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MICHIGAN DEPARTMENT OF ENVIRONMENTAL QUALITY
SURFACE WATER QUALITY DIVISION
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STAFF REPORT

WATER CHEMISTRY TREND MONITORING IN SYCAMORE CREEK AND HAINES DRAIN, INGHAM COUNTY, MICHIGAN 1990-1997

ACKNOWLEDGEMENTS

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SUMMARY AND CONCLUSIONS

1. Eight years of flow, water chemistry and landuse monitoring were performed in two small watersheds within Sycamore Creek (Marshall Drain and Willow Creek) and another Grand River watershed (Haines Drain) not in the Sycamore Creek drainage. The purpose was to measure the effectiveness of nonpoint source best management practice (BMP) implementation.

2. From 1990 to 1997, no till farming practices increased from 4% to 67% of the total watershed area in Haines Drain, 0% to 75% in Marshall Drain and from 4% to 35% in Willow Creek. A stream bank stabilization program was also implemented in Willow Creek. No quantitative measures of fertilizer use are available for the watersheds. In general farmers apply fertilizer at rates which account for the results of soil fertility testing.

3. A statistically significant downward trend in NO_2+NO_3 from an average of 2.3 mg/l in 1990 to an average of 1.7 mg/l in 1997 was detected in weekly Willow Creek grab samples after adjusting for flow and seasonal variability. A statistically significant increase in NO_2+NO_3 from an average of 2.8 mg/l in 1990 to 4.07 mg/l in 1997 was observed in Haines Drain after adjustment for flow and seasonal variability. These observations may reflect changes in nitrogen fertilizer application rates or may reflect changes in landuse or cropping patterns.

4. A statistically significant reduction in suspended solids and total phosphorus load occurred in Willow Creek storm runoff over the 8 years of monitoring. However, no similar trends in suspended solids were statistically detectable in the other two watersheds even though no till farming practices were adopted to a greater extent in these watersheds. A stream bank stabilization project was implemented in Willow Creek but not in the other two subwatersheds. The results suggest that the adoption of no till farming practices alone will not result in detectable reductions in suspended solids loads but when coupled with a stream bank erosion control program, detectable suspended solids load reductions are achieved in Sycamore Creek.

5. Of the three small subwatersheds sampled, Haines Drain produced significantly more surface runoff flow and suspended solids load than either Marshall Drain or Willow Creek in spite of having soils with similar hydrologic soil classifications, similar landuse and lower average field slope. Since loading models frequently use these factors to estimate spatial loading differences, this finding suggests that the application of models to target nonpoint source control measures may be highly uncertain without the benefit of actual stream monitoring to verify results.

6. Measured average annual sediment loading near the watershed outlet was only 6% - 12% of planning estimates that are based on erosion and delivery. The implications of this large discrepancy must be considered when using such planning estimates to target resources.

7. Measured average annual sediment loading near the watershed outlet was about 66% of the load estimated in a Total Maximum Daily Load (TMDL) for Sycamore Creek.

INTRODUCTION

Intensive water quality trend monitoring was conducted on Sycamore Creek and Haines Drain from 1990 through 1997. This project was funded by the Michigan Department of Environmental Quality and a special Section 319 grant from the United States Environmental Protection Agency. This monitoring program coincided with a very intensive effort under the United States Department of Agriculture (USDA) Hydrologic Unit Area (HUA) Program to implement best management practices (BMPs) in the Sycamore Creek watershed. The following Federal, State and local agencies participated in this effort:

- USDA Natural Resources Conservation Service
- USDA Farm Services Agency
- Ingham Conservation District
- Michigan State University Extension Ingham County
- Ingham County Drain Commissioner

Sycamore Creek was chosen for monitoring because of it's central location in the State, it's demonstrated water quality problems within the watershed and because it was considered representative of many southern Michigan agricultural watersheds. Haines Drain was chosen as an experimental control because it was close enough to the Sycamore Creek monitoring stations (within 6 miles) to experience the same weather but not part of the special BMP implementation initiative in Sycamore Creek.

The Sycamore Creek watershed is about 70% agricultural landuse but is experiencing a substantial increase in urban and suburban development. The soils are predominantly loam and sandy loam with field slopes up to 12% but averaging about 3-5%. Sedimentation and low dissolved oxygen are the most pervasive effects from nonpoint pollution in the watershed (Clark 1990, Suppnick 1996).

Sycamore Creek was selected for the development of a total maximum daily load (TMDL) pursuant to §303 of the Federal Clean Water Act because of the low dissolved oxygen problem. This TMDL was completed in September of 1996 (Suppnick 1996) and required a 52% reduction in sediment load to the stream to meet the dissolved oxygen standard in the stream. The most significant sources of sediment were found to be agricultural fields and stream banks. Implementation of sediment load reductions is voluntary but a great deal of cost share and technical assistance has been available to landowners since 1990 under the USDA Hydrologic Unit Area Program. In addition, a Section 319 nonpoint source implementation grant was awarded to the Ingham County Drain Commissioner for stream bank erosion control in Willow Creek, a tributary to Sycamore Creek.

The water chemistry monitoring was designed to measure the reduction in suspended solids and nutrient loads to Sycamore Creek as BMPs were implemented. The monitoring strategy was to select two small subwatersheds with a high erosion potential and monitor these watersheds along with a control watershed that was not within the Sycamore Creek watershed. Small subwatersheds were chosen for monitoring instead of the watershed outlet because they were expected to respond to BMPs more quickly and because it was less time consuming to monitor landuse and tillage practices in a small area. Figure 1 shows the location of sampling stations in Sycamore Creek (STORET stations).

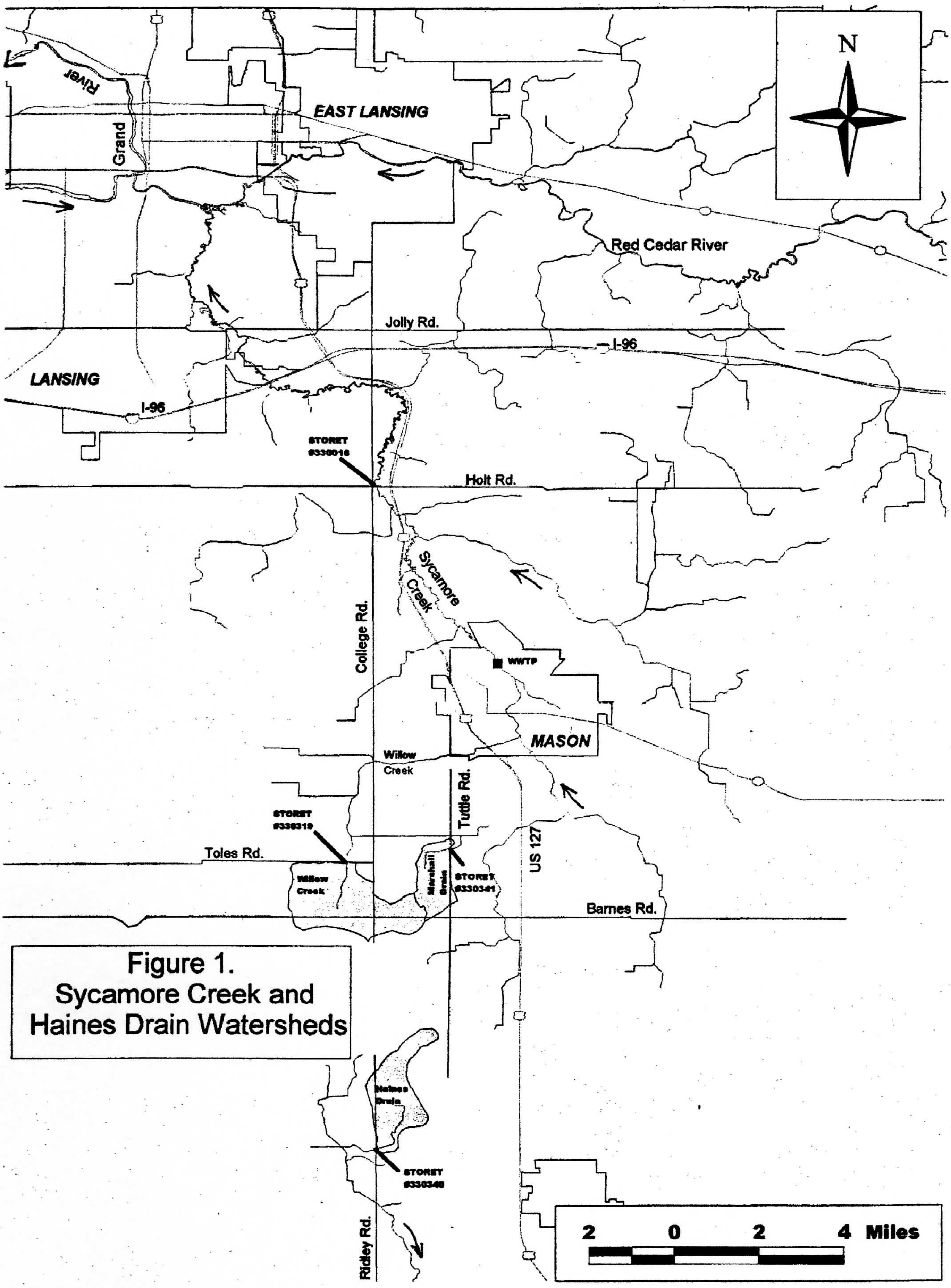

Figure 1.
Sycamore Creek and Haines Drain Watersheds

METHODS

The monitoring program had four components.

1. "Weekly" water chemistry grab sampling in three subwatersheds during the spring season of 1990-1997
2. Storm monitoring in the same 3 subwatersheds during the spring season of 1990-1997
3. Monitoring of landuse and tillage practices in the same 3 subwatersheds 1990-1997
4. Flow stratified year round sampling at a United States Geological Survey (USGS) gage near the watershed outlet for three years (1995-1997).

The soil characteristics of each of the three subwatersheds are summarized in Table 1 below.

Table 1. Physical Characteristics of the Three Monitored Subwatersheds

	Haines Drain	Willow Creek	Marshall Drain
Drainage Area (Acres)	848	1087	422
First Soil (most common)	An* 20 %	Ma 55 %	Co 45 %
Second Soil	Rd 19 %	Ed 15 %	Ma 38 %
Third Soil	By 15 %	Ca 7 %	Ca 5 %
Fourth Soil	Ca 10 %	Os 4 %	An 4 %
Fifth Soil	Co 8 %	Co 3 %	Ow 3 %
Soil Hydro Group A	6 %	1 %	6 %
Soil Hydro Group B	79 %	79 %	95 %
Soil Hydro Group C	7 %	8 %	5 %
Soil Hydro Group D	8 %	12 %	0 %
Avg. Field Slope	3.4 %	5.2 %	4.8 %

* Two letter codes refer to soil mapping unit classification

Landuse and Tillage Monitoring

Landuse and tillage practices in the three small subwatersheds listed in Table 1 were recorded annually from 1990-1997 by staff of the Natural Resources Conservation Service. A ten acre grid was superimposed on a USGS topographic map for each subwatershed which served as the template for storing landuse and tillage data in a spreadsheet (Appendix A).

Spring Storm Monitoring

Spring storm monitoring was conducted in the three subwatersheds using automatic samplers, bubbler flow meters and recording rain gages. Stream flow was measured periodically in each of the subwatersheds and stage-discharge correlations were determined and periodically updated by staff from the Land and Water Management Division of DEQ. Sampling began each year in the spring after all frost was out of the ground and the threat of freezing weather was judged to be minimal (usually March or April). Storm sampling continued until row crops had grown to the point of complete ground coverage (usually July). Automatic samplers were set to begin sampling after a 1-2 inch increase in stage. Samples were collected at intervals that ranged from 30 minutes to 6 hours. Samples were collected more frequently during the first part of the storm and less frequently at the end of the storm. To control laboratory expenses, not all collected samples were submitted for laboratory analysis. For each storm, an average of 8 samples and up to 22 samples were selected for analysis based on the following criteria:

- Chose at least one sample on the rising limb of the hydrograph
- Chose at least one sample near the hydrograph peak
- Chose at least two samples on the descending limb of the hydrograph
- Chose samples that are representative with respect to turbidity and amount of suspended solids
- Chose more samples for periods with higher apparent suspended solids loads

For each storm monitored, the total runoff volume was calculated by subtracting out baseflow. Baseflow was estimated graphically by drawing a straight line on the hydrograph between the time when runoff began and the time when runoff ended. The time when runoff ended was determined subjectively by considering the shape of the hydrograph, the time since peak flow and the concentration of suspended solids in samples. Total storm loads were determined by adding up the loads associated with each individual sample. The load corresponding to each individual sample was determined from the following equation:

$$L = C*Q*0.5*(T_{+1}-T_{-1})*2.45$$

Where: L = load associated with a sample in kilograms
C = concentration of pollutant in mg/l
Q = instantaneous flow at the time of sampling in cfs
T_{+1} = Time of next sample or end of storm
T_{-1} = Time of previous sample or beginning of the storm
2.45 = conversion factor with units of $sec \cdot l \cdot kg \cdot day^{-1} \cdot cub.\ ft^{-1} \cdot mg^{-1}$

The total rainfall depth and the erosive force of each storm (Erosion Index) were determined from the data provided by the recording rain gages using the method described in the USDA Guide to Conservation Planning (Wischmeier 1978).

Spring Grab Sampling

Grab samples were collected during the same season as the storm monitoring (approximately March through July). The initial sampling strategy used from 1990 through 1992 was to collect samples occasionally (2-7 samples per station per year) during non-runoff conditions only. Beginning in 1993 the grab sampling strategy changed to sampling weekly without regard to runoff conditions.

Flow Stratified Year Round Sampling

In 1995 a new sampling station with a different sampling strategy was established at the USGS stream flow gage at Holt Road. Flow was recorded by the USGS according to their procedures. An automatic sampler was installed in the USGS shelter and programmed to collect samples at 8 hour intervals all year. A weekly visit was made to the site at which time samples collected in the preceding week were selected for analysis using a flow stratified strategy (more samples selected for analysis at higher flows). This strategy resulted in an average of 150 samples collected per year. Annual loads were calculated using the Autobeale program (Richards 1996).

Laboratory Analysis

All water chemistry samples from all stations were analyzed by the Michigan Department of Environmental Quality Laboratory in Lansing Michigan for suspended solids, total phosphorus, ortho-phosphorus, Kjeldahl nitrogen, ammonia nitrogen, nitrite, nitrite plus nitrate, chemical oxygen demand (COD) and turbidity.

