E. Robert Baumann
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Final Report

HIGHWAY RUNOFF STUDY

Iowa DOT Project HR-1037
ISU-ERI-Ames-85208
ERI Project 1680

June 1985

The preparation of this report was financed in part through federal funds provided by the Federal Highway Administration.

Iowa Department
of Transportation

report

College of
Engineering
Iowa State University

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E. Robert Baumann
Principal Investigator

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Sanitary Engineering Section
Department of Civil Engineering

engineering
research institute
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PREFACE

The focus of highway runoff monitoring programs is on the identification of highway contributions to nonpoint source degradation of surface and groundwater quality. The results of such studies will assist the Iowa Department of Transportation (DOT) in the development of maintenance practices that will minimize the impact of highway transportation networks on water quality while at the same time maintain public safety.

Highway runoff monitoring research will be useful in developing a basis to address issues in environmental impact statements for future highway network expansions. Further, it will lead to optimization of cost effectiveness/environmental factors related to deicing, weed and dust control, highway drainage, construction methods, etc.

In this report, the authors present the data accumulated from a one-year study of runoff quantity and quality from two sections of Interstate Highway 35 near Ames with an interpretation of the significance of the data. The report will discuss the site setup, operational aspects of data collection, and problems encountered. In addition, recommendations are included to optimize information gained from the study.

1. INTRODUCTION

The Federal Highway Administration (FHWA), in cooperation with department of transportation personnel at the state level, has conducted research in a number of United States geographic locations in an effort to determine the environmental impact of highway transportation systems and highway maintenance practices currently in use. The information gathered in this program--known as FHWA Demonstration Project No. 56--will ultimately serve as a guide in the engineering design, construction, operation, and maintenance of highway systems to maintain public safety and minimize surface water and groundwater degradation. As part of that FHWA Demonstration Project No. 56, the Iowa Department of Transportation contracted the services of Iowa State University for the design, management, and operation of a highway runoff monitoring study as well as the evaluation of water quality and hydrologic data gathered in the one-year study.

In order to maximize the information that could be obtained from such a study, a unique topographic setting was selected that allowed the simultaneous, continuous monitoring of runoff quality and hydrographs from a flat (0.24 percent) highway median grade and a steep (2 percent) highway median grade. The study site was equipped to allow the simultaneous collection of continuous flow quantity data for each topographic setting during any given runoff event. Simultaneous (dual median slope) collection of discrete (grab) water samples throughout runoff events to observe the variation of runoff water quality at time intervals was also possible. In most cases, the discrete samples were composited on a flow proportional basis prior to analysis to observe the overall runoff event contaminant loadings.

The study was designed to incorporate three composited-sample runoff events for each of the two highway median slopes. In addition, discrete runoff samples from one event were to be collected and analyzed for each highway median slope to observe water quality variation during the runoff event. The water quality parameters selected for analysis were pH, conductivity, temperature, total solids, total suspended solids, chlorides, nitrate plus nitrite nitrogen, kjeldahl nitrogen, total phosphorous, chemical oxygen demand (COD), total organic carbon (TOC), oil and grease, fecal coliform, fecal streptococci, copper, lead, zinc, and iron. Polychlorinated biphenyls (PCB), hydrocarbons, Tordon, and 2,4-D parameters were limited to a one-time sampling and analysis because of the cost associated with the laboratory analytical procedures.

The automatic ISCO 2100 samplers selected for use allowed samples to be collected by three modes: (1) flow proportional mode, (2) constant time interval mode, and (3) variable time interval mode. This allowed the operator to exercise judgment in the determination of the appropriate sampling method for any given runoff event.

This study was unlike previous highway runoff studies because it included monitoring of the unsaturated soil zone and groundwater beneath the site. Lysimeters were installed in the unsaturated soil zone at depths of 5 feet and 10 feet within the median and near the dual culverts through which the highway median runoff waters discharge. The lysimeters allowed the monitoring of contaminants as they migrated downward to the shallow groundwater table.

Three stainless steel monitoring wells were installed at the site to monitor water quality in the groundwater table aquifer below the site. One of the wells was installed up gradient of the site, and the other two were installed in locations thought to be down gradient of the site. These locations did prove to be down gradient of the site.

2. PROJECT SITE LOCATION AND DESCRIPTION

The project study site is located near Ames, Iowa, along Interstate Highway 35, approximately three and one-half miles south of Highway 30 in the north-central and central portions of T 83 N, R 23 W, Section 31. The site location and topography is shown on the United States Geological Survey (USGS) quadrangle, Fig. 1. The site is near Iowa DOT I-35 Station 344+00 where runoff from the north and south is monitored as separate discharges using a dual flow monitoring station. The flat slope and steep slope areas contributing to the flow drain a section of Interstate 35 between the centerlines of the northbound and southbound traffic lanes to the median and downstream to culverts leading to the flow monitoring station.

The north drainage area contains 1.70 acres. The south drainage area contains 1.87 acres. Approximately 49 percent of each drainage area is paved. The highway median ditch grade slopes downward from the north (Station 353+80) to the double 24-inch concrete culvert site (Station 344+00) at approximately 0.24 percent and downward from the south (Station 333+00) to the culvert (Station 343+60) at approximately 2 percent. The topography at the 24-inch culvert discharges is relatively flat, sloping downward to the west and south. Runoff from the southern, steep slope is monitored with an H-flume. Runoff from the northern, flat slope is monitored with a Parshall flume.

Drainage on the east side of the interstate highway from Station 340+00 to Station 366+50 is controlled by the rerouted old Skunk River channel. Any highway-related runoff south of Station 340+00 and north

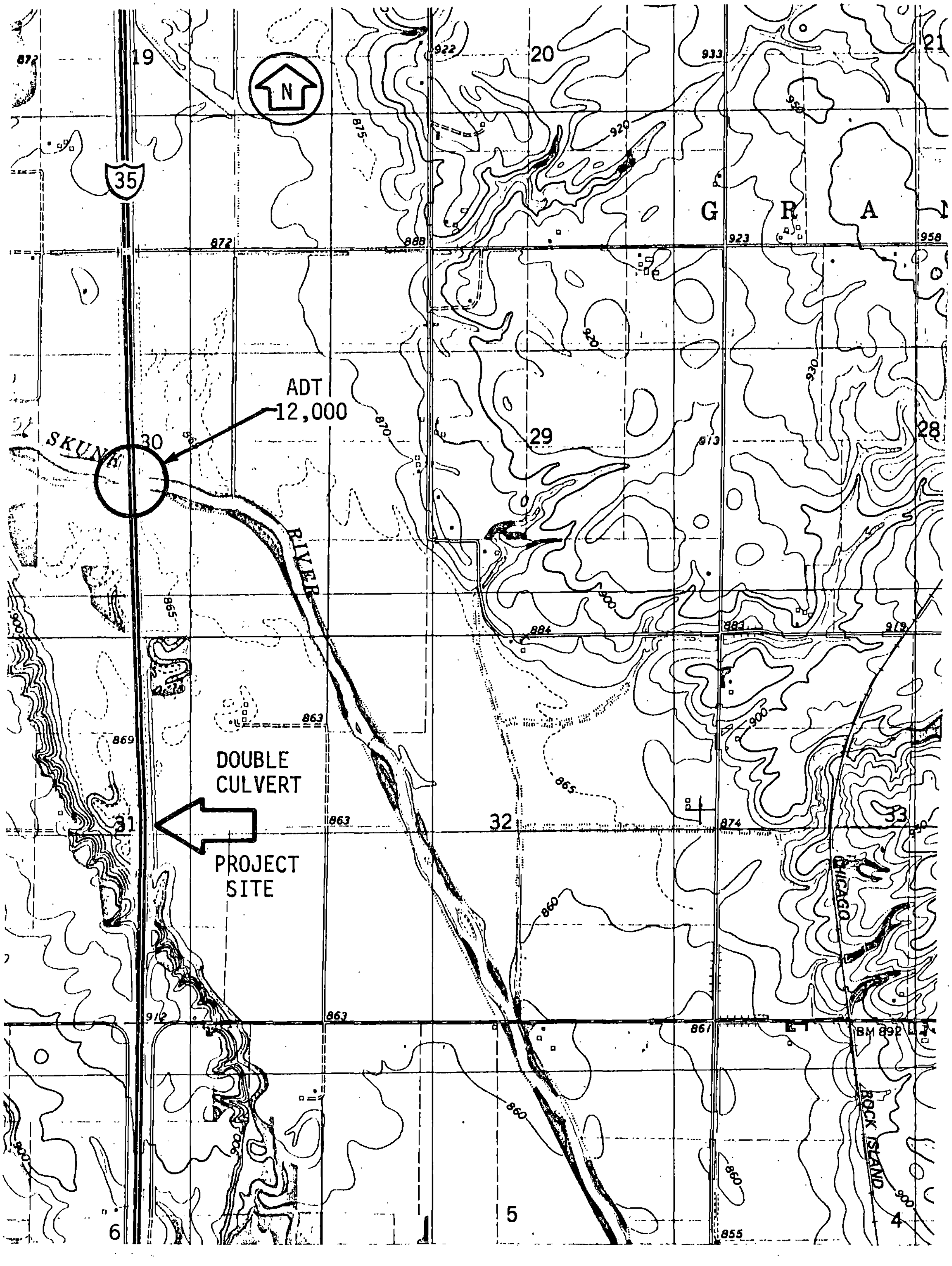


Fig. 1. United States Geological Survey quadrangle showing study site.

of Station 318+03, excluding median flow north of Station 333+00, reaches the rerouted old Skunk River channel flowing south or a creek flowing east and is not monitored. Drainage along the west side of Interstate 35 from Station 340+00 to Station 366+50 is controlled both by flow in relatively flat ditches and topographic depressions, channels, and cuts that intersect the ditches near the right of way. From information collected in a topographic survey by the Iowa DOT, it appears that runoff from this portion of Interstate 35's west lane and west right of way flows toward the west onto a relatively flat adjacent property and south into a small creek. Eventual discharge of Interstate 35 runoff in this area is to the present day Skunk River located east of the study site.

Local climatological history and relatively low permeability soils indicate that the 100-year storm may produce median ditch flows up to approximately 8 cubic feet per second (cfs) from the areas monitored. For normal runoff events, peak flows of 1 cfs to 3 cfs were anticipated and subsequently observed.

The average daily traffic (ADT) at the site is approximately 12,600 vehicles per day. Thus, the site is representative of relatively low volume traffic. The vehicular classification mixture is not known.

The Iowa DOT deicing operations use a blend of equal weight fractions of sand and deicing compound. The normal application rate is 300 pounds of the mixture per two-lane mile per application event. The deicing mixtures may be of two types. One is sodium chloride and sand containing 5% inert impurities and anticaking additives, ferrocyanide and ferric ferrocyanide. The second is calcium chloride and sand with 26% impurities. A calcium magnesium acetate mixture has been developed by the Iowa DOT but is not widely used as an alternative deicing compound because of cost considerations.

Pesticides are not used by the Iowa DOT. The herbicides in use are 2,4-D and Dow Chemical Tordon (4 Amino-3,5,6 Trichloropicolinic Acid or Picloram). The 2,4-D is applied as needed for spot control of weeds at mixtures of 1 pint per 30 gallons to 2 quarts per 15 gallons per acre. Tordon is used more frequently for control of Canadian Thistle. The composition of Tordon used by the Iowa DOT includes 16% disodium petraborate pentahydrate, 16% disodium petraborate dechazdrate, and 2.3% Picloram.

3. SITE SETUP AND GENERAL OPERATIONS

Construction at the site began on September 19, 1983. A site plan, Fig. 2, shows the location of all pertinent equipment, structures, and existing site features.

A fiberglass shed to house the flow monitoring/sampling equipment was placed on its foundation on September 19, 1983. The flumes were installed, leveled, planked, and backfilled by September 22. Existing drainage channels from the flumes to the edge of the right of way were improved and seeded on September 23. An adequate free drainage situation existed at both flume locations.

Installation of the flumes and provision of adequate drainage was more difficult than anticipated before construction began because extensive siltation of the west ditch had occurred since the completion of the highway. Up to 12 inches of silt had to be removed to allow flume placement at the culvert flowline elevations. This in turn required drainage improvements. The runoff flow from the southern 2.0 percent grade was monitored at the H-flume installation. The runoff flow from the northern 0.24 percent grade was monitored at the Parshall flume installation.

Groundwater monitoring wells and lysimeters were installed on September 28 and 29, 1983. The installation was directed and supervised by Harvey Gullicks, Project Manager. No significant difficulty was encountered. The boring logs and construction details are given in Figs. 3, 4, 5, and 6.

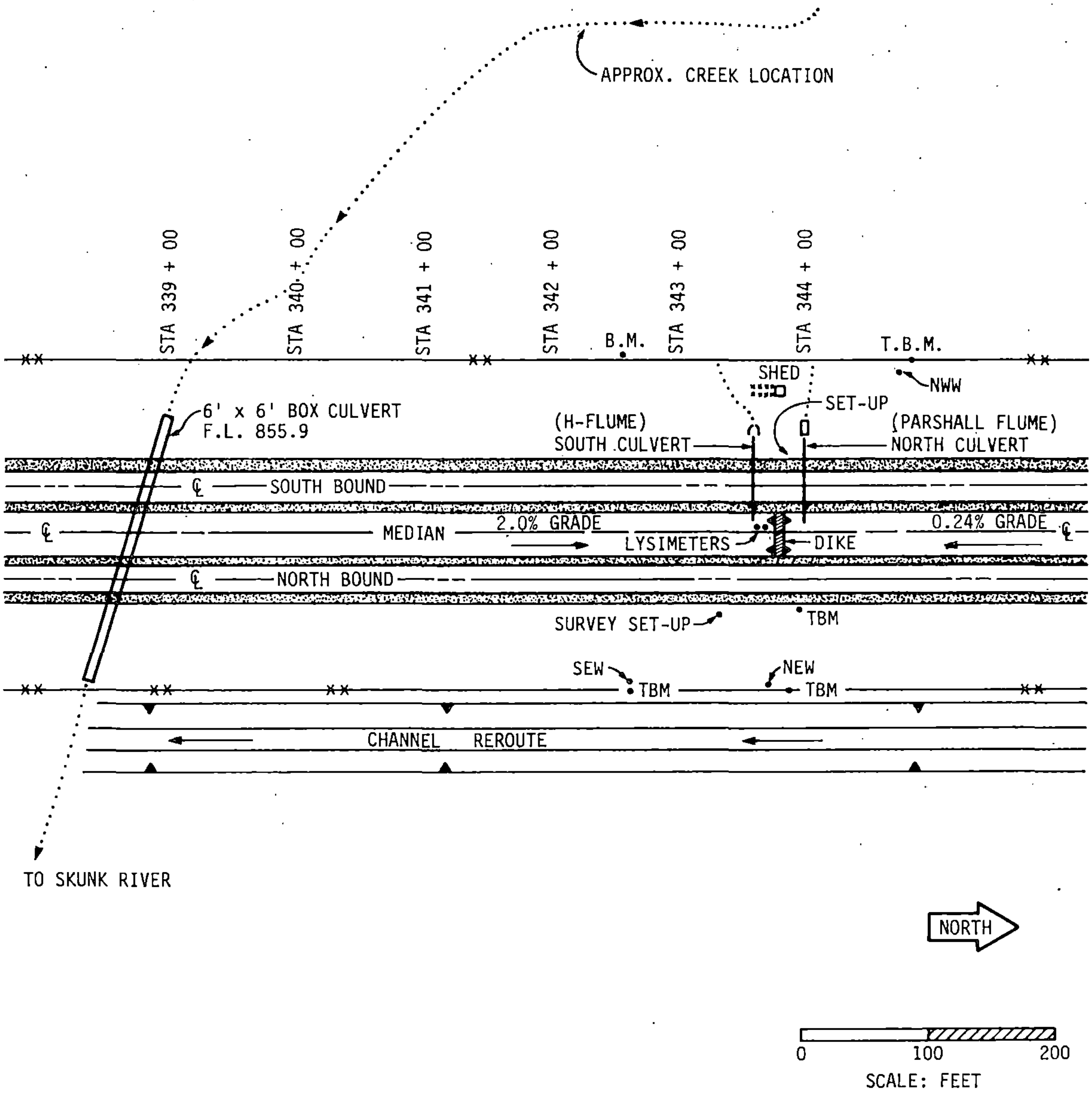


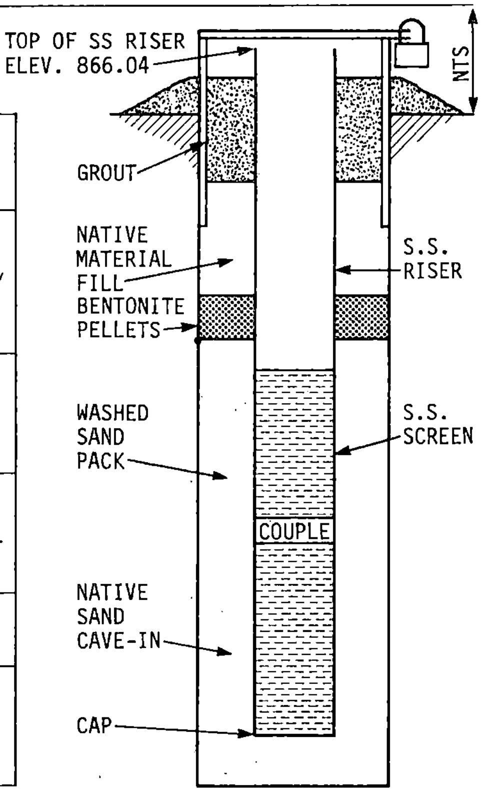
Fig. 2. Site plan of Iowa DOT highway runoff study.

