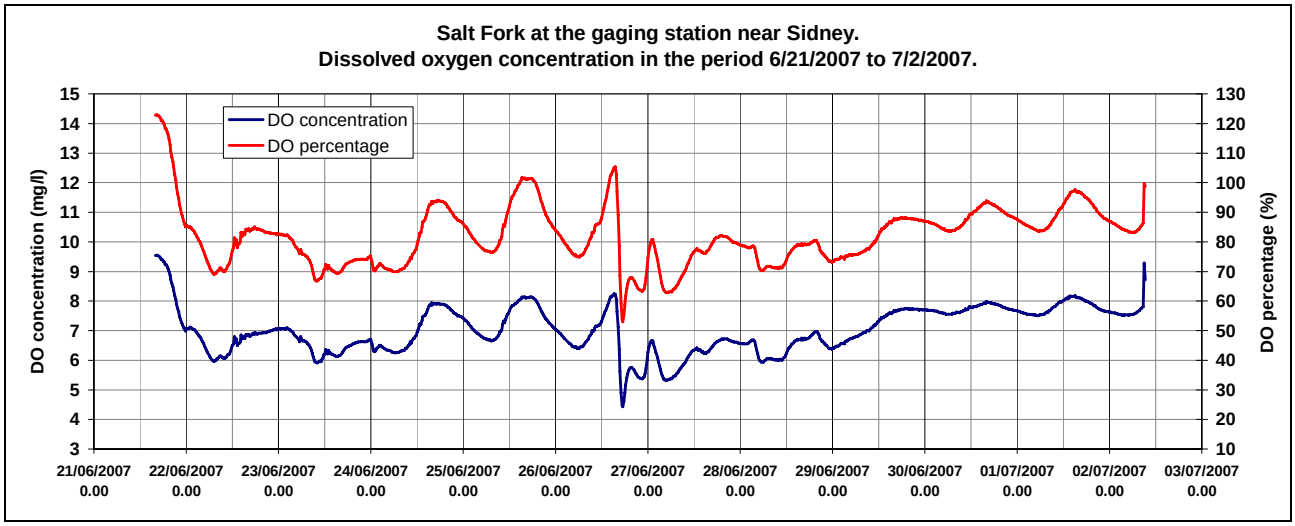


Figure 23. Salt Fork at the gaging station near Sidney: dissolved oxygen concentration in the period from June 21 to July 2 2007.

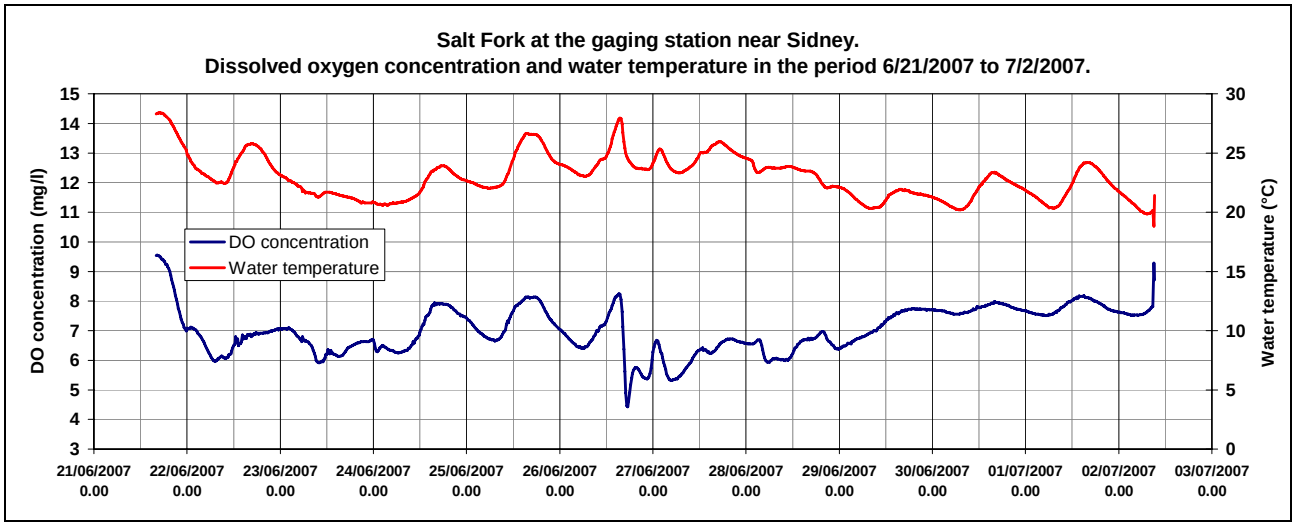


Figure 24. Salt Fork at the gaging station near Sidney: dissolved oxygen concentration and water temperature patterns in the period from June 21 to July 2 2007.

Comments and explanations about the temporal and spatial variability of the dissolved oxygen concentration

The continuous (15 minute) dissolved oxygen data collected from June 21 to July 2 2007 show a temporal variability mainly related to the water temperature temporal pattern. Follows a brief and simplified explanation for what observed in the field.

Normally, water is an environment poor of oxygen, given its low solubility, which is about 8 mg/l and depends on the altitude and water temperature and salinity. The presence of some pollutants, mainly organic, causes the decrease of the dissolved oxygen concentration and the consequent extinction of the aquatic aerobic organisms, because the decomposition of the organic matter by the aerobic bacteria consumes the dissolved oxygen. Along with the decrease of the dissolved oxygen concentration, other anaerobic organisms develop, producing toxic substances.

The organic matter is introduced in the water bodies through the sewer systems (as in this particular case), industrial drainage and the biogeochemical cycles. When its quantity is high, the number of micro organisms increases and, consequently, a high quantity of dissolved oxygen is consumed.

Generally two indicators are used for the organic matter in the water: the biochemical oxygen demand (BOD) ant the chemical oxygen demand (COD). They represent respectively the amount of oxygen necessary for the oxidation of the organic matter through the action of the aerobic bacteria or through a chemical agent. BOD is generally used to evaluate the impact of an organic matter load on the quality of a water body.

In a simple biochemical oxygen demand – dissolved oxygen model, the kinetic processes involving BOD are biomass decaying, oxidation, deposition and de-nitrification, and the kinetic processes involving DO are re-aeration, oxidation, nitrification, photosynthesis, respiration and sediment oxygen demand. Both the re-aeration and photosynthesis processes depend on the water temperature: an increase of temperature causes a decrease of the saturation dissolved oxygen concentration causing a decrease of the DO levels. On the other hand, the photosynthesis activity by plants and algae increases, so that supersaturated conditions can occur. This last process was observed during the two weeks of observation, and also on June 14 2007 (see Figure 20). The recovery in the dissolved oxygen concentration observed downstream from the St. Joseph WWTP (see Figure 17, Figure 18 and Figure 19) can be explained by the re-aeration and organic matter consumption processes.

Current Illinois EPA standards and former studies

Regarding the current Illinois EPA standards, the IPCB (Illinois Pollution Control Board) sets the Environmental Regulations for the State of Illinois [3]. The Part 302 is relative to the Water Quality Standards.

In particular, the Section 302.206 states that *"Dissolved oxygen (STORET number 00300) shall not be less than 6.0 mg/l during at least 16 hours of any 24 hour period, nor less than 5.0 mg/l at any time."*.

The former recent analysis by Tetra Tech [5] underlined, for the Saline Branch Ditch (segment BPJC08), that the DO standard of not less than the IEPA standard of 5 mg/l at any time was not violated based on Stage 2 sampling data: the document recommends the segment to be de-listed for DO impairment. This result is in agreement with what observed in June 2007.

Always according the Tetra Tech analysis, regarding the Spoon Branch (segment BPJD02), only one DO data point, 4.04 mg/l on August 30 2006 was below the IEPA standard: the document recommends a DO TMDL analysis to be developed for the segment. It could be interesting, for the next CEE 498 FM classes, to investigate this part of the Salt Fork watershed.

SEDIMENT LOAD AND CONCENTRATIONS

Given that excess sediment is an impairment to water quality to this reach, an estimation of the suspended sediment concentrations and of the mean daily load is presented in this chapter.

Suspended sediment concentration

For the Salt Fork USGS station near Sidney several suspended sediment data collected in the period from January 18 2006 to January 19 2007 are available. Table 7 reports the values of suspended sediment concentration and the sample type. The table reports also the value of gage height recorded by the continuous monitoring USGS station, when available.

Date mm/dd/yy	Time hh:mm	Concentration (mg/l)	Sample Type	Gage height (ft)
01/18/06	16:18	99	Box	
08/26/06	18:36	27	Box	
08/28/06	18:25	55	Box	
08/30/06	18:25	23	Box	
09/06/06	18:10	49	Box	
09/14/06	18:30	20	Box	
10/01/06	17:10	5	Box	0.88
10/03/06	16:30	51	Box	2.00
10/03/06	16:33	86	Box	1.98
10/03/06	16:35	159	Box	1.98
10/15/06	16:15	110	Box	0.88
10/16/06	17:45	47	Box	0.94
10/17/06	10:45	75	Box	4.52
10/21/06	13:50	14	Box	1.72
10/28/06	13:30	26	Box	
10/29/06	16:45	19	Box	
11/07/06	15:50	20	Box	1.54
11/10/06	16:23	24	Box	1.28
11/12/06	16:30	11	Box	1.55
11/16/06	20:45	191	Box	4.11
11/17/06	7:25	77	Box	4.22
11/17/06	8:00	76	Box	4.22
11/17/06	12:00	414	Grab	4.12
11/17/06	12:03	243	EWI	4.11
11/18/06	11:00	57	Grab	3.08
11/18/06	11:35	40	Grab	3.05
11/18/06	11:38	63	EWI	3.05
11/19/06	16:09	12	Grab	2.43
11/28/06	16:32	8	Grab	1.58
11/30/06	21:11	126	Grab	4.77
11/30/06	22:10	164	Composite	5.04
11/30/06	22:23	155	FSV-Box	5.11
11/30/06	22:25	111	FSV-Box	5.11
11/31/06	22:26	110	FSV-Box	5.11
12/01/06	8:05	218	FSV-Box	8.37
12/01/06	8:09	217	FSV-Box	8.37

Date mm/dd/yy	Time hh:mm	Concentration (mg/l)	Sample Type	Gage height (ft)
12/01/06	17:30	280	FSV-Box	9.35
12/02/06	11:18	66	FSV-Box	8.15
12/02/06	11:20	84	FSV-Box	8.15
12/02/06	11:25	113	FSV-Box	8.15
12/02/06	13:35	38	FSV-Box	7.77
12/03/06	12:20	29	FSV-Box	5.06
12/03/06	16:22	30	FSV-Box	4.82
12/04/06	9:45	53	FSV-Box	4.10
12/06/06	16:45	21	Grab	3.09
12/09/06	15:30	42	Grab	2.41
12/12/06	16:35	59	FSV-Box	
12/13/06	19:45	84	Box	
12/15/06	17:10	38	Box	3.42
12/21/06	22:15	86	Box	7.59
12/22/06	10:30	164	Box	8.66
12/22/06	14:25	192	Box	9.32
12/22/06	14:45	237	Cross Section	9.35
12/22/06	15:00	191	Box	9.38
12/22/06	21:15	280	Box	10.10
12/23/06	7:30	66	Box	10.13
12/23/06	8:32	129	Box	10.07
12/23/06	12:08	92	Box	9.69
12/23/06	12:08	92	FSV-Box	9.69
12/23/06	17:15	78	FSV-Box	9.06
12/24/06	12:20	55	FSV-Box	6.34
12/26/06	12:30	28	FSV-Box	4.21
12/26/06	15:12	22	FSV-Box	4.12
12/30/06	16:10	22	FSV-Box	2.83
12/31/06	8:16	71	FSV-Box	3.71
12/31/06	8:35	500	FSV-Box	3.87
12/31/06	14:55	124	FSV-Box	6.32
01/01/07	10:40	122	FSV-Box	7.89
01/01/07	11:00	98	FSV-Box	7.86
01/02/07	12:20	49	FSV-Box	5.43
01/05/07	14:30	121	FSV-Box	6.85
01/06/07	10:45	72	Box	5.63
01/13/07	15:43	178	Box	8.14
01/13/07	16:00	146	Box	8.16
01/14/07	15:18	71	Box	6.92
01/15/07	10:17	408	Box	10.63
01/15/07	10:37	299	Box	10.67
01/15/07	12:40	423	Box	10.91
01/15/07	15:07	1530	Box	11.11
01/15/07	15:12	591	Xsect	11.11
01/16/07	8:28	146	Box	10.84
01/19/07	16:02	20	Box	3.83

Table 7. Suspended sediment transport concentrations measured in the period from January 18 2006 to January 19 2007.

The maximum concentration value recorded in the set, which is the result of measurements made with different conditions of flow (gage height values between 0.88 ft and 11.11 ft) and mixing (given the possibility of sediment plumes coming in from the St. Joseph Drainage Ditch #3) is 1530 mg/l (on January 15 2007), the minimum is 5 mg/l (on October 1 2006). The mean value is 154 mg/l.
Figure 25 shows a demonstration of water samples for the evaluation of the suspended sediment concentration on June 19 2007.

Figure 25. Collection of water samples for the evaluation of the suspended sediment concentration.

The data reported in the Table 7 were used to find a relation between suspended sediment concentration and discharge and between suspended sediment concentration and turbidity. No seasonality correlation was made since the period of observation of the sediment concentration is too short for that.

Relation between suspended sediment concentration and discharge

For the USGS gaging station 03337848 near Sidney a set of gage height 15-min data values is available for the period from September 22 2006 to June 22 2007.
A rating curve for this station was worked up using 20 measurements gage height-discharge made available by USGS for the period from June 12 2006 to February 1 2007 plus four measurements made on June 14 2007 (with the Flow Tracker, the ADCP and the pigmy meter) and on June 21 (with the Flow Tracker). The 24 pairs of gage height *H* and discharge *Q* values are reported in the Table 8.

Date dd/mm/yyyy	Gage height (ft)	Discharge (cfs)
12/06/2006	10.97	2720.0
28/08/2006	2.00	157.0
30/08/2006	1.26	73.8
06/09/2006	1.61	112.0
17/09/2006	0.93	40.0
17/10/2006	4.52	530.0
10/11/2006	1.28	65.4
17/11/2006	4.14	464.0
18/11/2006	2.93	280.0
19/11/2006	2.42	206.0
01/12/2006	8.82	1850.0

Date dd/mm/yyyy	Gage height (ft)	Discharge (cfs)
22/12/2006	9.23	1980.0
23/12/2006	9.76	1900.0
23/12/2006	9.08	1600.0
24/12/2006	6.45	1010.0
26/12/2006	4.14	535.0
15/01/2007	11.08	2920.0
16/01/2007	10.91	2310.0
16/01/2007	9.91	1880.0
01/02/2007	2.23	197.0
14/06/2007 12:31 (Flow Tracker)	1.09	62.3
14/06/2007 14:43 (ADCP)	1.06	72.1
14/06/2007 15:58 (Pigmy meter)	1.05	55.1
21/06/2007 9:12 (Flow Tracker)	0.96	58.4

Table 8. Gage height and discharge measurements in the Salt Fork at the station 03337848 near Sidney for the period from June 12 2006 to June 21 2007.

Figure 26 shows the rating curve estimated using the values reported in the Table 8. The expression of the rating curve is the following:

$$\log_{10} Q[cfs] = 1.603 \log_{10} H[ft] + 1.718 \tag{1}$$

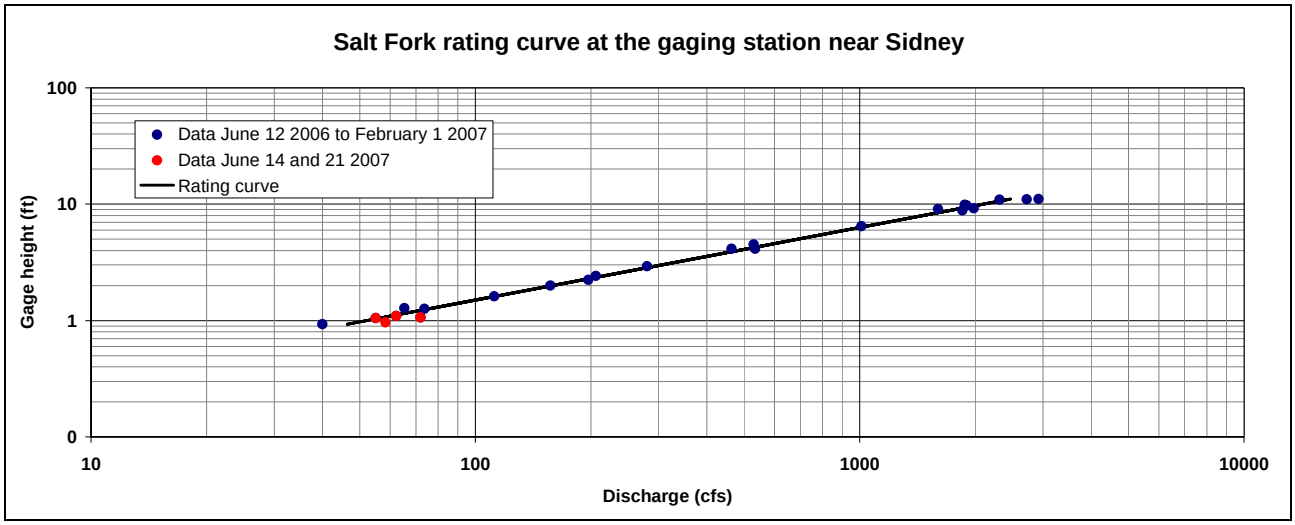


Figure 26. Salt Fork rating curve at the gaging station near Sidney.

USGS also developed a rating curve for the Salt Fork near Sidney and provided a time series discharge data. In particular, it made available the daily data and the 15-min discharge data from August 13 2006 to May 31 2007.

The discharge series from September 22 2006 to June 22 2007 obtained using the stage data recorded by the continuous monitoring USGS station near Sidney and the rating curve described by the equation (1) were integrated with the 15-min discharge data made available by USGS for the period from August 13 2006 to September 21 2006, in order to get a 314 days series.

A relation between the suspended sediment concentration *C* values reported in the Table 7 and the corresponding discharge *Q* values was then found (excluding 11 points), with the following expression (see also the Figure 27):

$$C[mg/l] = 0.0923\,Q[cfs] \tag{2}$$

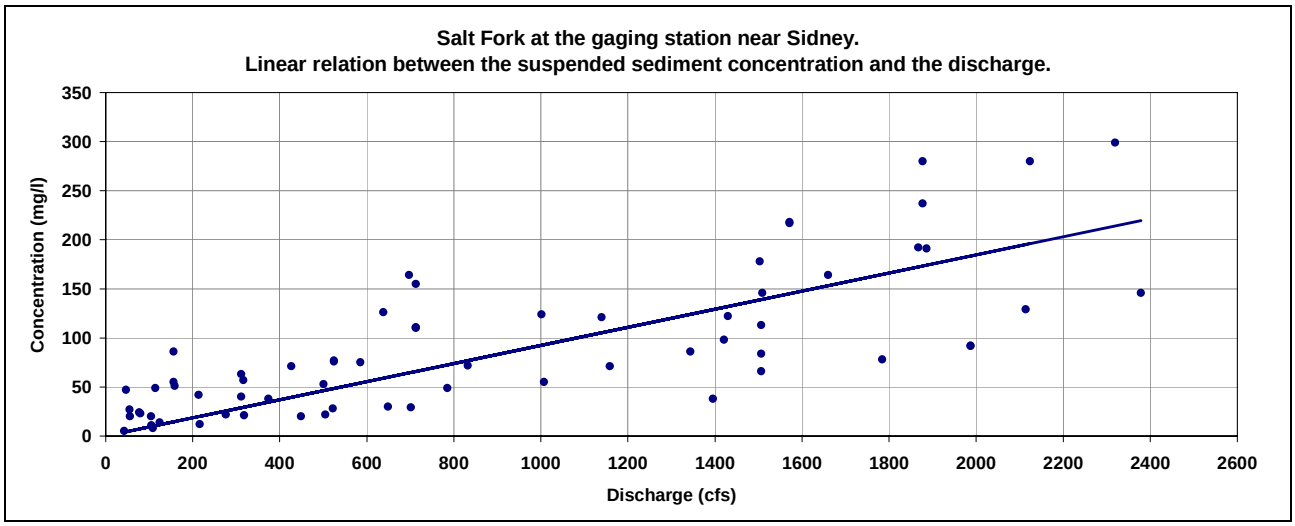


Figure 27. Salt Fork at the gaging station near Sidney: linear relation between the suspended sediment concentration and the discharge.

From a physical point of view, a quadratic curve should be more suitable to describe the relation between discharge and suspended sediment concentration, since the suspended sediment concentration can be considered as a linear function of the shear stress (once neglecting the wash load), which depends, in turbulent conditions, on the square of the discharge. On the other hand, the concentration-discharge data available do not show a parabolic pattern, since most of the concentration data were collected during low or medium flow. A fit parabolic curve based on all the data available has the following expression (see also the Figure 28):

$$C[mg/l] = 0.000061\,(Q[cfs])^2 + 0.027005Q[cfs] \tag{3}$$

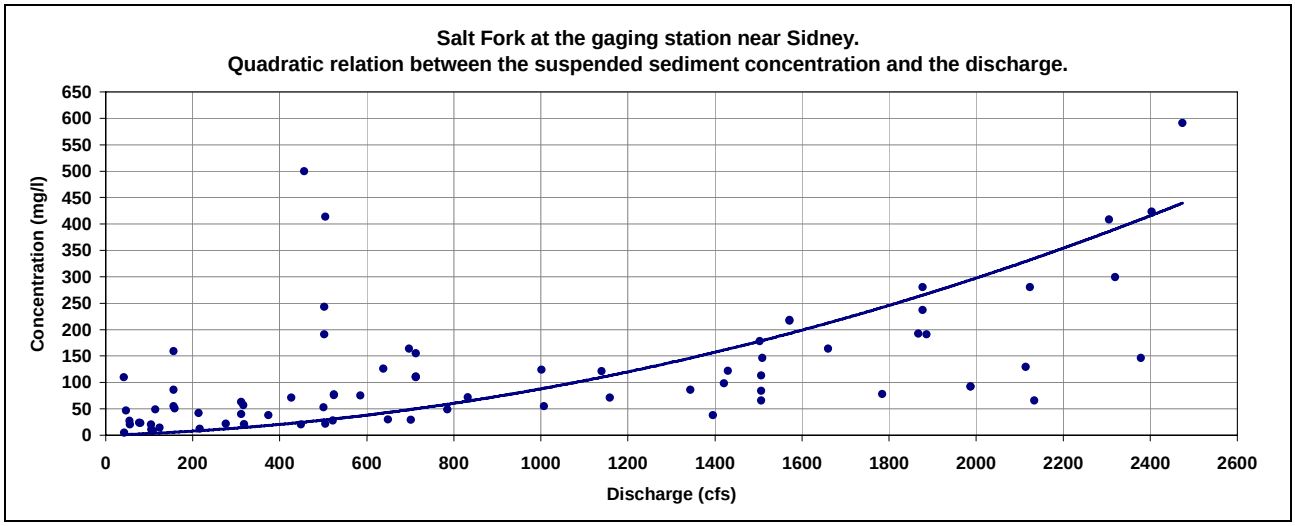


Figure 28. Salt Fork at the gaging station near Sidney: quadratic relation between the suspended sediment concentration and the discharge.