Landuse and Tillage Monitoring

The increased use of no till farming practices over time is shown in Figure 2 for each of the three subwatersheds. From 1990 to 1997, no till farming practices increased from 4% to 67% of the total watershed area in Haines Drain, 0% to 75% in Marshall Drain and from 4% to 35% in Willow Creek. Figure 3 shows the percentage of each subwatershed in continuous vegetative cover (pasture, hay, meadow, alfalfa or woods) over time. For each of the three subwatersheds, the percentage of land in continuous cover decreased. A detailed summary of landuse and tillage monitoring in the three subwatersheds is listed in Appendix B.

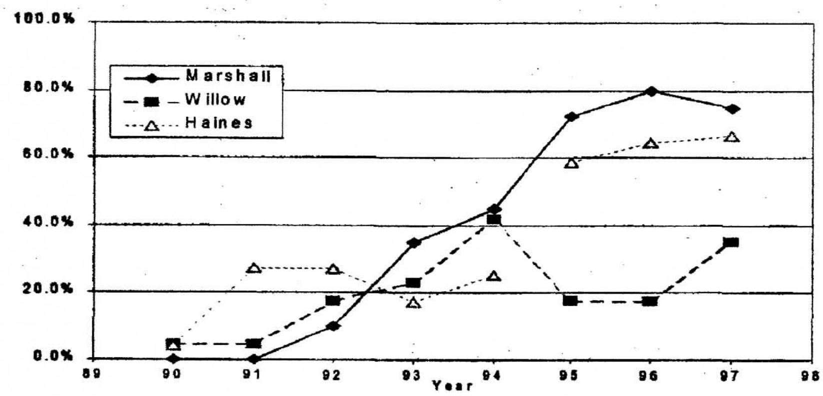

Figure 2. Percent of Subwatershed with Notill Cropland

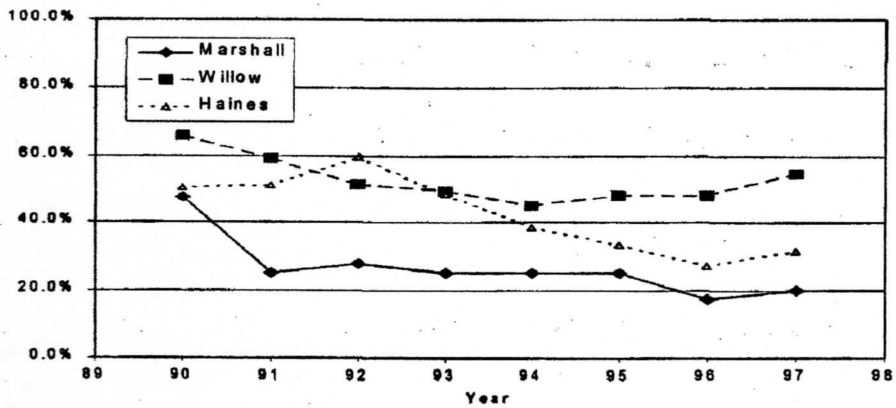

Figure3. Percent of Subwatershed with Continuous Cover

Other Practices Affecting Soil Erosion
In Marshall Drain there were no significant additional practices employed to reduce soil erosion beyond the measures accounted for in Appendix B. A gravel mine was established in Cell #1 of Marshall Drain during 1991. This gravel mine remained active through most of the monitoring period but no significant erosion was observed as a result of this gravel mine. Some repair of sub-surface field drains was done along the eastern edge of the Marshall Drain watershed during the monitoring program but are not well documented.

In Willow Creek, the Ingham County Drain Commissioner implemented a stream bank stabilization program between November 1995 and May 1996, upstream of the monitoring station, with funding from a Section 319 grant (Fishbeck Thompson Carr and Huber 1996). These BMPs included brush mattresses, live fascines, biolunkers, fiber rolls, rock rip rap, slope reduction, current deflectors, tree/branch revetments and underdrains. In addition, a total of 1040 trees and shrubs, including Streamco Willow and Dogwood, were planted along the stream throughout the approximately one mile long implementation area during December, 1995 and April, 1996.

In Haines Drain, grade stabilization structures were installed in cell #60 and #76 during 1991 along with some critical area seeding and subsurface drain system repair. In 1996, a pond was constructed in cell #96 just upstream of the Hanes Drain monitoring station. The disturbed soil was not properly stabilized resulting in a serious erosion problem which influenced 1996 and 1997 water quality data.

Grab Sampling Results
Appendix C lists the results of analysis of individual grab samples collected in the 3 subwatersheds. Generally, samples were collected during baseflow conditions. A summary of the average values for these grab samples is contained in Table 2.

Table 2. Summary of Average Values for Individual Grab Samples at Three Subwatersheds from 1990-1997

Station	Flow (cfs)	COD (mg/l)	NO2 (mg/l)	NO_2+NO_3 (mg/l)	NH3 (mg/l)	KN (mg/l)	O-P (mg/l)	T-P (mg/l)	Suspended Solids (mg/l)
Haines Drain	0.91	6.52	0.05	3.59	0.09	0.70	0.03	0.07	11.50
Willow Creek	2.77	5.65	0.02	2.00	0.04	0.54	0.004	0.03	11.18
Marshall Drain	0.36	11.90	0.05	3.12	0.08	0.67	0.03	0.05	6.49

The average stream flow was highest in Willow Creek at 2.77 cfs and lowest in Marshall Drain at 0.36 cfs. The average suspended solids concentration at Marshall Drain was lower than Haines Drain or

Willow Creek probably reflecting the lower water velocities at the Marshall Drain station under baseflow conditions.

The ortho-phosphorus concentration was notably lower at Willow Creek than the other two stations. The baseflow drainage in Willow Creek comes primarily from the organic soils that border the stream corridor, drain tiles and a gravel pit. This soil is predominantly classified as Edwards muck, a poorly drained organic soil found primarily in drainageways and depressional areas. These soils are primarily in woodland landuse. The other two subwatersheds are bordered by loamy soils.

Storm Sampling Results
The number of storms sampled in each subwatershed were:

Location	Number of Storms Sampled in 8 years
Haines Drain	38
Willow Ck.	39
Marshall Drain	32

Detailed storm sampling results are listed in Appendix D. The magnitude of runoff volume and pollutant loads was highly variable from storm to storm within each individual watershed. The amount of rainfall does not fully explain this variability. For example, in Haines Drain on May 25, 1991 a 0.7 inch rain event produced only 5,200 cubic feet of runoff; but on April 20, 1990 a 0.7 inch rainfall event produced 467,000 cubic feet of runoff a ninety fold difference in runoff.

The highest runoff coefficients observed for individual storms in each subwatershed were 44.3% in Haines Drain, 16.5 % in Marshall Drain and 9.2% in Willow Creek. The greatest amounts of suspended solids transported in a single storm were 13.0 metric tons in Marshall Drain, 15.0 metric tons in Willow Creek and 137 metric tons in Haines Drain. The second highest storm for Haines Drain was only 13.9 metric tons.

Subwatershed Flow Monitoring Results
Flow monitoring in Marshall Drain was complicated by backwater conditions during some runoff events. The Marshall Drain sampling station, at 422 acres, is about ¼ mile upstream from the confluence with a tributary which receives runoff from about 4,500 acres of land during runoff events. For larger storms this resulted in backwater conditions at the monitoring station about 2 hours after peak flow occurred. Flow measurements were made in Marshall Drain during the backwater conditions to better define this part of the hydrograph. For time periods when backwater conditions existed, the normal stage discharge curve was not used and flow was estimated using available information, which often included actual flow measurements.

In Willow Creek the channel substrate and shape was fairly stable from 1990 through 1993 and consequently the stage-discharge correlation was fairly stable for this time period. In 1994, the channel at the monitoring station started filling in with sediment causing significant shifts in the stage discharge correlation for each of the next 4 years (1994-1997).

Haines Drain had a fairly stable stage discharge correlation throughout the entire 8 years of monitoring.

Flow Stratified Year Round Sampling

The results of year round flow stratified sampling at Holt Road, are summarized in Table 3. Appendix E contains time plots for selected parameters (flow, suspended solids, phosphorus and NO_2+NO_3). The annual load of suspended solids varied from 1,608 to 2,346 metric tons per year. The 95% confidence intervals for annual loads of all the pollutants measured ranged from a low of ± 2% for NO_2+NO_3 in 1997 to a high of ± 50% for Ammonia in 1995 (Table 3). The average flow for the three years during water chemistry sampling at the gage was 59.2 cfs. The average flow for the entire period of record (10 years) at this gage is 54 cfs.

Table 3. Annual Loads Measured from November 1, 1994 through October 31, 1997 at Holt Road on Sycamore Creek

Year	Average Flow (cfs)	COD (KG)	95% Conf Interval +/- (%)	NO2 (KG)	95% Conf Interval +/- (%)	NO2+NO3 (KG)	95% Conf Interval +/- (%)	NH3 (KG)	95% Conf Interval +/- (%)
1995	69.89	1,825,767	5%	2,232	17%	157,722	3%	7,587	50%
1996	46.04	1,163,647	4%	4,689	11%	152,514	3%	7,155	18%
1997	61.56	1,430,571	3%	2,167	9%	230,551	2%	5,577	44%
Average=	59.16	1,473,328	4%	3,029	12%	180,262	3%	6,773	37%

Year		KN (KG)	95% Conf Interval +/- (%)	OP (KG)	95% Conf Interval +/- (%)	TP (KG)	95% Conf Interval +/- (%)	Suspended Solids (KG)	95% Conf Interval +/- (%)
1995		84,923	18%	2,197	8%	8,290	8%	2,346,285	19%
1996		67,624	10%	1,989	9%	7,041	17%	1,607,982	10%
1997		68,565	4%	2,563	13%	7,088	5%	1,658,987	15%
Average=		73,704	11%	2,249	10%	7,473	10%	1,871,085	15%

Subwatershed Monitoring
The purpose of the subwatershed sampling was to determine whether improved land management techniques reduced pollutant loads. Sampling was done in small subwatersheds because we believed that load reductions could be achieved sooner than in large watersheds and because it would be easier to implement BMPs throughout a smaller area than throughout the entire watershed. However, within the small subwatersheds, land management activities were diverse and data analysis was complicated by the fact that land management was a variable over which there was no strict experimental control.

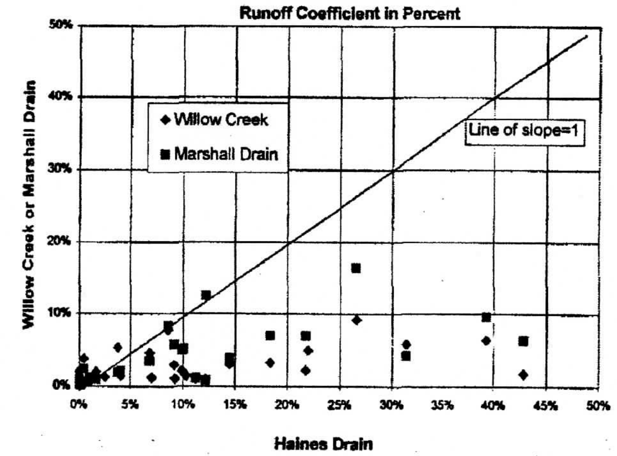

Figure 4. Runoff Coefficients for Individual Storms in Willow Creek and Marshall Drain Compared to Haines Drain

Of the three subwatersheds, Haines Drain produced more surface runoff flow than either Marshall Drain or Willow Creek. Figure 4 illustrates this characteristic of the watersheds by comparing runoff in the watersheds for paired storms. Because of this hydrologic characteristic of Haines Drain, individual storm loads of suspended solids were also generally higher in Haines Drain compared to either Willow Creek or Marshall Drain. As illustrated in Table 1 on page 4, Haines Drain has soils with hydrologic characteristics that are similar to Willow Creek and Marshall Drain. The increased flow in Haines Drain may reflect varying soil characteristics between the subwatersheds which are not fully explained by the hydrologic soil group classification system.

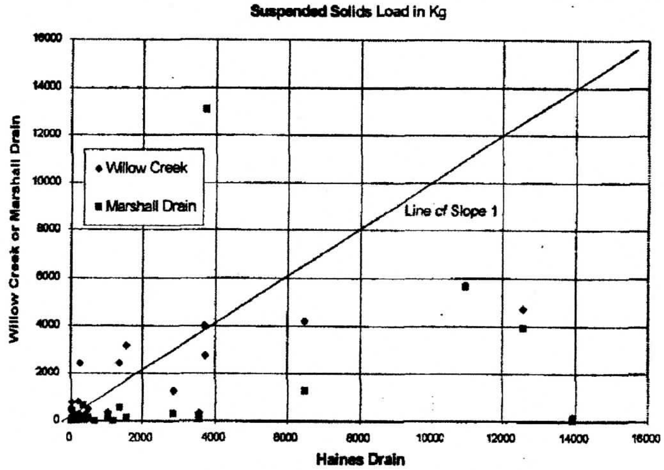

Figure 5. Suspended Solids Load for Individual Storms in Willow Creek and Marshall Drain Compared to Haines Drain (Axes Truncated at 16,000 Kg)

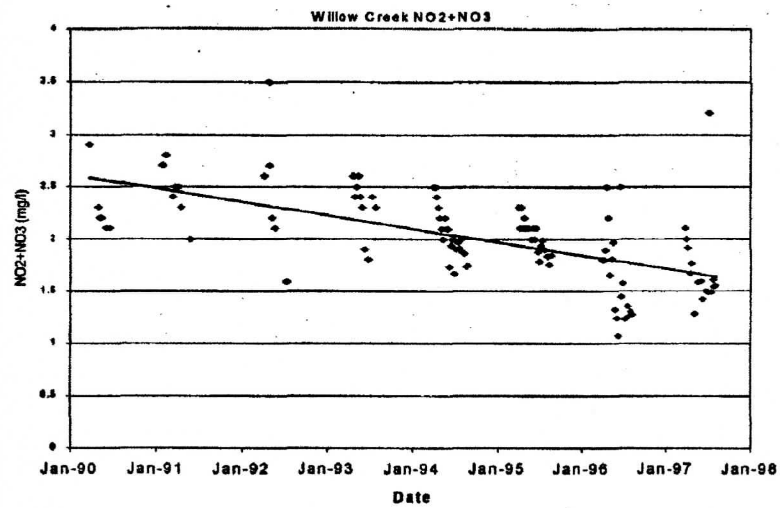

Figure 6. NO2+NO3 in Willow Creek Grab Samples

Weekly Willow Creek grab samples (Figure 6) exhibited a downward trend in NO_2+NO_3 from an average of 2.3 mg/l in 1990 to an average of 1.73 mg/l in 1997 that was statistically significant after adjustment for flow and seasonal variability (Grabow 1999). This trend in NO_2+NO_3 concentrations may reflect the adoption of nutrient soil testing and reduced nitrogen application to cropland by watershed farmers as a result of the USDA water quality program or changes in cropping patterns or landuse. No specific data on fertilizer use within the Willow Creek subwatershed are available however.