CLIENT: IOWA DEPARTMENT OF TRANSPORTATION
PROJECT: HIGHWAY RUNOFF MONITORING PROGRAM
PROJECT NO.: 474-20-15-00-1680
LOCATION: INTERSTATE HWY. 35, STATION 344, SOUTH OF AMES
DRILLED: SEPTEMBER 29, 1983 BY SHIVE HATTERY AND ASSOCIATES

DEPTH, FT.
0.0'

SURFACE ELEVATION 863.62

DEPTH, FT.		
3.0'	N=9	SILTY CLAY, TRACE SAND AND ROOTS, SLIGHTLY ORGANIC--TOPSOIL - DARK BROWN TO BLACK - MOIST - (CL-OL) QP = 1.75 TSF
5.0' 8.0'	N=8 N=4	SANDY SILT, TRACE CLAY-NUMEROUS THIN FINE TO VERY FINE HORIZONTAL SAND SEAMS FROM 5' TO 8' BROWN AND BROWNISH GRAY MOTTLED BECOMING GRAY WITH BROWN MOTTLING AT 5.0'-MOIST TO WET - (ML-SM), LOOSE
10.0' 11.3'	N=3	SILTY CLAY, TRACE VERY FINE SAND AND ORGANIC LENSES-MODERATELY PLASTIC-BROWNISH GRAY WITH BROWN MOTTLING-WET TO SATURATED-(CL-CH) QP = 0.5 TSF
14.5'	N=5 N=4	SILTY CLAY AND CLAYEY SILT WITH 2 TO 3 INCH HORIZONTAL FINE SAND SEAMS (MORE FREQUENT FROM 13.5' TO 14.5') AND TRACE ORGANICS-GRAY-SATURATED (CL-ML & SP SEAMS) SOFT TO FIRM
15.0' 16.0'	N=10	FINE TO MEDIUM SAND, TRACE TO LITTLE SILT-GRAY-SATURATED-(SP-SM) MEDIUM DENSE
20.0'	N=18 N=6	FINE TO COARSE SAND, LITTLE GRAVEL (20%) TRACE SILT AND TRACE HORIZONTAL THIN SILT SEAMS-GRAY-SATURATED-(SW) MEDIUM DENSE



END OF BORING AT 20.0 FEET. BORING AUGERED TO FULL DEPTH USING HOLLOW STEM AUGERS. NO WASH WATER OR DRILLING FLUID USED.

WELL CONSTRUCTION

RISER - 2' I.D. SCH. 5 STAINLESS STEEL
SCREEN - STAINLESS STEEL WIRE WOUND NO. 10 SLOT. LENGTH 10.3 FT. INCLUDES 0.4 FOOT WELDED COUPLE
BOTTOM OF SCREEN - ELEV. 845

WATER LEVEL DATA*

DATE:	12/19/83	2/1/84	4/11/84	5/3/84	7/20/84
WATER LEVEL:	9.68'	11.58'	8.63'	5.79'	9.50'
GR. WTR. ELEV.:	856.36	854.46	857.41	860.25	856.54
DATE:	9/23/84				
WATER LEVEL:	12.94'				
GR. WTR. ELEV.:	853.10				

DRAWN BY: HAG
DATE: 12/21/83

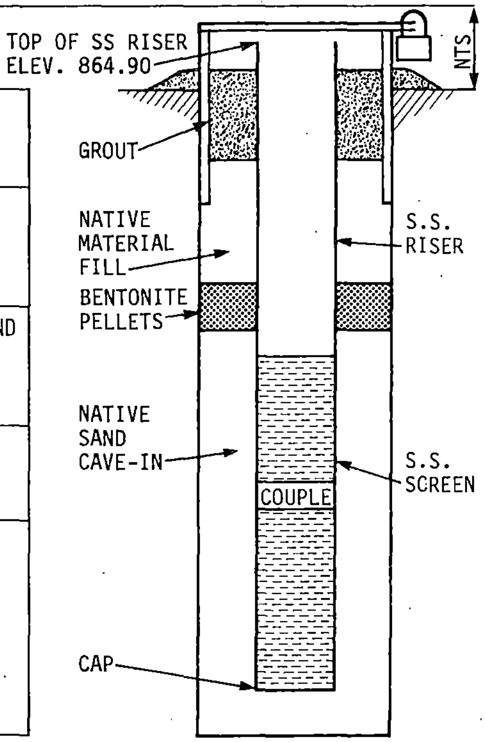
*NOTE: ALL WATER LEVELS REPORTED RELATIVE TO THE TOP OF THE S.S. RISER PIPE.

Fig. 3. Log of northwest well (NWW).

CLIENT: IOWA DEPARTMENT OF TRANSPORTATION
PROJECT: HIGHWAY RUNOFF MONITORING PROGRAM
PROJECT NO.: 474-20-15-00-1680
LOCATION: INTERSTATE HWY. 35, STATION 344, SOUTH OF AMES
DRILLED: SEPTEMBER 28, 1983 BY SHIVE HATTERY AND ASSOCIATES

DEPTH, FT.
0.0' SURFACE ELEV. 862.78

2.5'	N=11	SILTY FINE TO MEDIUM SAND, TRACE CLAY AND ROOTS, A FEW HORIZONTAL THIN SEAMS OF CLAY-TOPSOIL-BROWN TO DK BROWN-(SM-OL)-MED. DENSE
5.0' 6.3'	N=13	SILTY CLAY, TRACE SAND & ROOTS-TOPSOIL-DARK BROWN-MOIST TO WET (NR. 6 FT.)-(CL-OL) Q_p = 3.25 TSF PROBABLE ORIG. GRADE AT ~2.5' DEPTH
10.0' 10.5'	N=6 N=2	SILTY FINE SAND (~10-15% SILT), TRACE CLAY AND ROOTS-LT. BROWN TO BROWN-WET-(SM-SP) GRADING TO FINE TO MEDIUM SAND, TRACE SILT-BROWN-SATURATED-(SP-SM) - LOOSE
14.0'	N=3	FINE TO MEDIUM COARSE SAND, TRACE SILT-GRAY-SATURATED-(SP)-LOOSE A FEW SILT AND CLAY HORIZONTAL SEAMS
15.0' 20.0'	N=13 N=18 N=15	FINE TO COARSE SAND, LITTLE GRAVEL (~20%), TRACE SILT-GRAY-SATURATED-(SW)-MEDIUM DENSE



END OF BORING AT 20.0 FEET. BORING AUGERED TO FULL DEPTH USING HOLLOW STEM AUGERS. NO WASH WATER OR DRILLING FLUID USED.

WATER LEVEL DATA*

DATE:	9/29/83	12/19/83	2/1/84	4/11/84	5/3/84
WATER LEVEL:	11.18'	8.96'	10.92'	7.56'	4.79'
GR. WTR. ELEV.:	853.72	855.94	853.98	857.34	860.11

DATE:	7/20/84	9/23/84
WATER LEVEL:	8.46'	11.86'
GR. WTR. ELEV.:	856.44	853.04

WELL CONSTRUCTION

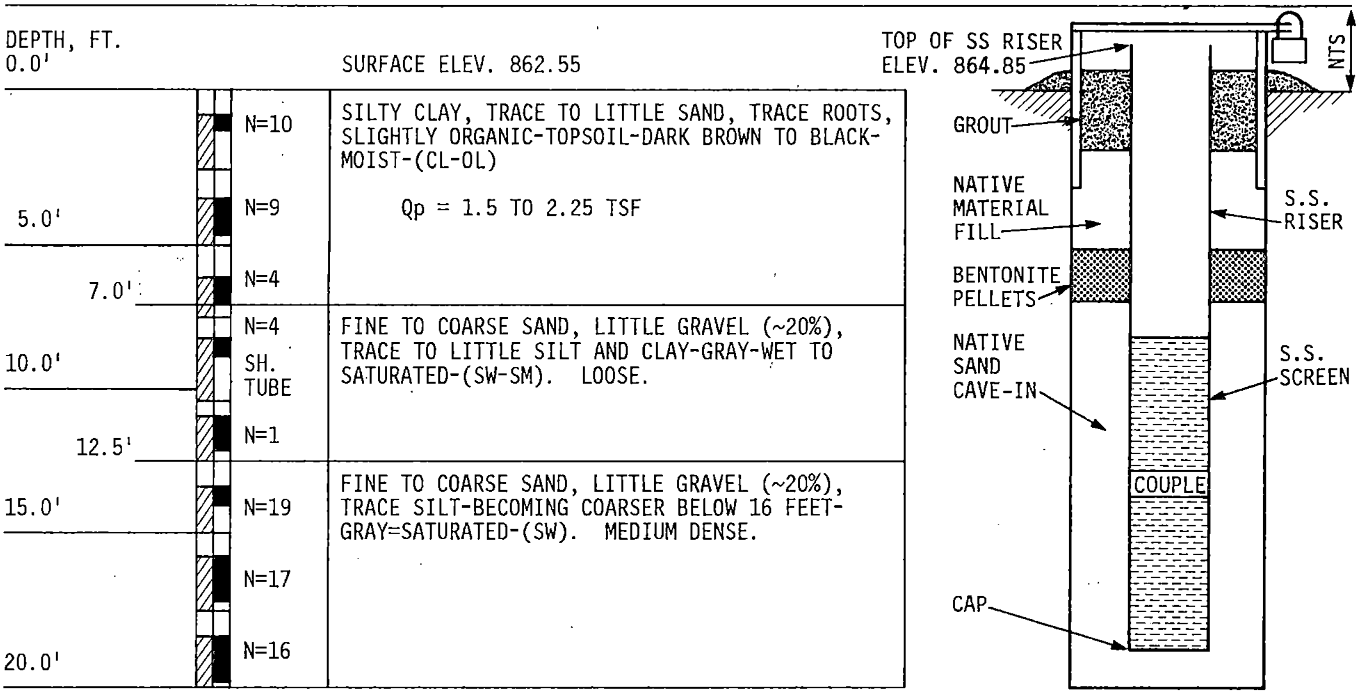
RISER - 2" I.D. SCH. 5 STAINLESS STEEL
SCREEN - STAINLESS STEEL WIRE WOUND NO. 10 SLOT. LENGTH 10.3 FEET, INCLUDING 0.4 FOOT WELDED COUPLE.
BOTTOM OF SCREEN - ELEV. 844

DRAWN BY: HAG
DATE: 12/21/83

*NOTE: ALL WATER LEVELS REPORTED RELATIVE TO THE TOP OF THE SS RISER PIPE.

Fig. 4. Log of northeast well (NEW).

CLIENT: IOWA DEPARTMENT OF TRANSPORTATION
PROJECT: HIGHWAY RUNOFF MONITORING PROGRAM
PROJECT NO.: 474-20-15-00-1680
LOCATION: INTERSTATE HWY. 35, STATION 344, SOUTH OF AMES
DRILLED: SEPTEMBER 29, 1983 BY SHIVE HATTERY AND ASSOCIATES



DEPTH, FT. 0.0' SURFACE ELEV. 862.55

	N=10	SILTY CLAY, TRACE TO LITTLE SAND, TRACE ROOTS, SLIGHTLY ORGANIC-TOPSOIL-DARK BROWN TO BLACK-MOIST-(CL-OL)
5.0'	N=9	Qp = 1.5 TO 2.25 TSF
7.0'	N=4	
	N=4	FINE TO COARSE SAND, LITTLE GRAVEL (~20%), TRACE TO LITTLE SILT AND CLAY-GRAY-WET TO SATURATED-(SW-SM). LOOSE.
10.0'	SH. TUBE	
12.5'	N=1	
15.0'	N=19	FINE TO COARSE SAND, LITTLE GRAVEL (~20%), TRACE SILT-BECOMING COARSER BELOW 16 FEET-GRAY=SATURATED-(SW). MEDIUM DENSE.
	N=17	
20.0'	N=16	

END OF BORING AT 20.0 FEET. BORING AUGERED TO FULL DEPTH USING HOLLOW STEM AUGERS. NO WASH WATER OR DRILLING FLUID USED.

WELL CONSTRUCTION

RISER - 2" I.D. SCH. 5 STAINLESS STEEL.
SCREEN - STAINLESS STEEL WIRE WOUND NO. 10 SLOT. LENGTH 10.3 FEET. INCLUDING 0.4 FOOT WELDED COUPLE.
BOTTOM OF SCREEN - ELEV. 844

WATER LEVEL DATA*

DATES:	9/29/83	12/19/83	2/1/84	4/11/84	5/3/84
WATER LEVEL:	11.18'	8.92'	10.83'	7.57'	4.79'
GR. WTR. ELEV.:	853.67	855.93	854.02	857.28	860.06
DATE:	7/20/84	9/23/84			
WATER LEVEL:	8.46'	11.89'			
GR. WTR. ELEV.:	856.39	852.96			

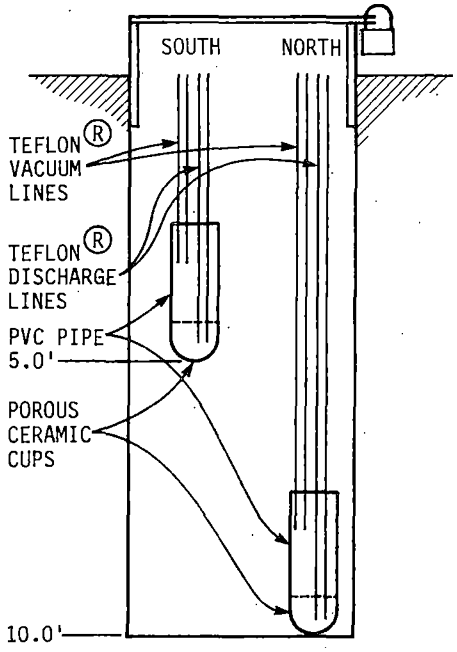
DRAWN BY: HAG
DATE: 12/21/83

*NOTE: ALL WATER LEVELS REPORTED RELATIVE TO THE TOP OF THE SS RISER PIPE.

Fig. 5. Log of southeast well (SEW).

CLIENT: IOWA DEPARTMENT OF TRANSPORTATION
PROJECT: HIGHWAY RUNOFF MONITORING PROGRAM
PROJECT NO.: 474-20-15-00-1680
LOCATION: INTERSTATE HWY. 35, STATION 344, SOUTH OF AMES
DRILLED: SEPTEMBER 29, 1983 BY SHIVE HATTERY AND ASSOCIATES

DEPTH, FT.	SURFACE ELEVATION
0.0'	SANDY CLAY, SOME SILT, TRACE GRAVEL - FILL - BROWN-(CL)
2.5'	
4.0'	SILTY CLAY, TRACE TO LITTLE SAND, TRACE ROOTS, SLIGHTLY ORGANIC-TOPSOIL-DARK BROWN TO BLACK - MOIST - (OL-CL) PROBABLE ORIG. GRADE AT 4.0'
5.0'	
7.5'	
10.0'	



END OF BORING AT 10.0 FEET. BORING AUGERED TO FULL DEPTH USING HOLLOW STEM AUGERS. NO WASH WATER OR DRILLING FLUID USED.

NO WATER ENCOUNTERED WHILE DRILLING PER SHIVE-HATTERY CREW.

LYSIMETER CONSTRUCTION*

BACKFILL AROUND POROUS CERAMIC CUPS IS OTTAWA SILICA SAND.

FILL ABOVE SILICA SAND IS WASHED SAND.

IMPERMEABLE SEAL AT GROUND SURFACE.

DRAWN BY: HAG
DATE: 12/21/83

*NOTE: EACH LYSIMETER INSTALLED IN A SEPARATE BORING, RATHER THAN IN ONE DRILLED HOLE.

Fig. 6. Log of lysimeter boring.

The rain gauge, flow meter, and automatic samplers arrived between October 17 and October 21, 1983. When ISU personnel began their installation on October 24, 1983, it was disovered that the liquid level sample actuators were only 22 feet long. Building placement required by the Iowa DOT made this length unsuitable since the building was 40 feet from the flumes. Additionally, the liquid level sample actuator was not compatible with simultaneous use of the flow meter to actuate the sampler. The situation was remedied by ordering a 50-foot liquid level sample actuator for the H-flume installation and using only the flow meter to actuate the Parshall flume sampler.

During dual flow monitoring events, the H-flume sampler (ISCO 2100) was actuated by the liquid level sample actuator when the water depth in the flume reached the actuator probe. Then, samples were collected immediately and at regular, timed intervals programmed into the sampler. A Steven's type-F water level recorder recorded the water level in the flume.

The Parshall flume sampler (ISCO 2100) was actuated on a flow proportional basis by signals from an ISCO 1870 flow meter (bubble type). A sample was collected each time a programmed volume of runoff passed through the flume.

The equipment was operational but not tested until November 14, 1983. Small precipitation events showed that the timbers used by the Iowa DOT to plank the entrance to the flumes (for safety reasons) were leaching detectable oil and grease on contact with the water. Therefore, ISU personnel proposed that the flume entrances be lined with plastic to minimize water-to-plank contact. The plastic was installed between November 21, 1983, and January 5, 1984. This appears to have been effective.

After July 26, 1984, flow was monitored and sampled only at the H-flume which collected runoff from the steeper 2% southern slope. The ISCO 1870 flow meter was moved from the Parshall flume to the H-flume to provide continuous, reliable flow monitoring and flow proportional sampling capability.

3.1. Bottle Washing and Sampler Preparation

The procedures used for preparation of the samplers and sample bottles during the study are detailed below. Field sample blanks were periodically returned to the analytical laboratory for analysis to check the effectiveness of the washing and preparation procedures.

Normal Wash:

1. Wash with hot soapy (Alconox) water.
2. Rinse with hot tap water.
3. Wash with 25% to 50% H_2SO_4 solution.
4. Rinse 5-6 times with distilled water (high purity source*).
5. Air dry in inverted position.
6. Cap and store until use.

Organic Parameter Sample Bottles Wash:

1. Wash with hot soapy (Alconox) water.
2. Rinse with hot tap water.

---

*Iowa State University, Engineering Research Institute Analytical Services Laboratory (ERI-ASL) reagent grade triple distilled water.

3. Rinse 5-6 times with distilled water (high purity source).
4. Rinse with pesticide grade methylene chloride or reagent grade hexane depending on the parameter of interest.
5. Air dry in inverted position.
6. Cap and store until use.

Sampler Preparation:

1. Automatic sampler flushed with deionized water; tubing changed between runoff events.
2. Teflon bailer for groundwater sampling washed in same manner as bottles for parameters of interest.

3.2. Sample Preservation

The preservation methods used for the various parameters in the study are shown below. Preservation was done in the field at the time of collection.