Once known the relation between discharge and suspended sediment concentration, the complete series of concentration values was generated for the period from August 13 2006 to June 22 2007, using both the linear and the quadratic relation. Some gage height values read by the monitoring

station have no physical meaning: in that case, the discharge and the corresponding concentration were set to zero. The following figure shows the concentration series for the period from August 13 2006 to June 22 2007.

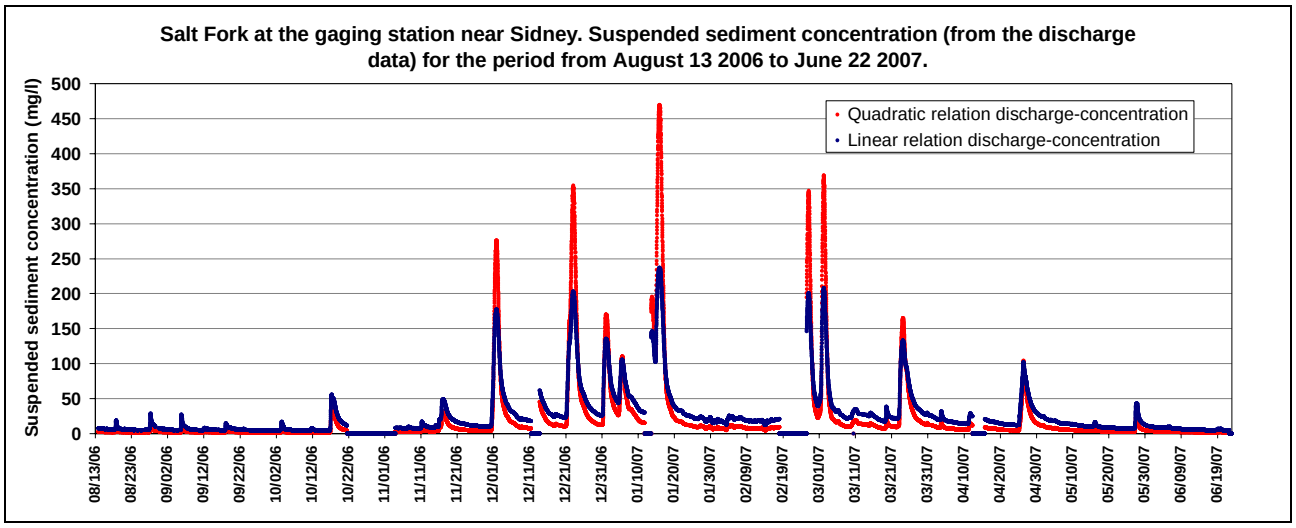


Figure 29. Salt Fork at the gaging station near Sidney: suspended sediment concentration (from the discharge data) for the period from August 13 2006 to June 22 2007.

Note that the maximum value of concentration obtained using the linear or quadratic curve concentration-discharge is 236.8 mg/l or 469.6 mg/l respectively, much less than the maximum value measured in the period from January 18 2006 to January 19 2007 (1530 mg/l, see Table 7). In other words, as will be also observed later, both the fit curve are not able to reproduce the high discharges, which carry most of the annual sediment load.

Relation between suspended sediment concentration and turbidity

For the period from September 22 2006 to June 22 2007, a set of turbidity 15-min data values is also available at the USGS gaging station 03337848 near Sidney.
Two relations between the suspended sediment concentration *C* values reported in the Table 7 and the corresponding turbidity values were found, one linear and the other logarithmic, with the following expressions (see also the Figure 30 and the Figure 31):

$$C[mg/l] = 2.0301\, Turbidity[NTU] \tag{4}$$

$$\log_{10}(C[mg/l]) = 1.0126 \log_{10}(Turbidity[NTU]) + 0.2375 \tag{5}$$

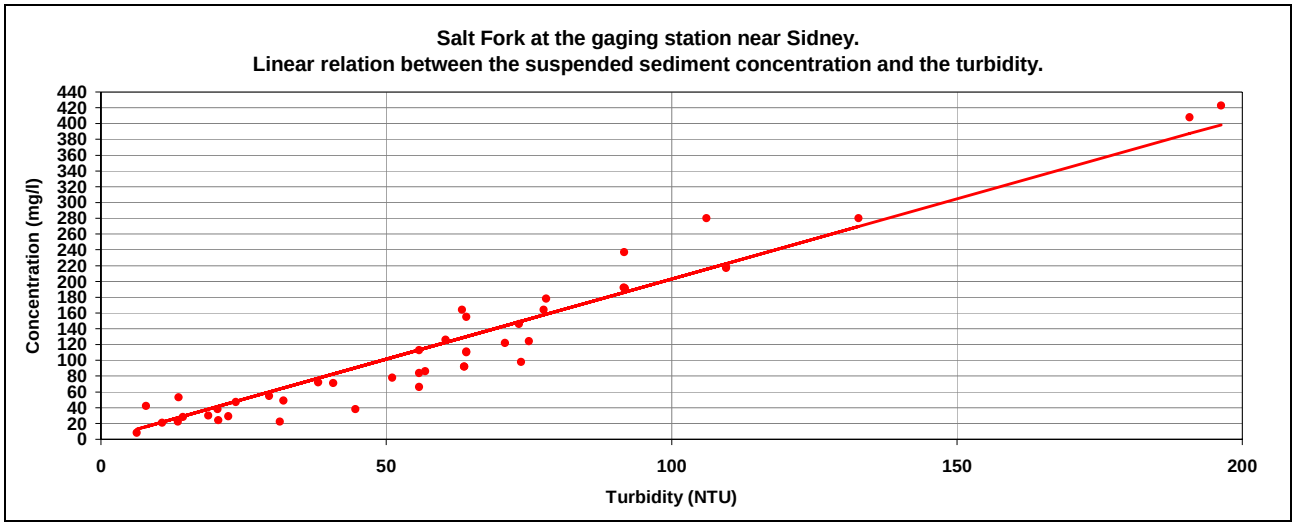


Figure 30. Salt Fork at the gaging station near Sidney: linear relation between the suspended sediment concentration and the turbidity.

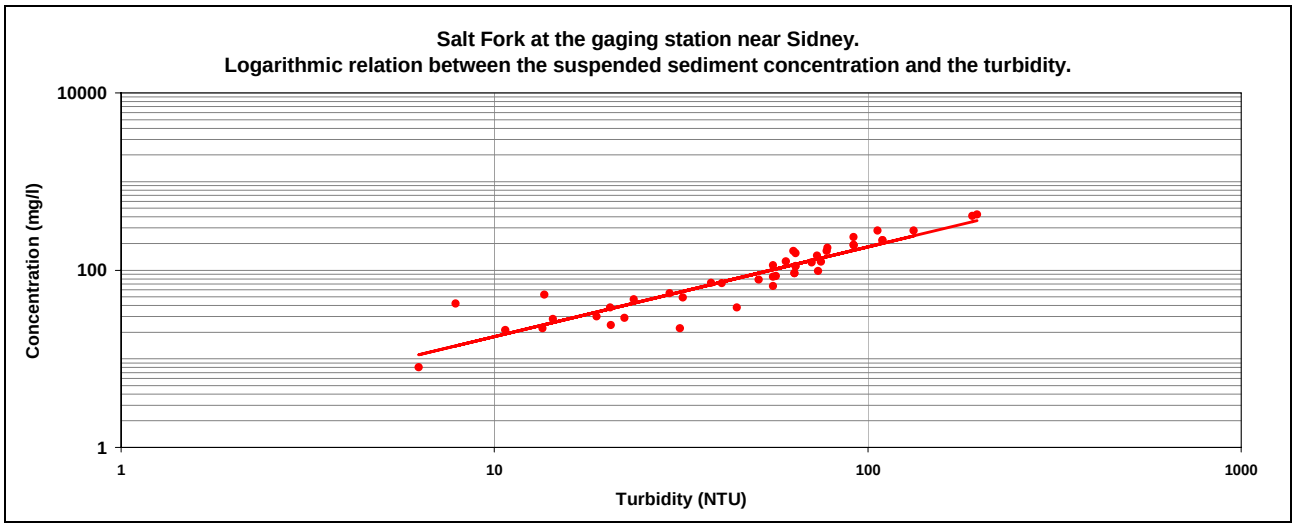


Figure 31. Salt Fork at the gaging station near Sidney: logarithmic relation between the suspended sediment concentration and the turbidity.

Both the fit lines were found considering only the low turbidity values (less than 200 NTU), whereas there is not a clear relation between concentration and turbidity for higher turbidity values. In fact, from the data available, for high turbidity values, it does not seem true that the higher the turbidity the higher is the suspended sediment concentration.

Once known the relation between suspended sediment concentration and turbidity, the complete series of concentration values was generated starting from the 15-min turbidity values from September 22 2006 to June 22 2007. Some turbidity values read at the continuous monitoring station have no physical meaning: in that case, the corresponding concentration was set to zero. Figure 32 shows the concentration series for the period from September 22 2006 to June 22 2007, calculated using the logarithmic expression (5) reported above.

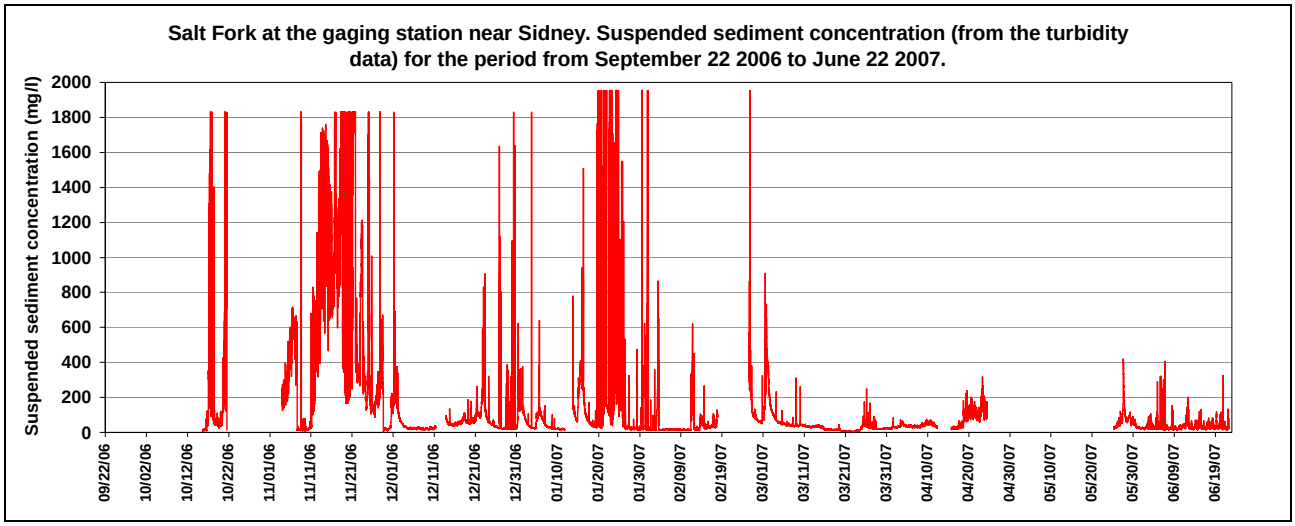


Figure 32. Salt Fork at the gaging station near Sidney: suspended sediment concentration (from the turbidity data) for the period from September 22 2006 to June 22 2007.

Note that the maximum value of concentration obtained using the curve concentration-turbidity is 1954.1 mg/l, consistently with the data collected during the period from January 18 2006 to January 19 2007 (whose maximum value is 1530 mg/l, see Table 7).

Calculation of the mean daily sediment load

From the concentration time series derived above using the concentration-discharge curve (which is basically a "black box" relation and it is not able to account for possible sediment plumes coming into the Salt Fork from the St. Joseph Drainage Ditch #3) or the concentration-turbidity curve (which is what USGS usually uses), it was possible to calculate the sediment load for the period considered, by summing the sediment load corresponding to each 15-min *i* period:

$$Load[ton] = \sum_i Q_i[cfs] \cdot C_i[mg/l] \cdot \left[0.3048^3 \cdot 1000 \frac{l}{ft^3} \cdot 15\min \cdot 60 \frac{s}{\min} \cdot 10^{-9} \frac{ton}{mg} \right] \quad (6)$$

The sediment load for the period from August 14 2006 (August 13 was not considered because incomplete) to June 22 2007, whose duration is 313 days, is 14356 tons or 17561 tons considering the linear or the quadratic discharge-concentration relation. These value correspond to a daily load of 45.9 tons/day or 56.1 tons/day respectively. In terms of daily load per unit area, for a drainage area of 254.84 mi^2, the values are 0.18 tons/day/mi^2 or 0.22 tons/day/mi^2 respectively.
The sediment load for the period from September 22 2006 to June 22 2007, whose duration is 274 days, based on the concentration-turbidity curve, is 27525 tons, corresponding to a daily load of 100.5 tons/day. Once again, considering a drainage area of 254.84 mi^2, the daily load per unit area is 0.39 tons/day/mi^2.

Comparison with the sediment load values from literature

The total and daily load of suspended sediment calculated above for the Salt Fork at the station near Sidney were compared with the Mackinaw River near Green Valley sediment data [8]. This river has similar hydrology and is sand-bedded, and it has a drainage area of 1073 mi^2 at the station near Green Valley.
For the USGS station 05568000 (Mackinaw River near Green Valley), the sediment load daily values are available for the period from October 1 1994 to September 30 1997, as shown in the

Figure 33. The mean daily load in this period is 973.9 tons/day, which corresponds to a load per unit area of 0.91 tons/day/mi^2 (maximum value 93.01 tons/day/mi^2, lowest 0.001 tons/day/mi^2).

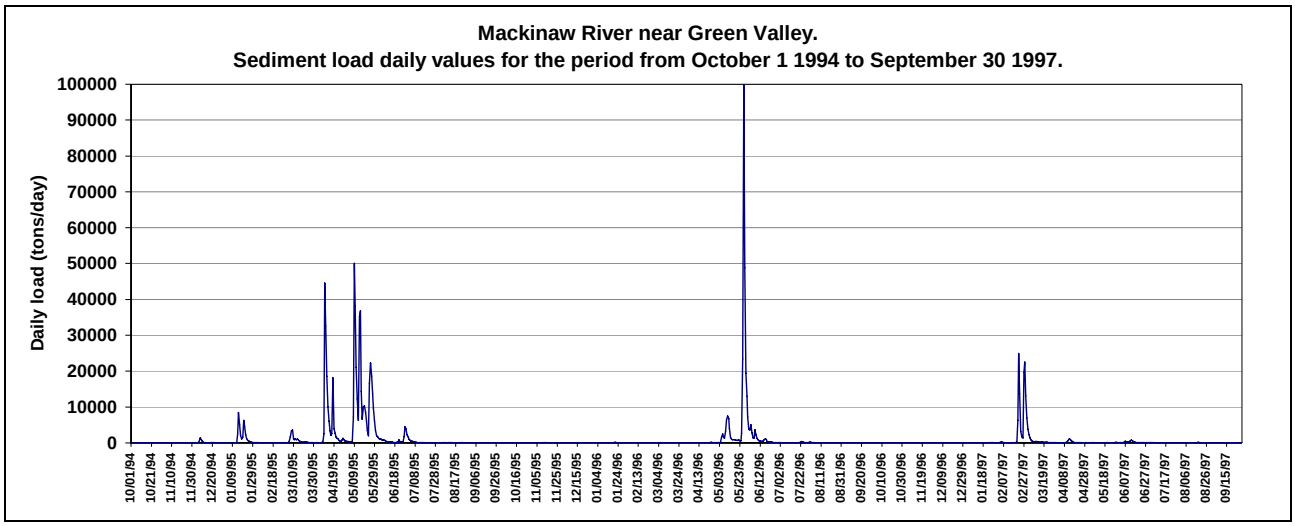


Figure 33. Mackinaw River near Green Valley: sediment load daily values for the period from October 1 1994 to September 30 1997.

Considering the same temporal window for which the Salt fork sediment load was calculated with the concentration-discharge relations (August 14 to June 22), the Mackinaw River data give:

- Aug 14 1995 - Jun 22 1996: 298920.7 tons, 952.0 tons/day, 0.89 tons/day/mi^2;
- Aug 14 1996 - Jun 22 1997: 144108.9 tons, 460.4 tons/day, 0.43 tons/day/mi^2.

Considering the same temporal window for which the Salt fork sediment load was calculated with the concentration- turbidity relation (September 22 to June 22), the Mackinaw River data give:

- Sep 22 1995 - Jun 22 1996: 297839.7 tons, 1083.1 tons/day, 1.01 tons/day/mi^2;
- Sep 22 1996 - Jun 22 1997: 143569.85 tons, 524.0 tons/day, 0.49 tons/day/mi^2.

The values for the Mackinaw River near Green Valley for 1996-97 are close to the ones obtained for the Salt Fork with the concentration-discharge curves (0.18 or 0.22 tons/day/mi^2) but especially with the turbidity-concentration curve (0.39 tons/day/mi^2), which is able to describe also high concentration events and therefore can be considered reasonable for the Salt Fork station near Sidney. However, new concentration, discharge and turbidity data could help in the future in fitting more accurate relations.

IMPACT OF THE WWTP EFFLUENTS ON THE LOW-FLOW HYDROLOGY AND FLOW DURATION CURVES

In this chapter, the impact of the effluents from the Urbana-Champaign and St. Joseph WWTP's on the Salt Fork low-flow hydrology is investigated, through the calculation of the flow duration curves at the USGS gaging stations near St. Joseph and near Sidney, the analysis of the flow measurements made in June 2007 and the data for the effluent discharges at the Urbana and Champaign Sanitary District North-East and St. Joseph WWTP's.

Flow duration curves at the USGS gaging stations near St. Joseph and near Sidney

For the USGS Gage 03336900 (Salt Fork near St. Joseph), the daily mean values of discharge are available for the water years 1959-1991 and for the water year 2005.
The following figure reports the statistics of monthly mean data for the water years 1959-1991 and 2005, by water year, which gives an idea about the Salt Fork flow regimes near St. Joseph.

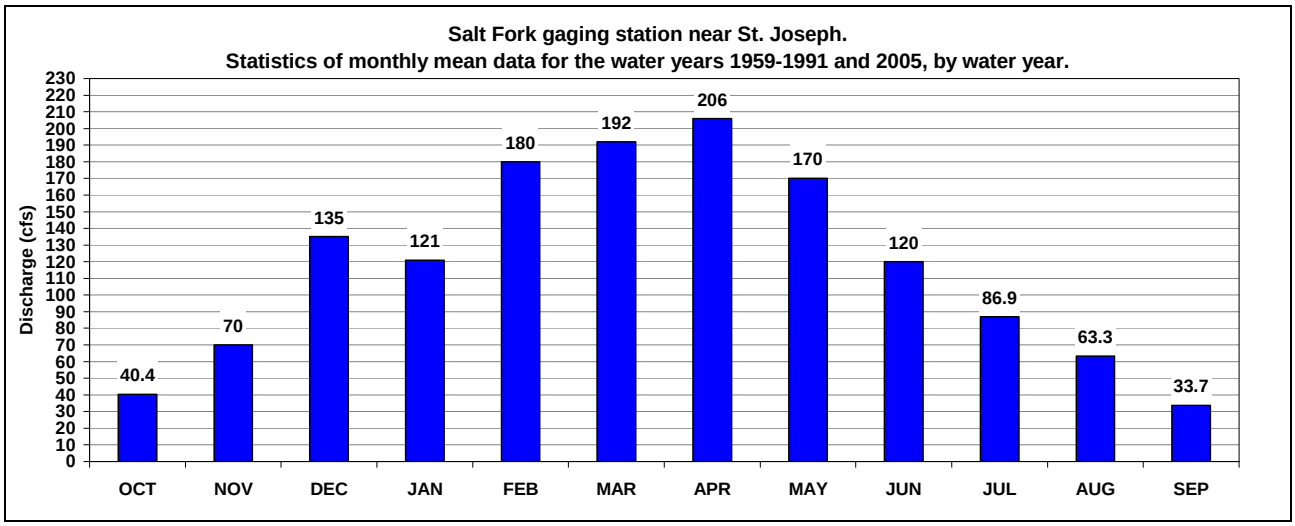


Figure 34. Salt Fork gaging station near St. Joseph: statistics of monthly mean data for the water years 1959-1991 and 2005, by water year.

Figure 35 shows the water discharge daily values for the water years 1959-1991 and for the water year 2005.

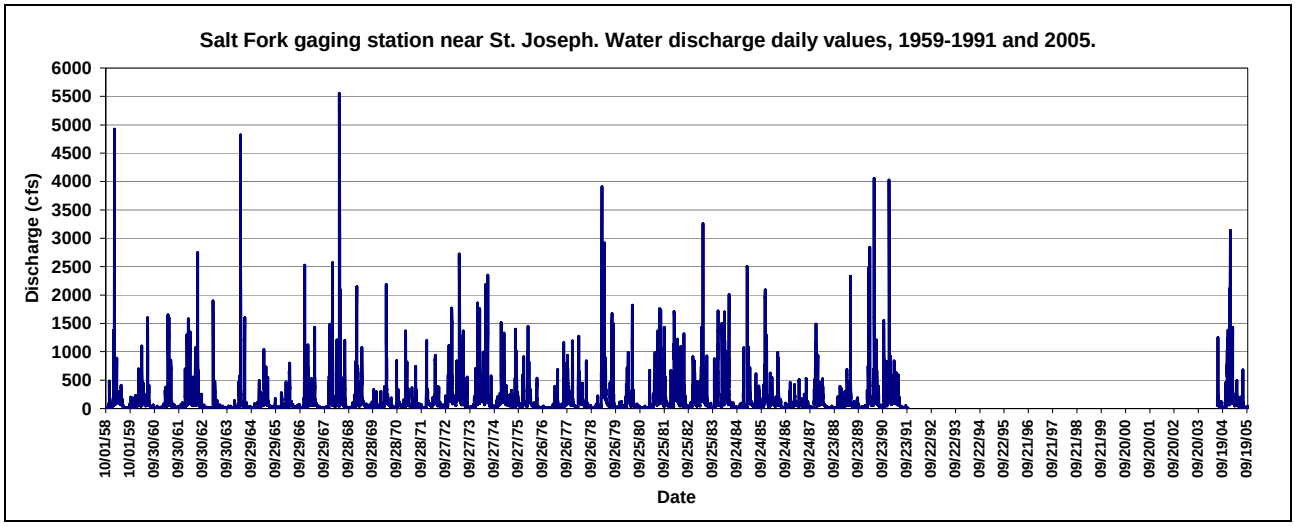


Figure 35. Salt Fork gaging station near St. Joseph: water discharge daily values for the water years 1959-1991 and 2005.