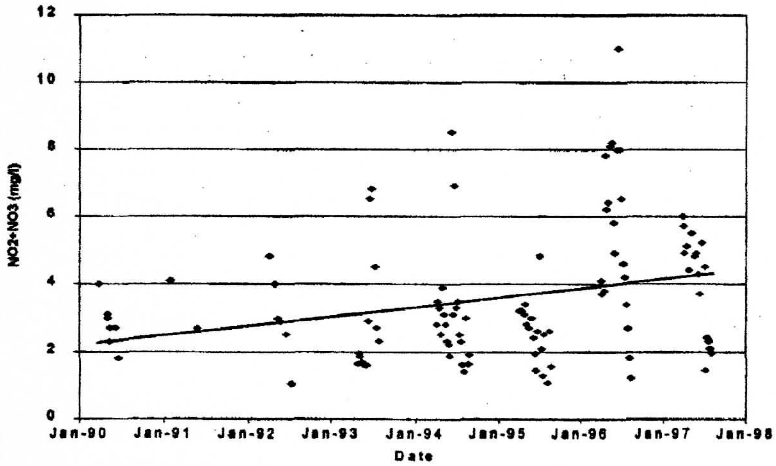

Figure 7. NO2+NO3 in Haines Drain Grab Samples

Figure 7 shows that Haines Drain weekly grab samples exhibited an upward trend in NO_2+NO_3 from an average of 2.8 mg/l in 1990 to 4.07 mg/l in 1997 that was statistically significant after adjustment for flow and seasonal variability (Grabow 1999). Since no fertilizer use data were available the reason for this increase is unknown but may be changes in fertilizer use or cropping patterns.

A statistically significant reduction in sediment and total phosphorus load occurred in Willow Creek storm runoff over the 8 years of monitoring (Grabow 1999). This was based on a regression analysis of storm loading over time after correcting for the variability in peak flow and runoff volume. Figure 8 is a plot of the residuals from the regression analysis of suspended solids loads over time illustrating the downward trend. Based on this analysis there was a 60% reduction in suspended solids concentration. A similar analysis for total phosphorus showed a 57% reduction in total phosphorus over the eight years of monitoring. However, no trends were statistically detectable in the other two watersheds. In Willow

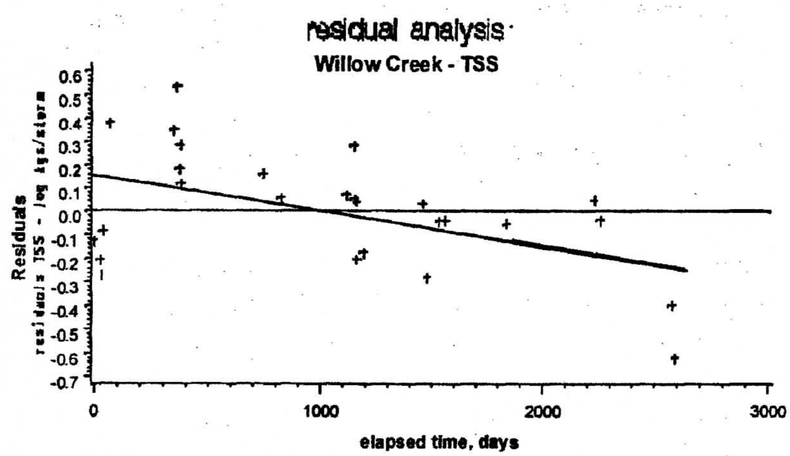

Figure 8. Residuals from Regression Model Using Peak Storm Flow and Runoff Volume to Predict Suspended Solids in Willow Creek

Creek, the water quality improvement was statistically linked to percent land in no-till. However, the two watersheds (Haines and Marshall) that did not show a statistically significant improvement, had a greater increase in no-till than Willow Creek, and therefore would have been expected to also show a water quality improvement. However, other land management practices which affect water quality also occurred such as the erosion problems associated with pond construction in Haines Drain and stream channel stabilization in Willow Creek. This suggests that land management factors affecting the riparian zone may have an equal or greater effect on suspended solids loads in these Grand River tributaries than no-till. The analysis of sediment sources that was performed as part of the TMDL for Sycamore Creek concluded that stream bank erosion was the predominant source of sediment to Willow Creek. Therefore the stream bank stabilization project implemented in Willow Creek may be responsible for the reduction in sediment and total phosphorus observed in Willow Creek.

Flow Stratified Year Round Sampling at Holt Rd.

Table 4 compares the unit area average annual loads of selected pollutants to other Michigan rivers as determined from a Great Lakes tributary sampling program conducted in the 1980s (Day 1990).

Table 4. Annual Loads of Selected Pollutants for Sycamore Creek Compared to other Michigan Streams

Stream	Drainage Area (sq. km.)	Years Sampled	Total Annual Flow ($m^3/m^2/Yr$)	Total Phosphorus (kg/ha/yr)	Suspended Solids (kg/ha/yr)	Ammonia (kg/ha/yr)	Nitrate (kg/ha/yr)
Sycamore Ck.	209	1995-1997	0.253	0.36	89.5	0.32	8.5
Black (St. Clair Co.)	1842	1984-1986	0.392	1.10	475	1.18	7.04
Clinton	1968	1984-1986	0.347	0.66	190	0.70	6.41
Rouge	1210	1984-1986	0.741 (0.58 is cooling water discharge)	1.18	252	4.19	5.86
Huron	2352	1984-1986	0.274	0.21	70	0.42	2.82
Ontonagon	3600	1984	0.342	0.31	289	0.11	0.43
Pere Marquette	1852	1984	0.409	0.18	31	0.72	0.75
St. Joseph	12124	1984	0.356	0.26	67	0.51	6.44

Comparisons between Sycamore Creek and the other streams should be made cautiously however since the Sycamore Creek sampling station is at a much smaller drainage area. Smaller streams are normally expected to have greater loads per unit area than larger streams (Novotny 1989).

The measured suspended solids load at Holt Road was compared to planning estimates performed by the SCS (1990) in their water quality plan for Sycamore Creek (Figure 9). The plan reported the

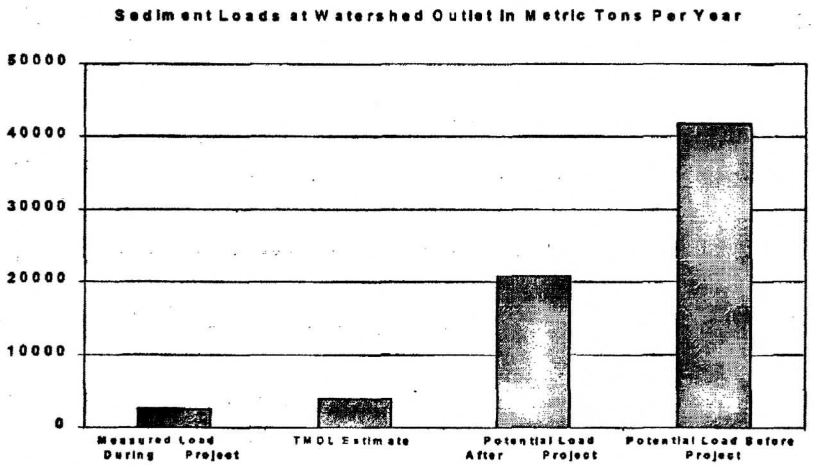

Figure 9. Measured Loads of Suspended Solids Compared to Planning Estimates of Sediment Delivery for Sycamore Creek

potential for a sediment load of 41,800 metric tons to be delivered to the entire watershed (109 square miles) at the start of the project in 1990. Based on the 1997 annual report for the Sycamore Creek Hydrologic Unit Area Project (USDA 1997), this potential load of sediment to the stream has been reduced to less than 20,860 metric tons. During 1994 to 1997, the last 3 years of the USDA project, we measured an average of 1,871 metric tons of suspended solids per year from all sources at a drainage area of 80.6 square miles. By adjusting for the difference in drainage area between the watershed outlet (109 square miles) and the monitoring station (80.6 square miles), the measured loads are estimated to be about 2530 metric tons per year at the watershed outlet. This is only 12 % of the potential load predicted by USDA at the end of the project. The USDA estimates do not include stream bank erosion.

This difference suggests that sediment delivery to the stream is much lower than expected especially when you consider that the planning estimates do not include bank erosion which was estimated in the TMDL to be almost half of the total load to the stream (Suppnick 1996). Since overall delivery of sediment to the stream was much lower than expected the actual area contributing sediment to the stream may also be a very small fraction of the watershed. Good management of this actual contributing land may be necessary to achieve further suspended solids load reductions in Sycamore Creek.

The TMDL analysis estimated the average annual sediment loading rate for Sycamore Creek at Harper Road (38.6 square mile drainage area) to be 1052 metric tons per year (Suppnick 1996). This estimate was based on a combination of monitoring and modeling for the portion of Sycamore Creek upstream of Harper Road. If this TMDL model loading estimate was adjusted for the greater drainage area of 80.6 square miles at Holt Road, then an annual average load of 3,900 metric tons per year of suspended solids is predicted at Holt road. This estimated annual average suspended solids load is about two times higher than the actual measured load.

In summary, the TMDL estimate which incorporated some monitoring data was accurate to within a factor of about 2 and the planning estimates that did not use monitoring data were in error by a factor of 8 or 16 depending on whether measured loads are compared to pre or post project estimates.

REFERENCES

Clark, Karen, A Biological Investigation of Sycamore Creek and Tributaries. Report # 90/075, Michigan Department of Natural Resources, Lansing, MI. 1990.

Day, Robert M., Estimated Loadings From Seven Michigan Tributaries and Recommendations for Tributary Sampling Strategies. Report # 90/010, Michigan Department of Natural Resources, Lansing, Michigan, 1990.

Fishbeck Thompson Carr and Huber Inc. Willow Creek Drain Final Report for Implementation Project. Final report from a Section 319 Grant, Fishbeck Thompson Carr and Huber Inc., Ada, Michigan, 1996.

Grabow, Garry. Personal communication of results of statistical analysis of Sycamore Creek water quality data to John Suppnick. North Carolina State University, Raleigh North Carolina, 1999.

Novotny, Vladimir, and Chesters, Gordon. Delivery of Sediment and Pollutants from Nonpoint Sources: A Water Quality Perspective. Journal of Soil and Water Conservation, Vol. 44 no. 6., 1989.

Richards, R. Peter, David B. Baker, Jack W. Kramer, and D. Ellen Ewing. Annual loads of herbicides in Lake Erie tributaries in Ohio and Michigan. Journal of Great Lakes Research 22: 414-428. 1996.

Soil Conservation Service. Sycamore Creek Watershed Water Quality Plan. Ingham County, Michigan. January 1990.

Suppnick, John D., Informational Total Maximum Daily Load For Dissolved Oxygen in Sycamore Creek. Report #96/049, Michigan Department of Environmental Quality, Lansing, MI. 1996.

United States Department of Agriculture, 1997 Annual Progress Report for the Michigan USDA Water Quality Hydrologic Unit Sycamore Creek Watershed. United States Department of Agriculture, East Lansing, Michigan 1997.

Wischmeier, Walter H. and Smith, Dwight D. Predicting Rainfall Erosion Losses- A Guide to Conservation Planning. Agricultural Handbook Number 537. United States Department of Agriculture, Springfield, Illinois, 1978.

APPENDIX A

Subwatershed Maps Showing 10 Acre Cells Used as a Template for Storing Landuse Data

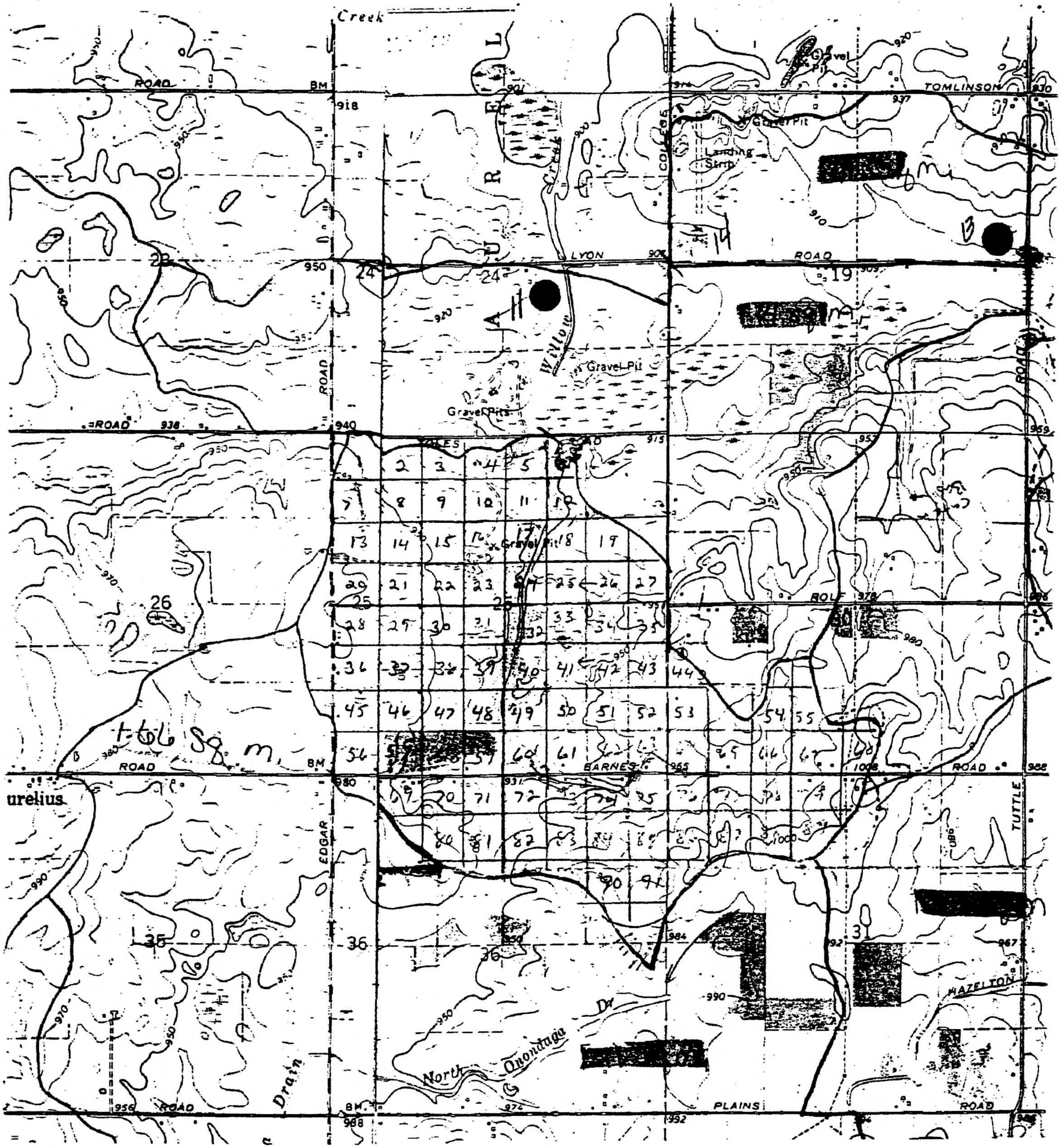

Figure A1. Willow Creek Subwatershed Map Showing 10 Acre Cells Used as a Template for Storing Landuse Data