Parameter	Preservation Method
pH, Temperature	Taken in field or within 1 hour
Conductivity, Chloride, Total Solids, Suspended Solids	Plastic bottles, 4° C storage
Herbicides, Hydrocarbons, PCB's	Dark glass bottles, 4° C storage, Teflon caps
Total Kjeldahl N, $(NO_3 + NO_2)$ - N, Total PO_4, COD, TOC	Plastic bottles, H_2SO_4 to pH < 2, 4° C storage
Oil and Grease	Glass bottles (when possible), H_2SO_4 to pH < 2, 4° C storage

Fecal Coliform and Fecal Streptococci	Glass bottles (when possible), 4° C storage (analyze as soon as possible)
Total Metals	Plastic bottles, HNO_3 to pH < 2, 4° C storage
Filterable Metals	Field filter through 0.45 μm filter, Plastic bottles, HNO_3 to pH < 2, 4° C storage

3.3. Analytical Methodology

All samples were analyzed by the ISU Engineering Research Institute Analytical Services Laboratory (ERI-ASL). Where applicable, the methods used were those found in Standard Methods for the Examination of Water and Wastewater, 15th Edition. The method used for 2,4-D and Tordon analyses was that presented in Methods for Organochlorine Pesticides and Chlorophenoxy Acid Herbicides in Drinking Water and Raw Source Water, USEPA-EMSL, 1978, pages 20-35. Similar methodology was used for the PCB analyses. The hydrocarbon analyses consisted of a 24-hour extraction with methylene chloride, Kuderna-Danish concentration, and capillary gas chromatography followed by comparison to known laboratory distilled water-hydrocarbon mixtures.

4. MONITORING DATA

4.1. Highway Maintenance

Deicing activities during the months of November 1983, December 1983, and January 1984 required the application of approximately 1,400 pounds of salt to the two traffic lanes comprising the south (steep) drainage area. Approximately 1,320 pounds of salt were applied to the two traffic lanes comprising the north (flat) drainage area. Approximately 280 pounds of additional salt were applied to each of the areas in February and March.

The equivalent salt loading per acre in each of the drainage areas was approximately 750-775 pounds per acre prior to the first snowmelt runoff. The annual loading rate was 900-940 pounds per acre.

Between January 13 and 24, 1984, the asphaltic concrete patches in the study area were oiled using Styrelf oil.

On April 4, 1984, the median ditch on the south (steep) slope was observed to be rutted from a vehicle which left the pavement. Subgrade drainage was installed by construction crews in the test area between May 18 and May 30, 1984. The median and shoulders were mowed between September 14 and 23, 1984. Mowing had not been done since late September 1983. It is not known if herbicides were applied in the study area during the monitoring period.

4.2. Precipitation

Between November 14 and December 14, 1983, field mice damaged the insulation in the tipping bucket rain gauge. A hole built into the bottom of the gauge housing serving as their entrance was covered to prevent mice from entering. The insulation damage continued to cause problems by interfering with the tipping bucket operation until February 15, 1984, when the problem with the erratic rain gauge behavior was solved. Precipitation data collected after February 15, 1984, have been reliable.

Local climatological data from the National Oceanic and Atmospheric Administration augmented with the project manager's daily weather notes were used to estimate test site precipitation prior to February 15, 1984. The data were also used to augment data obtained by the rain gauge at the site subsequent to February 15.

Daily precipitation from November 1, 1983, to October 31, 1984, is shown in Table 1. Air temperature patterns are also shown.

4.3. Runoff

Bitter cold and heavy snow precipitation occurred in December 1983. A warming trend occurred between January 3 and 8, 1984, but no runoff occurred at the site during this time. The flumes were completely plugged with snow from the December storms and had to be shoveled out on January 5, 1984. Also, the stilling wells were frozen solid making flow measurement impossible, had it been necessary. These problems plagued snowmelt runoff sampling efforts during the spring of 1984 as noted below.

Brief warming trends occurred in 1984 from January 24 to 28 and from January 31 to February 3. Highs were 35° F to 45° F during these

Table 1. Temperature* and precipitation** data.

	November 1983			December 1983			January 1984			February 1984		
		Temp.			Temp.			Temp.			Temp.	
Date	Precip.	H.	L.	Precip.	H.	L.	Precip.	H.	L.	Precip.	H.	L.
1	0.62 R	65	51	0.00	22	3	0.06 S	30	17	0.00	40	18
2	0.04 R	64	55	0.00	25	12	0.24 S	27	13	0.00	39	30
3	0.00	62	42	0.00	25	2	0.00	35	14	Tr	38	28
4	0.17 R	46	31	0.00	33	22	0.00	39	24	Tr	37	18
5	0.00	53	30	0.03 S	32	18	0.00	42	23	0.00	29	-5
6	Tr	53	46	0.09 S	21	15	0.00	39	30	0.00	17	-7
7	0.00	56	38	0.00	24	6	0.00	37	22	0.00	24	4
8	0.02 R	55	45	Tr	23	3	0.00	35	22	0.00	41	14
9	0.10 R	52	35	0.00	24	12	0.00	28	20	0.00	44	27
10	0.80 R	36	31	0.00	26	10	0.00	22	-5	0.00	40	31
11	0.00	37	28	0.02 S	33	25	0.00	19	-1	Tr	38	33
12	0.12 R-S	36	29	Tr	33	9	Tr	19	13	0.00	44	36
13	0.15 R	38	31	0.00	29	15	0.08 S	18	3	Tr	37	32
14	Tr	44	37	0.09 S	31	18	Tr	14	3	0.00	52	29
15	Tr	41	34	0.05 S	26	10	Tr	18	2	0.07 R	57	36
16	0.00	40	26	0.01 S	12	-7	Tr	18	6	0.20 R	55	39
17	0.00	48	26	0.03 S	2	-12	Tr	12	-5	Tr	40	32
18	0.00	52	31	Tr	-2	-17	0.00	7	-15	0.97 R	37	22
19	1.76 R	60	48	0.00	-9	-18	0.00	9	-13	0.05 R	37	30
20	0.02 R	58	36	0.00	1	-18	0.00	1	-18	Tr	45	25
21	0.00	43	30	0.15 S	11	-4	0.00	13	-17	0.00	52	26
22	0.00	39	32	0.00	-3	-18	0.00	29	0	0.00	62	31
23	0.41 R-S	37	22	0.00	-11	-18	Tr	32	21	0.00	58	33
24	0.54 R	30	20	0.00	-13	-21	0.03 S	33	14	0.00	43	28
25	0.00	36	10	0.00	-2	-20	0.00	39	14	0.00	48	28
26	0.00	35	26	0.00	15	-7	0.00	37	27	0.00	46	29
27	0.24 R	33	32	0.00	19	14	0.00	28	8	0.00	41	26
28	0.96 R-S	33	27	0.05 S	15	1	Tr	37	17	0.00	33	24
29	0.06 S	29	15	0.00	5	-8	0.00	32	20	0.00	35	18
30	Tr	18	11	0.00	18	-5	0.11 R	27	10			
31				0.00	26	16	0.00	32	8			
Site Total Precip.	5.81 (Ames data)			0.52 (Ames data)			0.52 (Ames data)			1.29 (site data)		
Total Precip. 2 mi. SE of Ames	5.81			0.52	Note: Frozen soil on 12/4/83		0.52	Note: Frozen soil		1.27	Note: Soil temperatures above freezing on 2/11/84	

Note: Precipitation in inches.

*Ames temperature data, °F

**Tr = trace, R = rain, S = snow.

Table 1. Continued.

Date	March 1984			April 1984			May 1984			June 1984		
		Temp.			Temp.			Temp.			Temp.	
	Precip.	H.	L.	Precip.	H.	L.	Precip.	H.	L.	Precip.	H.	L.
1	0.00	43	25	0.00	51	28	0.00	59	35	0.00	82	62
2	0.00	42	27	0.11 R	50	37	0.15 R	61	42	0.06 R	80	55
3	Tr	44	27	0.78 R	48	32	0.10 R	59	43	0.00	79	53
4	0.09 S-R	43	28	0.00	48	33	0.00	55	36	0.26 R	78	60
5	0.00	33	23	0.00	56	34	0.00	65	39	0.00	86	64
6	0.00	25	2	0.00	59	33	0.04 R	65	50	0.13 R	86	67
7	0.05 S	24	11	0.03 R	59	39	0.04 R	58	44	0.45 R	81	67
8	0.01 S	24	8	0.33 R	50	41	0.00	53	33	0.00	82	63
9	0.00	20	-5	0.02 R	47	39	0.00	63	38	0.72 R	83	62
10	0.00	32	3	0.00	55	43	0.00	72	44	0.00	74	57
11	0.10 S	30	6	0.10 R	54	44	0.04 R	73	53	0.00	78	53
12	0.04 S	23	9	0.18 R	55	48	0.00	72	46	0.37 R	78	65
13	0.00	29	18	0.09 R	48	40	0.00	76	57	2.35 R	80	68
14	0.00	36	30	0.05 R	47	42	0.00	71	44	1.83 R	81	60
15	Tr	36	28	0.04 R	57	41	0.05 R	71	52	0.00	80	60
16	Tr	32	22	0.00	60	43	0.00	73	50	0.57 R	84	63
17	0.08 S	33	24	0.00	57	38	0.00	86	51	0.22 R	84	69
18	0.00	30	23	0.00	59	33	0.16 R	85	66	0.00	82	66
19	0.20 S	29	24	0.00	57	32	0.33 R	73	60	0.00	83	60
20	0.02 S	31	25	0.00	58	38	0.00	78	53	0.00	83	63
21	Tr	34	29	0.70 R	56	41	0.00	79	53	0.36 R	83	65
22	0.00	38	26	0.11 R	42	32	0.30 R	78	58	0.06 R	86	64
23	0.00	45	25	0.00	58	34	0.00	72	46	0.00	86	63
24	0.00	46	26	0.00	65	40	0.41 R	79	65	0.00	81	58
25	0.00	49	28	0.00	69	41	0.92 R	68	49	0.01 R	86	62
26	0.03 R	48	32	0.00	81	57	0.00	62	42	0.39 R	90	66
27	0.00	41	34	0.39 R	80	56	0.35 R	63	48	0.00	89	60
28	0.00	48	33	0.00	59	36	1.52 R	62	44	0.00	82	58
29	0.00	45	28	2.08 R	58	40	0.00	62	41	0.00	82	59
30	0.00	43	26	0.07 R	47	34	0.00	69	42	0.00	78	57
31	0.00	47	26				0.00	78	49			
Site Total Precip.	0.62 (site data)			5.08 (site data)			4.39 (site data)			7.68 (site data)		
Total Precip. 2 mi. SE of Ames	1.40	Note: Soil temperatures predominantly above freezing		6.84	Note: No frost in soil		6.49			11.18 (5.56" on 6/13/84)		
8 miles WSW of Ames										6.58 (2.12" on 6/13/84)		

Note: Precipitation in inches.

*Ames temperature data, °F

**Tr = trace, R = rain, S = snow.

Table 1. Continued.

	July 1984			August 1984			September 1984			October 1984		
		Temp.			Temp.			Temp.			Temp.	
Date	Precip.	H.	L.	Precip.	H.	L.	Precip.	H.	L.	Precip.	H.	L.
1	0.00	79	56	0.00	84	60	0.00	97	72	0.00	67	32
2	Tr.	82	57	0.00	85	67	0.35 R	93	62	0.00	74	41
3	0.11 R	82	62	0.00	86	62	0.00	72	52	0.00	73	48
4	0.00	85	64	0.00	88	68	0.19 R	78	51	0.09 R	72	43
5	0.16 R	84	58	0.00	90	67	0.00	76	45	0.00	69	53
6	0.00	78	57	0.00	92	67	0.00	71	55	0.11 R	68	56
7	0.00	75	49	0.24 R	92	69	0.00	91	68	0.09 R	67	56
8	0.09 R	88	60	0.00	90	66	0.45 R	88	55	0.00	66	48
9	0.00	92	77	0.00	89	64	0.29 R	76	53	0.00	70	48
10	0.71 R	92	79	0.00	85	59	0.32 R	70	53	0.00	73	53
11	0.00	84	60	0.00	84	59	0.00	75	51	0.17 R	67	57
12	0.00	86	62	0.00	84	60	0.00	91	67	0.00	73	59
13	0.00	86	62	0.00	84	58	0.07 R	91	63	0.00	73	56
14	0.68 R	92	67	0.00	87	61	0.00	70	53	0.34 R	67	58
15	0.00	86	58	0.00	90	60	0.00	64	40	0.77 R	65	46
16	0.30 R	84	58	0.00	90	69	0.00	66	38	0.69 R	48	41
17	0.01 R	84	59	0.05 R	81	70	0.00	73	41	0.00	56	32
18	0.00	78	55	0.00	82	65	0.00	81	50	0.33 R	54	46
19	0.03 R	86	59	0.00	82	55	0.00	91	52	0.00	56	41
20	0.14 R	85	67	0.00	81	54	0.00	91	56	0.00	57	38
21	0.00	87	65	0.00	80	62	0.00	83	52	0.00	54	35
22	0.00	91	70	0.00	78	60	0.00	82	63	Tr	54	33
23	0.00	91	68	0.00	74	47	0.00	79	55	0.00	52	28
24	0.00	91	67	0.00	75	50	0.16 R	83	64	Tr	57	29
25	0.07 R	82	65	0.00	83	52	1.22 R	65	40	Tr	54	43
26	0.88 R	76	60	0.00	90	63	0.00	50	31	0.00	67	38
27	0.00	77	61	0.00	97	69	0.00	52	39	0.00	68	57
28	0.00	78	57	0.00	97	60	0.00	51	39	0.00	58	33
29	0.00	78	56	0.00	97	64	0.00	59	29	0.00	60	27
30	0.00	80	55	0.00	94	56	0.00	62	34	0.86 R	51	33
31	0.00	83	56	0.00	87	50					54	28
Site Total Precip.	3.18 (site data)			0.29 (site data)			3.05 (site data)			3.45 (site data)	ANNUAL 35.88 (site data)	
Total Precip. 2 mi. SE of Ames	3.87			0.12			3.19			3.38	44.59	

Note: Precipitation in inches.

*Ames temperature data, °F

**Tr = trace, R = rain, S = snow.

warming trends. Between February 8 and 15 a warming trend with highs from 40° F to 60° F occurred and melted all snow from the medians. A February 4 snowfall combined with high winds completely plugged the flumes once again, making automatic flow measurement and sampling impossible. The stilling wells were still frozen because of the protection provided by the earth backfill required around the flumes for safety reasons. Manual grab samples were obtained on February 9 at both the inlet and ponded discharge from the culverts. Ponding had occurred because the right-of-way fenceline was still laden with snow preventing free drainage of the median runoff discharged through the culverts.

Warm (33° F to 62° F) weather continued from February 15 to March 4 with brief cold spells and temperatures dropping below freezing at night. Below freezing temperatures and snow occurred from March 4 to March 21. Temperatures were in the 40° F range on March 22 and, generally, the 1984 spring season temperatures remained above freezing thereafter. The frozen stilling wells were freed of ice on April 4, 1984, making the site completely operational for the first time.

During the month of April, above average amounts of precipitation occurred, including a significant runoff event on April 29. Conditions during this event allowed ISU personnel to collect excellent data. The project manager was on site from the beginning of the event until its completion. Thus, manual as well as automated data were gathered. The manual and automated flow measurement data were in excellent agreement.

Officially, Ames received only 0.5 inch more precipitation than the long-term average in the first three months of 1984. However, precipitation for April and May were 6.84 inches and 6.49 inches, respectively--well above the long-term average values of 2.49 inches and 4.28 inches, respectively. In addition, the precipitation in June also set a new record; 11.18 inches were recorded in Ames versus a long-term average of only 5.21 inches. August was exceptionally dry. Ames received only 0.12 inch of rain in August.

Precipitation recorded at the site in 1984 has been as follows:

January through March	2.43 inches
April	5.08 inches
May	4.39 inches
June	7.68 inches
July	3.18 inches
August	0.29 inch
September	3.05 inches
October	3.45 inches

The precipitation recorded at the site was significantly below that recorded in Ames but was still well above average.

4.3.1. Snowmelt Data

The first spring thaw to contribute surface runoff because of snowmelt occurred from February 8 to 15, 1984. Runoff from snowmelt probably began late on February 8. Two random grab samples of the runoff from each flume were obtained on February 9. The analytical results are shown in Table 2. The samples are identified as follows: HI (steep slope) and PI (flat slope) represent H-flume and Parshall

ENGINEERING RESEARCH INSTITUTE
ANALYTICAL SERVICES LABORATORY
REPORT OF CHEMICAL ANALYSIS

TO: HARVEY GULLICKS
PROJECT: DOT 0209
DATE: FEB 16, 1984
BY:

Table 2. Report of chemical analysis 2/16/84. Grab samples collected 2/9/84.

DOT 0209	HI	HO	PI	PO	UNITS
COND	2910	2870	580	530	UMHO/CM*
TOT SOLIDS	173	****	328	****	MG/L**
SUSP SOLIDS	8.5	****	21	****	MG/L
CHLORIDE	46.1	46.8	136	127	MG/L
NO3+NO2-N	.06	****	.19	****	MG/L AS N
KJEL-N	1.41	****	2.37	****	MG/L AS N
TOTAL P	.28	****	.41	****	MG/L AS P
COD	21.8	****	43.2	****	MG/L
TOC	13	11	19	14	MG/L
TOT CU	6.8	6.6	5.0	5.0	UG/L***
TOT FE	28.7	75.7	62.5	95.4	UG/L
TOT PB	9.8	9.2	7.7	9.5	UG/L
TOT ZN	16	15	6.8	7.3	UG/L
pH		7.03			

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[*] micromhos per centimeter.

[**] milligrams per liter.

[***] micrograms per liter.

flume influent from the median, respectively. HO and PO represent ponded water samples downstream from the H-flume and Parshall flume outlets, respectively. The ponding downstream from the flume outlets was caused by snow collecting along the right-of-way fenceline that had not melted at the same rate as that in the right of way and median. Ponding of runoff, however, occurs naturally at the site only a short distance beyond the right of way in any case.

The snowmelt runoff from the flat median (PI and PO) had substantially higher concentrations of chloride than that of the steeper median (HI and HO). This may be a result of the first flush phenomenon since the highly soluble chloride would be transported rapidly with the first runoff. Runoff was observed to be more complete on the steeper slope at the time of sampling. The chloride concentration in the flat median runoff was approximately half the Environmental Protection Agency (EPA) drinking water standard of 250 mg/l. It is likely that the first flush concentrations were substantially higher than 125 mg/l and may have exceeded the drinking water standard.