Figure 36 and Figure 37 show the duration curve for the Salt Fork station near St. Joseph based on the daily discharge values for the years 1959-1991 and for the water year 2005, whose lowest and maximum values are 2 and 5550 cfs respectively.

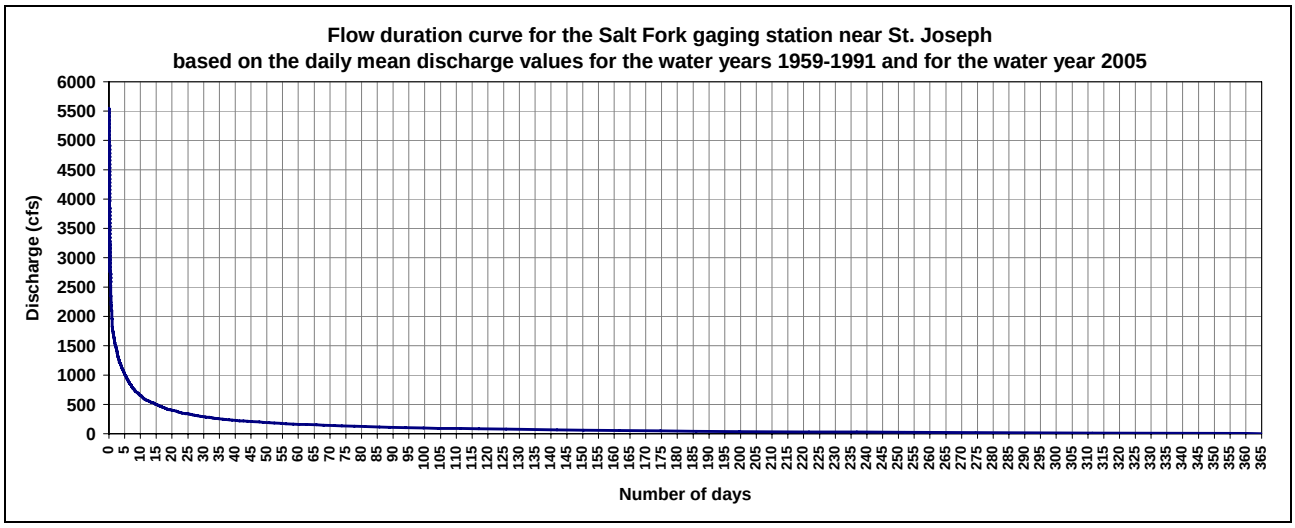


Figure 36. Salt Fork gaging station near St. Joseph: flow duration curve based on the daily mean discharge values for the water years 1959-1991 and for the water year 2005.

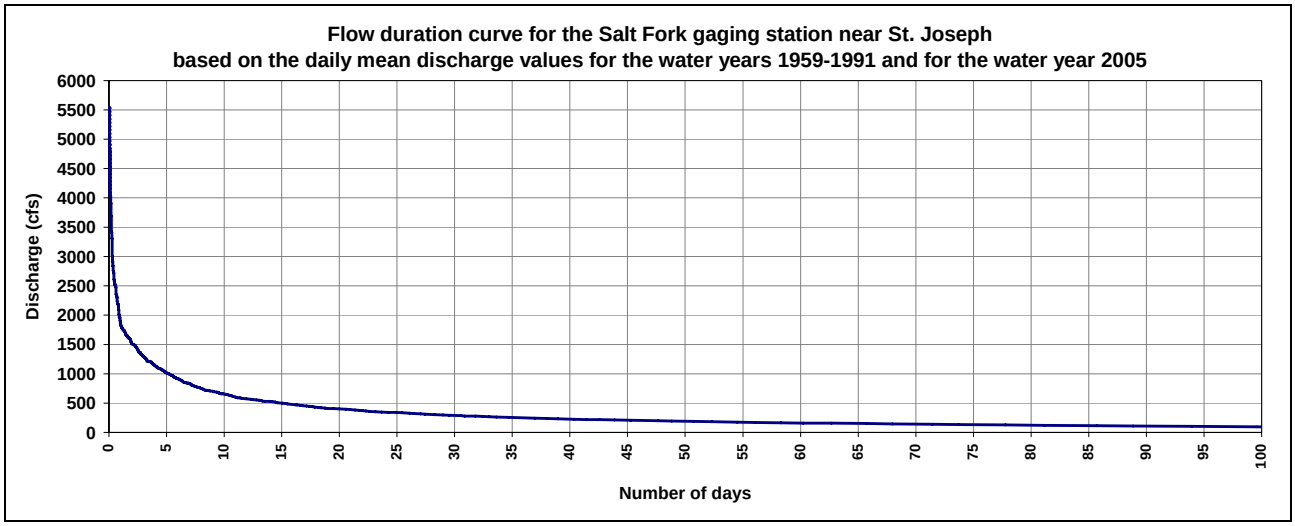


Figure 37. Salt Fork gaging station near St. Joseph: flow duration curve based on the daily mean discharge values for the water years 1959-1991 and for the water year 2005. Detail for the short durations.

According to the flow duration curve reported above, the 10th percentile flow for the period of record for the Salt Fork near St. Joseph is 9.2 cfs.

As already reported above, for the Salt Fork near Sidney, a 15-min gage height series from September 22 2006 to June 22 2007 (the corresponding discharge values were calculated with the rating curve introduced above) plus discharge data from August 13 2006 to September 21 from USGS are available. Figure 38 shows the resulting discharge series. Given that some gage height values read by the continuous monitoring station have no physical meaning, some values are missing.

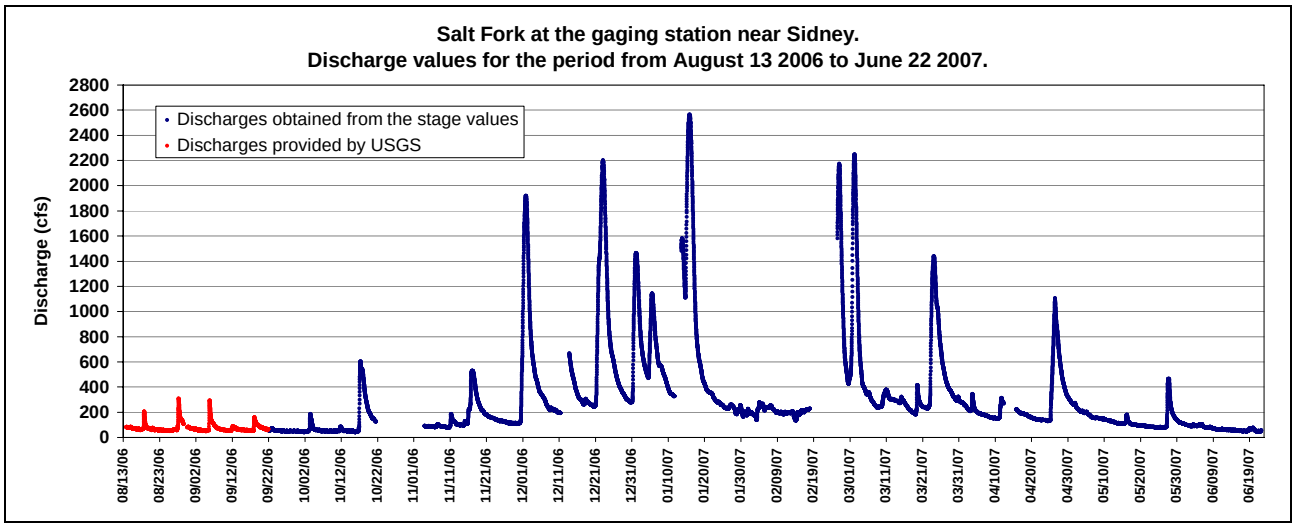


Figure 38. Salt Fork at the gaging station near Sidney: discharge values for the period from August 13 2006 to June 22 2007.

From the discharge data available (whose lowest and maximum values are 41 and 2564 cfs respectively), a flow duration curve (extended to 365 days even though the values available do not cover an entire year), reported in the Figure 39 and Figure 40.

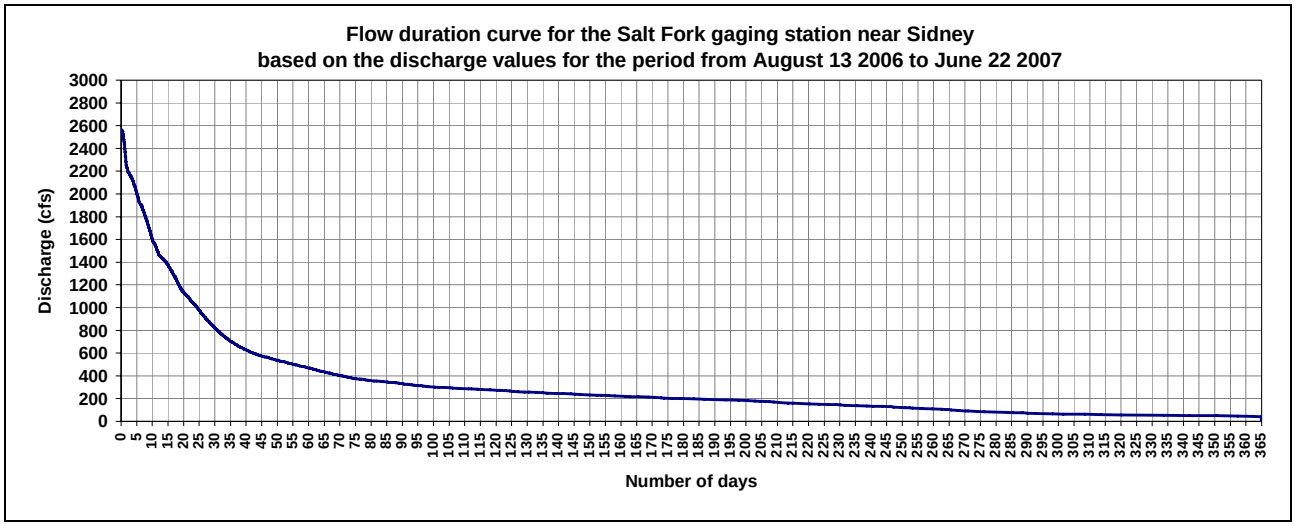


Figure 39. Salt Fork gaging station near Sidney: flow duration curve based on the discharge values for the period from August 13 2006 to June 22 2007.

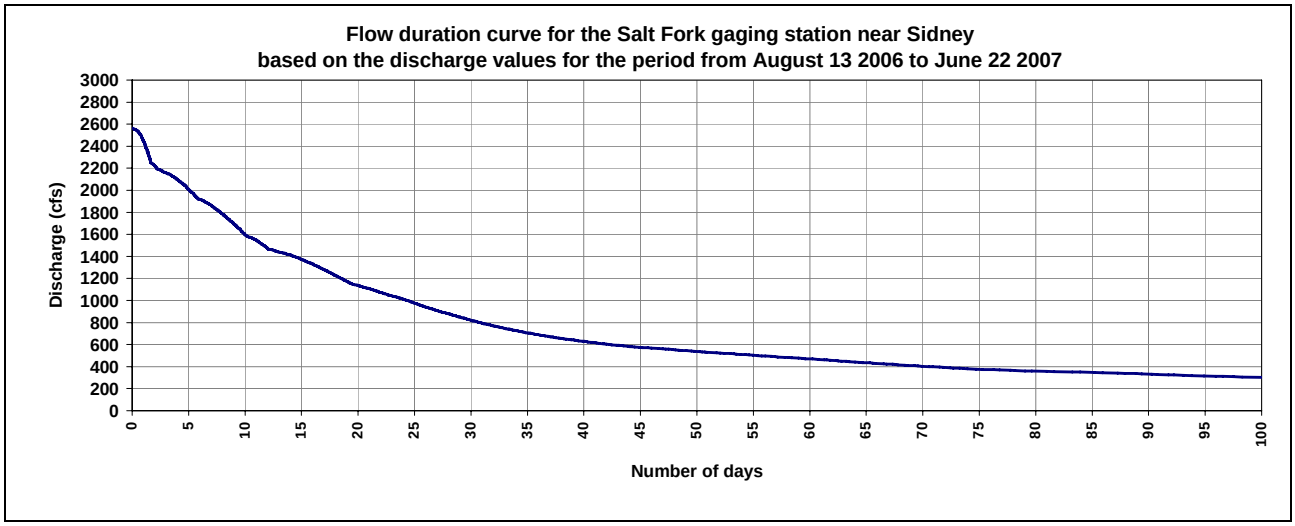


Figure 40. Salt Fork gaging station near Sidney: flow duration curve based on the discharge values for the period from August 13 2006 to June 22 2007. Detail for the short durations.

According to the flow duration curve reported above, the 10th percentile flow for the period of record for the Salt Fork near Sidney is 54.9 cfs. This value is much higher than the corresponding one for the Salt Fork near St. Joseph, which is equal to 9.2 cfs. This difference, along with the higher low-flow values near Sidney (minimum value 41 cfs versus 2 cfs for the station near St. Joseph, even though 15-min versus daily discharge data are compared), suggests that the Urbana and Champaign Sanitary District North-East and the St. Joseph WWTP's have an impact on the low-flow hydrology of the stream, even though the real entity of this contribution will be evaluated later in this chapter.

Since the flow data available for the station near Sidney refer to the period from August 14 2006 to June 22 2007, a flow duration curve relative to a period of 313 days (August 13 was not considered because incomplete) was calculated both for the station near Sidney and near St. Joseph (considering for this station the period from August 14 1959 to June 22 1991). Moreover, given that a 15-min discharge series was made available by USGS for the station near St. Joseph from May 1 2006 to July 11 2007, another flow duration curve for the period from August 14 2006 to June 22 2007 was worked out for the station near St. Joseph. The comparison between the three flow duration curves is shown in the Figure 41 and in the Figure 42.

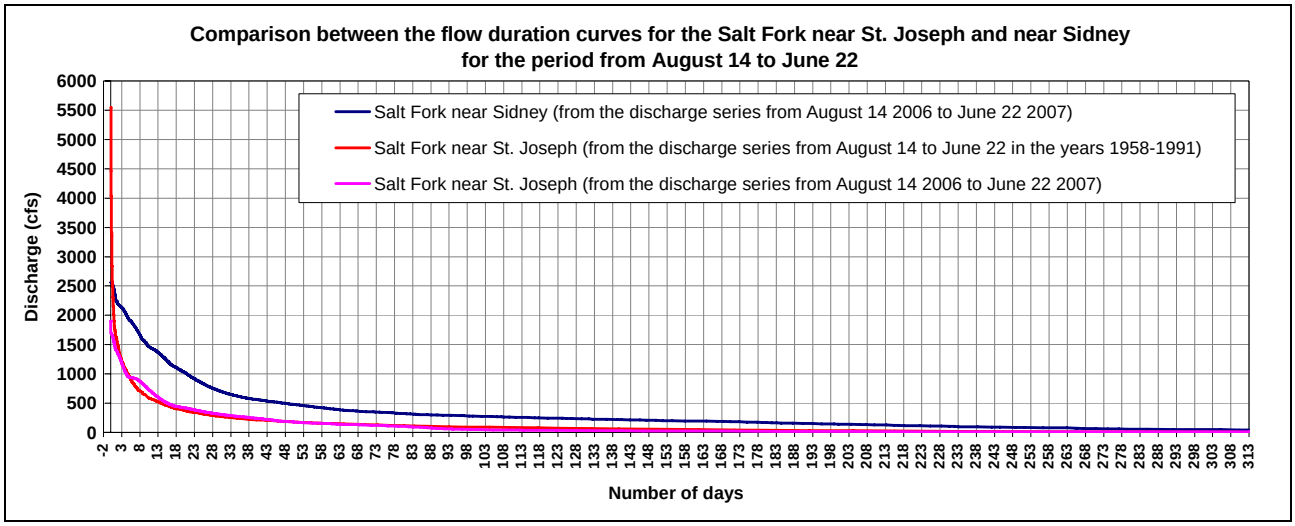


Figure 41. Comparison between the flow duration curves for the Salt Fork near St. Joseph and near Sidney for the period from August 14 to June 22.

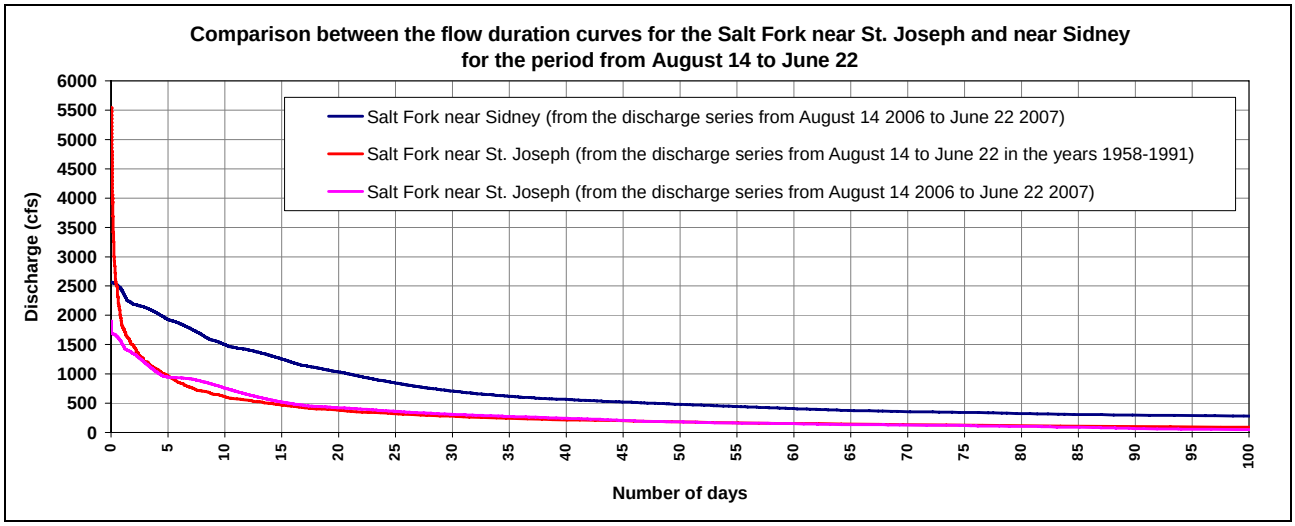


Figure 42. Comparison between the flow duration curves for the Salt Fork near St. Joseph and near Sidney for the period from August 14 to June 22. Detail for the short durations.

Once again, the comparison of the 10th percentile values (55.4 cfs for the Salt Fork near Sidney 2006-07, 8.7 cfs for the Salt Fork near St. Joseph 1958-91 and 12.4 cfs for the Salt Fork near St. Joseph 2006-07) suggests that the Urbana and Champaign Sanitary District North-East and the St. Joseph WWTP's have an impact on the Salt Fork low-flow hydrology.

Flow measurements in June 2007

On June 14 and 15 flow discharge measurements were made with the handheld Flow Tracker or the pigmy meter (using the mid-section discharge method) at different locations in the Salt Fork watershed, as reported in the Table 9.

Station ID	Stream	Description	Date	Time	Instrument	Discharge (cfs)
03336900	Salt Fork	USGS gaging station 03336900	06/15/2007	9.36.22	Flow Tracker	24.1
SSD	Stanton Special Ditch	Upstream from the confluence with the Salt Fork	06/15/2007	10.28.36	Flow Tracker	0.3
SF1	Salt Fork	Downstream from the confluence of the Stanton Special Ditch	06/15/2007	11.00.11	Flow Tracker	26.4
SBD	Saline Branch Ditch	Upstream from the confluence with the Salt Fork	06/15/2007	11.11.00 (start time)	Pygmy meter	28.1
SF2	Salt Fork	Downstream from the confluence of the Saline Branch Ditch	06/15/2007	N/A	Flow Tracker	N/A
03337810	Salt Fork	Downstream from the St. Joseph WWTP	06/15/2007	8.37.35	Flow Tracker	61.6
SJ2	SJ#2	Upstream from the confluence with the Salt Fork	06/15/2007	10.34.47	Flow Tracker	1.1
03337845	Salt Fork	Downstream from the confluence of the St. Joseph Ditch #2	06/15/2007	10.37.55	Flow Tracker	60.2
SJ3	SJ#3	Upstream from the confluence with the Salt Fork	06/14/2007	14.11.52	Flow Tracker	1.3
03337848	Salt Fork	USGS gaging station 03337848, downstream from the confluence of the St. Joseph Ditch #3	06/14/2007	12.31.03	Flow Tracker	62.3
03337848	Salt Fork	USGS gaging station 03337848, downstream from the confluence of the St. Joseph Ditch #3	06/14/2007	12.36.00	Pygmy meter	64.8
03337848	Salt Fork	USGS gaging station 03337848, downstream from the confluence of the St. Joseph Ditch #3	06/14/2007	15.58.30	Pygmy meter	55.1
SJ4	SJ#4	Upstream from the confluence with the Salt Fork	06/15/2007	10.03.57	Flow Tracker	1.4
SJ4	SJ#4	Upstream from the confluence with the Salt Fork	06/15/2007	10.40.19	Flow Tracker	1.2
03337850	Salt Fork	Downstream from the confluence of the St. Joseph Ditch #4	06/15/2007	11.36.49	Flow Tracker	64.3
SJ5	SJ#5	Upstream from the confluence with the Salt Fork	06/15/2007	11.44.54	Flow Tracker	3.4
03337900	Salt Fork	Downstream from the confluence of the St. Joseph Ditch #5	06/15/2007	9.48.04	Flow Tracker	63.6
Ditch 6	Ditch 6	Upstream from the confluence with the Salt Fork	06/15/2007	N/A	Estimated	0.08

Table 9. Discharge measurements on June 14-15 2007.