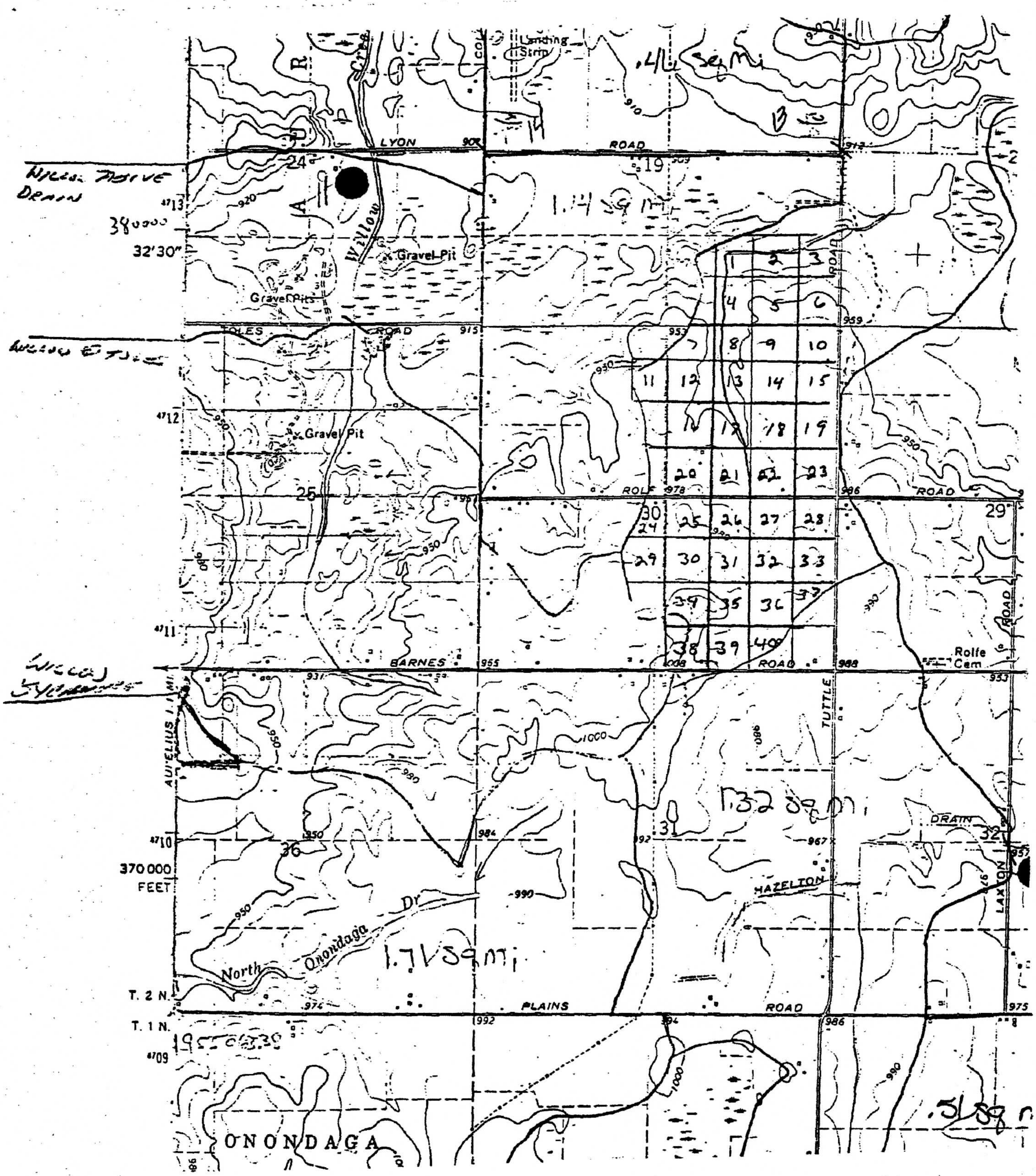

Figure A2. Marshall Drain Subwatershed Map Showing 10 Acre Cells Used as a Template for Storing Landuse Data

Original Grid

10-25-90
J. Suppnick

1.48 mi²

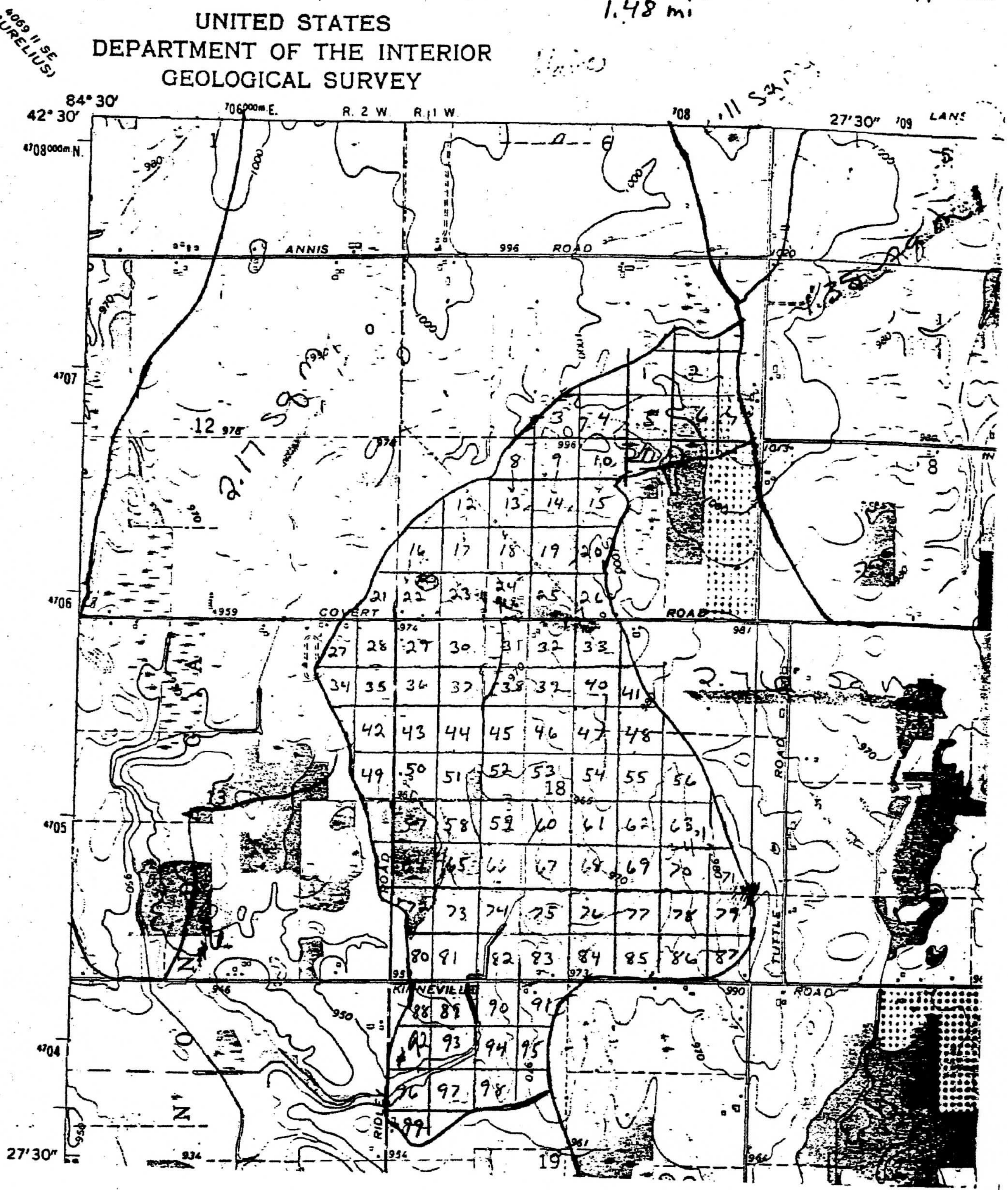

Figure A3. Haines Drain Subwatershed Map Showing 10 Acre Cells Used as a Template for Storing Landuse Data

APPENDIX B

Landuse and Tillage Monitoring Results for Marshall Drain Willow Creek and Haines Drain

Appendix B

Landuse and Tillage Monitoring Results for Marshall Drain

Year	1990	1991	1992	1993	1994	1995	1996	1997
B	0	0	19	0	0	0	0	1
C	14	21	2	15	11	0	0	0
NB	0	0	4	0	18	11	17	11
NC	0	0	0	3	0	15	13	2
NW	0	0		11	0	3	2	17
P	17	8	9	8	8	8	6	5
WH	7	8	3	0	0	0	0	0
WO	2	2	2	2	2	2	0	0
R							1	3
G	0	1	1	1	1	1	1	1
Total	40	40	40	40	40	40	40	40

Landuse and Tillage Monitoring Results for Willow Creek

Year	90	91	92	93	94	95	96	97
B	0	0	9	0	0	4	4	3
C	21	28	6	18	7	22	17	1
NB	0	4	14	1	23	3	16	6
NC	4	0	2	10	15	6	0	11
NW	0	0	0	10	0	7	0	15
P	45	38	30	18	14	16	16	21
WH	1	0	8	2	0	0	4	0
WO	12	12	12	12	12	12	11	12
R	3	4	5	15	15	16	17	17
GI	5	5	5	5	5	5	5	5
Other							1	
Total	91	91	91	91	91	91	91	91

Landuse and Tillage Monitoring Results for Haines Drain

Year	90	91	92	93	94	95	96	97
B	16	3	5	3	28	1	0	1
C	12	7	7	31	3	1	7	1
NB	1	0	17	2	10	14	39	19
NC	3	27	10	15	14	41	25	41
NW	0	0	0	0	1	3	0	6
P	31	33	38	31	18	14	7	9
WH	17	11	1	0	5	6	1	0
WO	17	16	17	15	17	17	18	19
R	2	2	4	2	3	2	2	3
Other								
Total	99	99	99	99	99	99	99	99

P= Established Pasture,meadow, hay, alfalfa
C= Conventional till Corn
WH= Conventional till Wheat
B= Conventional till Soybeans
NC= Notill corn
NW= Notill Wheat
NB= Notill Soybeans
Wo= Woods
R= Low Density Residential development
G= Active gravel mining
GI= Inactive gravel minng

APPENDIC C

Grab Sample Results from Marshall Drain
Willow Creek and Haines Drain

Table C1. Grab Samples From Marshall Drain

Marshall DATE	Marshall TIME	Marshall Flow (cfs)	Marshall COD (mg/l)	Marshall NO2 (mg/l)	Marshall NO2+NO3 (mg/l)	Marshall NH3 (mg/l)	Marshall KN (mg/l)	Marshall O-P (mg/l)	Marshall T-P (mg/l)	Marshall Residue (mg/l)	Marshall Turb (NTU)
5/2/90	15:45	0.07	8		2.3	0.04	0.45		0.03	4	
5/9/90	11:25	0.02	8		1.4	0.074	0.53		0.029	5	
5/14/90	14:48	0.02	7		1.4				0.023	4	
6/5/90	15:33	0.2	7		1.9				0.032	4	
6/19/90	11:55	0.07	6		1				0.04	4	
1/30/91	13:23		5	0.016	4.1	0.085	0.28	0.004	0.053	9	
5/29/91	10:30	0.3	13	0.083	3.2	0.03	0.39	0.011	0.041	8	
4/7/92	8:15	0.4	10	0.032	7.1	0.012	0.61	0.002	0.014	4	0.7
4/27/92	14:00	1	17		6.6	0.021	0.97		0.066	7	10
4/30/92	·13:10	0.6	16	0.018	5.9	0.012	0.74	0.01	0.025	4	1.5
5/11/92	9:00	0.3	5		3.7	0.033	0.42	0.012	0.017	4	
5/24/92	8:15	0.2	10		2.4	0.03	0.37	0.013	0.03	4	
7/13/92	13:55	0.07	5	0.028	0.97	0.055	0.47	0.022	0.046	10	
04/26/93	13:00	0.39	12		3.000	0.040	0.580		0.060	21	
05/03/93	11:40	0.41	6	0.330	2.700	0.500	0.470	0.012	0.028	4	
05/10/93	08:20	0.3	11	0.038	2.500	0.039	0.320	0.011	0.021	4	
05/17/93	08:45	0.18	7	0.038	2.100	0.072	0.290	0.010	0.023	4	
05/24/93	13:40	0.15	10	0.040	1.650	0.090	0.390	0.019	0.041	5	
06/02/93	13:50	0.15	6	0.025	1.670	0.052	0.300	0.005	0.030	4	
06/14/93	12:57	0.45	16	0.074	3.700	0.086	0.700	0.012	0.075	6	3.4
06/21/93	14:00	3.8	22		12.000	0.090	1.200		0.112	4	6
06/28/93	09:48	0.32	14	0.067	8.000	0.084	0.900	0.037	0.074	11	
07/06/93	12:20	0.28	11	0.065		0.500	0.480	0.028	0.042	7	
07/13/93	11:35	0.32	12	0.040	5.300	0.028	0.540	0.020	0.036	4	2.6
07/19/93	16:10	0.26	9	0.036	5.200	0.048	0.440	0.200	0.032	4	2.1
07/29/93	13:30	0.25	6	0.022	3.100	0.044	0.440	0.019	0.033	4	
04/08/94	12:00		6	0.011	3.20	0.014	0.33	0.008	0.016	4	2.5
04/14/94	12:00	0.5	18	0.016	5.40	0.2	0.61	0.012	0.032	4	2.2
04/19/94	12:00	0.05	12	0.015	4.20	0.016	0.39	0.01	0.03	4	2.5
04/26/94	12:00	0.26	13	0.033	2.70	0.014	0.38	0.006	0.029	4	2.6
05/03/94	12:00	0.45	5	0.024	5.30	0.018	0.43	0.01	0.023	4	1.7
05/10/94	12:00	0.34	20	0.038	4.10	0.036	0.43	0.01	0.018	4	2
05/17/94	12:00	0.23	8	0.014	3.10	0.032	0.33	0.06	0.02	4	2.1
05/24/94	12:00	0.2	11	0.068	1.89	0.39	0.90	0.014	0.05	5	3.4
06/01/94	12:00	0.16	6	0.069	1.42	0.1	0.43	0.024	0.045	6	2.5
06/07/94	12:00	0.13	11	0.112	1.08	0.24	1.03	0.032	0.058	8	3.6
06/14/94	12:00	0.12	11	0.091	2.70	0.19	0.66	0.036	0.064	9	3.6
06/21/94	12:00	0.07	5	0.069	0.94	0.18	0.59	0.48	0.074	8	4.3
06/28/94	12:00	0.36	15	0.056	6.50	0.082	0.73	0.035	0.062	4	2.4
07/05/94	12:00	0.24	28	0.055	3.30	0.11	1.07	0.001	0.105	6	3.6
07/12/94	12:00	0.12	10	0.038	2.60	0.06	0.43	0.027	0.041	6	4.1
07/19/94	12:00	0.11	7	0.021	1.64	0.05	0.29	0.027	0.039	7	2.7
07/26/94	12:00	0.23	11	0.023	1.48	0.056	0.43	0.03	0.041	9	4.7
08/02/94	12:00		7	0.01	0.64	0.052	0.35	0.027	0.049	4	2.4
08/09/94	12:00		11	0.009	0.72	0.04	0.35	0.022	0.038	5	2.9
08/16/94	12:00		23	0.012	2.40	0.034	0.73	0.077	0.105	4	3.5
08/26/94	12:00		12	0.011	1.75	0.054	0.49	0.027	0.039	4	4.5
08/30/94	12:00		8	0.009	1.60	0.034	0.32	0.02	0.025	5	3.4
04/04/95	12:00		8	0.011	3	0.02	0.4	0.007	0.032	4	2.2
04/12/95	09:57		22	0.02	3.4	0.026	0.92	0.029	0.086	4	13
04/17/95	16:10		8	0.023	2.9	0.025	0.46	0.009	0.022	5	1.7
04/26/95	10:05	0.4	9	0.021	2.7	0.022	0.28	0.006	0.016	4	
05/01/95	08:26	0.35	13	0.018	3.3	0.012	0.33	0.005	0.014	4	1.2
05/08/95	12:30	0.31	8	0.02	2.2	0.008	0.36	0.006	0.019	4	2.1
05/18/95	15:39	0.23	8	0.033	1.67	0.07	0.48	0.011	0.032	4	2.4
05/24/95	09:50	0.36	29	0.38	8.7	0.69	11	0.079	0.16	29	15
06/01/95	11:45	0.18	11	0.97	1.94	0.23	0.68	0.027	0.048	6	3.2
06/08/95	09:25	0.16	11	0.073	1.6	0.17	0.47	0.027	0.054	6	2.4
06/15/95	10:00	0.12	5	0.042	1.33	0.081	0.36	0.021	0.052	6	1.9
06/21/95	10:00	0.11	24	0.043	0.91	0.29	5	0.03	0.46	7	3.2
06/28/95	09:52	0.13	10	0.047	0.98	0.13	0.69	0.032	0.127	49	6.1
07/06/95	12:30	0.28	11	0.05	2.9	0.076	0.41	0.026	0.047	4	2.4
07/13/95	09:30	0.18	15	0.026	0.98	0.078	0.51	0.028	0.077	24	6.2