Snowmelt in February 1984, while it occurred in a relatively short time, did not create large flow rates through the flumes at the site. Although the flow measurement equipment was not operational, the authors observed a fairly continuous flow rate of 0.1 cfs to 0.2 cfs based on visual observations. As a result, suspended solids loadings were low. Concentrations of parameters which may be associated with suspended solids loadings were also fairly low, notably the metals and oxygen demand. The Kjeldahl nitrogen level, which is likely to be largely organic nitrogen based on the chemical oxygen demand (COD) results, was significant. However, it is unlikely that excessive levels of free ammonia exist [1].

Snowmelt in March 1984 was not sampled because of the nonoperational status of the flow measurement equipment. The Iowa DOT gathered additional snowmelt data in the spring of 1985. Those data are found in the Appendix of this report.

4.3.2. April 29, 1984, Runoff Event

The April 29, 1984, rainfall event was preceded by light showers from 11:45 a.m. to 1:45 p.m. Heavy rainfall began at 1:45 p.m. and continued with some variation in intensity until 5:12 p.m. Approximately 1.60 inches of rain fell between 1:45 p.m. and 5:12 p.m. for an average intensity of about 0.43 inch per hour. The intensity after 2:55 p.m. was about 0.52 inch per hour. The range of intensities during the event was from about 0.1 inch per hour to 0.6 inch per hour. Cumulative rainfall versus time is shown in Fig. 7.

Figures 8a and 9 show the hydrographs for the H-flume (collecting runoff from the steeper slope median) and the Parshall flume (collecting runoff from the flat median), respectively. The two flumes reached peak flows at nearly the same time, but the steeper slope runoff (H-flume) was considerably more responsive to changes in rainfall intensity. Actually, two separate peaks occurred early in the event for the steeper slope because of a brief reduction in rainfall intensity at about 2:20 p.m.

The peak flow rate recorded by the H-flume was 1.37 cfs and existed only momentarily. The peak flow recorded by the Parshall flume was 0.95 cfs. The basin lag time for the hydrographs is the time from the center of mass of the rainfall to the peak. Thus, the basin lag time

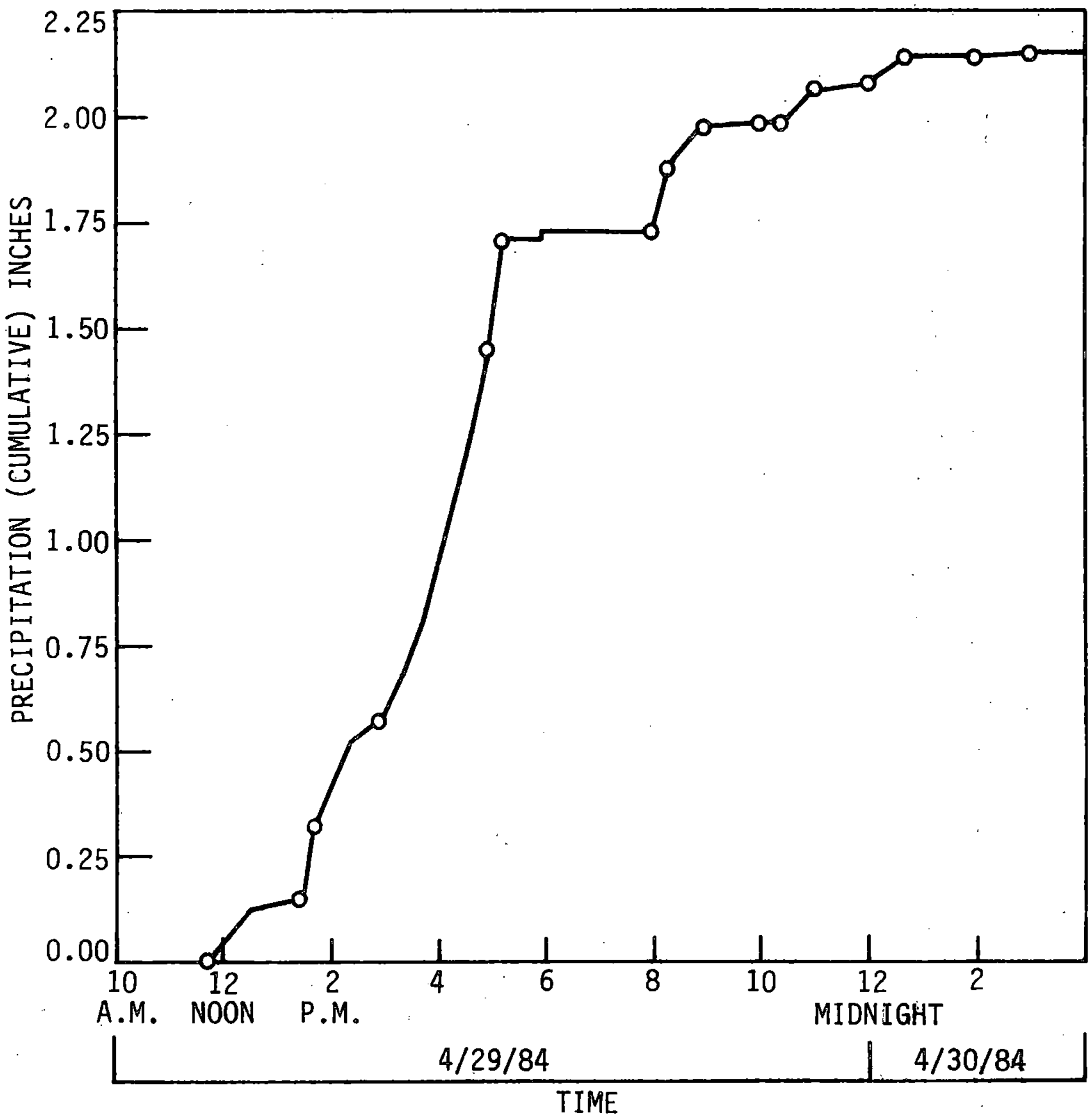

Fig. 7. Cumulative rainfall versus time 4/29/84 rainfall event.

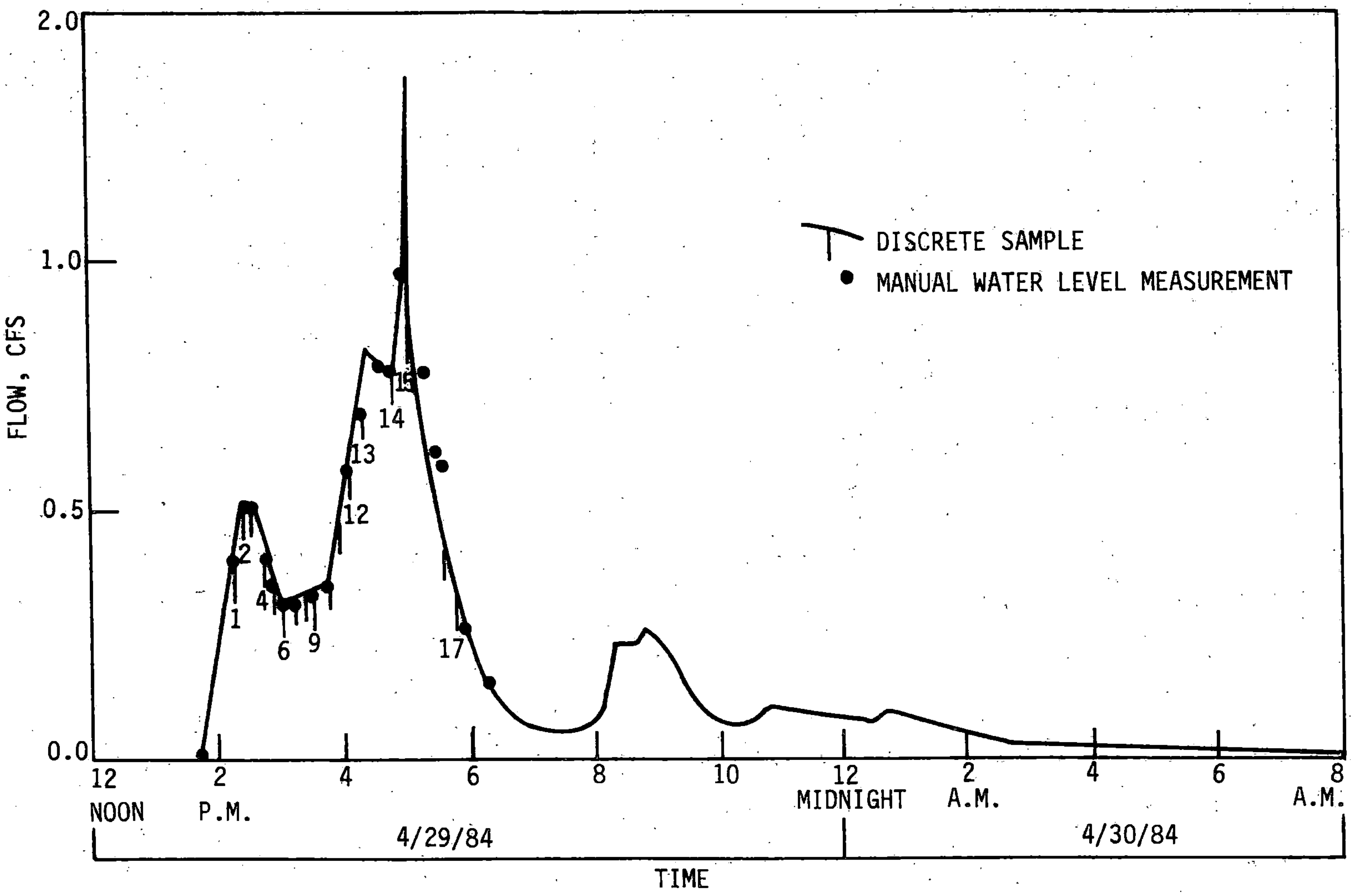

Fig. 8a. H-flume hydrograph 4/29/84 runoff event.

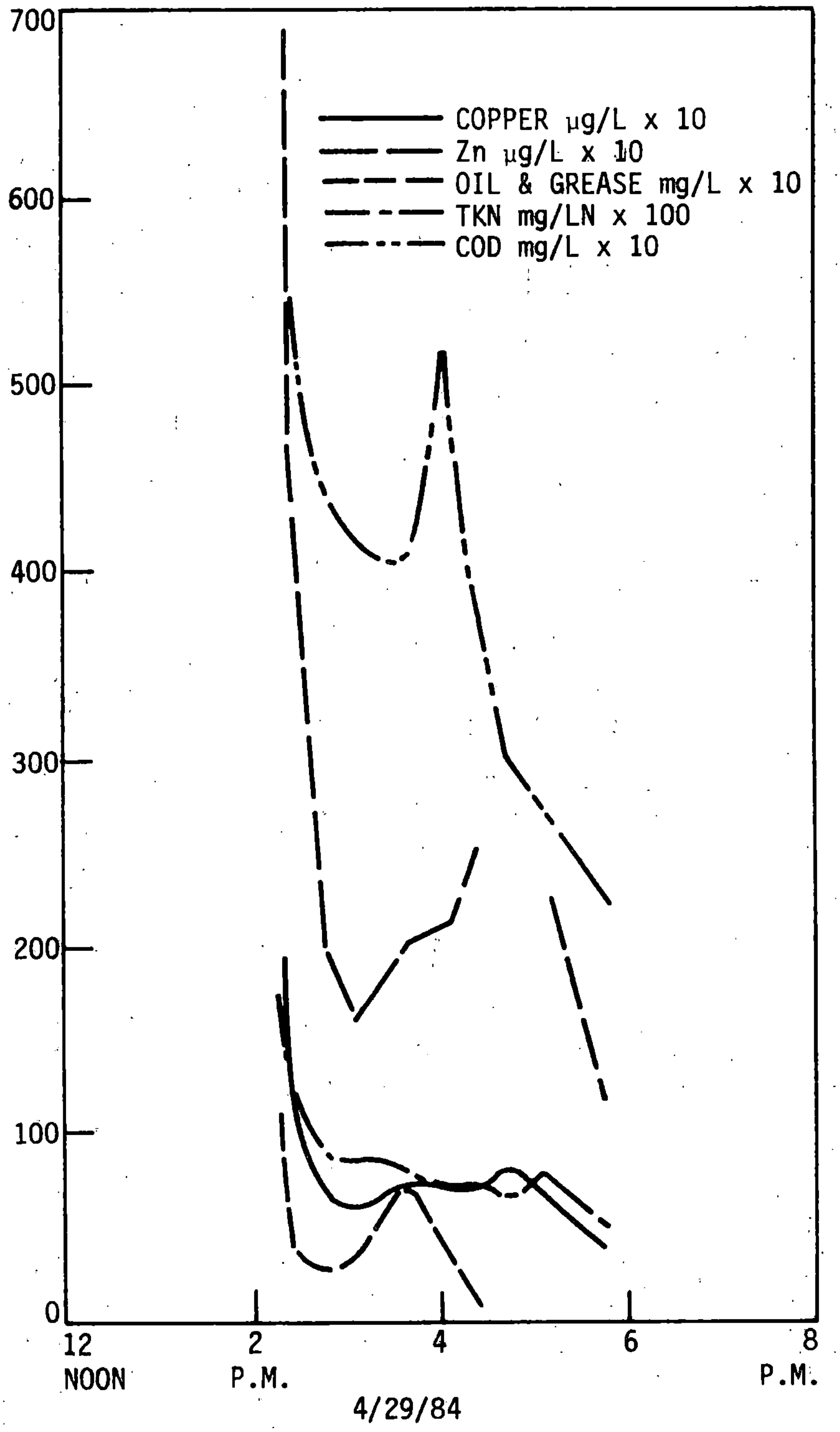

Fig. 8b. Analytical parameter concentrations (copper, Zn, oil and grease, TKN, and COD) versus time 4/29/84 event.

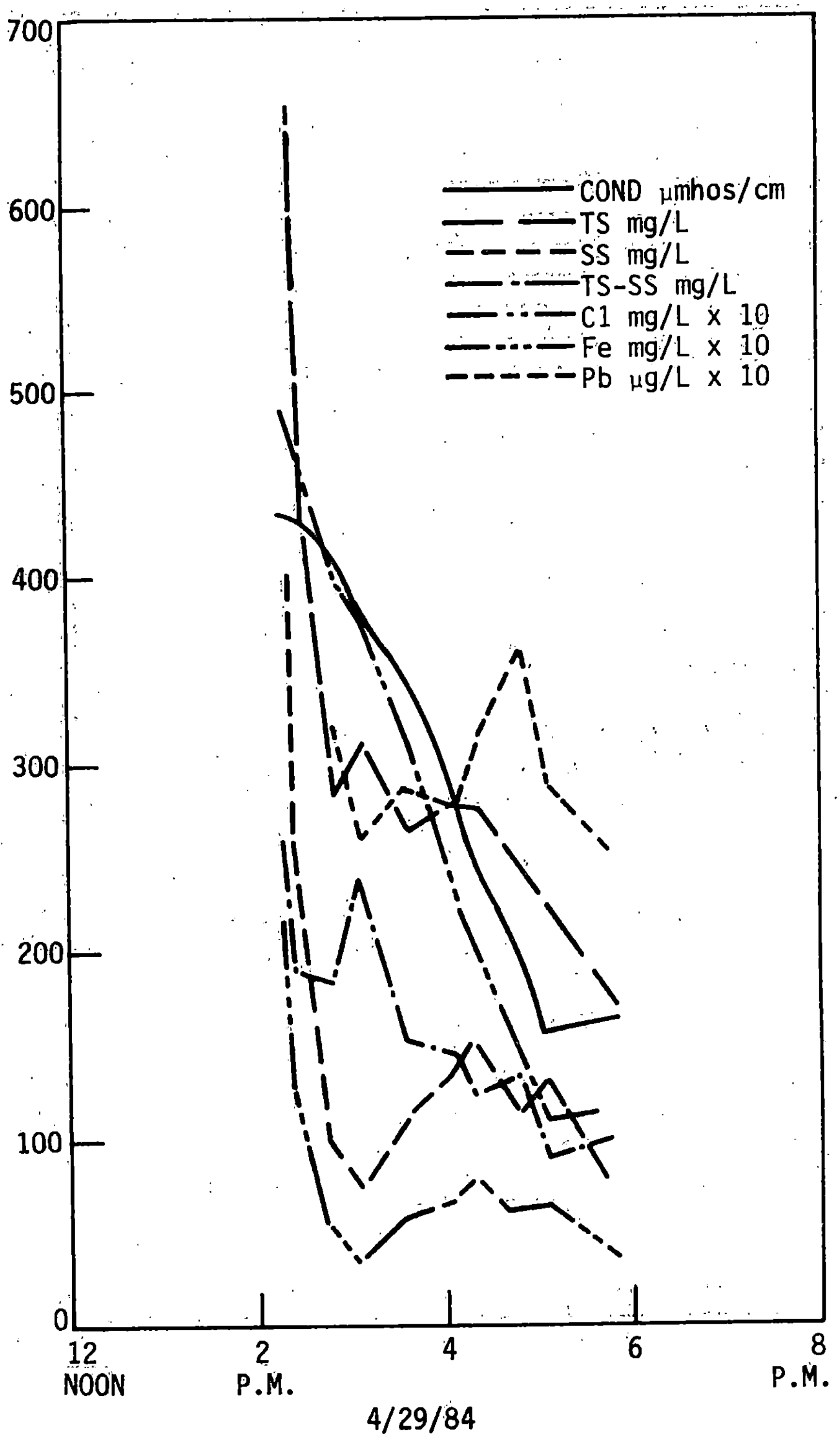

Fig. 8c. Analytical parameter concentrations (COND, TS, SS, TS-SS, Cl, Fe, and Pb) versus time 4/29/84 event.