Figure 43 shows the discharge values along the Salt Fork on June 14-15 2007, during a period of low flow.

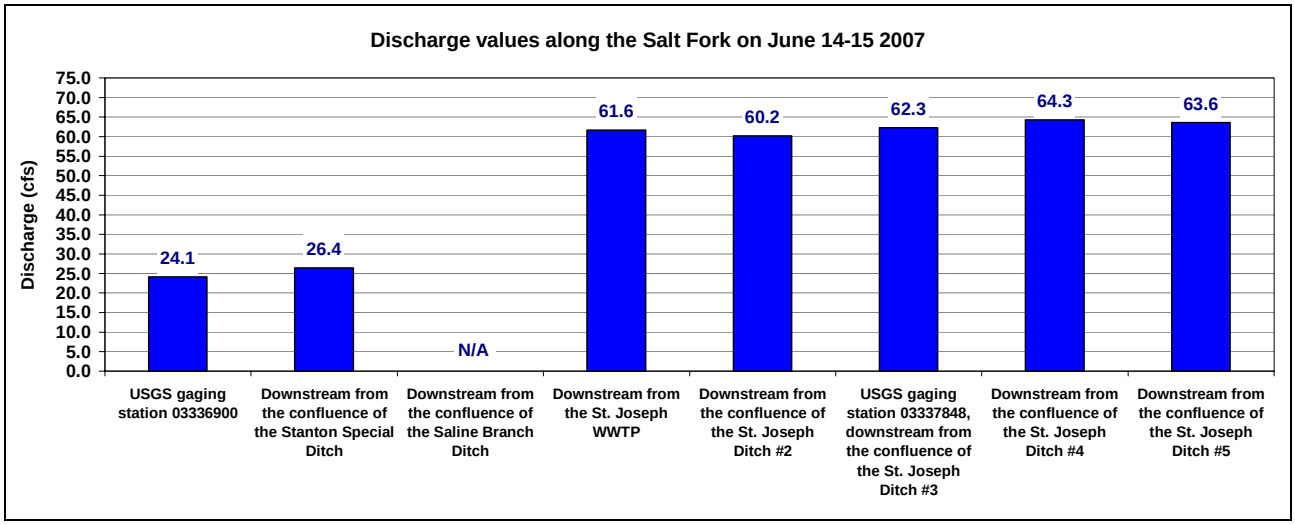


Figure 43. Discharge values along the Salt Fork on June 14-15 2007.

As it can be observed from the Figure 43, the difference between the discharge at the station located downstream from the St. Joseph WWTP (station 03337810) and the discharge at the station located downstream from the confluence with the Stanton Special Ditch (station SF1) on June 15 is 61.6 –

26.4 = 35.2 cfs. A part of this discharge comes from the Saline Branch Ditch, for which a pigmy meter discharge measurement of 28.1 cfs is available for June 15. A rough estimate of the St. Joseph WWTP effluent discharge on that day is therefore given by 35.2 – 28.1 = 7.1 cfs. This represents about the 11% of the discharge at the section located downstream from the St. Joseph WWTP on June 15 2007.
Another discharge measurement made with the Flow Tracker is available for the Saline Branch Ditch (on June 19 instead of June 15). On that day, the discharge value was 32.8 cfs. Using this value to roughly estimate the St. Joseph WWTP effluent discharge gives 35.2 – 32.8 = 2.4 cfs (4% of the discharge at the section located downstream from the St. Joseph WWTP). This estimate is closer than the previous one to the data available for the effluents of the St. Joseph plant for the period from January 1 2006 to June 30 2007, as reported in the following paragraph.

WWTP effluent discharge data

The St. Joseph WWTP effluent data, in million gallons per day, were converted in mean daily discharge in cfs, and the resulting effluent series, along with the precipitation series, is shown in the Figure 44.

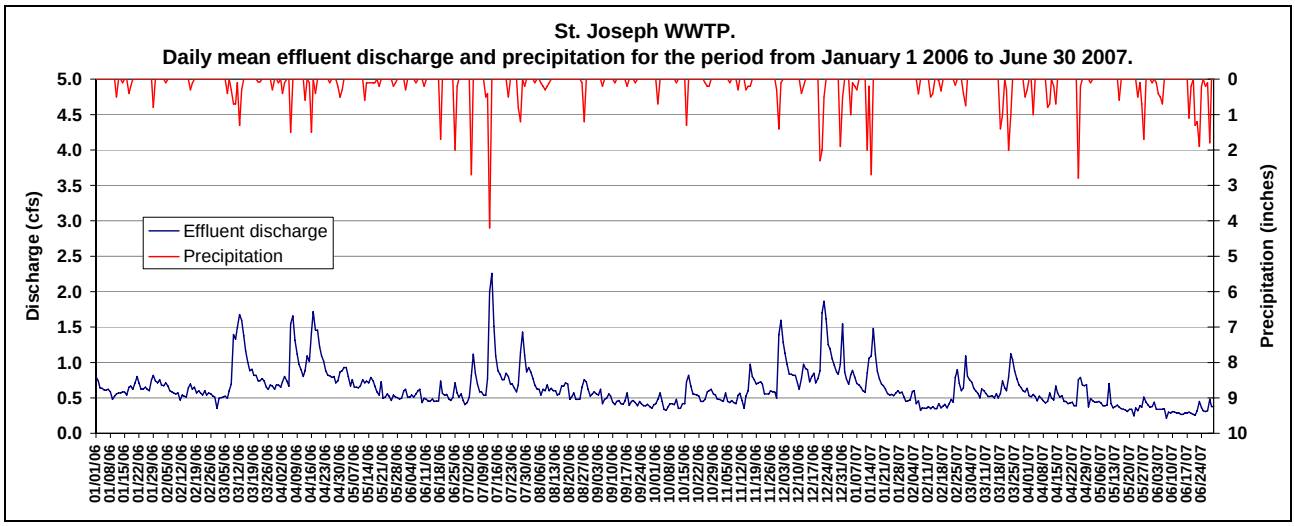


Figure 44. St. Joseph WWTP: daily mean effluent discharge and precipitation for the period from January 1 2006 to June 30 2007.

The mean daily effluent discharge on June 15 and June 19 was respectively 0.27 and 0.29 cfs, which represent only the 0.45% of the discharge measured at the station located downstream from the St. Joseph WWTP (station 03337810), equal to 61.6 cfs.
The difference between this percentage value and the one derived by the flow measurements in the previous paragraph suggests that the contribution of the stream indicated with an arrow in the Figure 45 on the left bank upstream from St. Joseph to the Salt Fork discharge is not negligible.

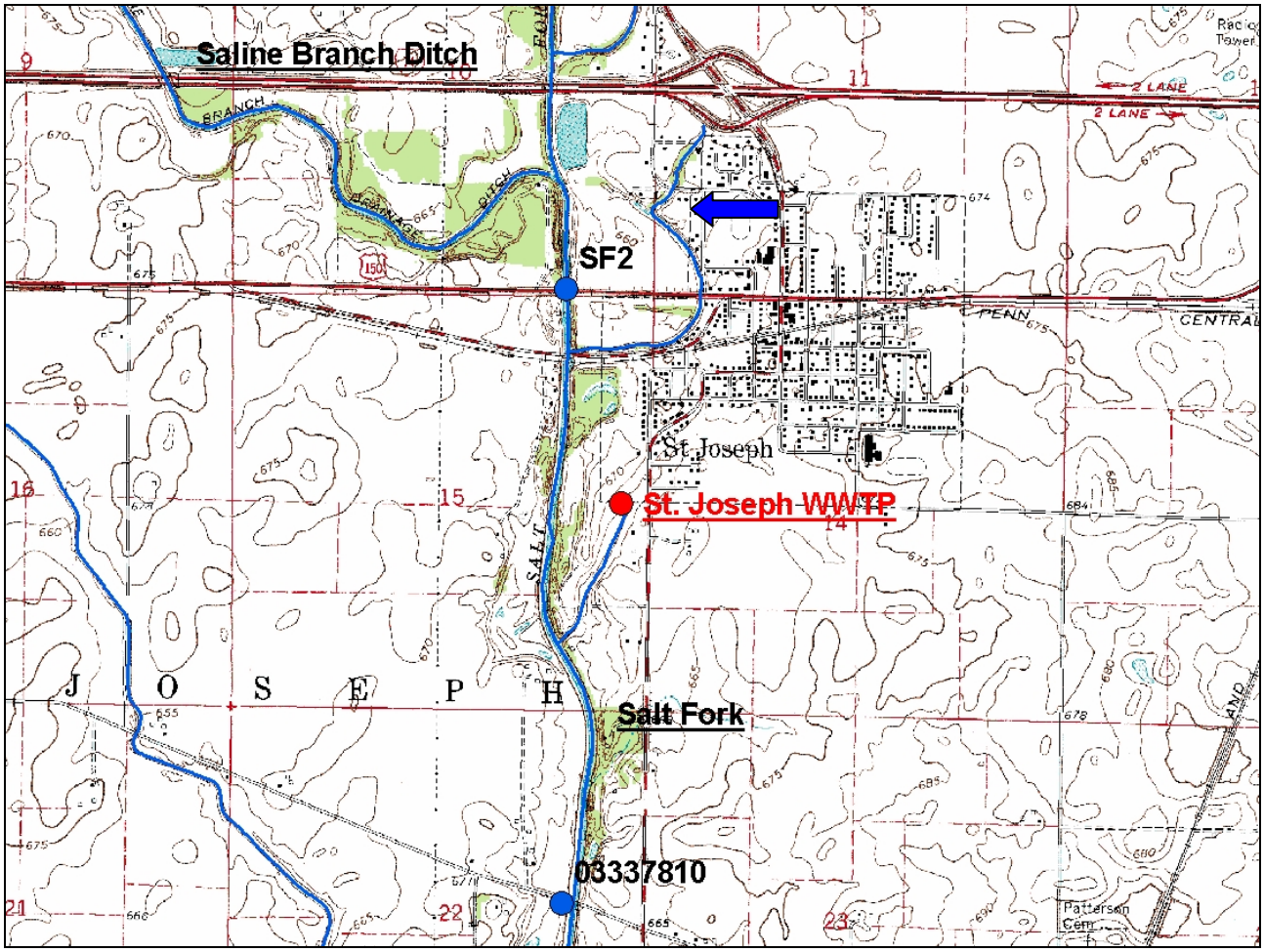


Figure 45. Main contributors to the Salt Fork flow at the station 03337810.

In order to understand if there are any trends in the St. Joseph WWTP effluent as a percentage of the total flow at the USGS station near Sidney, Figure 46 shows the comparison between the St. Joseph WWTP effluent discharge and the Salt Fork discharge near Sidney for the period from August 14 2006 to June 22 2007. The 15-min discharge values at the station near Sidney were converted in daily mean values and compared with the daily mean effluent discharge values, evaluating their ratio, whose range is between 0.04 and 1.43 % (as shown in the Figure 47). The percentage ratio peaks follow the effluent discharge peaks, which are related to the rain events. The base effluent flow is 0.21 cfs.

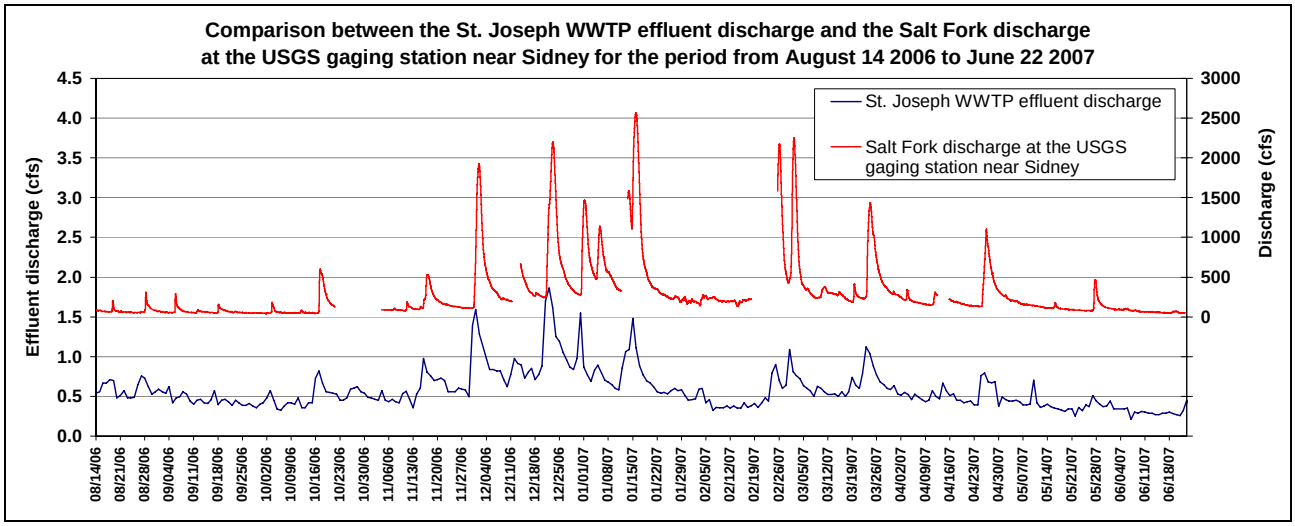


Figure 46. Comparison between the St. Joseph WWTP effluent discharge and the Salt Fork discharge at the USGS gaging station near Sidney for the period from August 14 2006 to June 22 2007.

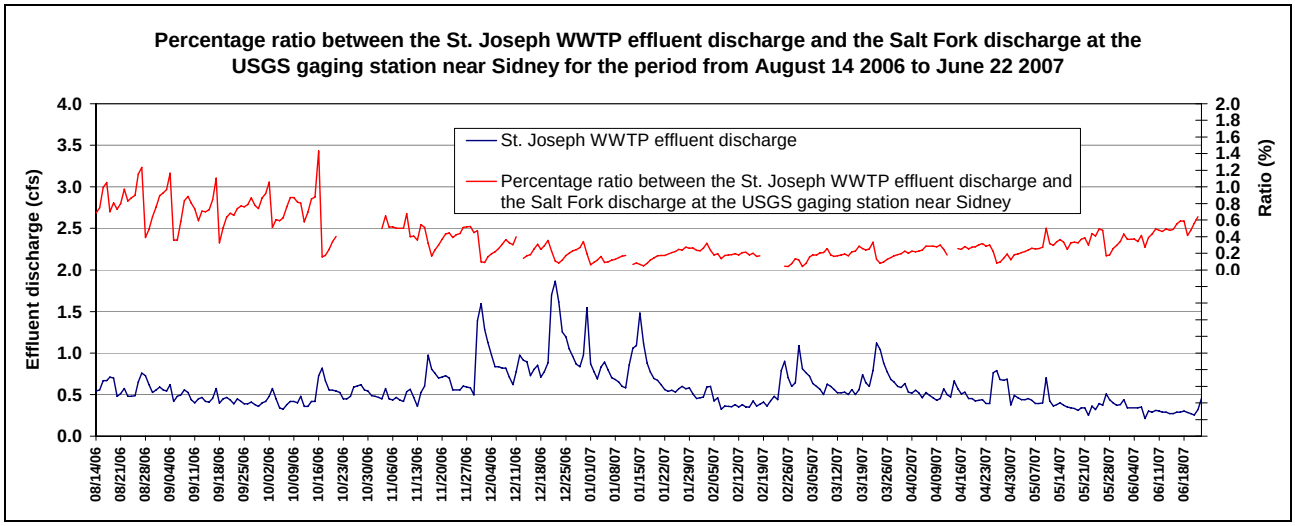


Figure 47. Percentage ratio between the St. Joseph WWTP effluent discharge and the Salt Fork discharge at the USGS gaging station near Sidney for the period from August 14 2006 to June 22 2007.

The data for the effluents from the Urbana and Champaign Sanitary District North-East plant are also available for the period from January 1 2006 to June 30 2007. As done for the St. Joseph WWTP, the discharge data, in million gallons per day, were converted in mean daily discharge in cfs, and the resulting effluent series, along with the precipitation series (from Illinois Water Survey), is shown in the Figure 48.

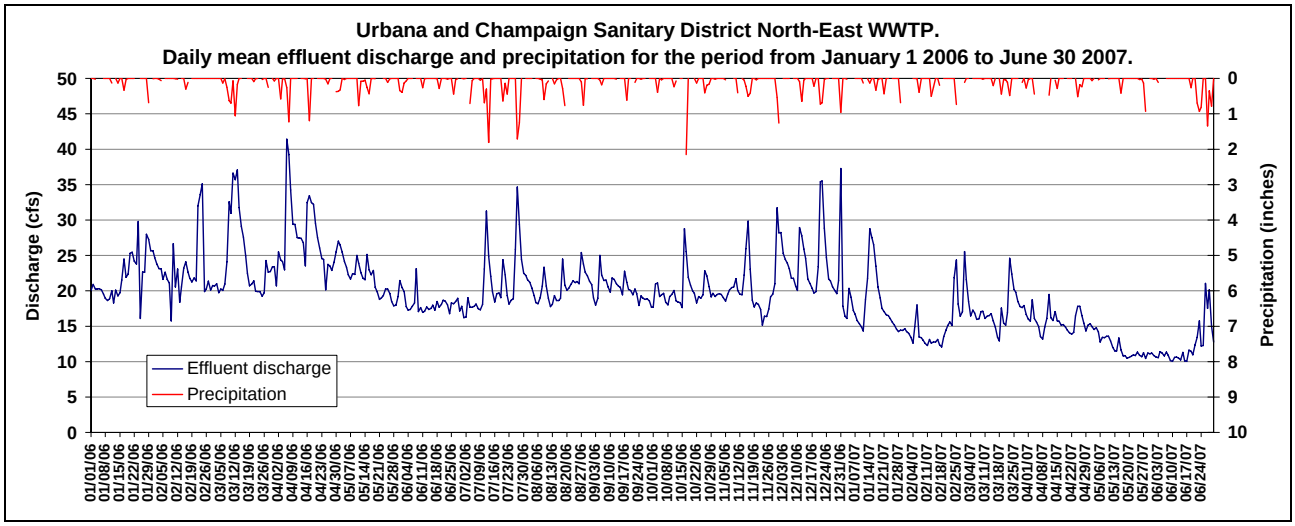


Figure 48. Urbana and Champaign Sanitary District North-East WWTP: daily mean effluent discharge and precipitation for the period from January 1 2006 to June 30 2007.

As it can be observed, the effluents from the Urbana and Champaign Sanitary District North-East WWTP are much greater then the ones coming from the St. Joseph WWTP, as expected. The mean effluent discharge from the Urbana and Champaign WWTP is 19.7 cfs (maximum 41.4 cfs, lowest 10.1 cfs, which represents the base effluent flow), whereas the mean effluent discharge from the St. Joseph WWTP is 0.6 cfs (maximum 2.3 cfs, lowest 0.2 cfs).

The effluents coming from the Urbana and Champaign WWTP are conveyed to the Saline Branch Ditch. As already reported above, a discharge of 28.1 cfs was measured with the pigmy meter on June 15 and a discharge of 32.8 cfs was measured with the Flow Tracker on June 19. The percentage contribution of the WWTP effluents to the Saline Branch discharge was 40.3 % (11.31 cfs/28.1 cfs) and 35.0 % (11.48 cfs/32.8 cfs) respectively. The contribution of the Urbana and Champaign WWTP to the flow in the Saline Branch Ditch is pretty high, which also means that the Saline Branch should be monitored as regards its water quality.

No data were made available for the effluents discharged from the Rantoul WWTP. A flow and water quality analysis in the upper Salt Fork could be interesting for the future CEE 498 Field Methods classes.

WATER-SUPPLY STUDY FOR SIDNEY

In this chapter the potential use of Salt Fork for the water supply of the village of Sidney is discussed.
The long-term discharge series available at the USGS station near St. Joseph was extended to the new station near Sidney with two different methods, one based on the comparison between the discharge series available for both the stations for the period from August 13 2006 to June 22 2007 and the other based on the comparison of the respective flow duration curves.

Discharge series extension to the station near Sidney: method 1

Figure 49 shows the comparison between the discharge 15-min series at the USGS stations near St. Joseph and Sidney for the period from August 13 2006 to June 22 2007.

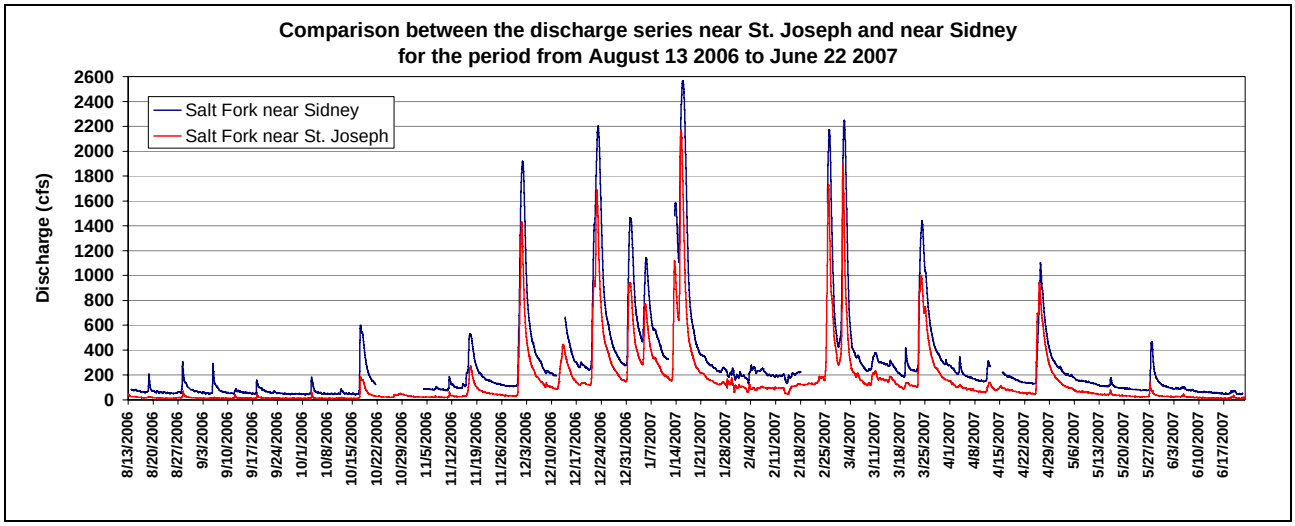


Figure 49. Comparison between the discharge series near St. Joseph and near Sidney for the period from August 13 2006 to June 22 2007.