Table C1. continued Grab Samples From Marshall Drain

Marshall DATE	Marshall TIME	Marshall Flow (cfs)	Marshall COD (mg/l)	Marshall NO2 (mg/l)	Marshall NO2+NO3 (mg/l)	Marshall NH3 (mg/l)	Marshall KN (mg/l)	Marshall O-P (mg/l)	Marshall T-P (mg/l)	Marshall Residue (mg/l)	Marshall Turb (NTU)
07/20/95	09:30	0.22	5	0.127	1.15	0.183	0.62	0.033	0.072	8	3.8
07/27/95	09:20	0.28	14	0.014	1.07	0.1	0.37	0.035	0.06	4	3.2
08/11/95	09:00			0.086	0.78	0.121	0.61	0.038	0.063	6	3.7
08/18/95	11:00			0.04	0.97	0.072	0.64	0.046	0.07	4	3
08/28/95	09:15		5	0.033	0.84	0.064	0.34	0.035	0.07	6	3.3
4/4/96	8:50	0.45	18	0.019	3	0.048	0.37	0.011	0.021	4	3.5
4/9/96	9:16	0.34	10	0.014	2.9	0.032	0.3	0.01	0.026	4	3.6
4/18/96	12:00	0.38	8	0.014	3.5	0.026	0.4	0.053	0.041	4	3.6
4/23/96	9:30	0.41	5	0.029	7.9	0.04	0.67	0.011	0.028	4	1.9
4/30/96	8:41	0.38	24	0.032	8.2	0.036	1.02	0.032	0.08	13	13
5/7/96	9:45	0.38	10	0.019	3.9	0.02	0.36	0.011	0.021	4	2.4
5/14/96	11:30	0.49	26	0.016	4.6	0.022	0.85	0.023	0.065	4	2
5/22/96	10:27	1.02	21	0.072	8.5	0.014	1.01	0.016	0.061	13	4
5/30/96	9:30	0.45	13	0.017	3.4	0.018	0.51	0.013	0.056	4	1.8
6/4/96	9:20	0.38	6	0.035	2.3	0.054	0.36	0.013	0.026	4	2.4
6/11/96	10:30	0.41	10	0.048	6.1	0.062	0.58	0.011	0.035	4	2.3
6/20/96	21:07	1.48	23	0.113	6.9	0.07	1.07	0.074	0.123	8	5.4
6/25/96	11:00	0.72	12	0.056	5.2	0.08	0.68	0.028	0.046	4	3.4
7/2/96	11:00	0.49	15	0.049	3.5	0.06	0.56	0.016	0.047	4	3.2
7/10/96	10:00	0.41	12	0.013	1.02	0.024	0.32	0.017	0.034	4	2.1
7/16/96	10:00	0.41	10	0.011	0.52	0.032	0.36	0.016	0.036	5	2.4
7/24/96	11:20	0.30	10	0.005	0.49	0.032	0.34	0.019	0.042	7	1.9
7/31/96	7:50	0.38	15	0.005	0.49	0.032	0.31	0.02	0.043	11	2.9
8/6/96	13:00	0.41	6	0.008	0.35	0.037	0.44	0.023	0.038	15	1.5
8/13/96	10:30	0.30	5	0.005	0.4	0.025	0.26	0.012	0.037	8	0.8
4/1/97	10:50	0.85	9	0.016	7.2	0.05	0.54	0.011	0.017	4	1
4/7/97	13:06	0.80	18	0.02	7.2	0.05	0.68	0.006	0.018	4	0.9
4/13/97	12:00	0.60	16	0.017	4.9	0.05	0.5	0.004	0.015	4	0.6
4/22/97	13:50	0.45	5	0.019	3.3	0.05	0.41	0.007	0.015	4	0.7
4/29/97	12:00	0.35	5	0.016	1.84	0.013	0.42	0.004	0.02	4	0.6
5/13/97	12:51	0.48	16	0.011	4.4	0.05	0.45	0.002	0.021	7	0.7
5/28/97	9:20	0.25	21	0.027	3.9	0.05	1.01	0.006	0.092	6	1.1
6/4/97	9:20	0.23	18	0.046	4.1	0.05	0.69	0.02	0.039	4	1.7
6/10/97	9:11	0.10	24	0.033	2.2	0.25	0.11	0.008	0.1	5	1.2
6/17/97	8:40	0.20	17	0.021	3	0.05	0.49	0.013	0.029	4	1.2
6/30/97	9:21	0.30	.15	0.036	4.5	0.11	0.58	0.016	0.049	12	1.5
7/8/97	14:45	0.30	19	0.024	3.4	0.05	0.59	0.029	0.045	7	2.5
7/15/97	15:00	0.30	12	0.009	2.8	0.05	0.52	0.021	0.038	4	2.1
7/22/97	10:30	0.28	14	0.009	1.1	0.032	0.52	0.025	0.045	4	2.2
7/29/97	10:30	0.20	7	0.008	0.91	0.029	0.33	0.029	0.043	10	1.7
8/5/97	9:44	0.23	8	0.007	0.85	0.032	0.35	0.023	0.037	7	2
8/11/97	11:07	0.18	10	0.007	0.84	0.03	0.39	0.024	0.046	4	1.5

Table C2. Grab Sample Results From Haines Drain

Haines Date	Haines Time	Haines Flow (cfs)	Haines COD (mg/l)	Haines NO2 (mg/l)	Haines NO2+NO3 (mg/l)	Haines NH3 (mg/l)	Haines KN (mg/l)	Haines O-P (mg/l)	Haines T-P (mg/l)	Haines Residue (mg/l)	Haines Turb (NTU)
3/26/90	15:00	2	13	0.014	4	0.02	0.66	0.008	0.023	5	1.5
5/2/90	15:25		23		3	0.01	0.85		0.041	8	
5/4/90	11:22	0.9	25		3.1	0.11	0.94		0.057	9	
5/9/90	13:05	0.6	17		2.3	0.022	0.7		0.04	6	
5/14/90	17:00	0.7	16		2.7				0.041	5	
6/5/90	17:08	0.6	16		2.7				0.07	7	
6/19/90	10:40	0.4	18		1.8				0.123	16	
1/30/91	13:45		9	0.016	4.1	0.03	0.42	0.03	0.043	5	
5/29/91	10:10	0.4	21	0.129	2.7	0.31	1.07	0.044	0.103	14	
4/7/92	10:15	0.9	16	0.013	4.8	0.004	0.48	0.004	0.021	6	2
4/30/92	12:55	2	20	0.014	4	0.02	0.79	0.027	0.054	7	6.4
5/11/92	10:45	0.6	20		3	0.01	0.73	0.015	0.046	4	
5/24/92	9:45	0.4	18		2.9	0.058	0.67	0.022	0.057	5	
6/17/92	11:45	0.3	8	0.088	2.5	0.124	0.78	0.034	0.061	11	
7/13/92	13:10	0.2	14	0.023	1.03	0.05	0.52	0.048	0.094	16	
04/26/93	15:00	1.5	19		1.650	0.015	0.600		0.480	7	
05/03/93	12:35	0.95	17	0.014	1.960	0.016	0.700	0.005	0.450	4	
05/10/93	09:45	1.05	27	0.021	1.870	0.016	0.770	0.012	0.056	4	
05/17/93	10:20	1.05	23	0.033	1.700	0.200	0.860	0.064	0.117	4	
05/24/93	14:50	0.532	21	0.066	1.620	0.140	0.760	0.055	0.088	5	
06/02/93	15:20	0.548	21	0.053	1.600	0.146	0.690	0.025	0.070	5	
06/14/93	11:50	1.1	30	0.870	2.900	0.570	1.560	0.041	0.183	59	16
06/21/93	13:45	8.5	37		6.500	0.220	1.580		0.340	26	15
06/28/93	11:20	8.1	33	0.058	6.800	0.160	1.790	0.139	0.380	91	
07/06/93	12:00	0.95	13	0.075		0.078	0.650	0.072	0.113	13	
07/13/93	13:57	0.95	22	0.059	4.500	0.066	0.640	0.045	0.088	8	2.5
07/19/93	14:40	0.564	17	0.036	2.700	0.054	0.720	0.031	0.061	9	2.8
07/29/93	13:00	0.564	20	0.037	2.300	0.060	0.570	0.032	0.057	5	
04/08/94	12:00		7	0.1	2.80	0.03	0.54	0.012	0.026	4	2.2
04/14/94	12:00		25	0.11	3.50	0.022	0.66	0.017	0.046	7	2.4
04/19/94	12:00	1.13	17	0.014	3.30	0.024	0.56	0.012	0.031	4	1.6
04/26/94	12:00	0.6	30	0.014	2.50	0.046	1.34	0.008	0.115	20	2.2
05/03/94	12:00	1.27	16	0.013	3.90	0.018	0.75	0.009	0.042	4	1.5
05/10/94	12:00	0.89	20	0.014	3.10	0.016	0.68	0.006	0.05	7	1.5
05/17/94	12:00	0.58	18	0.017	2.80	0.034	0.72	0.007	0.048	6	1.9
05/24/94	12:00	0.5	14	0.059	2.30	0.31	0.86	0.012	0.068	7	1.7
06/01/94	12:00	0.4	10	0.069	2.20	0.22	0.62	0.029	0.059	6	2.1
06/07/94	12:00	0.41	13	0.092	1.88	0.31	0.75	0.04	0.066	7	2.9
06/14/94	12:00	0.85	20	0.12	8.50	0.28	1.06	0.04	0.097	11	4.2
06/21/94	12:00	0.49	14	0.106	3.10	0.18	0.73	0.037	0.013	24	5.9
06/28/94	12:00	1.48	24	0.068	6.90	0.14	1.05	0.061	0.113	11	2.2
07/05/94	12:00	1.18	23	0.078	3.30	0.14	1.03	0.001	0.136	21	6.9
07/12/94	12:00	0.5	13	0.052	3.50	0.05	0.57	0.035	0.053	6	1.8
07/19/94	12:00	0.43	9	0.041	2.50	0.058	0.53	0.031	0.054	11	2.4
07/26/94	12:00	0.66	22	0.029	2.30	0.04	0.38	0.025	0.045	6	1.8
08/02/94	12:00		14	0.027	1.59	0.05	0.52	0.036	0.086	21	2.8
08/09/94	12:00		12	0.022	1.39	0.046	0.48	0.027	0.055	7	2
08/16/94	12:00		26	0.018	3.00	0.036	0.83	0.07	0.109	8	2.6
08/26/94	12:00		21	0.023	1.61	0.056	0.76	0.08	0.119	5	2.7
08/30/94	12:00		16	0.021	1.93	0.048	0.43	0.033	0.058	9	2
04/04/95	12:20		15	0.008	3.2	0.016	0.5	0.007	0.045	11	2.4
04/12/95	10:52	0.95	24	0.014	3.2	0.022	0.88	0.075	0.153	12	7
04/17/95	16:47	1.63	17	0.013	3.2	0.014	0.48	0.006	0.031	5	1.5
04/26/95	09:36	1	13	0.014	3.1	0.024	0.42	0.004	0.02	6	
05/01/95	09:01		16	0.014	3.4	0.022	0.45	0.004	0.02	4	1
05/08/95	12:45		12	0.014	2.8	0.013	0.51	0.005	0.025	4	1.6
05/18/95	16:25	0.56	15	0.036	2.7	0.098	0.56	0.008	0.035	4	1.8
05/24/95	08:40	1.04	21	0.082	3	0.6	2	0.04	0.092	17	5.1
06/01/95	10:00	0.47	12	0.071	3	0.1	0.45	0.021	0.051	11	2.6
06/08/95	08:15	0.48	16	0.083	2.4	0.22	0.61	0.027	0.051	5	2.5
06/15/95	08:45	0.43	7	0.081	1.95	0.23	0.59	0.027	0.055	7	2.4
06/21/95	09:00	0.39	10	0.086	1.44	0.177	0.57	0.043	0.07	5	2.4
06/28/95	08:42	0.49	16	0.07	2.6	0.086	0.55	0.024	0.055	10	1.8