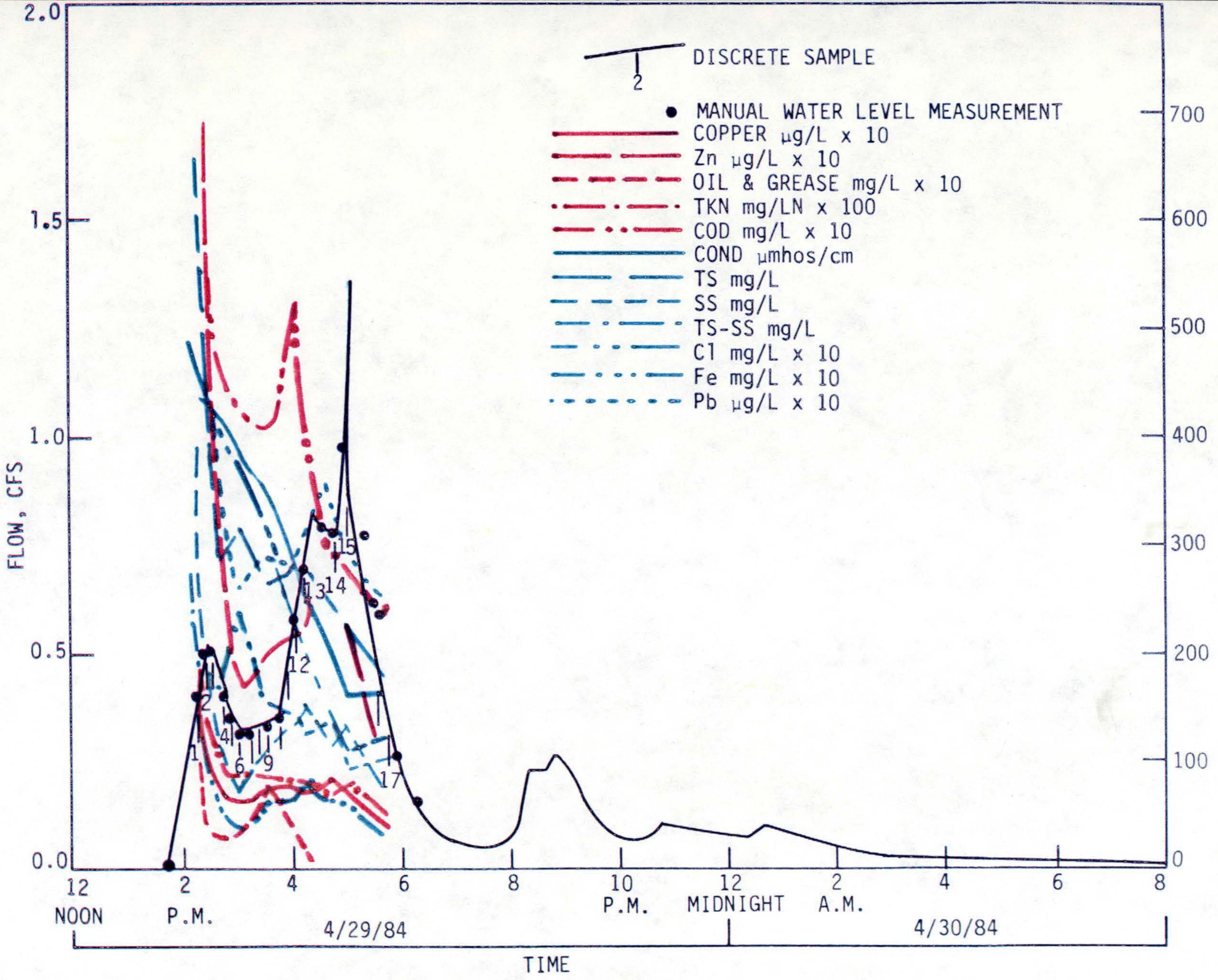

Fig. 8d. Consolidation of Figures 8a, 8b, and 8c.

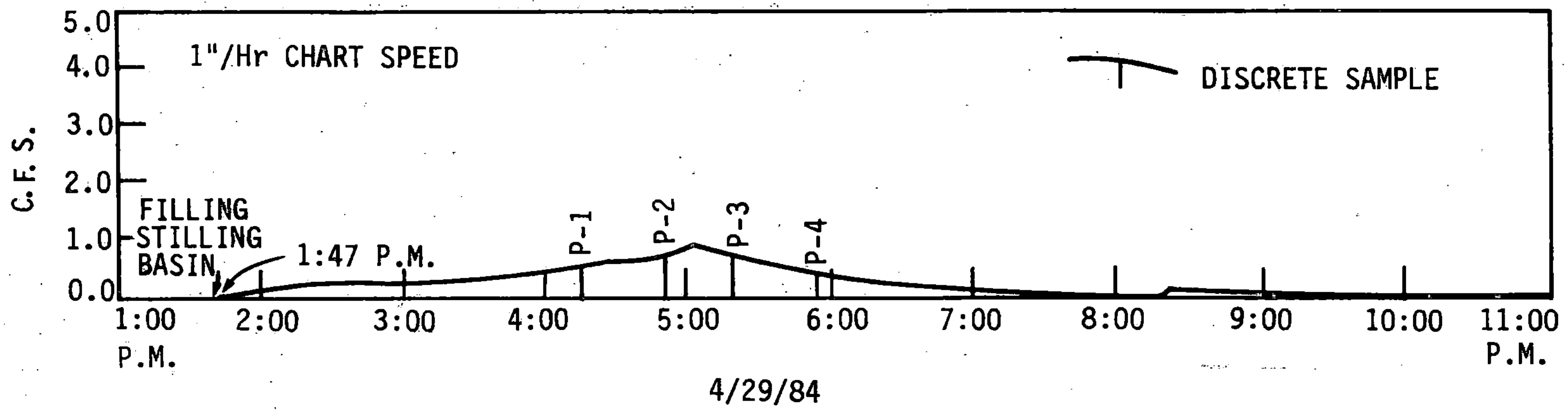

Fig. 9. Parshall flume hydrograph 4/29/84 runoff event.

was about 74 minutes for the Parshall flume watershed. For the H-flume watershed, the basin lag time was 40 minutes to 50 minutes, based on the data of the three separate peaks on the hydrograph. Total runoff from the flat median area was approximately 9,800 cubic feet or 1.59 inches per acre from 1:45 p.m. to 8:00 p.m. Total runoff from the steeper slope was approximately 8,200 cubic feet or 1.21 inches per acre from 1:45 p.m. to 8:00 p.m. The relative volumes of runoff from each area were undoubtedly the result of a higher degree of saturation and a lesser infiltration in the flat slope soils and/or lateral variation of rainfall.

Runoff samples were collected at discrete time intervals by the ISCO samplers. Four samples were collected from the Parshall flume. Sixteen samples were collected from the H-flume. In addition, one manual sample, sample 17, was collected from the H-flume. The chronological locations of the samples are shown on the hydrographs, Figs. 8a and 9. H-flume samples 1, 2, 4, 6, 9, 12, 13, 14, 15, and 17 were analyzed. Parshall flume samples P-1, P-2, P-3, and P-4 were analyzed. The list of analytical parameters and results are shown in Table 3. The H-flume sample analyses were also plotted chronologically to show trends related to the peak flow; see Figs. 8b, 8c, and 8d.

Notable correlations of flow and analytical parameter values for the H-flume samples are

1. The highest value for all parameters occurred in the first sample representing a first flush phenomenon.
2. Chloride and conductivity values both exhibited decreasing approximately straight line behavior. Figure 10 demonstrates

ANALYTICAL SERVICES LABORATORY
REPORT OF CHEMICAL ANALYSIS

TO: HARVEY GULLICKS
PROJECT: DOT 0430
DATE: May 8, 1984
BY:

Table 3. Report of chemical analysis 5/8/84. Discrete samples collected 4/29/84 and 4/30/84.

DOT 0430	1	2	4	6	9	12	13	14	15	17	P1	P2	P3	P4	UNITS
PH	8.10	8.05	8.04	8.04	8.04	7.93	8.00	8.04	8.05	7.91	7.84	7.98	7.93	7.94	-LOG H+
COND	433	433	415	384	346	285	249	199	158	166	248	192	172	172	UMHO/CM*
TS	658	452	282	312	262	280	280	246	224	172	186	151	213	146	MG/L**
SS	399	260	100	74	110	136	156	114	134	72	59	44	28	23	MG/L
CL	49.0	45.7	40.0	38.0	30.9	22.4	20.3	15.0	10.8	11.6	20.9	14.8	12.5	11.2	MG/L
NO_3+NO_2N	0.17	0.12	0.13	0.07	0.07	0.08	0.08	0.11	0.06	0.05	0.07	0.07	0.06	0.07	MG/L N
TKN	1.80	1.32	0.86	0.85	0.76	0.70	0.74	0.64	0.76	0.49	0.66	0.66	0.47	0.49	MG/L N
TOT P	0.41	0.33	0.17	0.15	0.19	0.19	0.22	0.20	0.22	0.15	0.15	0.12	0.11	0.075	MG/L P
COD	72.4	55.5	46.0	41.7	40.4	52.0	40.0	29.5	27.2	22.5	34.2	25.4	22.5	20.9	MG/L
TOC	22	19	16	14	13	13	12	11	9.4	7.4	11	9.2	9.8	7.8	MG/L
OIL&GR	11	3.8	2.6	3.4	7.8	3.2	<2	<2	<2	<2	14	2.4	<2	<2	MG/L
F. COLI	13	****	27	****	30	****	****	>1100	****	****	>125	>980	****	****	ORG/.1L
F. STREP	>2000	****	>2000	****	>2000	****	****	>2000	****	****	>200	>2000	****	****	ORG/.1L
TOT CU	19.3	12.1	6.2	5.9	7.1	6.6	6.6	8.0	6.7	3.7	4.3	3.3	3.5	2.1	UG/L***
TOT FE	21.5	12.7	5.04	3.88	5.99	6.55	7.58	6.18	6.23	3.05	1.79	1.39	1.03	0.87	MG/L
TOT PB	78	51	32	26	29	28	31	36	29	25	9.8	10.0	7.5	6.6	UG/L
TOT ZN	101	47	20	16	20	21	24	127[a]	23	12	22	8.6	6.1	5.1	UG/L

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*micromhos per centimeter.

**milligrams per liter.

***micrograms per liter.

[a] worm in sample 14.

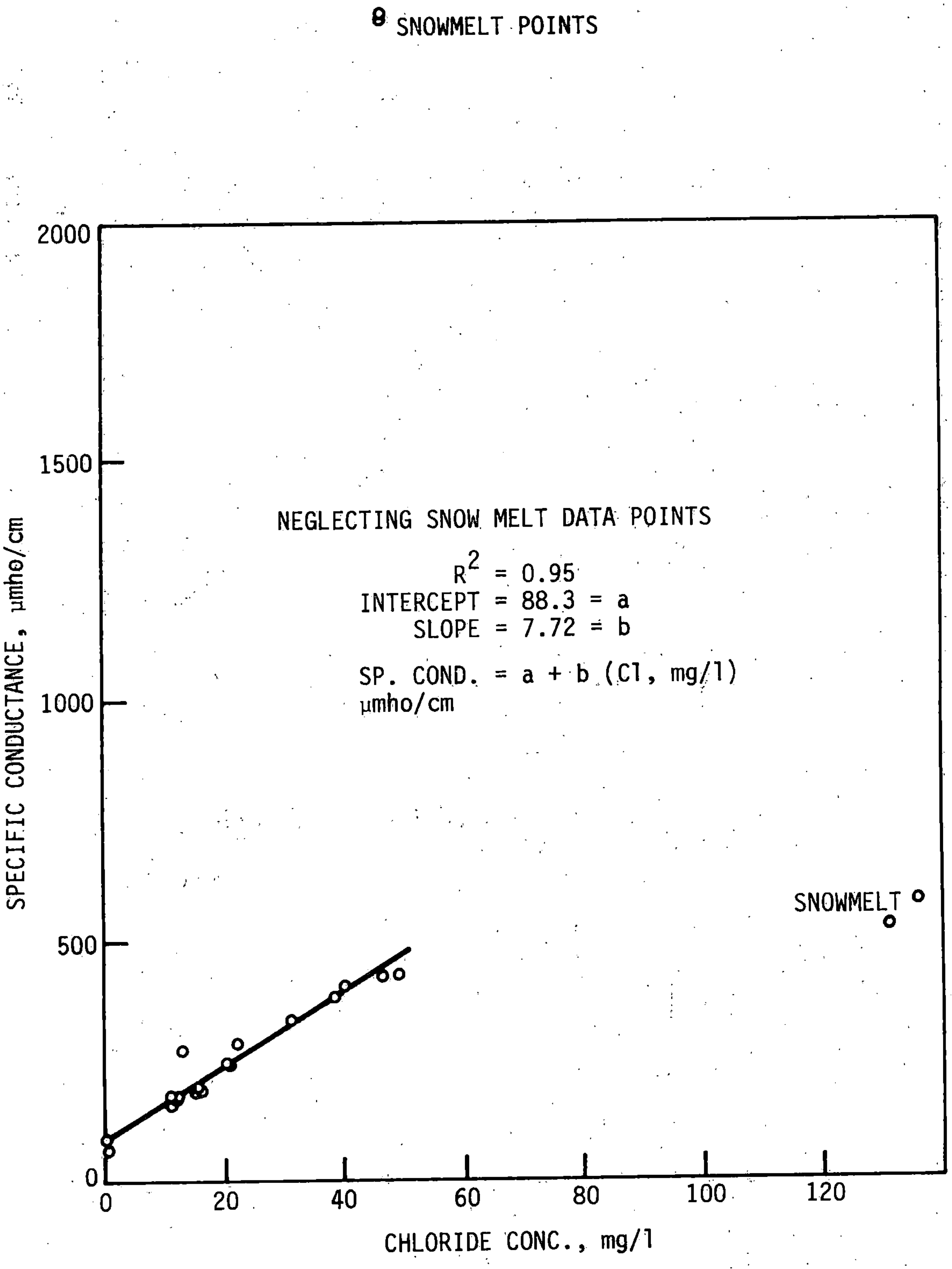

Fig. 10. Chloride concentration vs. specific conductance of Interstate Highway 35 runoff. Data from all runoff events.

that the conductivity and chloride concentrations are directly related if snowmelt data are ignored.

3. The metals (Fe, Pb, Cu, and Zn), total solids (TS), and suspended solids (SS) all exhibited peaks coinciding approximately with the peak flow. The value of total solids less suspended solids, however, was constantly decreasing. Thus, metals concentrations appear to be related primarily to suspended solids loading. This is demonstrated further by Fig. 11, which includes data from all runoff events. The correlation between iron and suspended solids concentrations is excellent. The correlation of copper, lead, and zinc concentrations to suspended solids concentrations is fair.
4. Fecal streptococci and fecal coliform analyses indicate an animal (nonhuman) source.
5. All analytical parameter values were lower in the Parshall flume runoff than in the H-flume runoff. Furthermore, trends relating flow rate to parameter concentrations were not evident, except for the first flush phenomenon.
6. First flush sample parameter values were occasionally in excess of the EPA drinking water maximum contaminant levels.

The pH of the steeper slope runoff was of the order of 7.9 to 8.1, slightly higher than that of the flat slope runoff. This is likely due to the buffering effect of the suspended sediment load differences. Conductivity and chloride in the runoff appeared to be related. Chloride levels observed in the first flush were elevated above background levels. The chloride levels observed during this

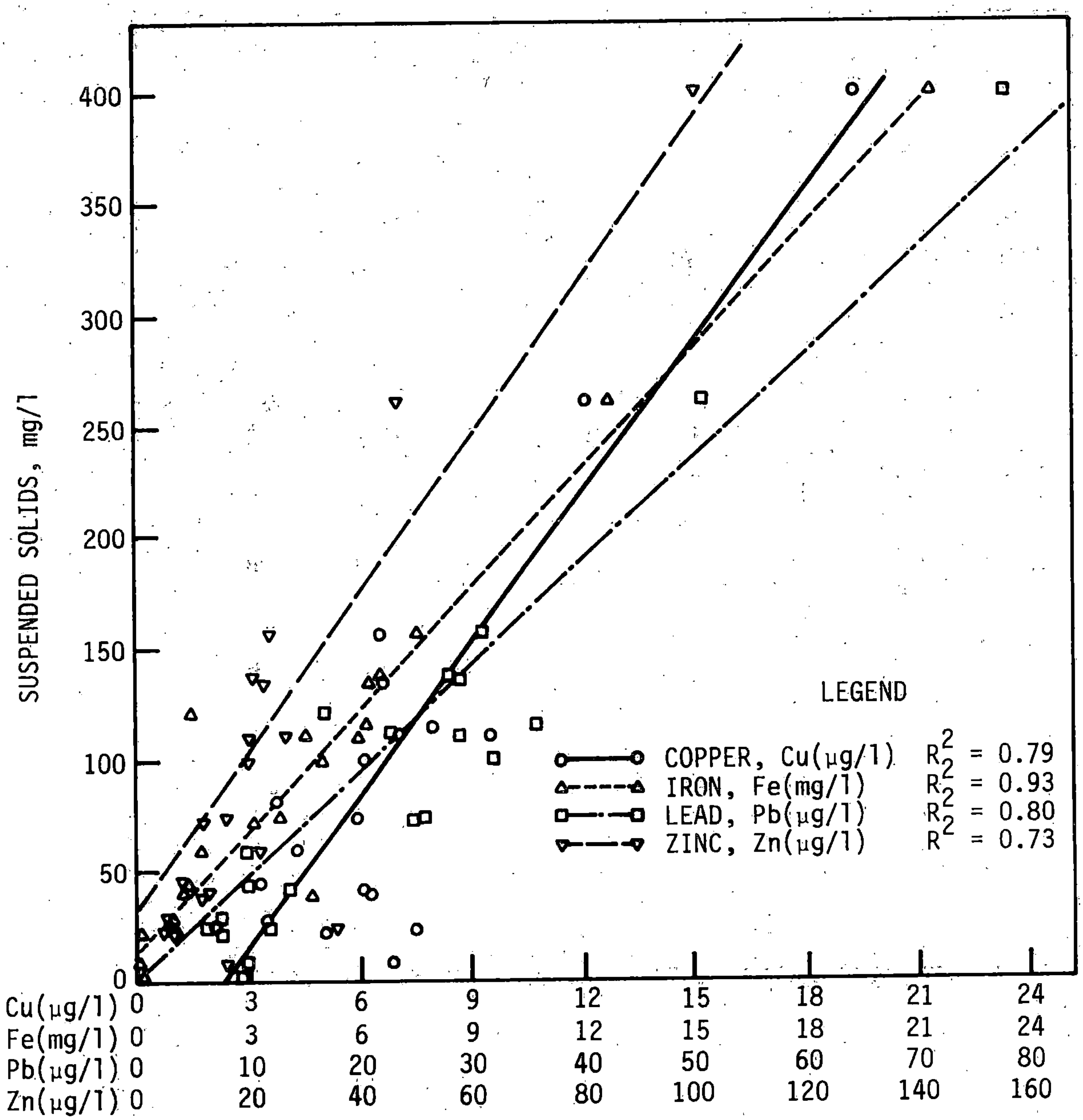

Fig. 11. Metal concentrations vs. suspended solids concentration. Data from all runoff events.

runoff event were, however, substantially lower than those observed in random grab samples of snowmelt runoff collected on February 9, 1984.