A relation between the discharge value near St. Joseph and the corresponding one near Sidney was worked out, resulting in the following expression (see also the Figure 50):

$$Q_{Sidney}[cfs] = 1.5208\, Q_{St.\,Joseph}[cfs] \tag{7}$$

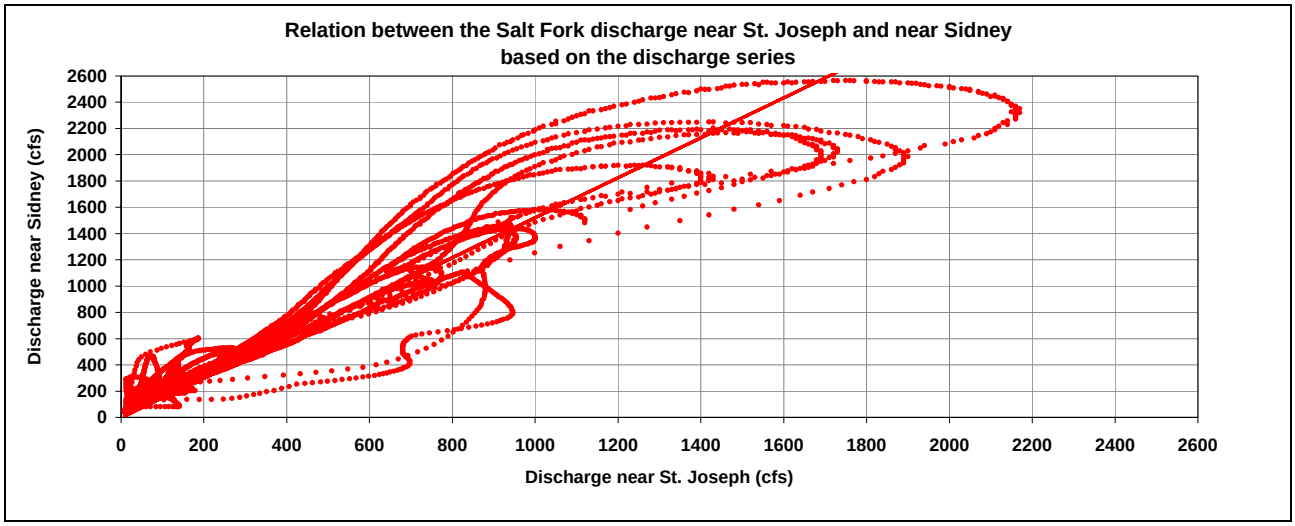


Figure 50. Relation between the Salt Fork discharge near St. Joseph and near Sidney based on the discharge series.

Discharge series extension to the station near Sidney: method 2

Looking at the flow duration curves for both the gaging station at St. Joseph and the new gaging station at Sidney, a relation between the Salt Fork discharge near St. Joseph and the ratio between the Salt Fork discharge near Sidney and near St. Joseph was derived. The relation has the following expression (see also the Figure 51):

$$\frac{Q_{Sidney}[cfs]}{Q_{St.\ Joseph}[cfs]} = 14.733\left(Q_{St.\ Joseph}[cfs]\right)^{-0.3258} \tag{8}$$

The relation was obtained considering the flow duration curve near St. Joseph for the period from September 22 to June 22 in the years 1959-91 and comparing the discharge values near St. Joseph and near Sidney corresponding to the same duration.

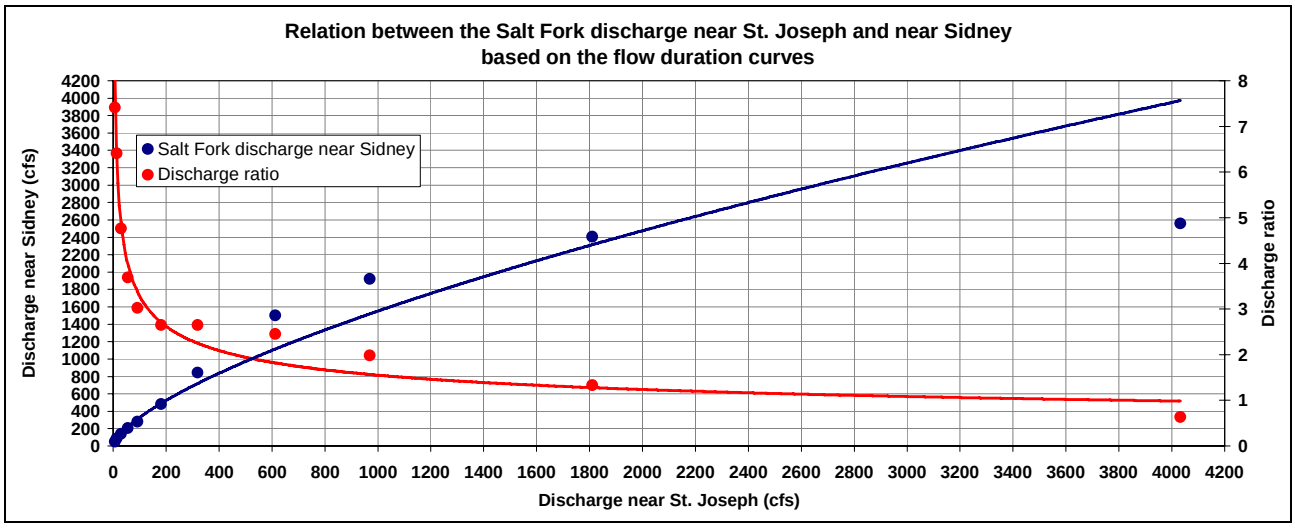


Figure 51. Relation between the Salt Fork discharge near St. Joseph and near Sidney based on the flow duration curves.

The ratio values found are between 0.6 and 7.4. The Table 10 reports the ratio calculated for the flow measurements (Flow Tracker, pigmy meter and ADCP) on June 14-15 2007.

Station ID	Description	Date	Time	Instrument	Discharge (cfs)	Ratio Sidney/St. Joseph
03336900	USGS gaging station near St. Joseph	06/15/2007	9.36.22	Flow Tracker	24.1	-
03337848	USGS gaging station near Sidney	06/14/2007	12.31.03	Flow Tracker	62.3	**2.58**
03337848	USGS gaging station near Sidney	06/14/2007	12.36.00	Pigmy meter	64.8	**2.69**
03337848	USGS gaging station near Sidney	06/14/2007	15.58.30	Pigmy meter	55.1	**2.29**
03337848	USGS gaging station near Sidney	06/14/2007	15.58.30	ADCP	72.1	**2.99**

Table 10. Ratio between the discharge values near Sidney and near St. Joseph according to the flow measurements made on June 14-15 2007.

Water supply evaluation

The daily mean values of discharge available for the USGS Gage 03336900 near St. Joseph for the water years 1959-1991 and for the water year 2005 were therefore synthetically "extended" to the station near Sidney, using both the methods presented in the previous paragraphs (see Figure 52 for the method 1 and Figure 53 for the method 2).

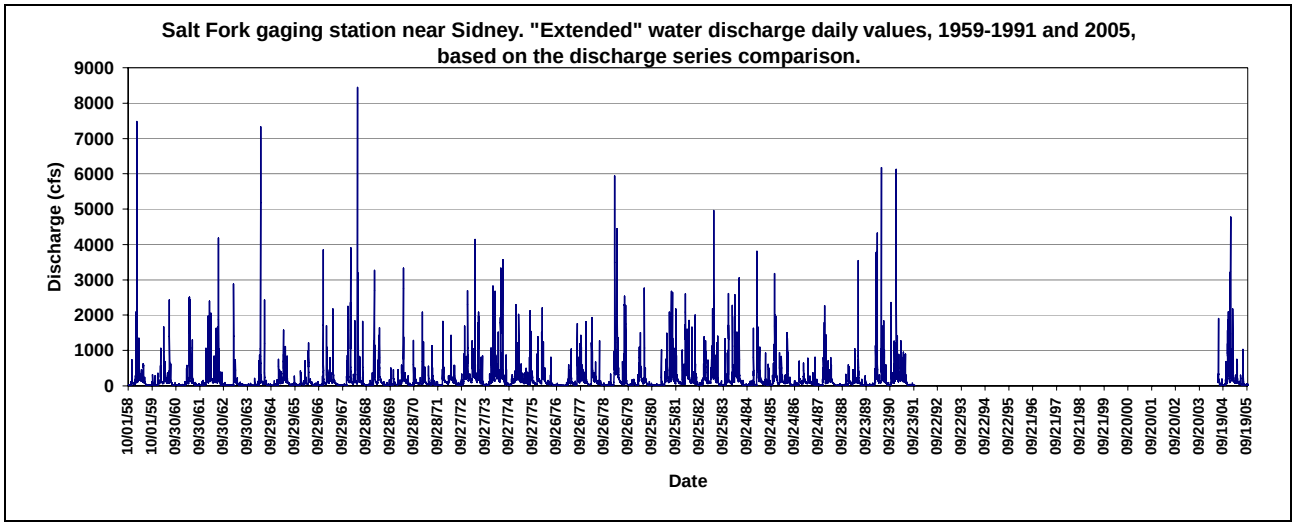


Figure 52. Salt Fork gaging station near Sidney: "extended" water discharge daily values, 1959-1991 and 2005, based on the discharge series comparison.

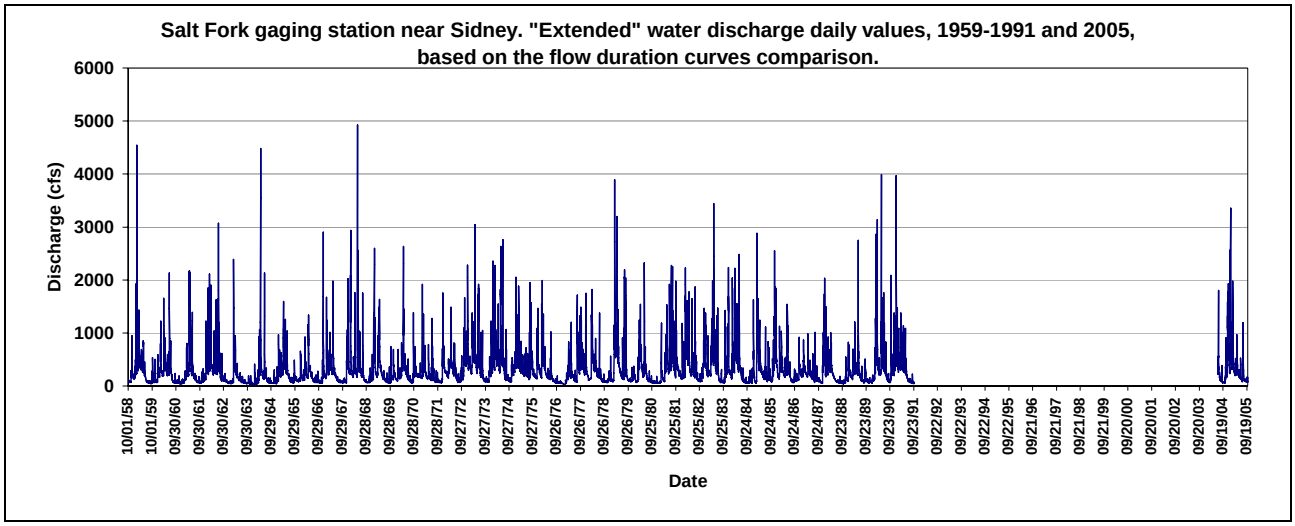


Figure 53. Salt Fork gaging station near Sidney: "extended" water discharge daily values, 1959-1991 and 2005, based on the flow duration curves comparison.

The "extended" series based on the discharge series comparison (method 1) has a maximum discharge value of 8440 cfs, whereas the one based on the flow duration curves comparison (method 2) has a maximum discharge value of 4928 cfs. For both the "extended" discharge series, a duration curve was calculated. The Figure 54 shows the comparison between the flow duration curve at the two stations near St. Joseph and near Sidney.

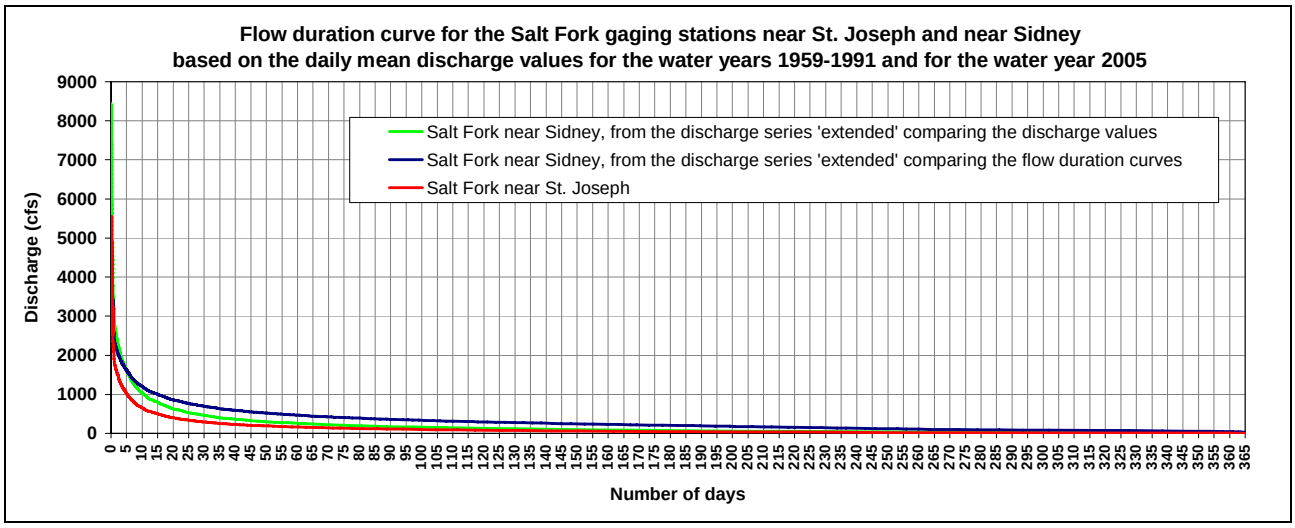


Figure 54. Flow duration curve for the Salt Fork gaging stations near St. Joseph and near Sidney based on the daily mean discharge values for the water years 1959-1991 and for the water year 2005.

In order to give an evaluation about the possible use of the Salt Fork for the water supply of the village of Sidney, the Figure 55 and the Figure 56 show the water volumes for each of the water years considered and for both the stations near St. Joseph and near Sidney (calculated using both the method 1 and 2).

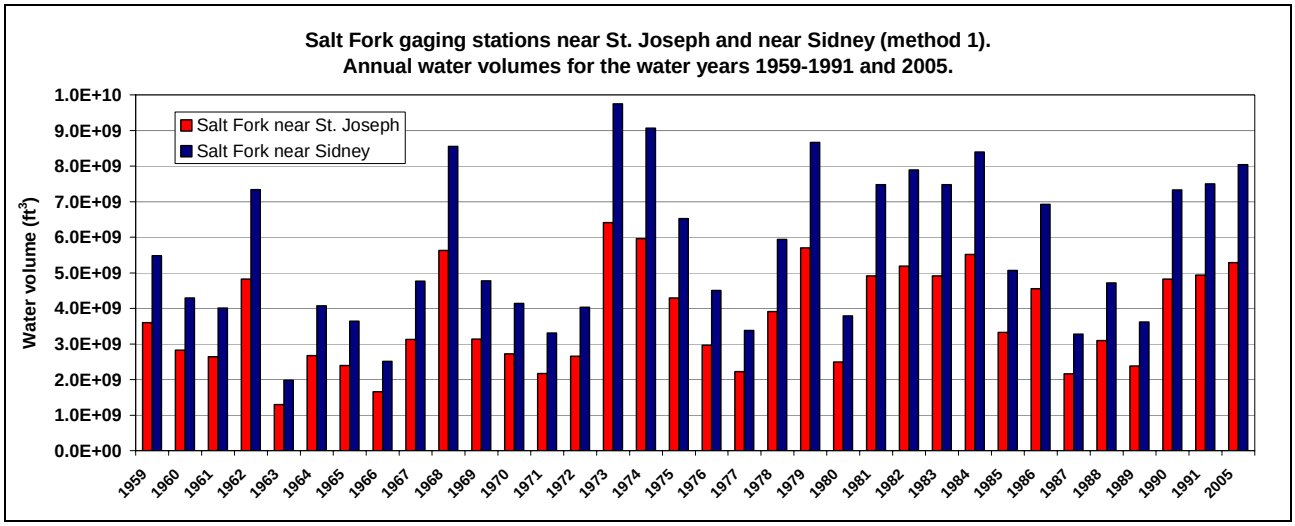


Figure 55. Salt Fork gaging stations near St. Joseph and near Sidney (method 1). Annual water volumes for the water years 1959-1991 and 2005.

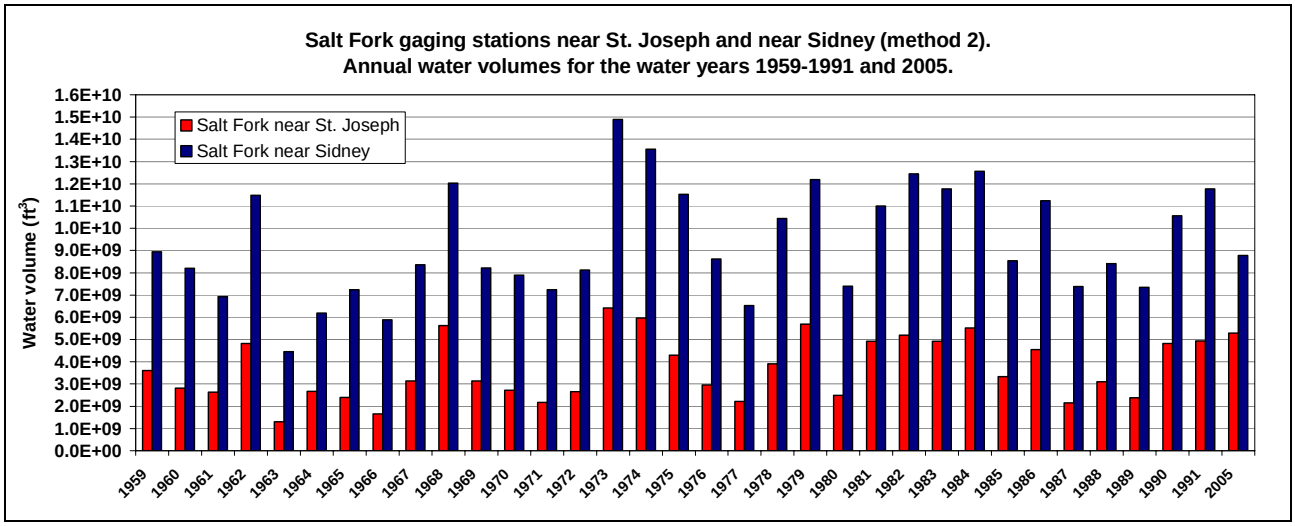


Figure 56. Salt Fork gaging stations near St. Joseph and near Sidney (method 2). Annual water volumes for the water years 1959-1991 and 2005.

For the method 1, the resulting mean yearly water volume at the station located near Sidney is 5.7E+09 ft^3 (the maximum value is 9.8E+09 ft^3, the minimum value is 2.0E+09 ft^3). For the method 2, the mean yearly water volume is 9.4E+09 ft^3 (the maximum value is 1.5E+10 ft^3, the minimum value is 4.5E+09 ft^3).

The water-supply demand of the village of Sidney (1062 people in 2000) can be quantified as 30 gal/day/person, which corresponds to a yearly demand of 1.6E+06 ft^3, which is widely lower than the water volume flowing through the station near Sidney every year. Of course this does not ensure that the water supply demand would be met by a water-supply system taking water from the Salt Fork: a deeper analysis should be done to define the minimum and maximum discharge of water captation, the possibility of failure of the system at meeting the demand, the possibility to store water in reservoirs, etc. This kind of analysis is beyond the scopes of the present project.

BANK AND BED STABILITY

As part of the stream restoration investigation, bank and bed stability has to be determined. In this chapter, the velocity data collected from the Flow Tracker and the Nortek Acoustic Doppler Velocimetry (ADV) were used to compute the near bed shear stress at the station near Sidney and at various locations in the watershed.

Hydraulic variables ranges according to the Flow Tracker measurements

As already reported above, on June 14 and 15 2007, flow discharge measurements were made with the Flow Tracker (handheld ADV) at different locations in the Salt Fork watershed (see Table 9). Other measurements were made on June 19 for the Saline Branch Ditch and for the St. Joseph Ditch #3 and on June 21 for the St. Joseph Ditch #3 and the Salt Fork station 03337848 near Sidney, downstream from the confluence with the St. Joseph Ditch #3. The Table 11 reports the values of depth, width, area, mean velocity and discharge measured on June 14, 15, 19 and 21 at different locations in the watershed.
The measurements were made considering a number of stations for each section variable from 8 to 39 (according to the width of the section), with a water temperature between 77.2 and 84.5 °F, and uncertainty values between or 2.1 and 7.6 % (ISO) or between 2.1 and 19 % (statistical) with an observed greater uncertainty level for the ditches.

Station ID	Stream	Description	Date	Time	Depth (ft)	Total width (ft)	Total area (ft^2)	Mean velocity (ft/s)	Discharge (cfs)
03336900	Salt Fork	USGS gaging station 03336900	06/15/2007	9.36.22	1.21	50.0	60.4	0.40	24.1
SSD	Stanton Special Ditch	Upstream from the confluence with the Salt Fork	06/15/2007	10.28.36	0.30	4.0	1.2	0.25	0.3
SF1	Salt Fork	Downstream from the confluence of the Stanton Special Ditch	06/15/2007	11.00.11	0.77	43.0	33.1	0.80	26.4
03337810	Salt Fork	Downstream from the St. Joseph WWTP	06/15/2007	8.37.35	0.89	78.0	69.7	0.88	61.6
SJ2	SJ#2	Upstream from the confluence with the Salt Fork	06/15/2007	10.34.47	0.41	9.5	3.9	0.28	1.1
03337845	Salt Fork	Downstream from the confluence of the St. Joseph Ditch #2	06/15/2007	10.37.55	1.36	69.0	93.6	0.64	60.2
SJ3	SJ#3	Upstream from the confluence with the Salt Fork	06/14/2007	14.11.52	0.86	11.8	10.1	0.13	1.3
03337848	Salt Fork	USGS gaging station 03337848, downstream from the confluence of the St. Joseph Ditch #3	06/14/2007	12.31.03	0.97	74.0	71.5	0.87	62.3
SJ4	SJ#4	Upstream from the confluence with the Salt Fork	06/15/2007	10.03.57	0.45	9.1	4.1	0.34	1.4
SJ4	SJ#4	Upstream from the confluence with the Salt Fork	06/15/2007	10.40.19	0.41	9.4	3.8	0.32	1.2
03337850	Salt Fork	Downstream from the confluence of the St. Joseph Ditch #4	06/15/2007	11.36.49	0.82	75.0	61.5	1.05	64.3
SJ5	SJ#5	Upstream from the confluence with the Salt Fork	06/15/2007	11.44.54	0.70	15.0	10.5	0.32	3.4
03337900	Salt Fork	Downstream from the confluence of the St. Joseph Ditch #5	06/15/2007	9.48.04	1.54	71.0	109.2	0.58	63.6
SBD	Saline Branch Ditch	Upstream from the confluence with the Salt Fork	06/19/2007	11.13.31	1.29	51.0	65.9	0.50	32.8
SJ3	SJ#3	Upstream from the confluence with the Salt Fork	06/19/2007	12.23.54	0.89	10.0	8.9	0.30	2.7

Station ID	Stream	Description	Date	Time	Depth (ft)	Total width (ft)	Total area (ft^2)	Mean velocity (ft/s)	Discharge (cfs)
SJ3	SJ#3	Upstream from the confluence with the Salt Fork	06/21/2007	10.19.17	0.68	11.7	7.9	0.15	1.2
03337848	Salt Fork	USGS gaging station 03337848, downstream from the confluence of the St. Joseph Ditch #3	06/21/2007	9.12.25	0.98	73.0	71.7	0.82	58.4

Table 11. Flow Tracker measurement data for June 14, 15, 19 and 21 2007.