Table C2 continued. Grab Sample Results From Haines Drain

Haines Date	Haines Time	Haines Flow (cfs)	Haines COD (mg/l)	Haines NO2 (mg/l)	Haines NO2+NO3 (mg/l)	Haines NH3 (mg/l)	Haines KN (mg/l)	Haines O-P (mg/l)	Haines T-P (mg/l)	Haines Residue (mg/l)	Haines Turb (NTU)
07/06/95	10:42	0.64	14	0.064	4.8	0.056	0.5	0.02	0.057	10	2.1
07/13/95	08:30	0.41	16	0.052	2.1	0.05	0.51	0.036	0.081	22	6.8
07/20/95	08:30	0.35	11	0.028	1.26	0.055	0.54	0.038	0.1	34	7.2
07/27/95	09:45	0.54	31	0.042	2.5	0.07	0.95	0.046	0.118	27	7.5
08/11/95	08:30			0.018	1.06	0.044	0.48	0.041	0.089	15	4.4
08/18/95	10:45			0.045	2.6	0.08	1.17	0.099	0.22	45	12
08/28/95	08:45		10	0.015	1.55	0.034	0.39	0.032	0.069	10	2.5
4/4/96	9:20	0.53	18	0.014	4.1	0.042	0.51	0.005	0.023	4	1.5
4/9/96	9:50	0.46	6	0.01	3.7	0.028	0.4	0.008	0.017	4	1.8
4/18/96	12:00	0.64	14	0.013	3.8	0.012	0.57	0.006	0.034	4	1.3
4/23/96	8:45	0.56	5	0.022	7.8	0.034	0.81	0.014	0.041	4	1.8
4/30/96	9:32	0.72	24	0.016	6.2	0.03	0.92	0.053	0.098	13	4.6
5/7/96	10:30	0.8	13	0.02	6.4	0.012	0.42	0.003	0.015	4	0.9
5/14/96	9:30	1.5	17	0.024	8.1	0.012	0.58	0.004	0.017	4	0.8
5/22/96	8:58	0.92	16	0.04	8.2	0.034	0.99	0.017	0.056	4	1.8
5/30/96	8:30	0.58	6	0.033	5.8	0.03	0.64	0.009	0.021	5	1.3
6/4/96	8:30	0.53	10	0.064	4.9	0.14	0.71	0.009	0.029	4	1.8
6/11/96	9:30	0.72	10	0.059	8	0.13	0.74	0.014	0.04	4	1.8
6/20/96	18:41	0.72	23	0.049	11	0.12	1.22	0.007	0.109	20	5.1
6/25/96	10:00	0.49	14	0.109	8	0.23	1.01	0.055	0.088	9	2.7
7/2/96	10:30	0.64	11	0.125	6.5	0.18	0.79	0.019	0.05	11	4.1
7/10/96	9:15	0.67	14	0.074	4.6	0.11	0.62	0.027	0.075	20	7.5
7/16/96	10:15	0.49	15	0.085	4.2	0.09	0.65	0.021	0.063	38	5.6
7/24/96	11:00	0.58	12	0.087	3.4	0.1	0.58	0.03	0.059	12	4.8
7/31/96	7:40	0.64	8	0.054	2.7	0.07	0.49	0.029	0.056	12	4.5
8/6/96	12:00	0.53	8	0.036	1.8	0.037	0.42	0.026	0.064	62	13
8/13/96	10:00	0.58	6	0.015	1.19	0.031	0.36	0.026	0.053	15	1.7
4/1/97	12:15	0.45	21	0.015	6	0.05	0.6	0.052	0.035	4	4.3
4/7/97	13:50	0.44	23	0.017	5.7	0.05	0.75	0.007	0.036	8	3.7
4/13/97	12:00	1.25	20	0.014	4.9	0.05	0.57	0.006	0.02	4	0.9
4/22/97	14:20	0.89	12	0.022	5.1	0.05	0.61	0.009	0.024	10	1.1
4/29/97	12:00	1	14	0.031	4.4	0.05	0.57	0.009	0.029	4	0.8
5/13/97	13:10	1.42	18	0.026	5.5	0.05	0.58	0.002	0.022	4	0.8
5/28/97	9:50	1.17	19	0.025	4.8	0.05	0.8	0.004	0.043	8	1.1
6/4/97	9:50	1.17	22	0.033	4.9	0.05	0.7	0.009	0.034	8	0.8
6/10/97	9:42	0.92	17	0.057	4.3	0.07	0.6	0.013	0.036	4	1.3
6/17/97	9:30	0.83	15	0.095	3.7	0.14	0.68	0.025	0.045	4	1.6
6/30/97	9:51	0.78	10	0.118	5.2	0.09	0.7	0.021	0.046	9	2.3
7/8/97	15:00	0.78	25	0.07	4.5	0.06	0.71	0.017	0.059	16	4.8
7/15/97	15:30	0.48	11	0.011	1.44	0.032	0.33	0.001	0.01	5	1.2
7/22/97	11:00	0.43	21	0.029	2.4	0.05	0.67	0.022	0.062	9	3.2
7/29/97	11:00	0.38	9	0.015	2.3	0.028	0.54	0.019	0.056	17	2.8
8/5/97	9:57	0.36	9	0.015	2.1	0.038	0.54	0.023	0.057	19	6.2
8/11/97	11:20	0.38	5	0.009	1.97	0.011	0.46	0.012	0.04	4	1.3

Table C3. Grab Sample Results From Willow Creek

Willow DATE	Willow TIME	Willow Flow (cfs)	Willow COD (mg/l)	Willow NO2 (mg/l)	Willow No2+NO3 (mg/l)	Willow NH3 (mg/l)	Willow KN (mg/l)	Willow O-P (mg/l)	Willow T-P (mg/l)	Willow Residue (mg/l)	Willow Turb (NTU)
3/26/90	12:00	3	10	0.014	2.9	0.014	0.53	0.003	0.023	14	3.9
5/2/90	15:40	3	11		2.3	0.01	0.64		0.029	5	
5/9/90	13:52	3	10		2.2	0.02	0.49		0.021	6	
5/14/90	15:50	3	14		2.2				0.023	8	
6/5/90	16:18	3	9		2.1				0.027	15	
6/19/90	11:20	2	9		2.1				0.2	14	
1/30/91	13:31		10	0.015	2.7	0.04	0.32	0.003	0.043	7	
2/12/91	12:06			0.015	2.8	0.006	0.3	0.003	0.015	9	
3/14/91	10:30		11		2.4	0.008	0.43	0.001	0.019	7	2
3/25/91	13:50	3			2.5	0.014	0.39		0.022	7	
4/7/91	15:35	3			2.5	0.016	0.44	0.001	0.02	12	
4/19/91	9:25	2			2.3	0.02	0.54	0.001	0.019	9	
5/29/91	10:40	2	15	0.013	2	0.028	0.48	0.002	0.03	13	
4/7/92	9:15	3	15	0.012	2.6	0.012	0.58	0.001	0.019	8	1.9
4/27/92	11:30	4	27		3.5	0.022	1.02		0.033	14	2.7
4/30/92	12:30	3	20	0.013	2.7	0.018	0.6	0.005	0.025	10	2.1
5/11/92	10:00	3	16		2.2	0.018	0.53	0.002	0.024	10	
5/24/92	8:50	2	15		2.1	0.012	0.62	0.002	0.024	15	
7/13/92	14:40	2	18	0.011	1.59	0.026	0.5	0.004	0.027	16	
04/26/93	13:40	4	19		2.600	0.028	0.610		0.031	15	
05/03/93	11:20	4.19	23	0.016	2.400	0.042	0.720	0.003	0.038	17	
05/10/93	09:00	3.44	21	0.017	2.500	0.030	0.600	0.002	0.029	9	
05/17/93	09:45	3.1	17	0.015	2.600	0.026	0.430	0.002	0.019	11	
05/24/93	14:20	3.16	17	0.016	2.400	0.026	0.570	0.003	0.041	27	
06/02/93	14:30	3.02	14	0.014	2.300	0.034	0.530	0.003	0.024	13	
06/14/93	13:50	4.07	43	0.019	1.900	0.084	1.160	0.003	0.099	78	7.4
06/28/93	12:20	3.44	40	0.015	1.800	0.054	1.150	0.009	0.066	33	
07/06/93	11:20	3.44	22	0.016		0.042	0.880	0.005	0.063	40	
07/13/93	13:00	4	24	0.015	2.400	0.044	0.560	0.002	0.029	12	2.3
07/29/93	14:00	3.44	13	0.014	2.300	0.044	0.580	0.004	0.023	10	
04/08/94	12:00		7	0.021	2.50	0.034	0.46	0.003	0.015	7	1.7
04/14/94	12:00	5.03	26	0.017	2.50	0.024	0.68	0.001	0.017	12	1.4
04/19/94	12:00	4.66	19	0.018	2.40	0.026	0.50	0.004	0.018	6	1.6
04/26/94	12:00	4.47	14	0.018	2.30	0.022	0.42	0.002	0.018	7	1.3
05/03/94	12:00	4.49	19	0.019	2.20	0.032	0.69	0.002	0.031	5	1.3
05/10/94	12:00	4.33	12	0.019	2.10	0.028	0.49	0.004	0.018	14	1.5
05/17/94	12:00	4.11	20	0.017	2.00	0.034	0.59	0.001	0.031	18	2.5
05/24/94	12:00	3.97	14	0.021	2.20	0.14	0.62	0.004	0.028	11	1.5
06/01/94	12:00	3.52	10	0.017	2.10	0.042	0.41	0.005	0.016	9	1.5
06/07/94	12:00	3.44	11	0.017	2.10	0.052	0.48	0.005	0.023	9	1.6
06/14/94	12:00	3.98	16	0.019	1.73	0.068	0.57	0.007	0.023	9	1.3
06/21/94	12:00	3.52	8	0.02	1.93	0.046	0.50	0.004	0.022	8	1.6
06/28/94	12:00	4.45	28	0.018	2.00	0.076	0.77	0.009	0.033	13	2.1
07/05/94	12:00	3.93	23	0.019	1.67	0.064	0.89	0	0.048	21	3.9
07/12/94	12:00	3.92	14	0.016	1.90	0.044	0.59	0.004	0.025	10	1.8
07/19/94	12:00	3.75	12	0.015	1.97	0.044	0.53	0.006	0.028	15	2.2
07/26/94	12:00	4.69	15	0.015	1.91	0.042	0.47	0.008	0.024	8	1.7
08/02/94	12:00		13	0.013	2.00	0.04	0.51	0.004	0.022	10	1.8
08/09/94	12:00		10	0.011	1.87	0.036	0.45	0.003	0.021	8	1.8
08/16/94	12:00		32	0.013	1.86	0.054	0.97	0.001	0.045	22	2
08/26/94	12:00		18	0.009	1.73	0.048	0.61	0.004	0.021	4	1.6
08/30/94	12:00		16	0.013	1.74	0.056	0.50	0.003	0.019	10	1.7
04/04/95	12:45		9	0.011	2.3	0.026	0.41	0.002	0.014	4	1
04/12/95	09:44		23	0.012	2.1	0.022	0.82	0.002	0.017	6	0.9
04/17/95	17:08		17	0.013	2.3	0.026	0.53	0.001	0.019	9	1.4
04/26/95	09:55		11	0.015	2.1	0.038	0.38	0.002	0.013	4	
05/01/95	09:38		16	0.016	2.2	0.028	0.42	0.001	0.011	4	0.08
05/08/95	13:15		16	0.015	2.1	0.03	0.42	0.002	0.014	5	0.08
05/18/95	17:15		8	0.018	2.1	0.05	0.46	0.001	0.012	4	0.8
06/01/95	11:10		13	0.021	2	0.074	0.41	00:05	0.016	4	0.08
06/08/95	09:00		14	0.02	2.1	0.08	0.42	0.033	0.016	4	1.4
06/15/95	09:15		5	0.018	2	0.07	0.38	0.002	0.02	4	1.2
06/21/95	09:45		14	0.019	2.1	0.064	0.55	0.004	0.026	16	2.5

Table C3. continued. Grab Sample Results From Willow Creek

Willow DATE	Willow TIME	Willow Flow (cfs)	Willow COD (mg/l)	Willow NO2 (mg/l)	Willow No2+NO3 (mg/l)	Willow NH3 (mg/l)	Willow KN (mg/l)	Willow O-P (mg/l)	Willow T-P (mg/l)	Willow Residue (mg/l)	Willow Turb (NTU)
06/28/95	09:10		11	0.018	1.88	0.068	0.41	0.002	0.014	7	1
07/06/95	11:35		12	0.02	1.78	0.072	0.46	0.003	0.02	4	1.6
07/13/95	09:15		14	0.018	1.94	0.05	0.39	0.035	0.015	5	1.2
07/20/95	09:15		8	0.016	1.99	0.058	0.44	0.004	0.016	4	1.3
07/27/95	09:50		14	0.017	1.9	0.056	0.36	0.004	0.014	4	1.2
08/11/95	08:50			0.015	1.83	0.048	0.4	0.004	0.017	8	2.3
08/18/95	11:20			0.019	1.75	0.062	0.92	0.009	0.047	24	4.2
08/28/95	09:00		10	0.015	1.84	0.06	0.46	0.006	0.025	12	2.5
4/4/96	9:40	1.39	21	0.012	1.8	0.05	0.42	0.004	0.018	5	1.8
4/9/96	10:20	1.00	6	0.011	1.8	0.024	0.29	0.003	0.014	4	1.9
4/18/96	12:00	1.39	21	0.012	1.89	0.016	0.55	0.003	0.028	12	2
4/23/96	9:45	1.59	5	0.012	2.5	0.044	0.75	0.003	0.029	12	2.4
4/30/96	10:26	1.69	23	0.011	2.2	0.03	0.68	0.003	0.02	7	1.7
5/7/96	11:15	1.49	21	0.011	1.65	0.02	0.45	0.002	0.016	6	1.5
5/14/96	10:30	3.45	20	0.011	1.81	0.016	0.57	0.002	0.017	8	1.6
5/22/96	7:13	2.29	22	0.031	1.97	0.03	0.9	0.001	0.034	18	1.8
5/30/96	9:00	1.69	17	0.012	1.32	0.04	0.44	0.005	0.02	6	1.8
6/4/96	9:00	1.49	9	0.012	1.24	0.042	0.52	0.003	0.024	12	2.2
6/11/96	10:00	1.39	18	0.012	1.07	0.047	0.71	0.001	0.032	12	2.6
6/20/96	20:06	3.62	46	0.074	2.5	0.051	1.3	0.044	0.08	48	5
6/25/96	10:30	1.69	21	0.013	1.44	0.091	0.8	0.004	0.027	6	1.7
7/2/96	10:00	1.59	16	0.01	1.57	0.07	0.58	0.002	0.028	12	2.7
7/10/96	9:45	1.49	14	0.01	1.23	0.048	0.41	0.004	0.02	6	1.8
7/16/96	10:45	1.39	13	0.01	1.24	0.039	0.51	0.003	0.023	14	3
7/24/96	11:30	1.59	9	0.01	1.35	0.042	0.42	0.004	0.02	6	2
7/31/96	8:00	1.39	11	0.008	1.26	0.037	0.46	0.005	0.027	13	3.1
8/6/96	12:45	1.29	8	0.008	1.3	0.042	0.42	0.006	0.021	23	2.8
8/13/96	10:15	1.85	13	0.007	1.27	0.048	0.53	0.003	0.024	13	1.8
4/1/97	13:30	2.95	24	0.01	2.1	0.012	0.73	0.008	0.04	28	3.8
4/7/97	14:18	1.70	23	0.018	2	0.02	0.46	0.008	0.013	4	1.2
4/13/97	14:40	1.48	15	0.008	1.91	0.017	0.42	0.002	0.011	4	1.2
4/22/97	14:30	1.59	11	0.1	1.67	0.015	0.35	0.002	0.011	4	1.2
4/29/97	14:30	1.48	10	0.011	1.76	0.018	0.39	0.001	0.01	4	1.2
5/13/97	13:30	1.48	11	0.011	1.28	0.023	0.41	0.001	0.012	6	1.1
5/28/97	10:15	1.48	13	0.011	1.58	0.03	0.49	0.001	0.023	12	1.4
6/10/97	10:15	2.61	10	0.014	1.59	0.048	0.4	0.002	0.016	5	1.4
6/17/97	10:45	1.36	11	0.011	1.42	0.041	0.42	0.001	0.014	4	1.3
6/30/97	10:18	2.61	15	0.014	1.5	0.057	0.34	0.002	0.018	4	1.1
7/8/97	15:30	1.41	17	0.014	1.49	0.058	0.55	0.004	0.02	9	1.6
7/15/97	16:00	2.25	16	0.049	3.2	0.038	0.58	0.026	0.055	12	3.7
7/22/97	11:30	3.66	14	0.011	1.49	0.036	0.36	0.003	0.013	4	1.2
7/29/97	11:30	2.48	7	0.01	1.61	0.041	0.38	0.002	0.015	11	1.9
8/5/97	10:14	3.23	10	0.01	1.54	0.042	0.34	0.003	0.013	6	1.3
8/11/97	11:54	2.69	5	0.009	1.55	0.029	0.38	0.001	0.01	4	1.2