Highway maintenance and operations did not contribute significant amounts of nitrogen and phosphorus to surface waters at the test site during the April 29 event. Oil and grease were observed to be significant in the first flush. It was also observed that oil and grease levels may fluctuate significantly. This may be because of flushing of oil and grease as "rafts" of contaminants rather than by discrete particle flushing. Total organic carbon (TOC) and chemical oxygen demand (COD) were elevated above background levels in the first flush samples. COD also exhibited a secondary peak in concentration that does not appear to be directly related to the peak flow or suspended sediment load.

4.3.2. Other Runoff Events

Additional runoff events occurred in May, June, September, and October 1984. The runoff flow rate from some events was recorded, and the runoff was sampled. For some events, however, operational and equipment problems prevented complete data collection. For these events, the data collected were evaluated to maximize the interpretation of runoff events in which samples were collected and analyzed.

There were two major operational and equipment malfunctions during the warmer weather monitoring program. First, earthworm penetration and rapid algal build-up at the ISCO flow meter bubble tube negated some of the Parshall flume hydrograph data. The earthworm problem was corrected by surrounding the tube with wire mesh. The algal build-up required more frequent summer maintenance visits. Secondly, the mechanical clock used in the Steven's recorder occasionally stopped, presumably because of humidity build-up or because of a rough gear tooth. Another Steven's recorder became available that was substituted for the one previously used.

In order to gather more hydrological data from the steeper slope drainage area, the ISCO flow meter bubble tube was installed in the H-flume on July 26, 1984, so that the runoff flow from the 2 percent grade was monitored continuously with fewer mechanical malfunctions. Excellent data had been collected from the flat (0.24 percent) drainage area up to July 26 and was deemed to be sufficient from a hydrological evaluation standpoint.

The data for the important runoff events of May, June, September, and October 1984 are presented in Figs. 12 through 25 and Tables 4 through 11. Figures 12 through 17 present the cumulative precipitation versus time for the events of May 24-25, June 13, June 14-15, June 16, September 24-25, and October 14-15, 1984, respectively. Figures 18 through 25 present the hydrographs for these runoff events.

Table 4 presents suspended solids and conductivity data for four discrete samples from the May 24-25 runoff event. The analytical values in Table 4 may be used to approximate chloride and metals concentrations from Figs. 10 and 11. Tables 5, 6, 7, and 8 present sample analyses for events of June 14-15, September 10, September 24-25, and October 14-15, 1984, respectively. The data in Table 6 are for a grab sample of the first runoff after July 26, 1984. The flow during the September 10 runoff did not exceed 0.001 cubic feet per second.

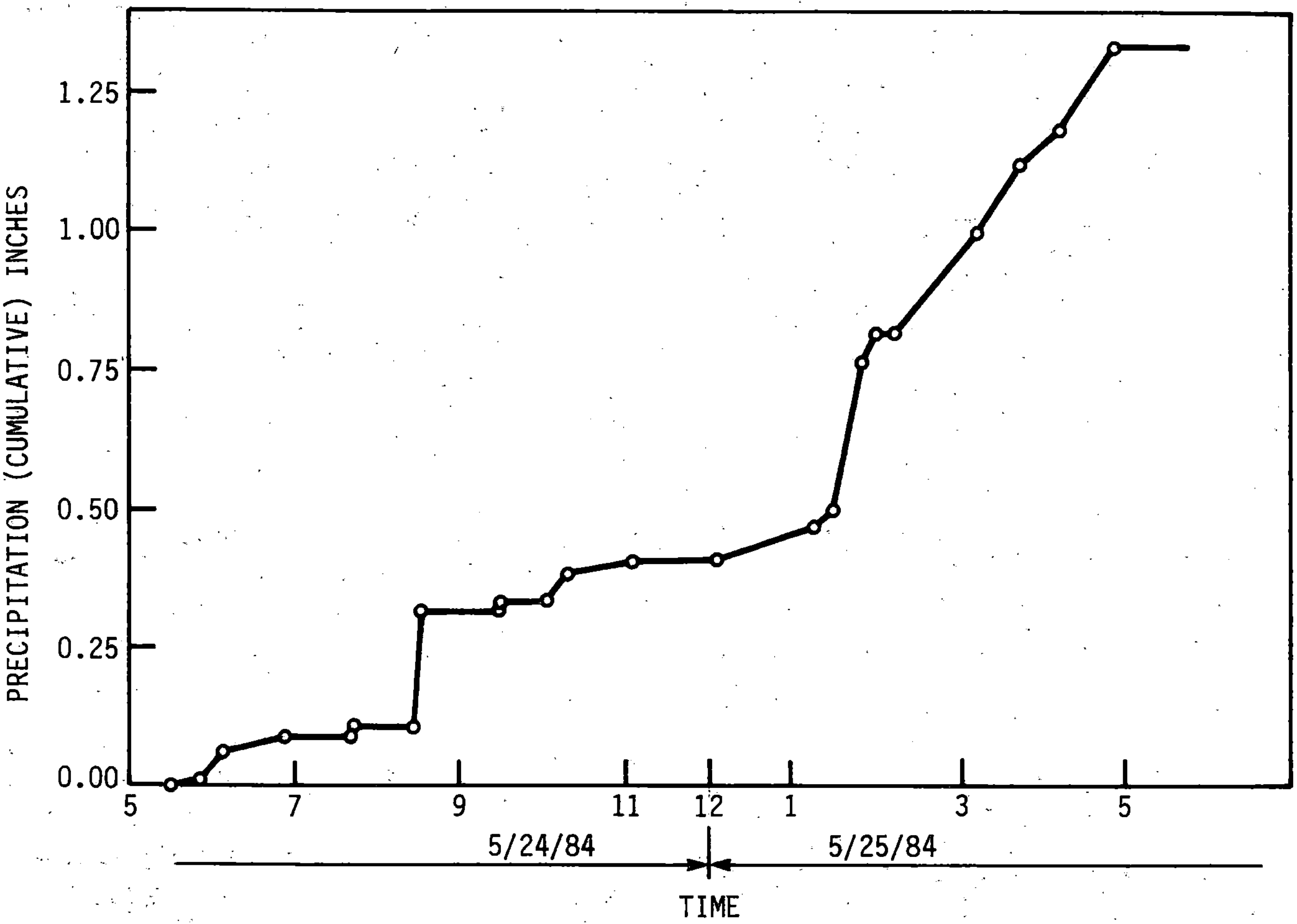

Fig. 12. Cumulative rainfall vs. time 5/25/84 rainfall event.

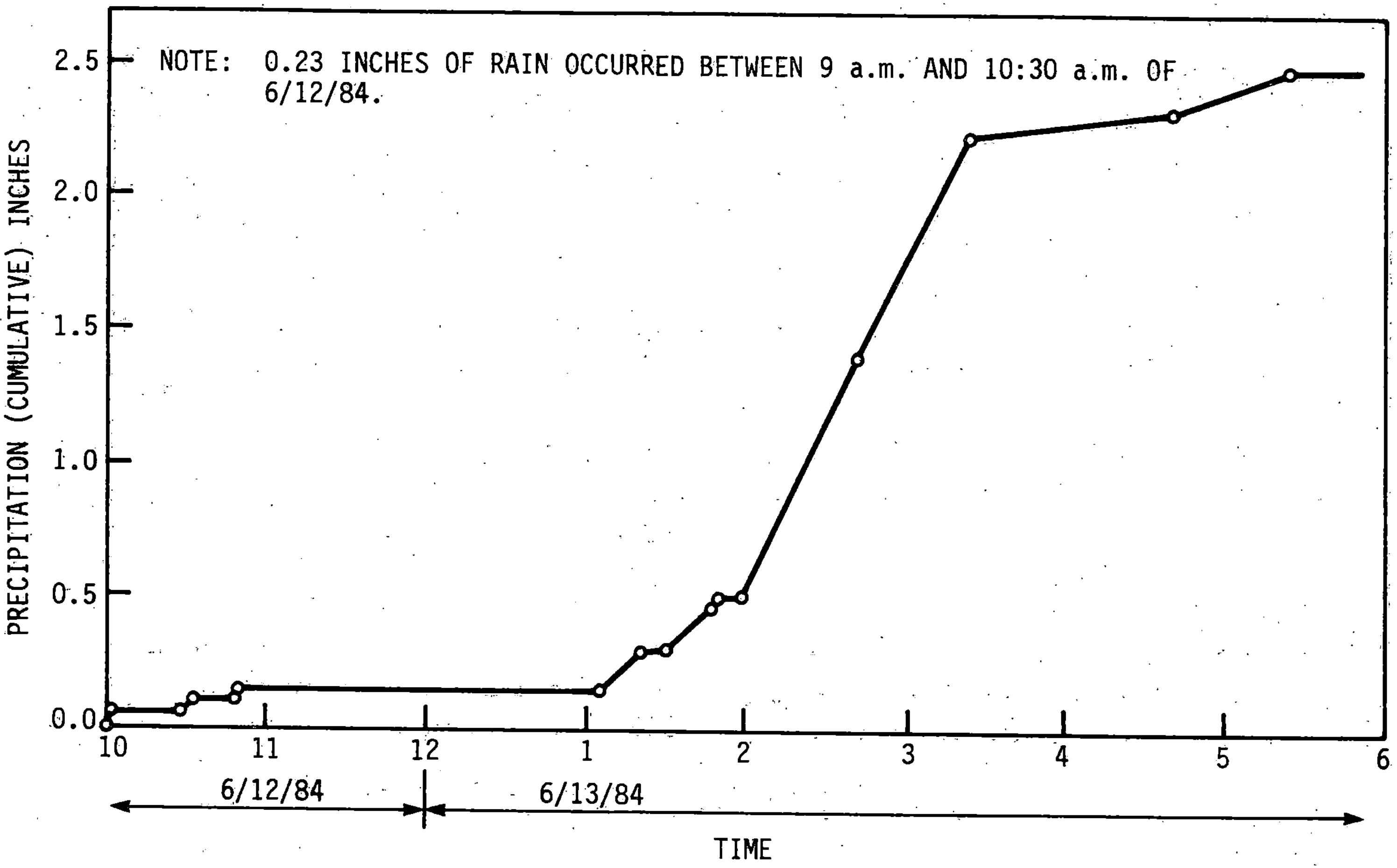

Fig. 13. Cumulative rainfall vs. time 6/13/84 rainfall event.

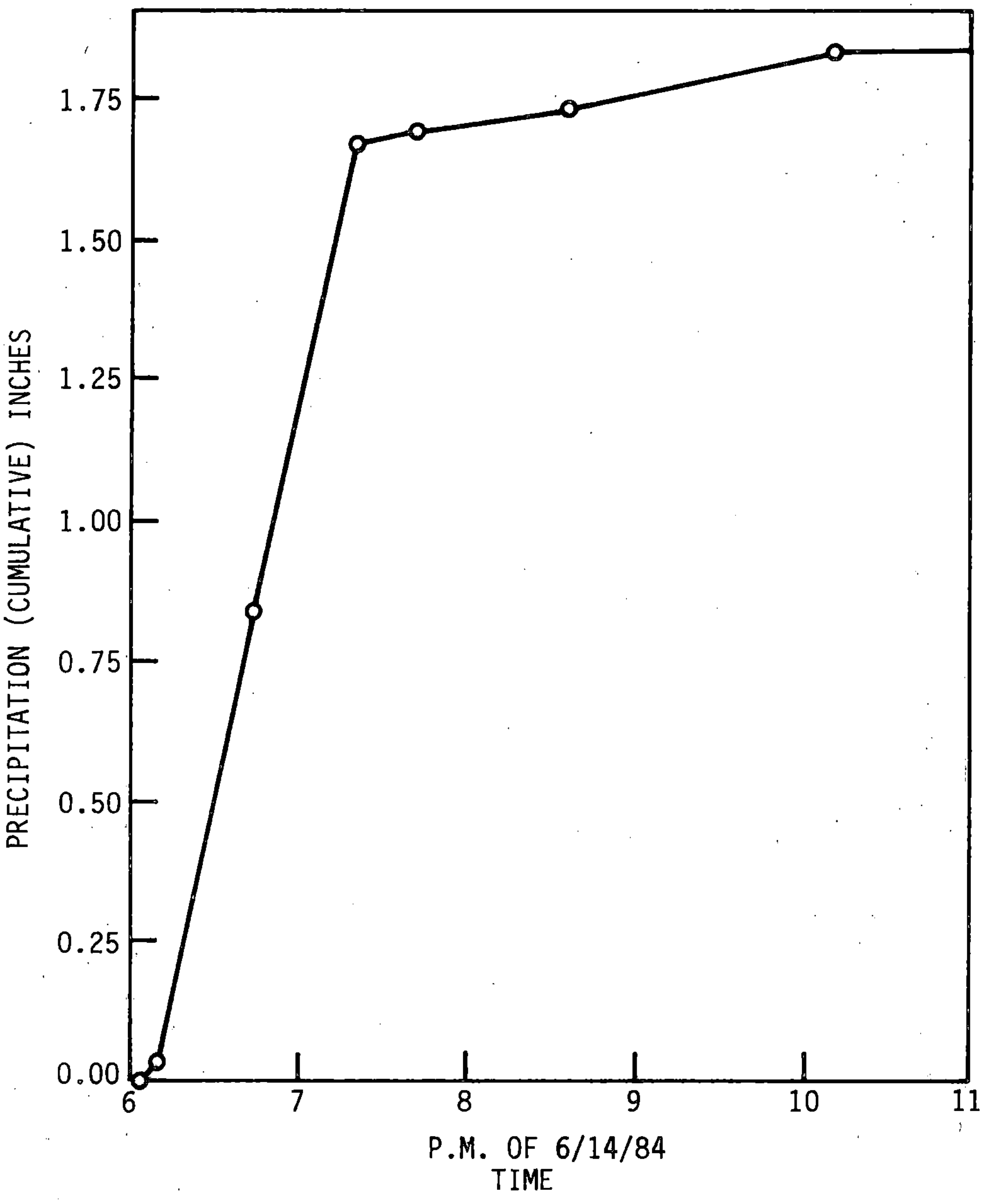

Fig. 14. Cumulative rainfall vs. time 6/14/84 rainfall event.

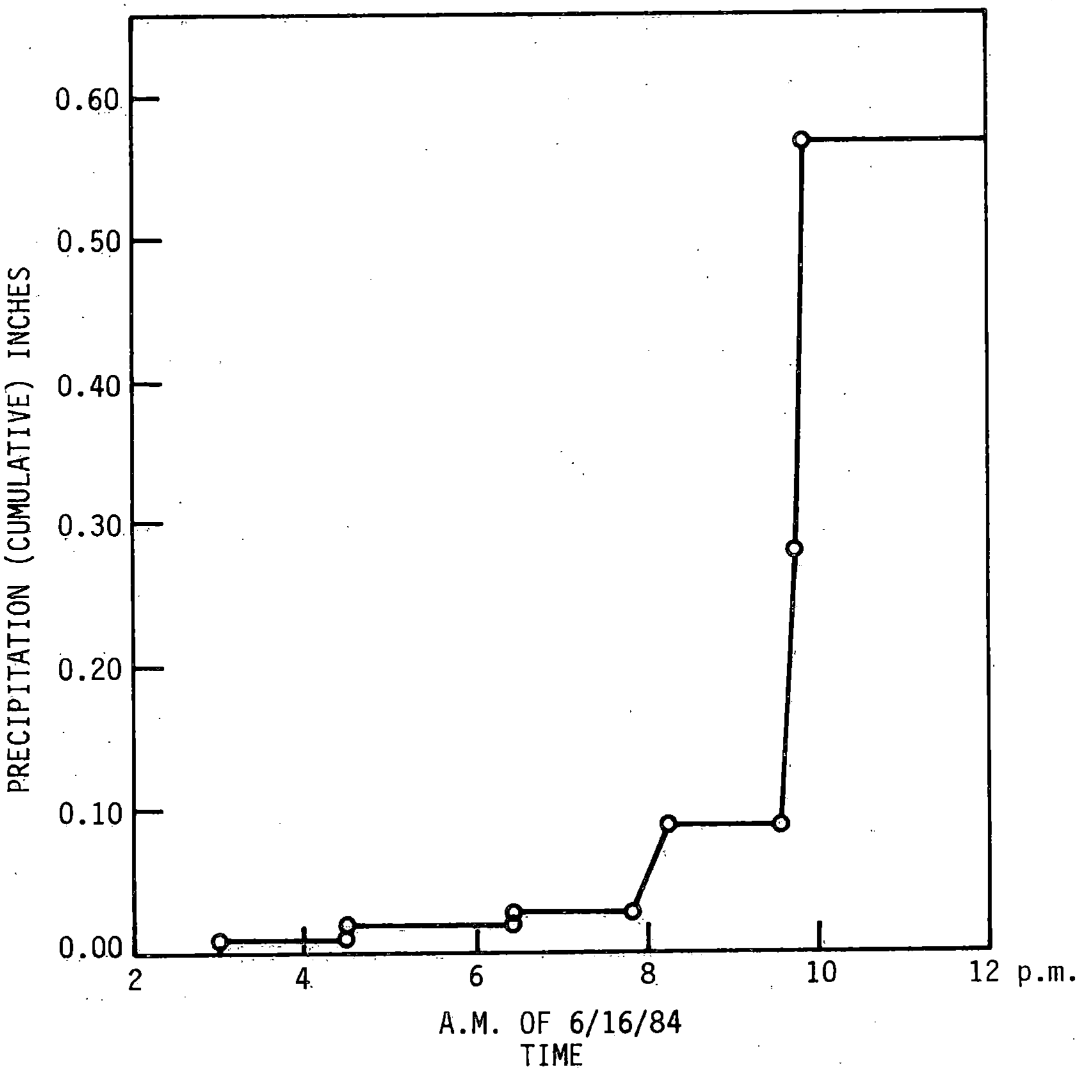

Fig. 15. Cumulative rainfall vs. time 6/16/84 rainfall event.