Description of the ADV measurements

On June 14, two Nortek Acoustic Doppler Velocimetry (ADV) probes were put in the Salt Fork at the station near Sidney (see Figure 57), using a 25 Hz sampling rate.
The probe called "Probe 0" was put near the right bank at 4.1 ft from the edge of the water (where the total depth was 1.52 ft), whereas the probe called "Probe 1" was put near the center of the channel (where the total depth was 1.5 ft).

Figure 57. ADV probes in the Salt Fork.

For each probe three data sets were collected, characterized by different depth of the probe tip and of the sample volume, as indicated in the following tables.

Data set #1 (start data set at 12.38.11, 90271 sample in file, 3610.84 s total time)

Data set #1		Distances to boundary	
Probe	**Serial number**	**From probe tip**	**From sample volume**
Probe 0	N0388	9.45 cm	4.23 cm
Probe 1	N0349	11.44 cm	1.69 cm

Table 12. ADV data set #1.

Data set #2 (start data set at 14.28.15, 53104 sample in file, 2124.16 s total time)

Data set #2		Distances to boundary	
Probe	**Serial number**	**From probe tip**	**From sample volume**
Probe 0	N0388	6.24 cm	1.03 cm
Probe 1	N0349	16.51 cm	6.76 cm

Table 13. ADV data set #2.

Data set #3 (start data set at 15.34.17, 61026 sample in file, 2441.04 s total time)

Data set #3		Distances to boundary	
Probe	**Serial number**	**From probe tip**	**From sample volume**
Probe 0	N0388	14.62 cm	9.41 cm
Probe 1	N0349	18.33 cm	8.58 cm

Table 14. ADV data set #3.

The ADV data were reviewed, filtered and analyzed with the WinADV software, developed by the U.S. Department of the Interior, Bureau of Reclamation [9] (see Figure 58).

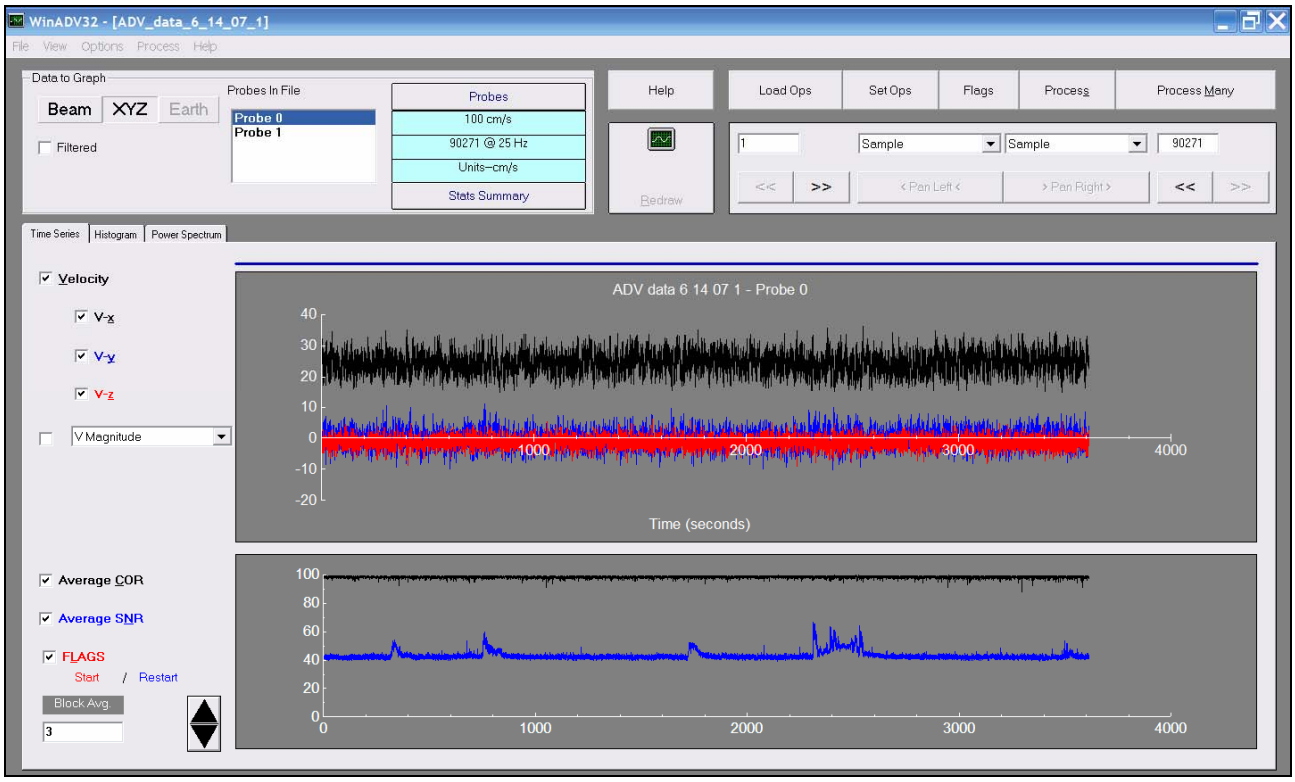


Figure 58. WinADV software.

Near bed shear stress at various locations in the watershed

The near bed shear stress τ_0 was calculated at different locations and on different days using the data gotten by the Flow Tracker flow measurements (see Table 11), using two different procedures, one based on the assumption of equivalent wide rectangular channel and the other based on the logarithmic profile.

Method of the equivalent wide rectangular channel

The following expression, based on the assumption of equivalent wide rectangular channel, calculates the near bed shear stress τ_0 (Pa or psf)

$$\tau_0 = \rho g H S \tag{9}$$

where ρ is the water density (equal to 1000 kg/m^3 or 1.94 slugs/m^3), g is the acceleration of gravity (9.81 m/s^2 or 32.2 ft/s^2), H is the flow depth (in m or ft) and S is the bed slope.
Figure 59 and Figure 60 show the shear stress values (in Pa) calculated along the Salt Fork and in some of its tributaries on June 14, 15, 19 and 21 2007. The bed slope in the expression (9) was estimated for each location from the elevations and distances read from the DTM (Digital Terrain Model) available for the area. Given that DTM's in general do not have a sufficient resolution to "capture" the river bed, this procedure has to be considered really approximated, giving anyway better results then using a constant slope for all the locations equal to 0.005 (mean thalweg slope in the Salt Fork in the survey reach near Sidney, from the cross section 1 to the cross section 6, as explained later in this document). Another option might be considering, instead of the bed slope S in the expression (9), the water surface slope as approximation of the friction slope, but in this case no enough data are available to make a reasonable guess of the water surface slopes at the different locations in the watershed.
The estimated slopes were 0.001 (Salt Fork stations 03336900, SF1, 03337810, 03337845 and 03337900 and St. Joseph Drainage Ditch #2), 0.002 (Salt Fork station 03337850, Stanton Special Ditch, Saline Branch Ditch and St. Joseph Drainage Ditch #3, #4 and #5) and 0.003 (Salt Fork station 03337848).

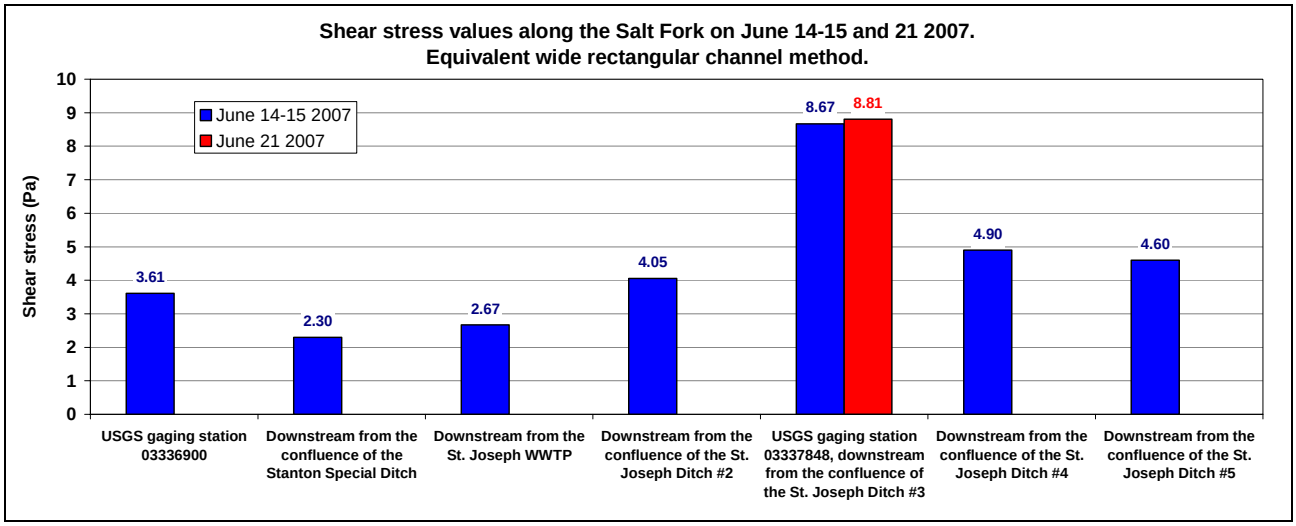


Figure 59. Shear stress values along the Salt Fork on June 14-15 and 21 2007 (equivalent wide rectangular channel method).

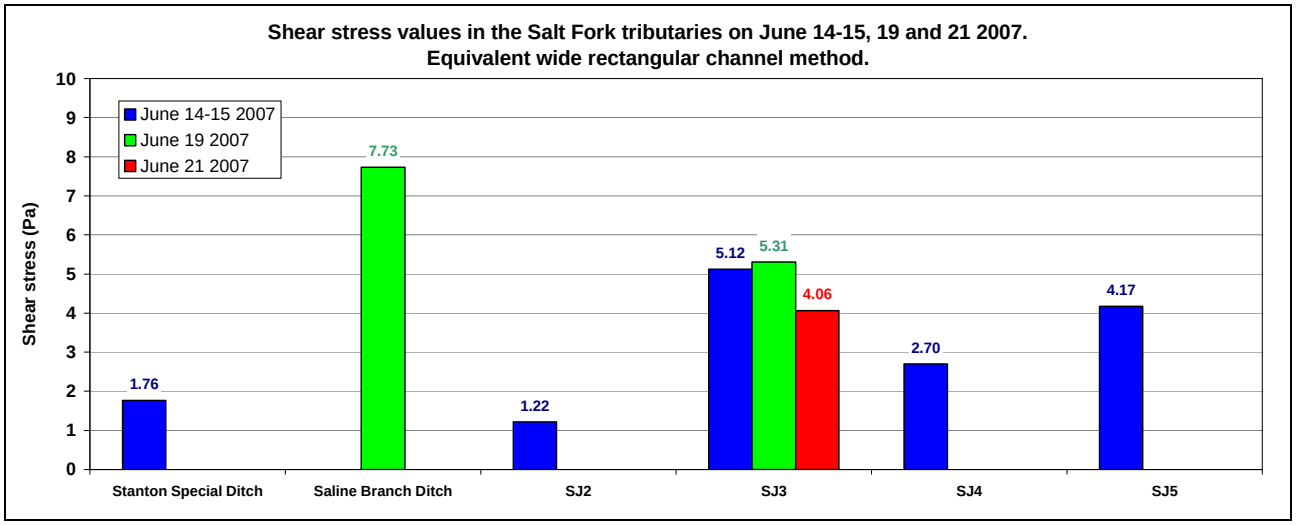


Figure 60. Shear stress values in the Salt Fork tributaries on June 14-15, 19 and 21 2007 (equivalent wide rectangular channel method).

This method is strongly dependent on the slope term, so the consistency of the near bed shear stress values has to be evaluated. A more reliable method to calculate them, given the data available, is presented in the next paragraph.

Method of the logarithmic profile

In this method, the horizontal velocity u is assumed to follow a logarithmic vertical profile with the following expression

$$\frac{u}{u_*} = \frac{1}{\kappa} \ln z + c_0 \tag{10}$$

where κ is the Von Karman's constant, equal to 0.41, z is the distance from the bed, c_0 is an integration constant and $u*$ is the shear velocity.
For each of the stations were Flow Tracker measurements are available, the logarithmic velocity profile was calculated once known the mean flow velocity in the cross section (from Table 11).
Once estimated the parameters of the expression (10), the near bed shear stress τ_0 is calculated as follows

$$\begin{aligned} &\frac{u_*}{\kappa} = m \quad \Rightarrow \quad u_* = m\kappa \\ &\tau_0 = \rho (u_*)^2 \end{aligned} \tag{11}$$

where ρ is the water density (1000 kg/m^3).
The resulting near bed shear stresses are shown in the Figure 61and Figure 62.

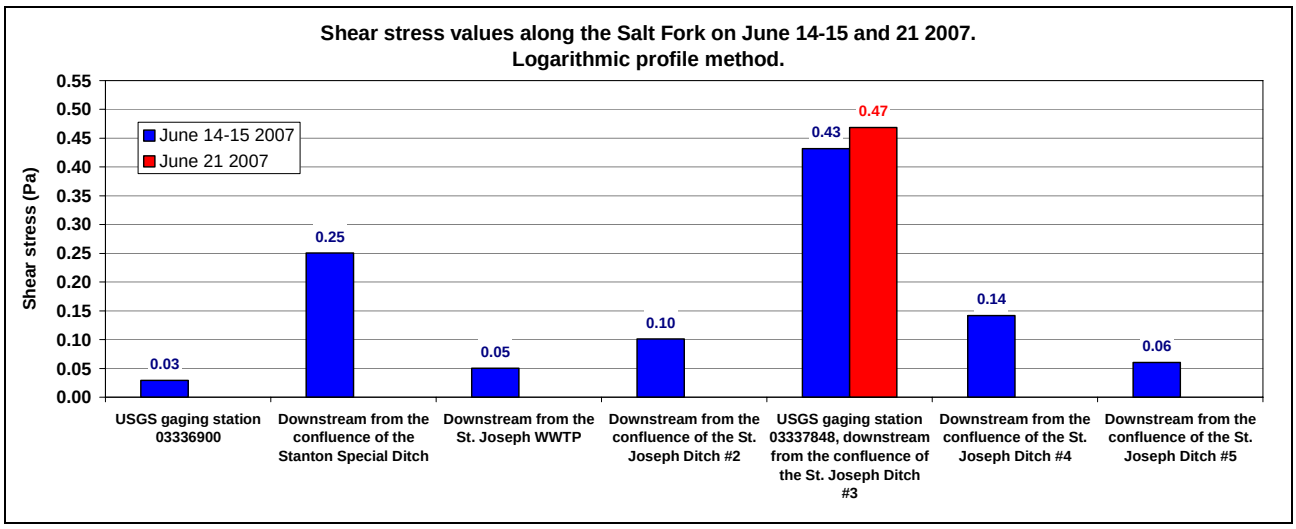


Figure 61. Shear stress values along the Salt Fork on June 14-15 and 21 2007 (logarithmic profile method).

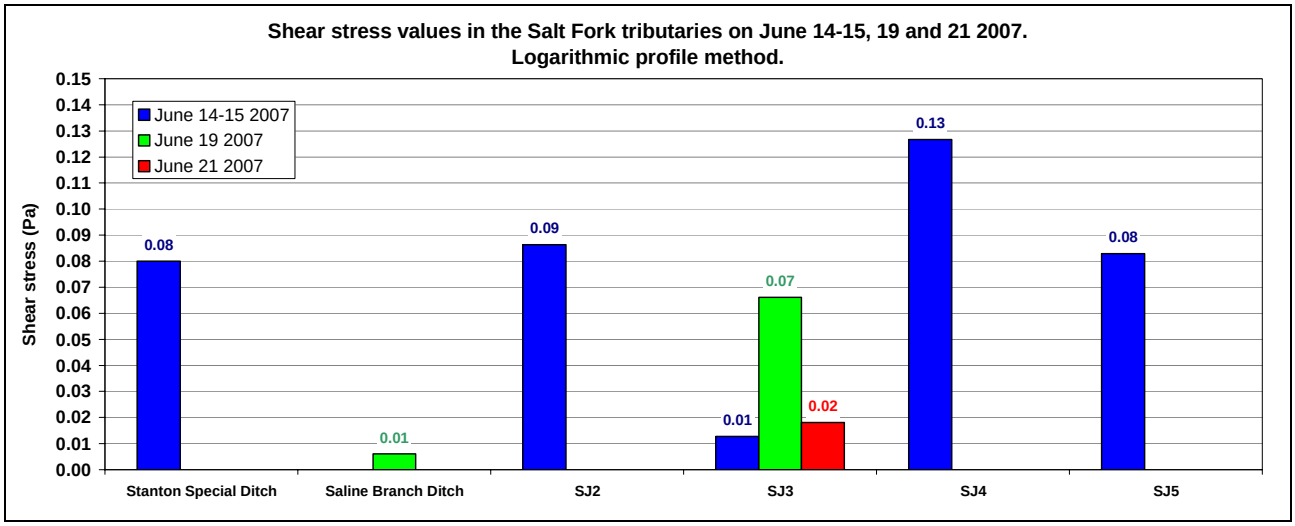


Figure 62. Shear stress values in the Salt Fork tributaries on June 14-15, 19 and 21 2007 (logarithmic profile method).

The order of magnitude of the mean near bed shear stresses obtained with the logarithmic profile method is different from the one obtained with the wide rectangular channel method, and more consistent with the results presented later and based on the ADV data. Therefore, these are the near bed shear stresses to be considered.
Some observations can be made regarding the shear stress values obtained above:

- the mean bed shear stress along the Salt Fork does not show relevant changes, since the mean flow velocity does not change very much in the downstream direction (it is between 0.13 and 1.05 ft/s), given that both the discharge and the flow width increase in the downstream direction. The reach with the greatest shear stress is the one near Sidney (station 03337848);
- as regards the Salt Fork tributaries, the St. Joseph Ditch #4 is characterized by the greatest shear stresses. In general the ditches show a certain activity in terms of sediment transport, as can be observed also from the bedforms which characterize the bed (see Figure 63) and from the sediment plumes sometimes observed at the confluence of the St. Joseph Ditch #3 into the Salt Fork near Sidney;
- considering a representative grain size of 0.0625 mm (between very fine sand and coarse silt) and a sediment density of 2650 kg/m^3, the critical shear stress for incipient motion is 0.09 Pa, comparable with the stress values shown in Figure 61 and Figure 62;
- the variability of the velocity along the cross section observed with the Flow Tracker (see Figure 64) suggests that there is a difference between the shear stress at the center of the channels and near the banks. In particular, for the Salt Fork, a greater percentage of silt was observed on the banks, where the velocity and the shear stress are lower than in the center of the channel, were sand is predominant. This cross section shear stress variability will be investigated in the following paragraph, using the ADV data.

Figure 63. Turbidity and bedforms in the St. Joseph Drainage Ditch #3.

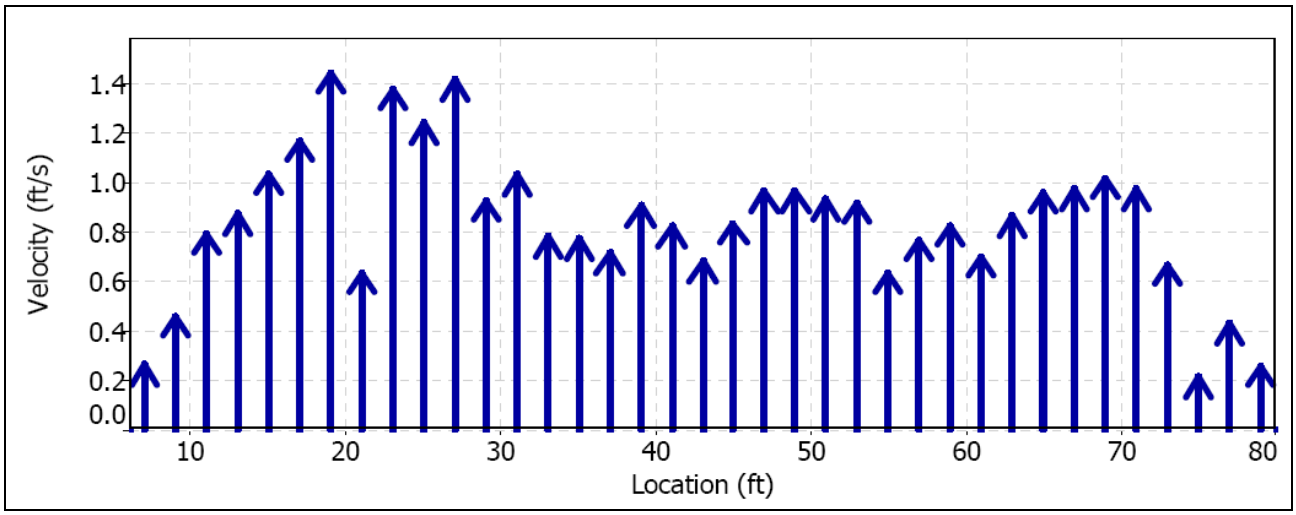


Figure 64. Flow velocity variability along the cross section (the figure is relative to the station 03337848 near Sidney).

Near bed shear stress at the station near Sidney

The near bed shear stress at the section located near Sidney (station 03337848) was calculated, on the right bank and in the center of the channel, considering the ADV data and using both the method of the slope of the best fit line through the vertical profile and the method of the extrapolation of the Reynolds stresses to the bed.