APPENDIX D

Storm Event Sampling Results for Marshall Drain Willow Creek and Haines Drain

Table D1. Marshall Drain Storm Event Sampling Results 1990 - 1997

Date	Marshall Rainfall (IN)	Marshall Max 30 min INTENSITY (IN/30 MN)	Marshall ANTECEDENT MOISTURE 1 DAY (IN)	Marshall ANTECEDENT MOISTURE 2 DAY (IN)	Marshall ANTECEDENT MOISTURE 5 DAY (IN)	USLE EI (100'S)	Marshall PEAK FLOW (CFS)	Marshall RUNOFF VOLUME (CUB FT)	Marshall RUNOFF VOLUME (% RAIN)	Marshall RUNOFF VOLUME (in)	Marshall BASE FLOW (CFS)	Marshall SUSPEND SOLIDS (KG)	Marshall TOTAL PHOSPH (KG)	Marshall Event Mean SS (mg/l)
20-Apr-90	0.65	0.08	0	0	0.25	0.58	2.28	69317	6.96%	0.05	0.36	0	0	0
04-May-90	0.5	0.13	0	0	0	0.76	0.45	8711	1.14%	0.01	0.07	2.26	0.018	9
12-May-90	0.32	0.05	0	0	0.12	0.53	0.17	1260	0.26%	0.00	0.02			
15-May-90	0.9				0.4	1.92	0.45	11538	0.84%	0.01	0.02	4.44	0.0327	14
17-May-90	0.78	0.2	0.25	0.9	1.25	1.93	2.28	75287	6.30%	0.05	0.26	82	0.378	38
14-Jun-90	0.7		0	0	0		0.65	12246	1.14%	0.01	0.02	0	0	0
27-Mar-91	0.85		0.05	0.05	0.2	6.2	3.82	125730	9.66%	0.08	0.29	1280	3.18	359
04-Apr-91	0.35		0	0	0	0.18	0.53	6000	1.12%	0.00	0.38	0	0	0
09-Apr-91	0.82	0.45	0	0	0.35	6.18	2.76	72220	5.75%	0.05	0.51	562	1.42	275
15-Apr-91	0.72	0.14	0	0	0.68	1.67	2.64	56865	5.16%	0.04	0.53	144	0.49	89
19-Apr-91	0.83	0.1	0	0	0.54	0.94	2.98	88749	6.98%	0.06	0.49	292	1.09	116
23-Apr-91	0.4	0.24	0	0	0.94	1.26	1.52	23589	3.85%	0.02	0.65	43.4	0.199	65
25-May-91	0.58	0.24	0	0.15	0.15	1.84	0.36	1885	0.21%	0.00	0.18			
24-Apr-92	1.6	0.39			0.6	5.9	9.3	405000	16.52%	0.26	0.7	3940	10.1	344
14-Jul-92	1.15	0.35			0.5	6	1	41300	2.34%	0.03	0.2	50	0.22	43
19-Apr-93							16	488508			0.25	13073	28	945
04-May-93	0.37	0.24			0.34	1.524	0.64	5637	0.99%	0.00	0.38	16	0.06	100
07-Jun-93	1.61	0.3			1.2	6.337	2.1	84710	3.43%	0.06	0.2	138	0.58	58
14-Jun-93	0.45	0.3			0.48	2.254	0.47	5499	0.80%	0.00	0.23	12	0.05	77
19-Jun-93	2.14	0.65			0.45	17.60	11.4	273000	8.33%	0.18	0.18	5654	12.75	731
12-Apr-94	0.9	0.18				1.89	4.93	116225	8.43%	0.08	0.62	35	0.22	11
30-Apr-94	0.48	0.07			1.33	0.347	1.05	8202	1.12%	0.01	0.38	27	0.15	116
20-Jul-94	0.97	0.22			0.46	8.69	0.49	2688	0.18%	0.00	0.22	114	0.24	1498
26-Apr-95	0.64	0.075				0.5	1.28	20427	2.08%	0.01	0.4	53.5	0.22	92
10-May-95	0.36	0.1				0.48								0
04-Jul-95	0.83	0.7				10.5	0.48	14418	1.13%	0.01	0.14	4.9	0.05	12
10-May-96	1.14	0.4				4.98	4.07	86039	4.93%	0.06	0.41	647	2.4	266
21-May-96							3.63	32168			0.41	179	1	196
18-Jun-96							26.5	670000			0.27	10846	21.9	572
05-Apr-97	0.5	0.07				0.4	3.75	96123	12.55%	0.06	0.86	50.5	0.46	19
05-May-97	0.56	0.13				0.86	1.27	16124	1.88%	0.01	0.63	34.4	0.15	75
19-May-97	0.61	0.25				2.07	2.89	39436	4.22%	0.03	0.74	51.3	0.27	46
23-Jun-97	0.57	0.3			0.73	2.72	1.69	31462	3.60%	0.02	0.3	32.3	0.19	36

Table D2. Willow Creek Storm Event Sampling Results 1990 - 1997

Date	Willow Rainfall (IN)	MAXIMUM 30 MIN INTENSITY (IN/30 MN)	ANTECEDENT MOISTURE 1 DAY (IN)	2 DAY (IN)	5 DAY (IN)	Willow USLE EI (100'S)	Willow PEAK FLOW (CFS)	Willow RUNOFF VOLUME (CUB FT)	Willow RUNOFF VOLUME (% RAIN)	Willow RUNOFF VOLUME (in)	Willow BASE FLOW (CFS)	Willow SUSPEND SOLIDS (KG)	Willow TOTAL PHOSPH (KG)	Willow Event Mean SS (mg/l)
10-Apr-90	0.75	0.05	0	0	0	0.35	4.5	41359	1.40%	0.01	3.5	235	0.301	201
20-Apr-90	0.75	0.1	0	0	0.2	0.83	4.35	63585	2.15%	0.02	3.06			
04-May-90	0.62	0.15	0	0	0	1.10	3.62	14970	0.61%	0.00	2.5	64.8	0.201	153
12-May-90	0.45	0.05	0.05	0.05	0.25	0.23	3.46	20700	1.17%	0.01	2.9	64.1	0.1	109
15-May-90	0.9				0.7	1.84	4.1	34592	0.97%	0.01	2.98			
17-May-90	0.7	0.15	0.3	0.87	1.35	1.38	4.9	46975	1.70%	0.01	3.38	327.5	0.517	246
14-Jun-90	0.95	0.78	0	0	0	13.75	4.3	23412	0.62%	0.01	2.62	468	0.758	706
27-Mar-91	1.09	0.47	0.12	0.12	0.25	7.9	5.94	275075	6.40%	0.07	2.66	4211	5.43	541
04-Apr-91	0.4	0.05	0	0	0	0.21	3.19	31554	2.00%	0.01	2.51			
09-Apr-91	0.84	0.59	0	0	0.4	7.67	5.18	95531	2.88%	0.02	2.66	2427	3.2	897
15-Apr-91	0.7	0.11	0	0	0.75	0.89	4.26	51703	1.87%	0.01	2.58	497	1.29	339
19-Apr-91	0.88	0.08	0	0	0.52	0.8	4.64	112373	3.24%	0.03	2.58	1249	2.77	392
23-Apr-91	0.28	0.18	0	0.06	0.92	0.77	4.1	32792	2.97%	0.01	2.73	293	0.52	316
27-Apr-91	0.27	0.1	0	0	0.28	0.30	2.96	13266	1.25%	0.00	2.58			
05-May-91	0.52	0.16	0	0	0	0.97	3.04	26493	1.29%	0.01	2.28			
25-May-91	0.48	0.16	0	0.15	0.15	0.88	2.13	11527	0.61%	0.00	1.9			
24-Apr-92	1.65	0.33			0.43	4.9	8.1	599000	9.20%	0.15	2.3	4732	9.1	279
14-Jul-92	1.05	0.36			0.55	5.83	7.75	157000	3.79%	0.04	2.36	2418	3.9	544
19-Apr-93							17.54	1137000			3.02	2764	6.86	86
04-May-93	0.49	0.32			0.45	2.46	5.26	37800	1.96%	0.01	3.79	461	0.7	431
05-Jun-93	0.8	0.1			0.5	0.996	4.77	29573	0.94%	0.01	3	528	0.73	630
07-Jun-93	1.54	0.47			0.8	8.88	7.43	272000	4.48%	0.07	3	3186	3.9	414
14-Jun-93	0.5	0.36			0.74	3.28	4.98	36027	1.83%	0.01	2.74	376	0.48	369
19-Jun-93	1.97	0.67			0.5	18.7	10.4	602800	7.75%	0.15	2.74	5698	8.8	334
18-Jul-93	0.87	0.71			0.2	12.50	7.43	91240	2.66%	0.02	3.5	899	1.34	348
12-Apr-94	0.9	0.18				1.89	6.79	47764	1.34%	0.01	4.5	802	1.25	593
30-Apr-94	0.48	0.07			1.33	0.347	6.4	19710	1.04%	0.00	4.7	189	0.4	339
23-Jun-94	3.85	0.5			0	25.5	11.8	148100	0.97%	0.04	3.5	4007	7.7	955
20-Jul-94	0.97	0.22			0.46	8.69	6.9	55700	1.46%	0.01	4	770	1.9	
26-Apr-95	0.64	0.075				0.52	2.7	35005	1.39%	0.01	1.7	95.7	0.13	97
10-May-95							5.3	121728			2.2	475	0.8	138
30-Jun-95							3	103304			1.32	47	0.15	16
10-May-96	1.13	0.41				5.6	4.23	93946	2.11%	0.02	1.69			
21-May-96	0.9	0.25				3.35	4.83	38187	1.08%	0.01	2.59	376	0.64	348
18-Jun-96	3.18	0.34				14.7	14.1	618837	4.93%	0.16	1.79	14953	20.4	853
05-Apr-97							3.96	75088			1.8	51.5	0.25	24
05-May-97	0.7	0.19				1.22	4.59	146861	5.32%	0.04	2.1	305	0.5	73
19-May-97	0.63	0.15				1.25	4.48	144307	5.81%	0.04	1.19	173	0.38	42
23-Jun-97							7.27	176553			2.31	312	0.62	62