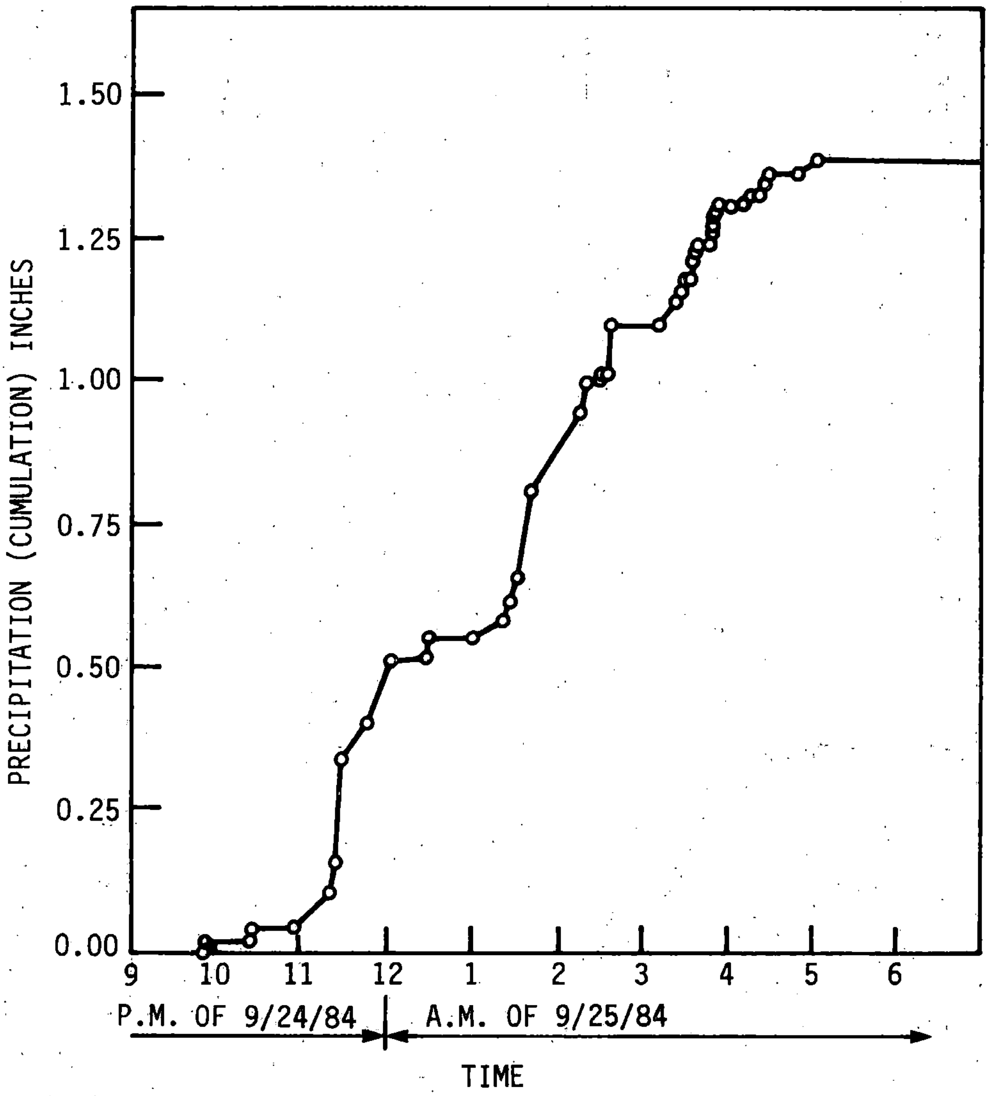

Fig. 16. Cumulative rainfall vs. time 9/25/84 rainfall event.

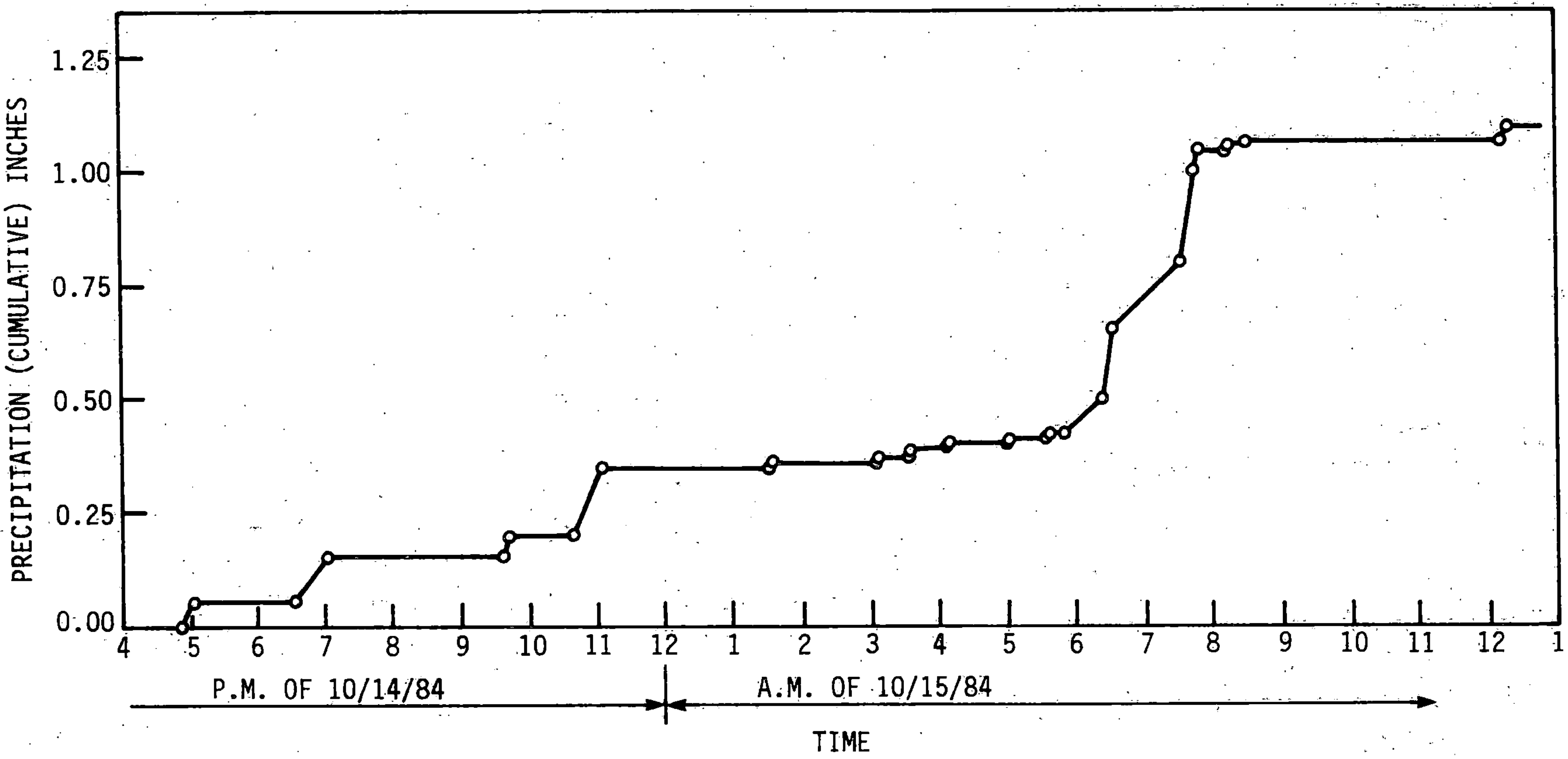

Fig. 17. Cumulative rainfall vs. time 10/15/84 rainfall event.

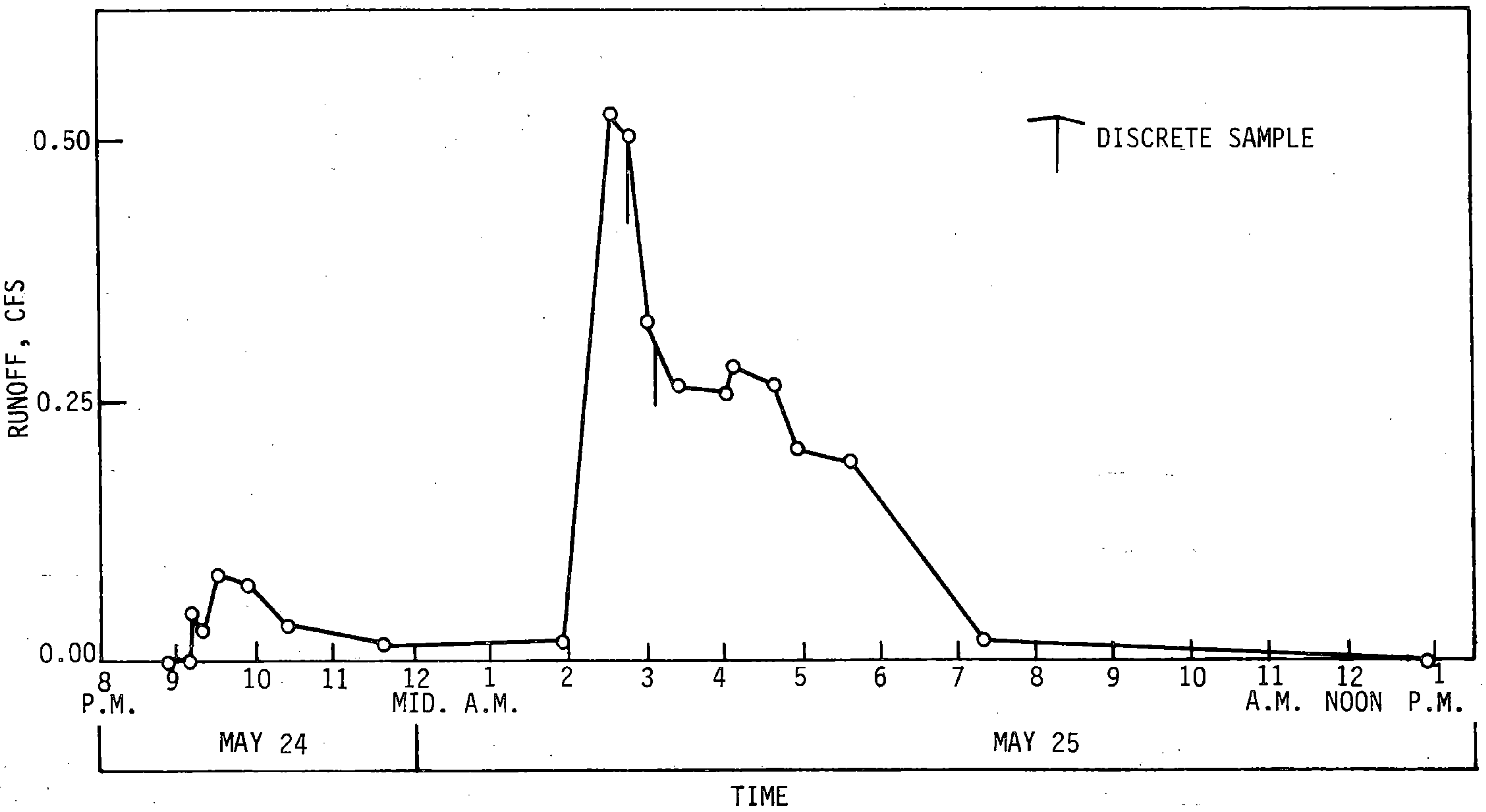

Fig. 18. H-flume hydrograph 5/24/84 and 5/25/84 events.

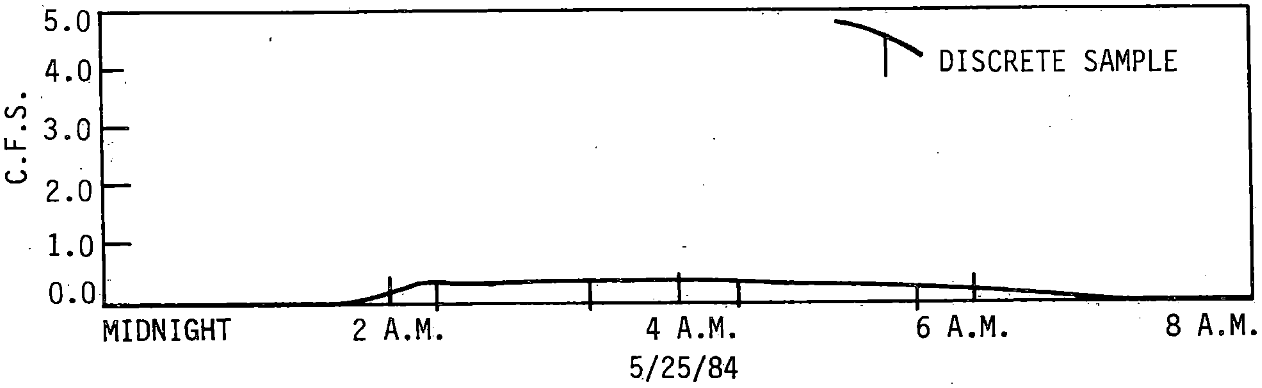

Fig. 19. Parshall flume hydrograph 5/24/84 and 5/25/84 event.

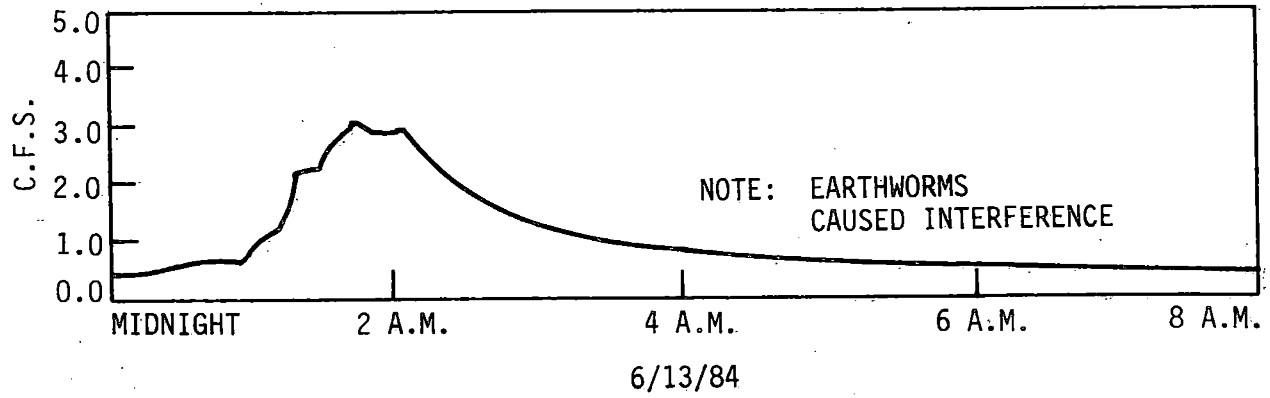

Fig. 20. Parshall flume hydrograph 6/13/84 events.

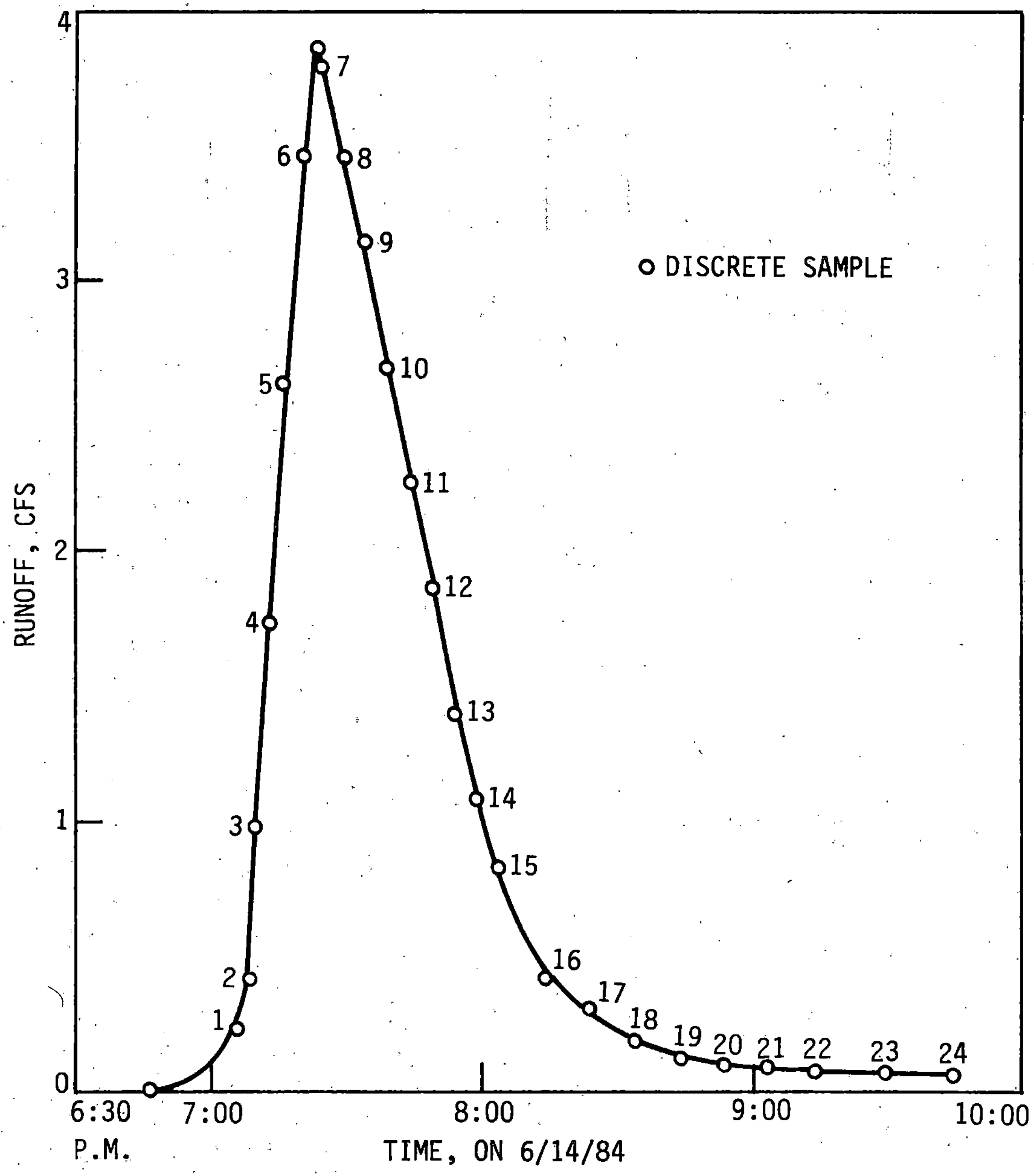

Fig. 21. H-flume hydrograph 6/14/84 event.