Method of the slope of the best fit line through the vertical profile

The Figure 65, the Figure 66, the Figure 67 and the Figure 68 show the mean values of the horizontal velocity at three different locations in the vertical profile for both the Probe 0 (near the right bank at 4.1 ft from the edge of the water) and the Probe 1 (near the center of the channel), along with the interpolated logarithmic vertical profile according to the expression (10). The distance from the bed (which is the distance of the sample volume from the bed, see Table 12, Table 13 and Table 14) is represented both in linear and logarithmic scale.

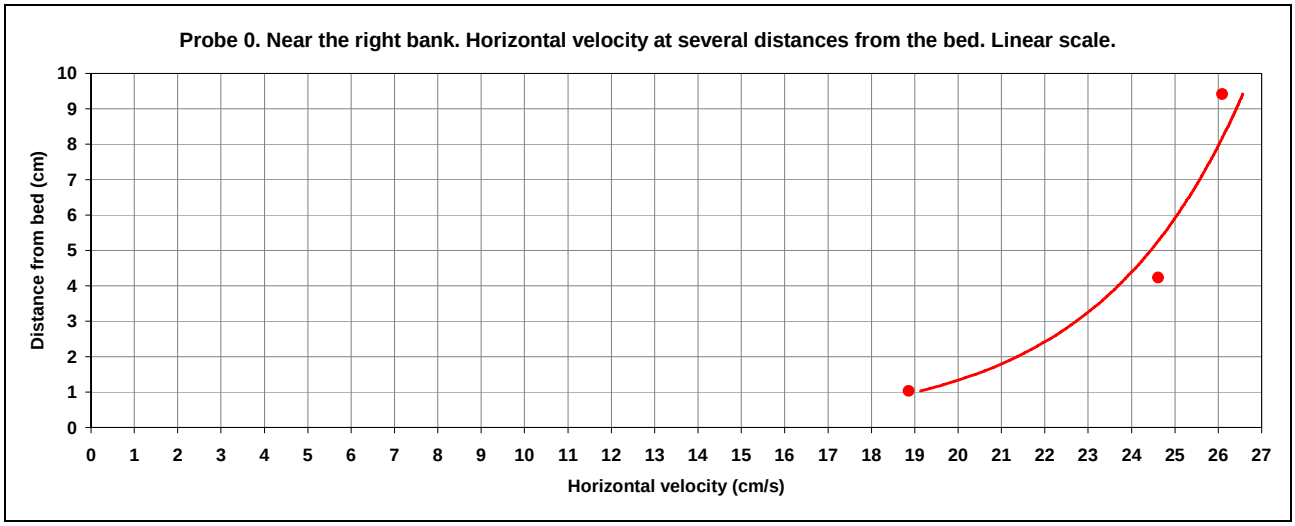


Figure 65. Probe 0, near the right bank: horizontal velocity at several distances from the bed. Linear scale.

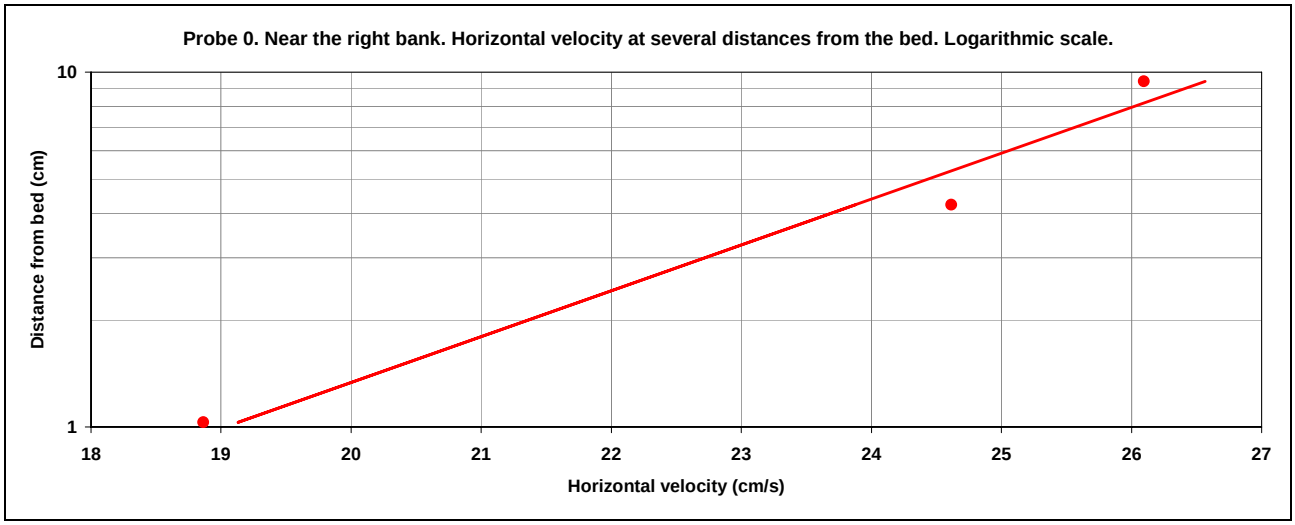


Figure 66. Probe 0, near the right bank: horizontal velocity at several distances from the bed. Logarithmic scale.

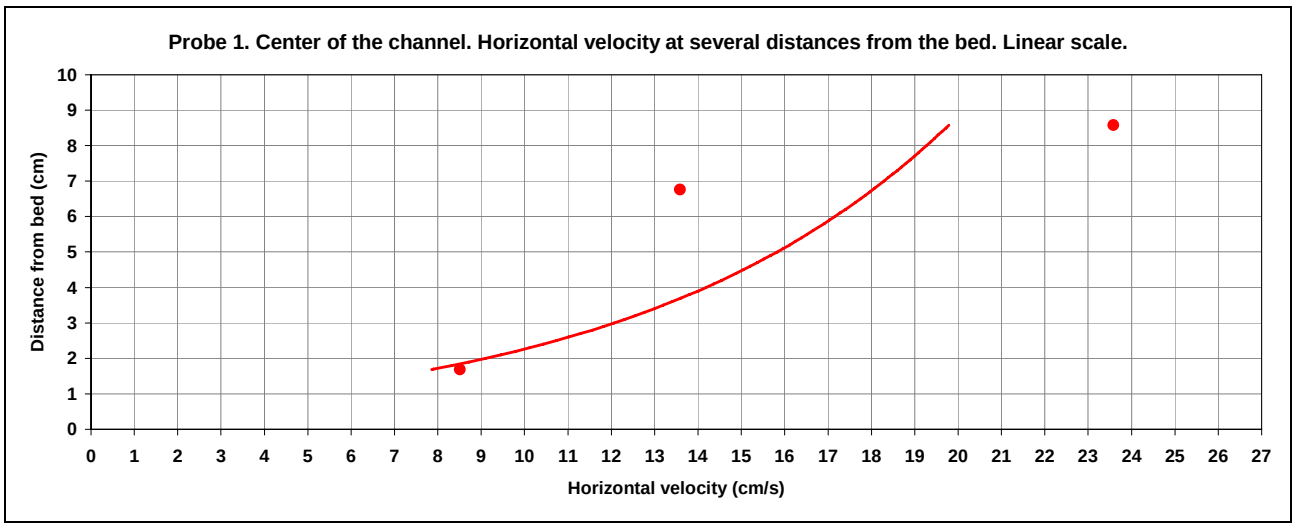


Figure 67. Probe 1, center of the channel: horizontal velocity at several distances from the bed. Linear scale.

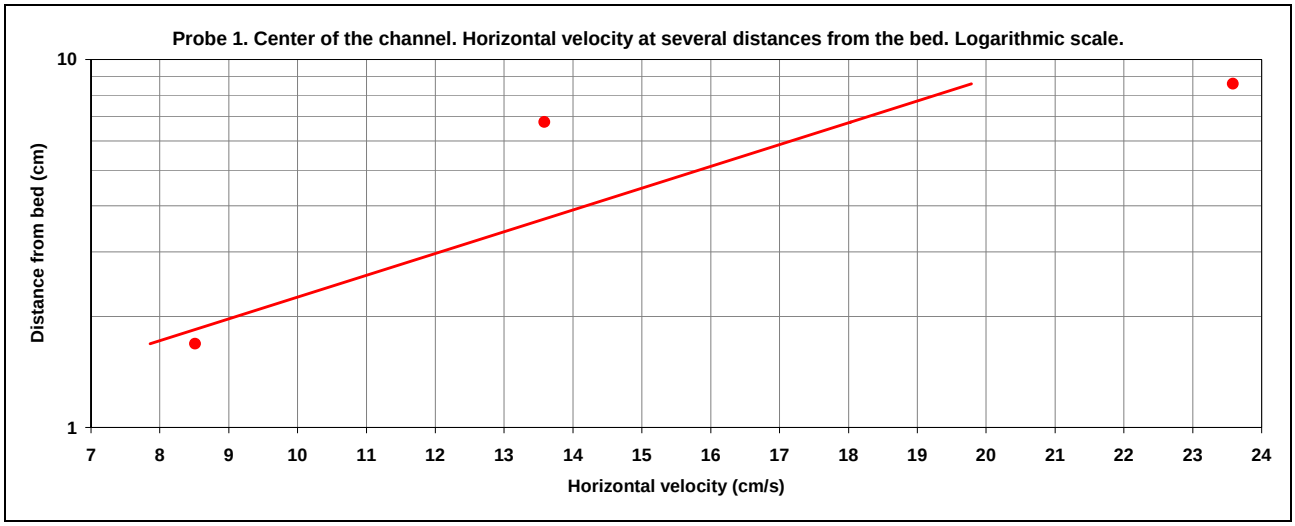


Figure 68. Probe 1, center of the channel: horizontal velocity at several distances from the bed. Logarithmic scale.

For the Probe 0 (near the right bank) the resulting shear velocity u_* is 1.4 cm/s, corresponding to a shear stress τ_0 of 0.19 Pa.
For the Probe 1 (near the center of the channel) the shear velocity u_* is 3.0 cm/s and the shear stress τ_0 is 0.91 Pa.
Note that the fit lines were calculated with only three points so the results are affected by the lack of more data. Moreover, looking at the Figure 65 and the Figure 67, the horizontal velocity data for the Probe 1 do not seem to follow a logarithmic vertical profile, so the resulting near bed shear stress value cannot be considered as reliable.
The order of magnitude of the shear stresses obtained using the method of the slope of the best fit line through the vertical profile is different from the one of the stresses obtained with the assumption of equivalent wide rectangular channel, which has to be considered too approximate in this case and too depending on the local slope, for which good data are not available, as already explained above.

Method of the extrapolation of the Reynolds stresses to the bed

The Reynolds stresses are those stresses in the equation of motion that are attributed to the turbulent fluctuations. According to Schlicting (1979), the shear stress parallel to flow τ'_{xz} is

$$\tau'_{xz} = -\rho \overline{u'w'} \tag{12}$$

where x is the flow direction, z the vertical direction, ρ the water density and u' and w' the turbulent fluctuation velocity components in the x and z direction respectively.
The Figure 69 and the Figure 70 show the results obtained using this procedure for the Probe 0 and the Probe 1.

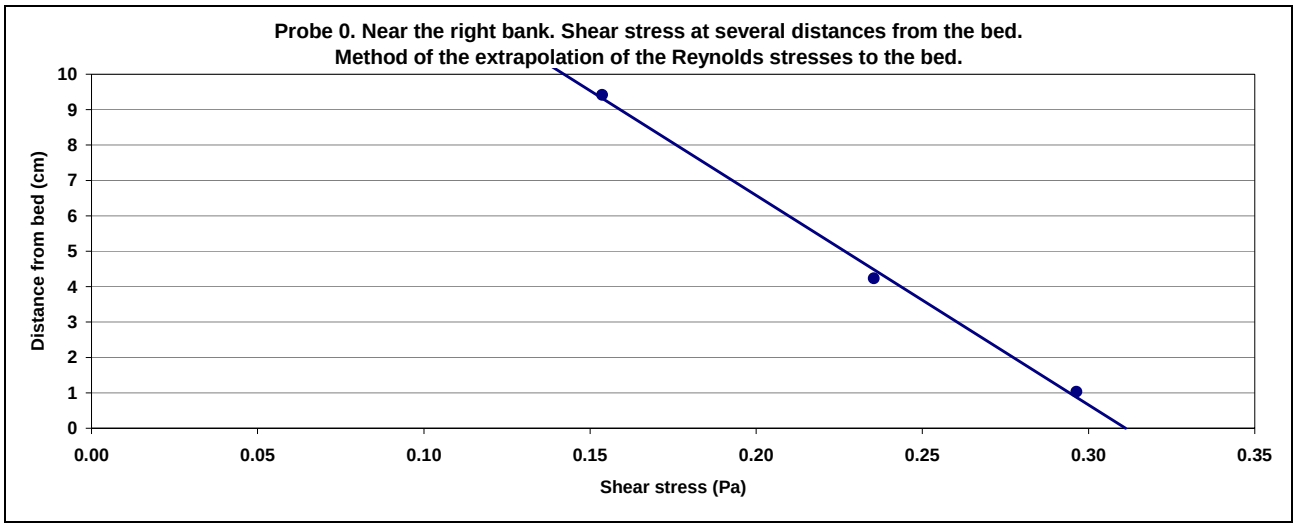


Figure 69. Probe 0, near the right bank: shear stress at several distances from the bed (method of the extrapolation of the Reynolds stresses to the bed).

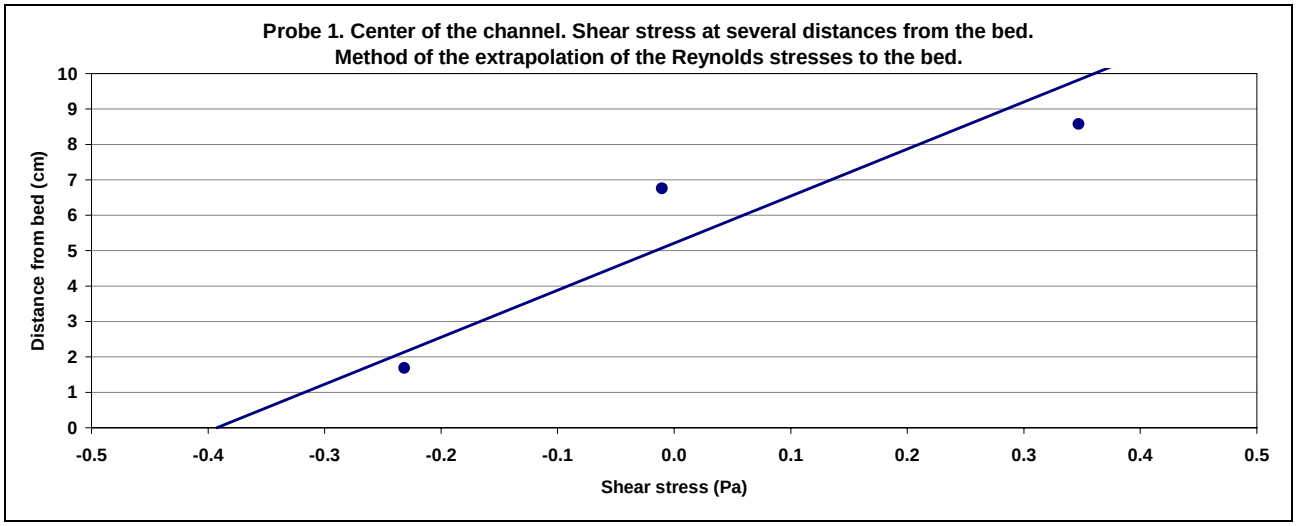


Figure 70. Probe 1, center of the channel: shear stress at several distances from the bed (method of the extrapolation of the Reynolds stresses to the bed).

Fitting a straight line with the stress values calculated according to the expression (12) provides a near bed shear stress of 0.31 Pa for the Probe 0 and 0.39 Pa for the Probe 1. The result is not very different from the near bed shear stress calculated with the method of the slope of the best fit line through the vertical profile for the Probe 0 (0.19 Pa), whereas there is a difference in the case of the Probe 1, for which the measurements are not really good to calculate a near bed shear stress.
Moreover, the shear stress pattern for the Probe 1 is pretty interesting, because, despite of the direction of the flow, which is downstream (see Figure 67), the near bed shear stress is negative, that is, its direction is upstream. Without going into much detail, which is beyond the scope of this study, the reason of this might be the presence of bedforms, which characterize the Salt Fork bed near Sidney (for more details, see Rodríguez, 2003 [10]).

BANK-FULL STREAMFLOW DISCHARGE

In this chapter, the bank-full streamflow discharge is estimated, as part of the stream restoration investigation. Two different methods were used:

- rating curve for the Salt Fork near Sidney;
- HEC-RAS steady flow simulations.

Estimation of the bank-full streamflow discharge with the rating curve for the Salt Fork near Sidney

Extending the rating curve worked up above in the report for the Salt Fork station near Sidney (station 03337848) gives a zero-discharge gage height of 0.3 ft (see Figure 71), which is the gage height corresponding to the thalweg elevation for the cross section 1 (642.3 ft, see the Figure 72 in the next paragraph). Given that the right bank elevation is 653.3 ft (see the Figure 72 in the next paragraph), its corresponding gage height is 0.3 + (653.3 – 642.3) ft = 11.3 ft. This gage height value gives a discharge value, that is an estimation of the bank-full discharge, of 2543 cfs, according to the rating curve expression (1).

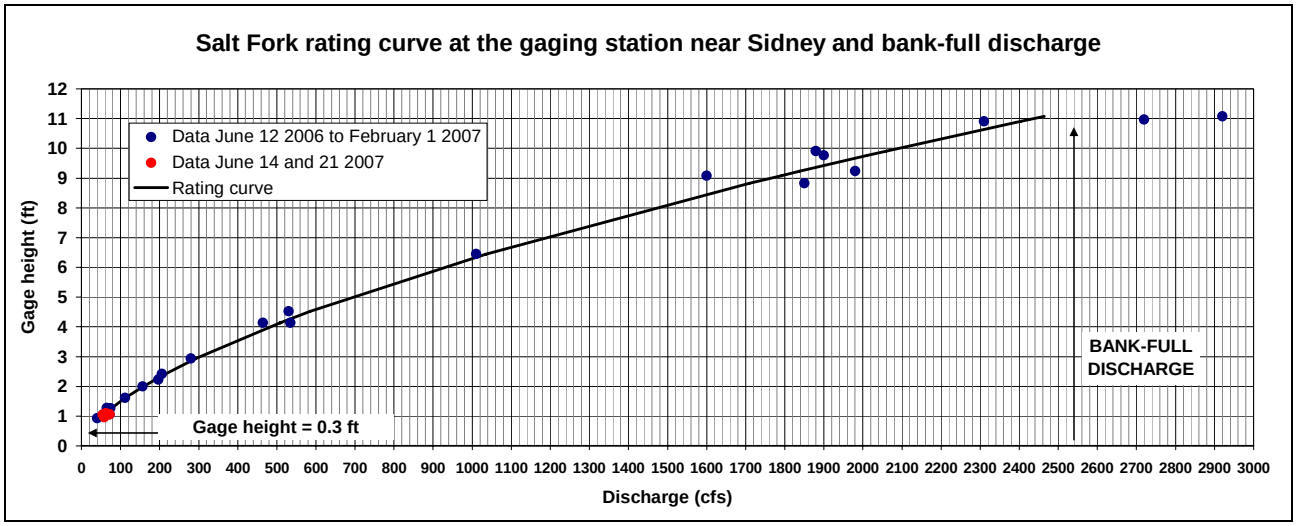


Figure 71. Salt fork rating curve at the gaging station near Sidney and bank-full discharge.

Estimation of the bank-full streamflow discharge with steady flow simulations

For the Salt Fork near Sidney, total station survey data are available. With the program SAM 2.1 [11], six cross sections were extracted along a 900-ft reach, having the characteristics reported in the Table 15 and shown in the following figures.

The slope at each sections was calculated as the mean slope of the reaches located upstream and downstream from the section. The cross section 1 is coincident with the USGS gage near Sidney cross section. The width of the sections from bank to bank varies from 94.6 ft and 112.7 ft.

Cross section	Thalweg elevation (ft)	Distance from the section downstream (ft)	Bed Slope at the section (ft/ft)
Cross section 1	642.3	200.4	-0.002
Cross section 2	642.7	147.0	0.000
Cross section 3	642.5	139.2	0.014
Cross section 4	638.9	139.6	0.013
Cross section 5	638.9	240.6	0.002
Cross section 6	638.1	-	0.003

Table 15. Salt Fork cross sections considered for the calculation of the bank-full streamflow discharge.

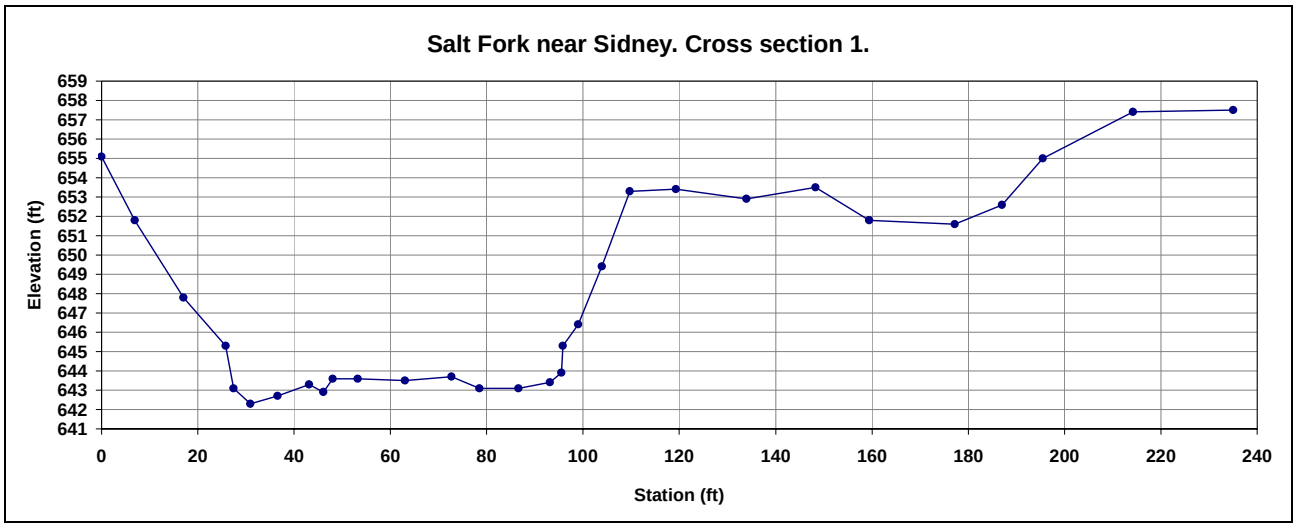


Figure 72. Salt Fork near Sidney: cross section 1.