Table D3. Haines Drain Storm Event Sampling Results 1990 - 1997

Date	Haines Rainfall (IN)	MAXIMUM 30 MIN INTENSITY (IN/30 MN)	ANTECEDENT MOISTURE 1 DAY (IN)	ANTECEDENT MOISTURE 2 DAY (IN)	ANTECEDENT MOISTURE 5 DAY (IN)	Haines USLE EI (100'S)	Haines PEAK FLOW (CFS)	Haines RUNOFF VOLUME (CUB FT)	Haines RUNOFF VOLUME (% RAIN)	Haines RUNOFF VOLUME (in)	Haines BASE FLOW (CFS)	Haines SUSPEND SOLIDS (KG)	Haines TOTAL PHOSPH (KG)	Haines Event Mean SS (mg/l)
10-Apr-90	0.75	0.05	0	0	0	0.36	9.9	237463	10.29%	0.08	2.4	367	1.73	55
20-Apr-90	0.7	0.13	0	0	0.2	0.97	16.3	467764	21.71%	0.15	2.2	1184	4.72	89
04-May-90	0.55	0.15	0	0	0	1.00	1.1	16699	0.99%	0.01	0.7	0	0	0
12-May-90	0.55	0.07	0	0	0.25	0.40	0.6	0	0.00%	0.00	0.6	0	0	0
15-May-90	1.18				0.55	4.29	8.6	440181	12.12%	0.14	0.61	659	3.13	53
17-May-90	0.85	0.2	0.17	1.14	1.55	2.36	27.4	1121320	42.86%	0.36	2.55	3556	19.3	112
14-Jun-90	0.1	0.1	0	0	0		0.5	0	0.00%	0.00	0.45	0	0	0
22-Mar-91	0.5	0.22	0	0		1.89	4.95	103582	6.73%	0.03	1.1	570	2.54	194
23-Mar-91	0.2	0.035	0	0.5		0.08	3.9	51600	8.38%	0.02	2.3	78	1.1	53
27-Mar-91	0.76	0.41	0.07	0.07	0.34	5.68	20.3	918690	39.27%	0.30	2	6459	32	248
04-Apr-91	0.35	0.07	0	0	0	0.27	1.5	0	0.00%	0.00	1.18			
09-Apr-91	0.77	0.53	0	0	0.35	6.66	7	216405	9.13%	0.07	1.18	1353	4.96	221
15-Apr-91	0.64	0.13	0	0	0.68	0.95	8.3	197640	10.03%	0.06	1.7	497	3.71	89
19-Apr-91	1.13	0.12	0	0	0.5	1.53	15.7	638175	18.35%	0.21	1.9	2842	17	157
23-Apr-91	0.33	0.2	0	0.06	1.2	0.95	8.15	146739	14.45%	0.05	3.7	409	1.89	98
27-Apr-91	0.31	0.1	0	0	0.4	0.36	2.4	23832	2.50%	0.01	1.9			
25-May-91	0.7	0.27	0.13	0.35	0.35	2.63	0.55	5288	0.25%	0.00	0.32			
24-Apr-92	1.8	0.37			0.85	6.3	35.5	1472000	26.57%	0.48	2.5	12560	55.7	301
14-Jul-92	1.1	0.45			0.65	8.10	1.02	15494	0.46%	0.01	0.25	263	0.404	599
19-Apr-93	1.6	0.17				3.593	43.2	2181000	44.28%	0.71	1.3	3720	15.4	60
04-May-93	0.2	0.2			0.5	0.866	1.36	10197	1.66%	0.00	0.9	33	0.16	114
05-Jun-93	0.7	0.1			0.55	0.861	0.82	4955	0.23%	0.00	0.548	23.6	0.15	168
07-Jun-93	1.64	0.4			1.25	7.82	9.1	343363	6.80%	0.11	0.82	1551	15.9	160
14-Jun-93							1.05	2144			0.9	40	0.15	659
19-Jun-93	2.3	0.69			0	24	24.1	604000	8.53%	0.20	1.36	10950	41.6	640
12-Apr-94							4.65	227573			0.6	200	1.6	31
30-Apr-94	0.47	0.06			1.37	0.26	6.52	162000	11.20%	0.05	2.2	145	1.2	32
23-Jun-94	3.61	0.51			0.43	23.6	20.5	1025000	9.22%	0.33	1	3697	21.1	127
20-Jul-94							0.93	7377			0.45	27	0.2	129
26-Apr-95	0.57	0.08				0.46	2.97	70610	4.02%	0.02	0.93	108	0.46	54
24-May-95							1.8	54827			0.62	85	0.56	55
10-May-96	0.55	0.08				0.36	6.85	167304	9.88%	0.05	0.78	334	2.1	70
21-May-96	1.05	0.21				3.2	10.4	227097	7.03%	0.07	0.8	1032	3.6	160
18-Jun-96	2.3	0.37				11.3	24.8	1553000	21.94%	0.50	0.7	137388	48.5	3124
05-Apr-97	0.42	0.06				0.28	6.11	156886	12.13%	0.05	1.58	160	1.18	36
05-May-97	0.52	0.17				0.87	3.31	59671	3.73%	0.02	0.89	229	0.53	136
19-May-97	0.94	0.32				4.38	29.2	907734	31.37%	0.29	1.5	13913	26.9	541
21-Jun-97	1.37	0.63				12.48	12.9	211000	5.00%	0.07	0.92	2735	6.25	458

APPENDIX E

Plots of Flow Suspended Solids Total Phosphorus and NO_2+NO_3 at Holt Road for 1995-1997

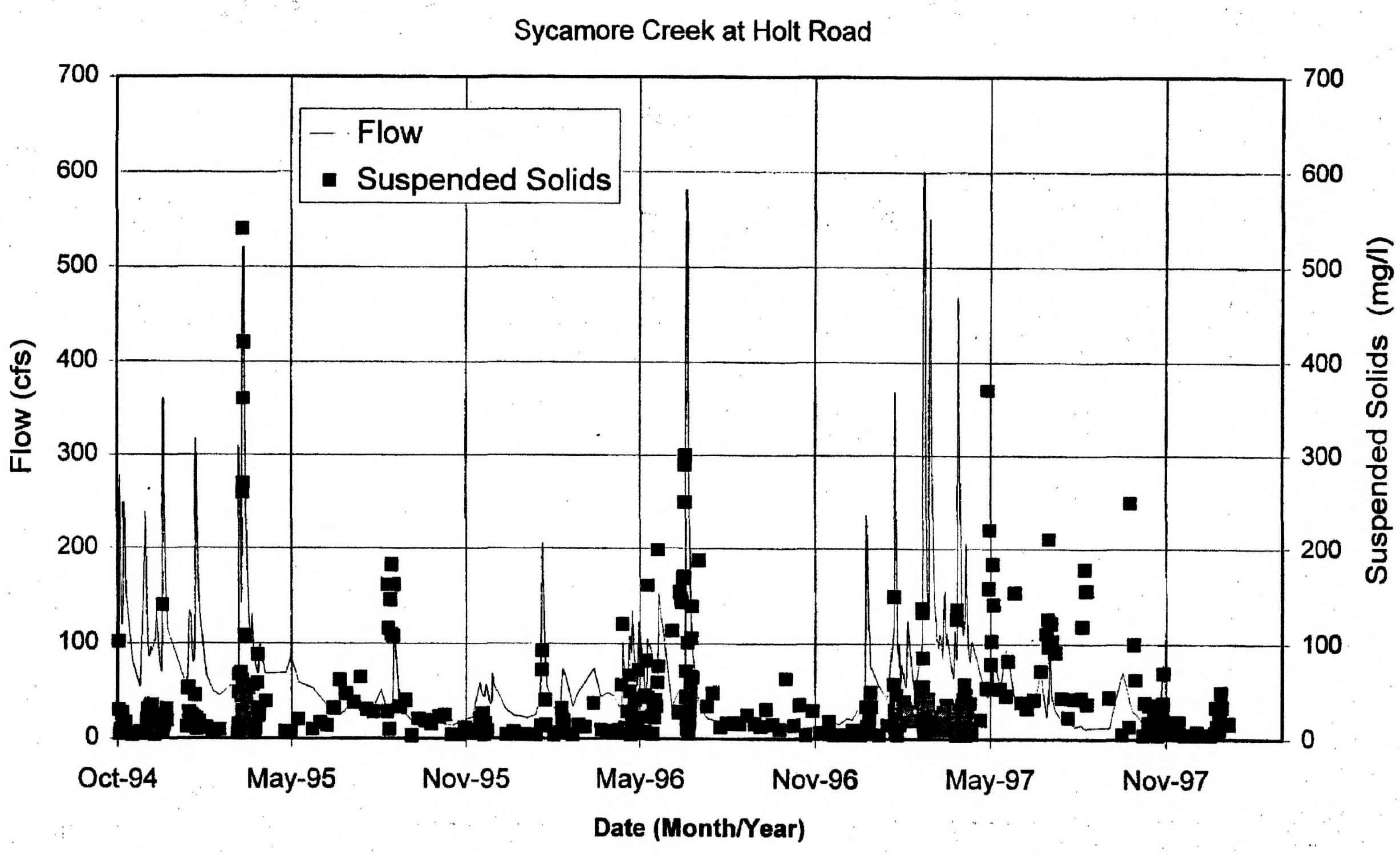

Figure E1. Flow and Suspended Solids at Holt Road

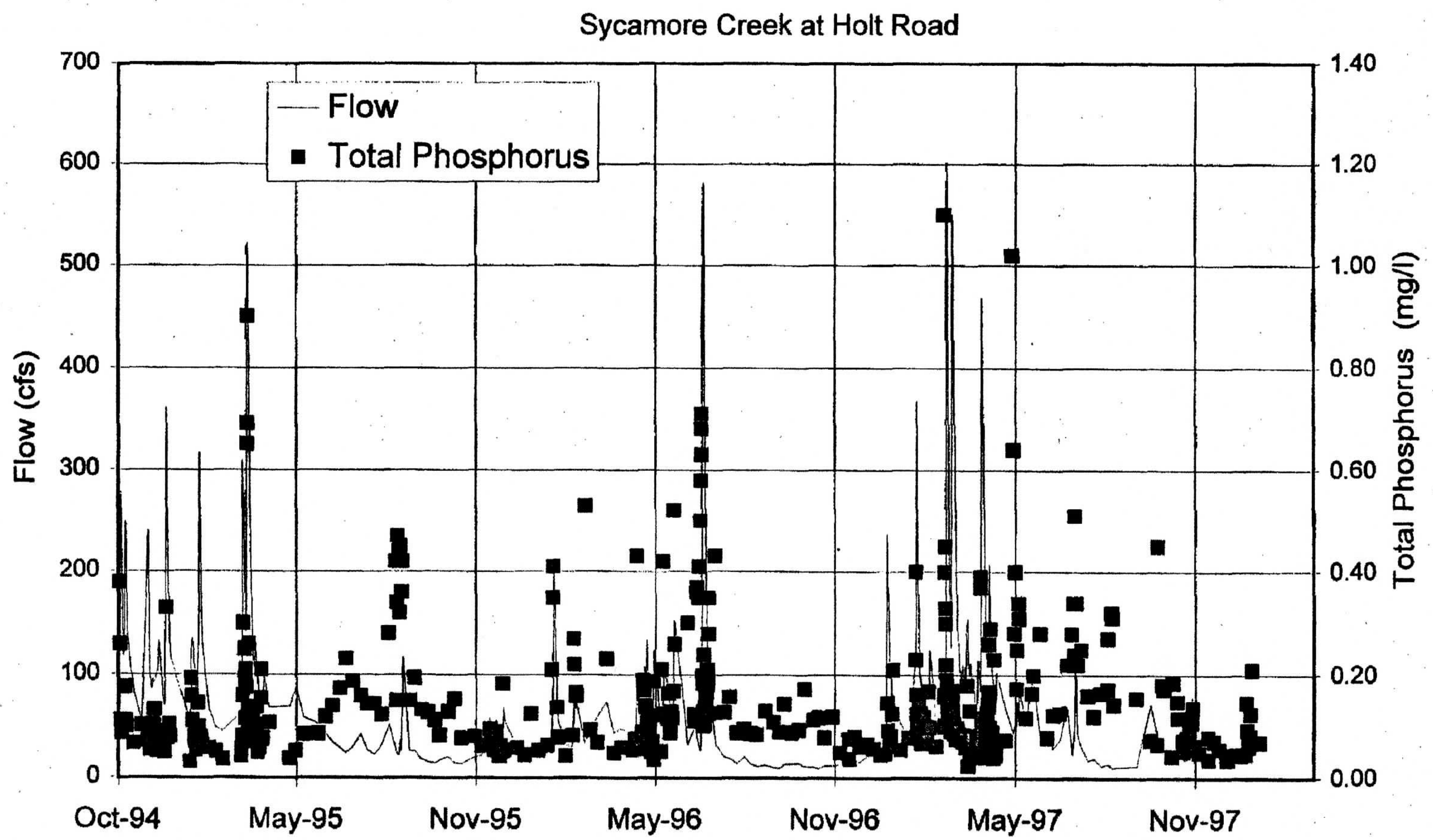

Figure E2. Flow and Total Phosphorus at Holt Road

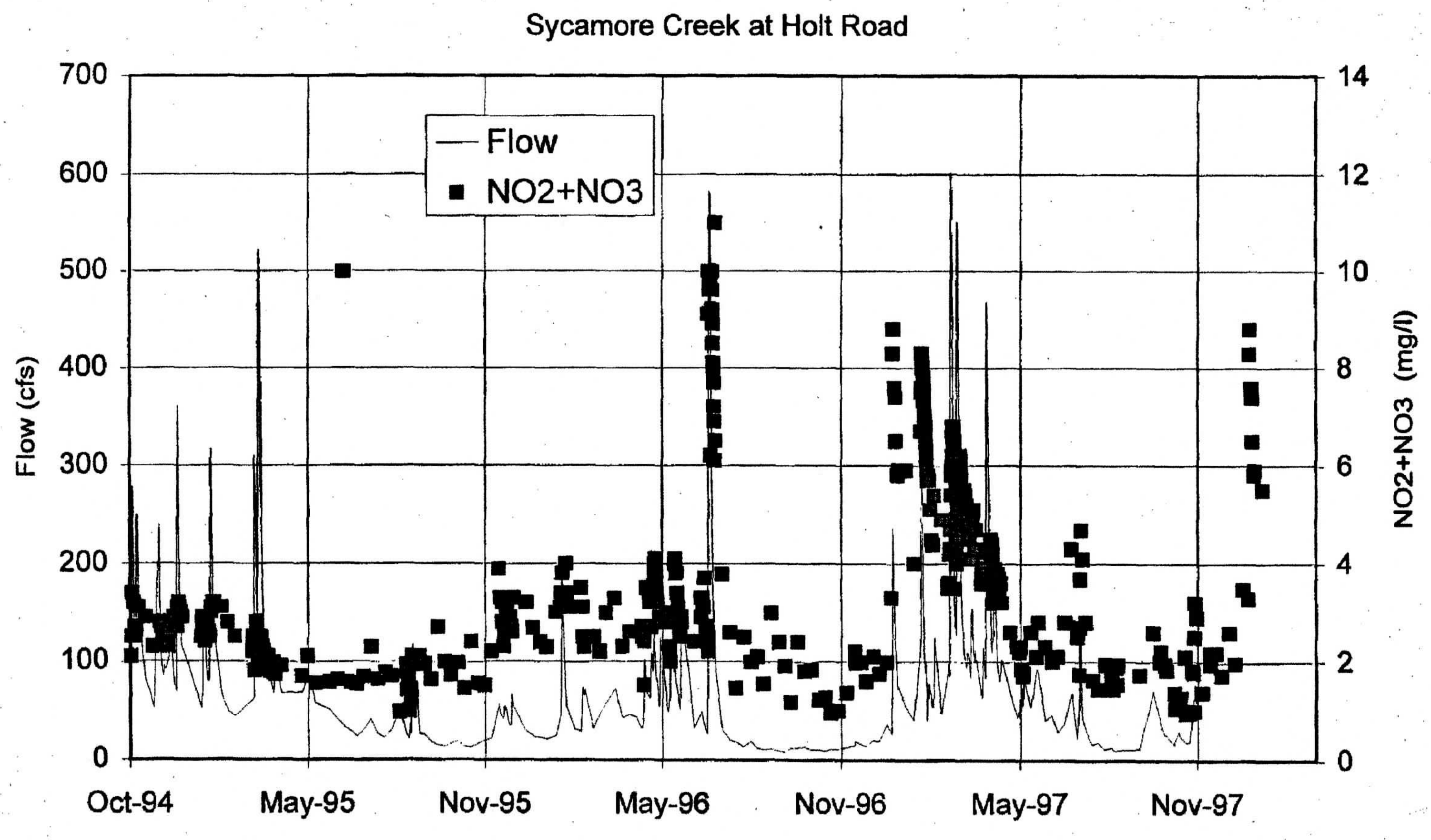

Figure E3. Flow and NO2+NO3 at Holt Road