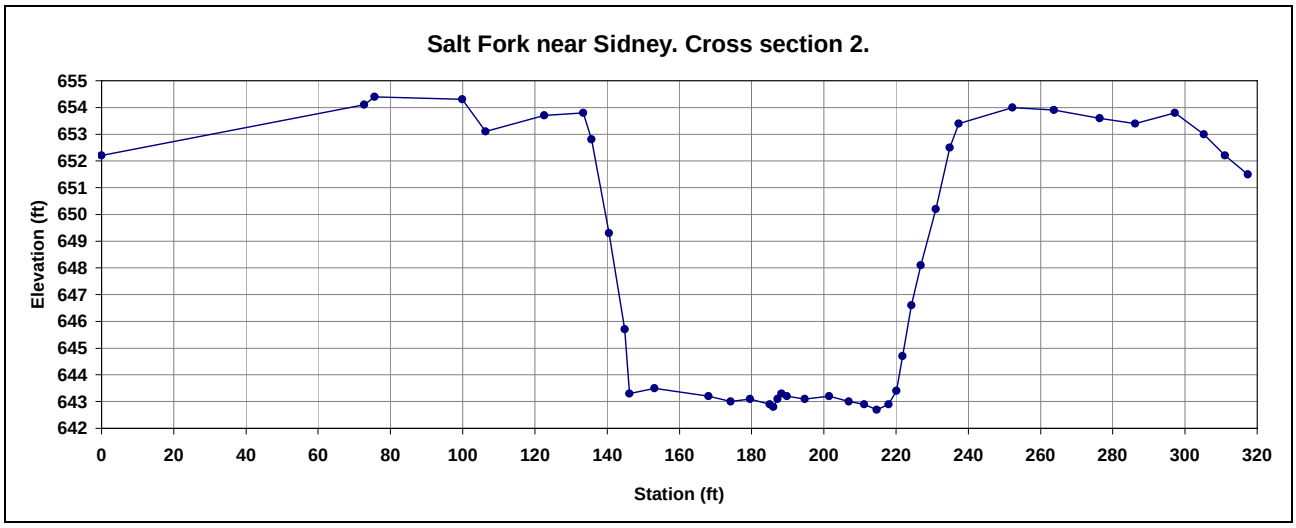


Figure 73. Salt Fork near Sidney: cross section 2.

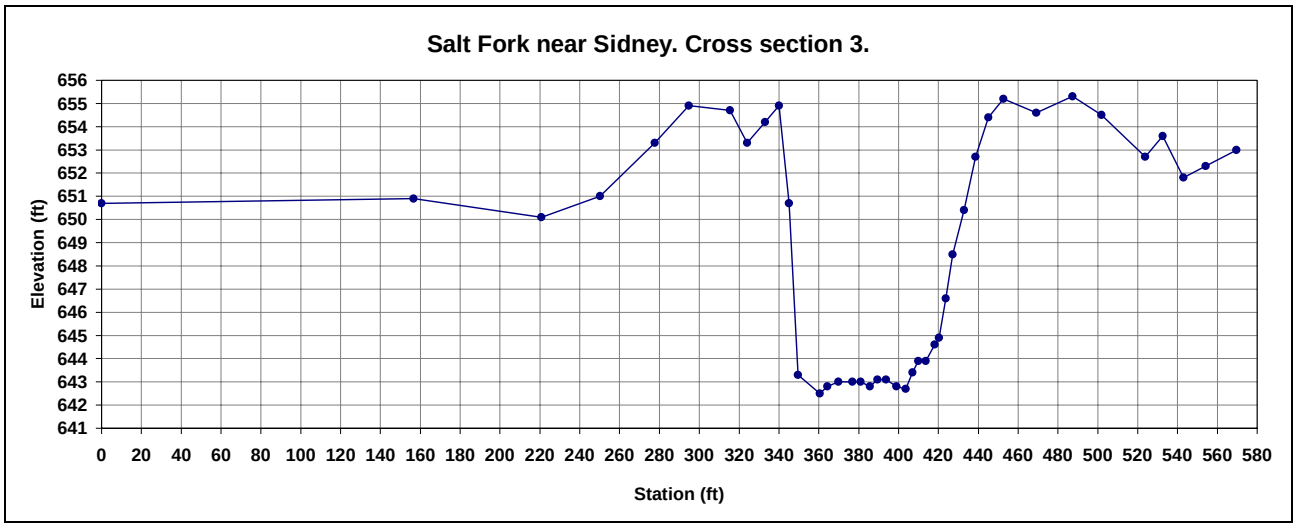


Figure 74. Salt Fork near Sidney: cross section 3.

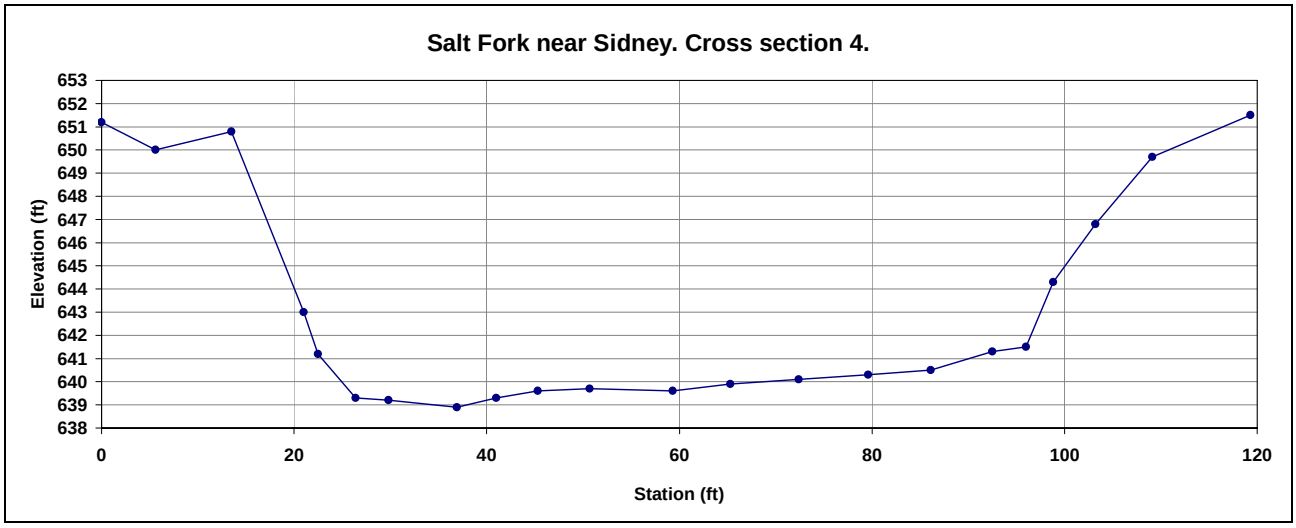


Figure 75. Salt Fork near Sidney: cross section 4.

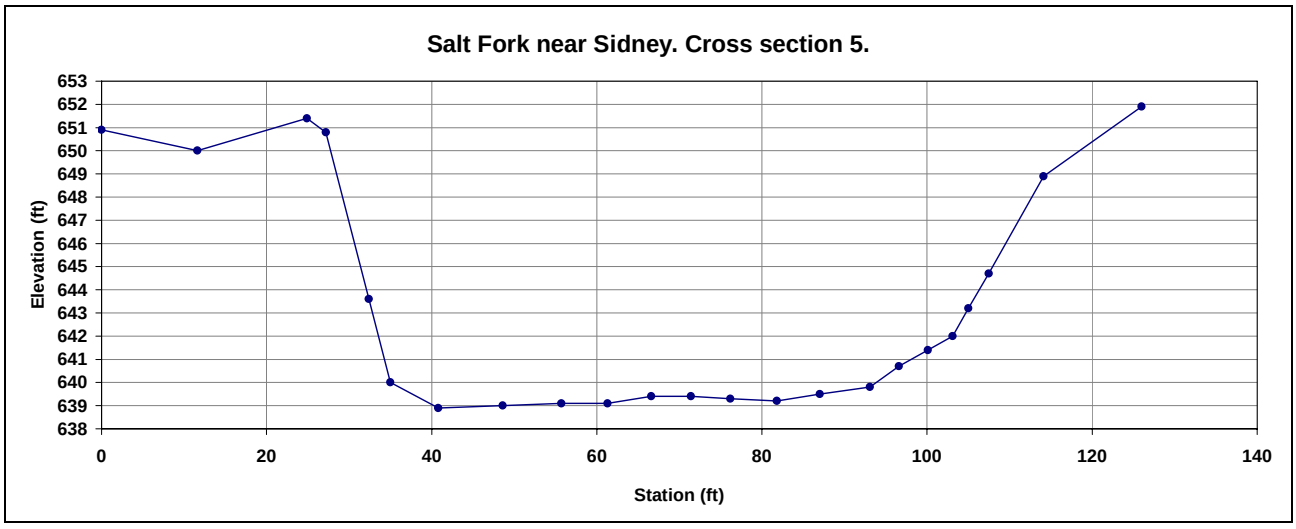


Figure 76. Salt Fork near Sidney: cross section 5.

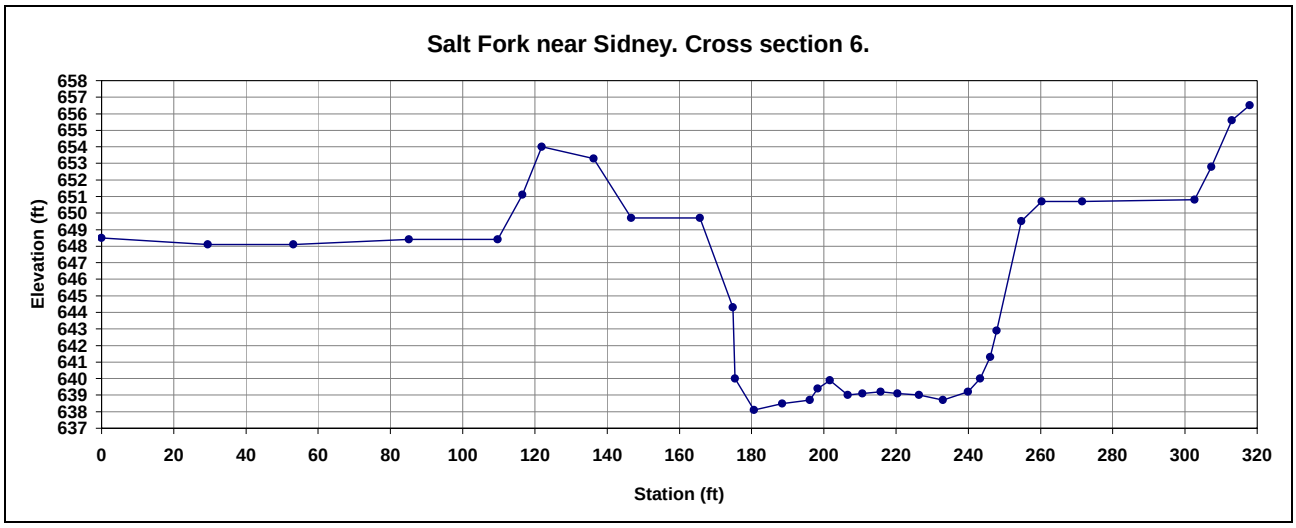


Figure 77. Salt Fork near Sidney: cross section 6.

The estimation of the bank-full discharge was made using the one-dimensional hydrodynamic program HEC-RAS, developed by the U.S. Army Corps of Engineers [12]. "Levees" were set on some of the banks in order to simulate the steady and subcritical flow for a series of increasing discharge values. The cross sections were interpolated with a constant distance of 10 ft.
The resistance was estimated in terms of Manning's roughness coefficient. Considering the table reporting the values of the coefficient provided by Chow (1959, [13]), a value of 0.1 can be assigned to the channel, which can be described as a "minor natural stream" characterized by the presence of deep pools and woody debris (see Figure 78). Moreover, in a so high value for the Manning's coefficient, the backwater effect is "embedded", given that, downstream from the reach here analyzed, the Salt Fork conveyance is lower, causing a water level raise upstream (not considered if a normal depth is set as downstream boundary condition as done in the present analysis).
According to the HEC-RAS simulation runs, the bank-full discharge at the cross section 1 (corresponding to the USGS gage near Sidney) is about 2700 cfs, as shown by the Figure 79. The result is consistent with the one obtained in the previous paragraph, equal to 2543 cfs.

Figure 78. Presence of deep pools (picture on the left) and woody debris (picture on the right) in the Salt Fork near Sidney.

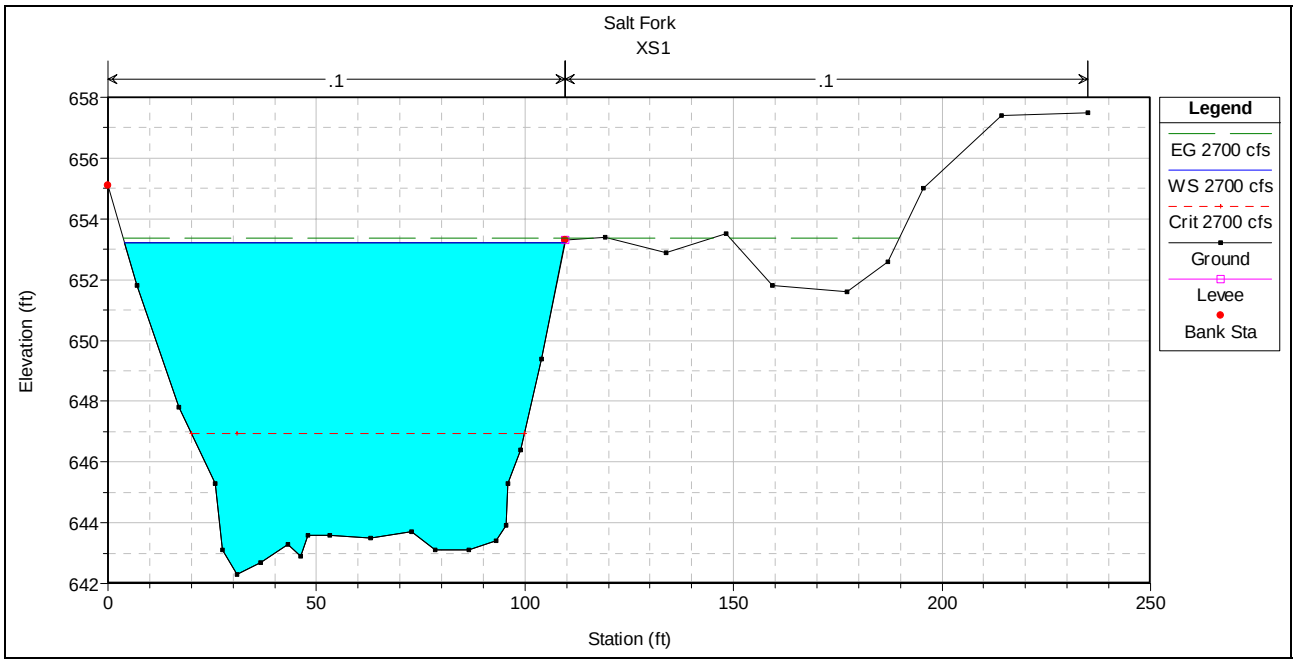


Figure 79. Bank-full discharge at the cross section 1 according to the HEC-RAS simulations.

VIABILITY OF A CONSTRUCTED WETLAND

In this chapter, the viability of a constructed wetland in the floodplain at the location of the gaging station near Sidney (see Figure 81) is discussed. At least another wetland was already constructed in the Salt Fork watershed (see Figure 81).
The wetland, in terms of stream restoration, could be a good enhancement to the ecosystem in the reach. It would represent an environment at the interface between the truly terrestrial ecosystem and the aquatic system, creating an ecotone able to host considerable biodiversity.
A wetland area requires to be inundated or saturated by surface or ground water at a frequency and duration sufficient to support a prevalence of vegetation typically adapted for life in saturated soil conditions.

Groundwater data and sediment cores

On June 12 2007, a shallow observation well was installed and sediment cores were collected through the GeoProbe (see Figure 80). The Table 16 summarizes the groundwater data collected during the two weeks from June 14 to June 21 2007 (see also Figure 80).

Date	Water level (below the ground level)	Method
6/14/2007	5.42	Electric tape
6/15/2007	5.97	Steel tape
6/15/2007	7.82	Electric tape
6/19/2007	10.95	N/A
6/21/2007	11.05	N/A

Table 16. Groundwater data collected at the location of the gaging station near Sidney.

During the period of observation, the water table level kept on decreasing since no significant rainfall were recorded in the area.
According to the topographic survey made on June 14 2007, the elevation of the base of the groundwater well is 652.72 ft. This means that between June 14 and June 21 the water table elevation was between 647.30 and 641.67 ft.
As reported above, for the gage cross section a survey is available (Cross section 1). The thalweg elevation is 642.3 ft and during the period from June 14 to June 21 several measurements made with the Flow Tracker and the pigmy meter indicated the presence of a mean flow depth of about 0.9-1 ft. It seems therefore that the groundwater is contributing to the flow in the river, at least for low flow regimes.
On June 12 2007 several sediment cores were collected (see Figure 80). The resulting vertical soil profile can be described as follows:

- depth from 0 to 4 ft: silt, brown color, organic with roots. Soil zone, dry;
- depth from 4 to 8 ft: tan silt;
- depth from 8 to 12 ft: silty sand, tan color;
- depth from 12 to 14.25 ft: silty sand and mild gray silt/clay.

Figure 80. Sediment cores inspection (picture on the left) and groundwater measurements (picture on the right).

Anecdotal evidences

The landowner provided anecdotal evidences of flooding events in the area where the well was installed (see Figure 81).

Hydrological and hydraulic conditions

According to the considerations made in the previous chapter, the bank-full discharge at the gaging station near Sidney is around 2550-2700 cfs. In the discharge series derived for the period from August 13 2006 to June 22 2007, this value was exceeded once (see Figure 38). This means that the right floodplain is flooded relatively frequently (even though the period of observation is not sufficiently long to make general considerations), which is positive in the view to construct a wetland in that area. Moreover, from the flow duration curve derived for the Salt Fork at the gaging station near Sidney (see Figure 54), the duration of a discharge of 2500 cfs is around 1.7 days, showing the capability of providing water for the wetland.

Evaluation of the viability for the wetland

Wetlands require that at least for some of the time water saturates the soil. Without going into much detail, from the analysis presented in this document and from some anecdotal evidences, it appears that the Salt Fork flow regime at the station near Sidney would allow for constructing a wetland on the right floodplain. On the other hand, the groundwater data seem to indicate a high transmissivity value for the aquifer, implying the risk of losing too much water from the wetland. Moreover, the water table levels reported in the Table 16 suggest that the construction of a wetland would require a big excavation work, with consequent high costs.

In conclusion, a deeper evaluation of the viability of a wetland on the Salt Fork right floodplain near Sidney requires more measurements of the water table levels, a study on the permanence time of the water in the wetland (according to what indicated by the U.S. Environmental Protection Agency and by the U.S. Army Corps of Engineers) and an economic analysis on the construction costs.

Figure 81. Salt Fork right floodplain near Sidney (picture on the upper left), existing wetland upstream from the St. Joseph WWTP (picture on the upper right) and possible location of the wetland near Sidney (lower center).

FURTHER COMMENTS AND SUGGESTIONS FOR THE NEXT FIELD METHODS CLASSES

In this chapter, some further comments on the data available and several suggestions for the next field methods classes are presented, beyond the ones already mentioned in the document.

Additional water quality data were collected on June 19 2007 (see Figure 82) at two different locations (Salt Fork USGS gaging stations near St. Joseph, station 03336900, and near Sidney, station 03337848). Data from the laboratory analysis of the samples are available and relative to dissolved oxygen, pH, conductance, temperature, hardness, major inorganics (carbon dioxide, calcium, magnesium, potassium, sodium, chloride, fluoride, silica, sulfate, ammonia, nitrate, nitrite, nitrogen, orthophosphate, phosphorus, hydrogen ion, iron and manganese) and other parameters (acid neutralizing capacity, alkalinity and residue).

Figure 82. Water quality sample collection (picture on the left) and laboratory activities (picture on the right).

As regards the dissolved oxygen concentration, the value measured at the station 03337848, equal to 6.6 mg/l (saturation percentage 78%), is consistent with the value measured with the YSI handheld probe the same day, equal to 6.63 mg/l (see Figure 19). Similarly, the value measured at the station 03336900, 15.8 mg/l (saturation percentage 206%), shows a good agreement with the YSI probe reading, equal to 15.32 mg/l (see Figure 19). It would be interesting to investigate the supersaturated conditions observed at this station in the future.
Moreover, the data available for all the other water quality parameters at the stations 03337848 and 03336900, along with the EPA data available for several substances from 1999 for the Salt Fork near St. Joseph and for the Saline Branch Ditch might allow to schedule a future water quality campaign to deeply investigate the water quality conditions of Salt Fork. The analysis could be very useful and interesting since, according to a recent study by Tetra Tech, Inc., 2007 [5], pH, nitrate, total ammonia, iron, boron and phosphorus represent impairments for the Salt Fork watershed.

Another future water quality activity might be an intensive campaign along the Salt Fork to attest the impairment caused by the possible “non environmental friendly” landowner located upstream from the USGS gaging station near Sidney and, in general, by the village of Sidney, which does not have a treatment plant.

From 2008, the St. Joseph WWTP effluents will be disinfected, therefore it would be interesting to evaluate the effects on the Salt Fork water quality conditions, with a particular attention for “new”

contaminants characterized by very low concentration values. Moreover, besides the water quality parameters in the water column, the presence of contaminants in the sediments should be investigated.

Regarding the dissolved oxygen concentration, it might be useful to try to relate it to the dredging activities along the Salt Fork (dredging with removal of trees causes the absence of shade, the water temperature increases, as the photosynthetic activity, with a consequent reduction of the dissolved oxygen levels).

Regarding the suspended sediment concentration, other samples should be collected to increase the number of data for estimating more accurate relations concentration-discharge and concentration-turbidity. In addition, comparing the results obtained by the EWI (equal width increment) and EDI (equal discharge increment) procedures might provide useful information about the sediment transport distribution across the cross sections.

Finally, the groundwater quality should be analyzed, and the role of clay in the sorption of some contaminants should be investigated.

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