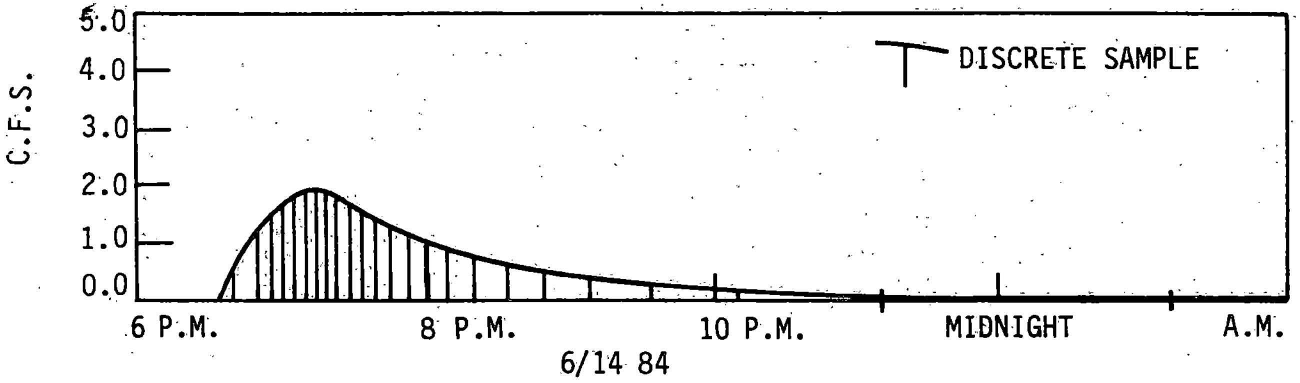

Fig. 22. Parshall flume hydrograph 6/14/84 event.

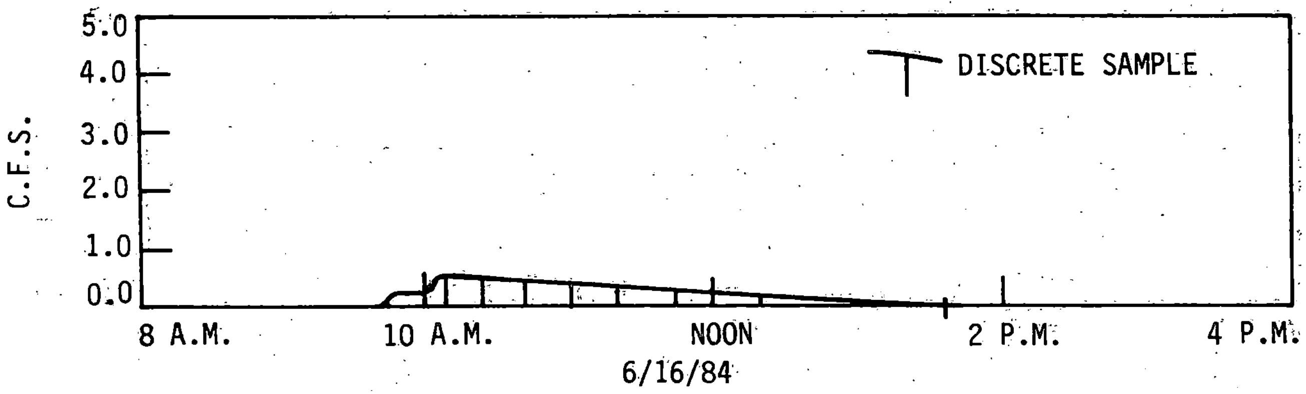

Fig. 23. Parshall flume hydrograph 6/16/84 event.

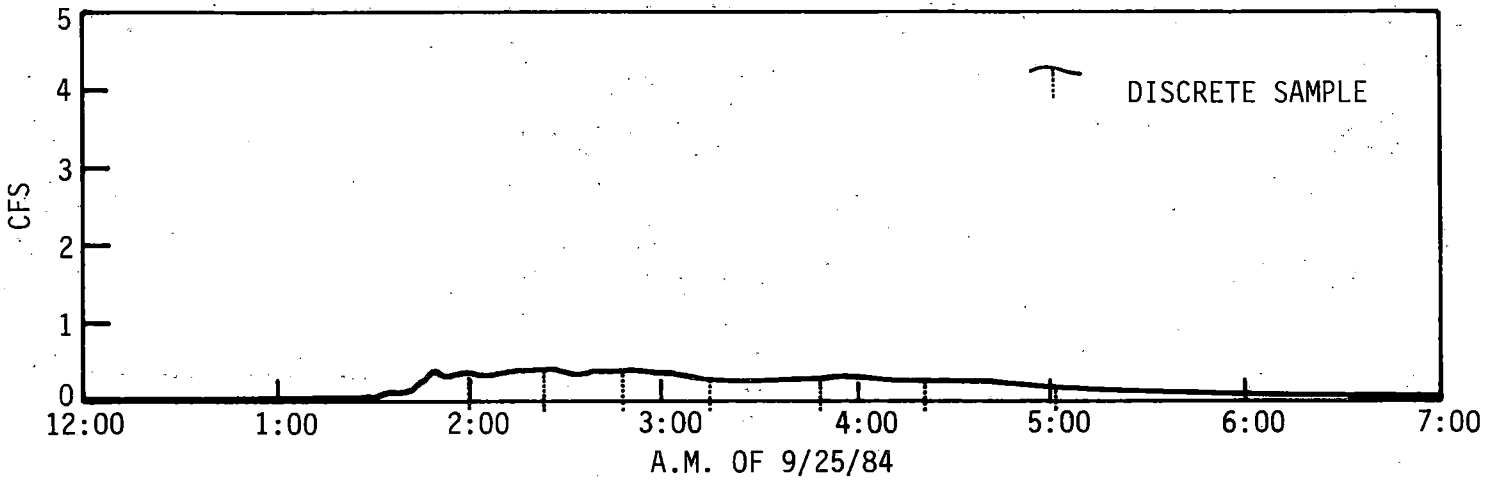

Fig. 24. H-flume hydrograph 9/25/84 event.

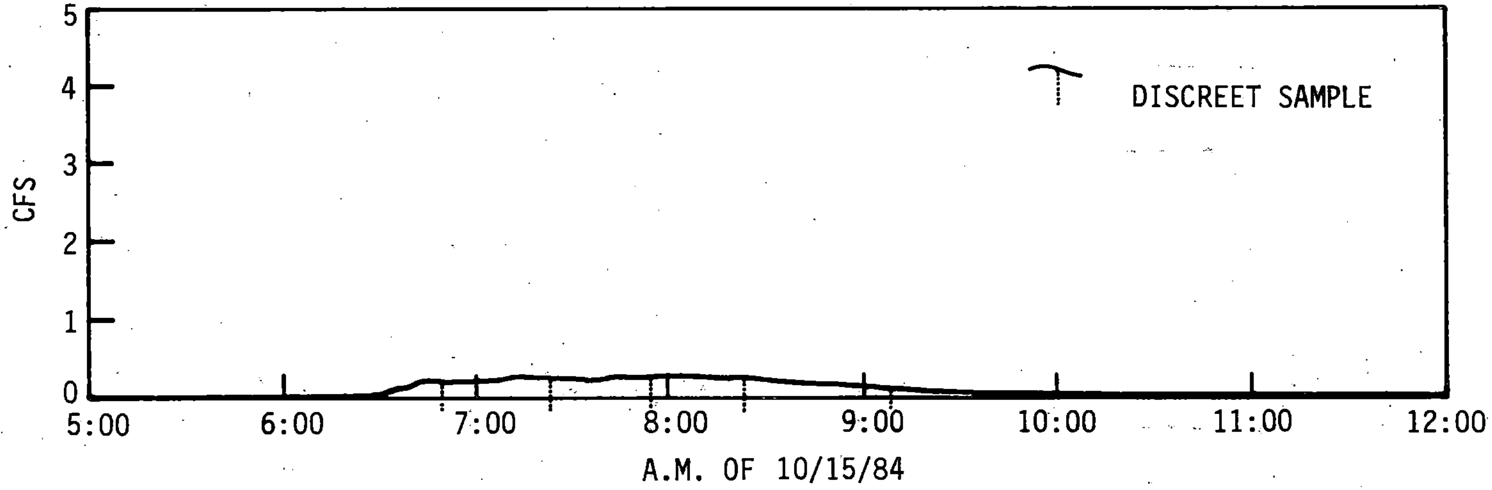

Fig. 25. H-flume hydrograph 10/15/84 event.

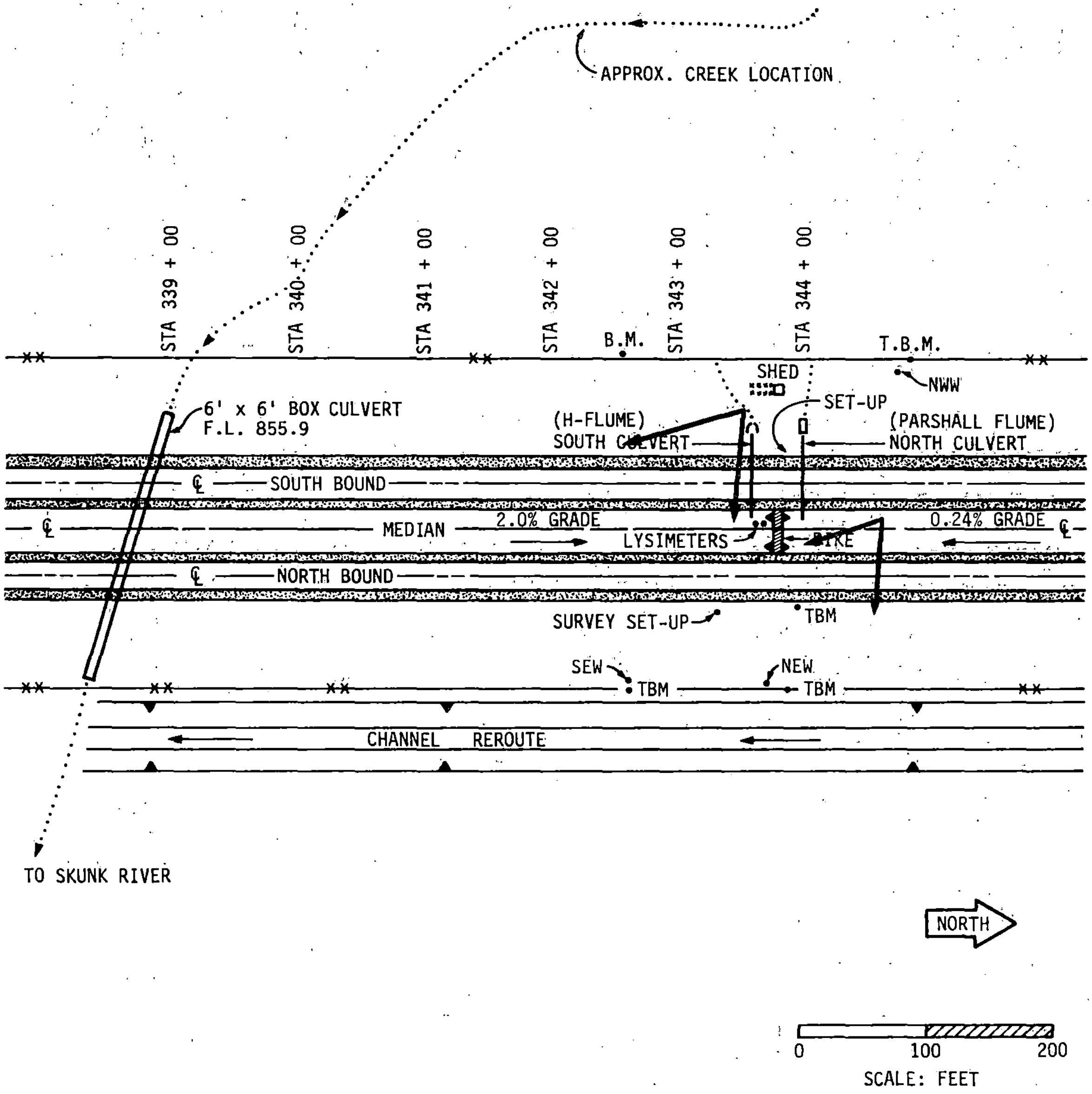

Fig. 26. Direction of groundwater flow in Iowa DOT highway runoff study. (Range of observations shown as arrows).

ENGINEERING RESEARCH INSTITUTE

ANALYTICAL SERVICES LABORATORY

REPORT OF CHEMICAL ANALYSIS

TO: HARVEY GULLICKS

PROJECT: DOT 0525

DATE: MAY 30, 1984

BY:

Table 4. Report of chemical analysis 5/30/84. Discrete samples collected 5/25/84.

		COND UMHO/CM*	SUSP.SOLID MG/L**
Parshall flume	1A	337	50
Parshall flume	2A	291	21
Parshall flume	3A	243	14
Parshall flume	4A	236	12
H-flume	1B	490	84
H-flume	2B	512	30

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*micromhos per centimeter.

**milligrams per liter.

ENGINEERING RESEARCH INSTITUTE
ANALYTICAL SERVICES LABORATORY
REPORT OF CHEMICAL ANALYSIS

TO: HARVEY GULLICKS
PROJECT: DOT 0618
DATE: JUNE 25, 1984
BY:

Table 5. Report of chemical analysis 6/25/84. Composite samples collected on 6/14/84 and 6/15/84.

DOT 0618	PARSHALL	H FLUME	UNITS
PH	7.35	7.52	-LOG H+
COND	68	93	UMHO/CM*
TS	122	184	MG/L**
SS	40.9	111	MG/L
CL	<2	<2	MG/L
NO3+NO2N	.22	.19	MG/L N
TKN	.52	.65	MG/L N
TOT P	.12	.17	MG/L P
COD	21.9	24.8	MG/L
TOC	11	12	MG/L
OIL&GR	2.4	<2	MG/L
F. COLI	400	900	ORG/.1L
F. STREP	9800	2700	ORG/.1L
TOT CU	6.2	9.6	UG/L***
TOT FE	1.28	4.59	MG/L
TOT PB	14	23	UG/L
TOT ZN	13	27	UG/L

SAMPLES WERE COLLECTED ON 6/15, BUT WERE NOT AVAILABLE FOR ANALYSIS UNTIL 6/18. THIS IS EXCESSIVE HOLDING TIME FOR PH AND BACTERIA.

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*micromhos per centimeter. **milligrams per liter. ***micrograms per liter.

ENGINEERING RESEARCH INSTITUTE

ANALYTICAL SERVICES LABORATORY

REPORT OF CHEMICAL ANALYSIS

TO: HARVEY GULLICKS

PROJECT: DOT 0910

DATE: SEPTEMBER 27, 1984

BY: Dave Schoeller

Table 6. Report of chemical analysis 9/27/84.

DOT 0910	GRAB SAMPLE RUNOFF	UNITS
TOTAL SOLIDS	338	MG/L*
VOLUME	****	ML
TOT IRON	.11	MG/L
TOT LEAD	9.54	UG/L**
OIL & GREASE	1.4	MG/L
CHLORIDE	33.6	MG/L
SUSP. SOLIDS	3.7	MG/L
pH	8.1	$-\text{LOG } H^+$

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*milligrams per liter.

**micrograms per liter.

ENGINEERING RESEARCH INSTITUTE

ANALYTICAL SERVICES LABORATORY

REPORT OF CHEMICAL ANALYSIS

TO: HARVEY GULLICKS

PROJECT: DOT 0925

DATE: OCTOBER 5, 1984

BY:

Table 7. Report of chemical analysis 10/5/84.

DOT 0925	COMPOSITE H FLUME	DISCRETE SAMPLE 1	UNITS
PH	7.20	****	-LOG H+
SPEC COND	193	****	UMHO/CM*
TOT SOLIDS	188	278	MG/L**
SUSP SOLIDS	38	121	MG/L
CHLORIDE	16.2	23.9	MG/L
FECAL COLI	430	****	ORG/100ML
FECAL STREP	10,000	****	ORG/100ML
NO3+NO2-N	.31	****	MG/L AS N
TKN	1.35	****	MG/L AS N
TOC	22	****	MG/L
COD	42.7	****	MG/L
T-PO4	1.48	****	MG/L AS PO4
TOTAL CU	6.3	****	UG/L***
TOTAL FE	4.74	1.48	MG/L
TOTAL PB	<10	17	UG/L
TOTAL ZN	12	****	UG/L
OIL AND GREASE	1.9	****	MG/L

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* micromhos per centimeter. ** milligrams per liter. *** micrograms per liter.

ENGINEERING RESEARCH INSTITUTE
ANALYTICAL SERVICES LABORATORY
REPORT OF CHEMICAL ANALYSIS

TO: HARVEY GULLICKS, P.E.
PROJECT: DOT 1015
DATE: NOVEMBER 6, 1984
BY: J. A. GAUNT

Table 8. Report of chemical analysis for composite H-Flume sample 11/6/84.

DOT 1015	Composite H-Flume 1015	Units
Total Solids	216	mg/L
Suspended Solids	23	mg/L
Chloride	13.3	mg/L
Spec. Cond.	276	UMHO/cm*
COD	43	mg/L**
TOC	18	mg/L
Oil & Grease	18	mg/L
$NO_3 + NO_2$ - N	0.02	mg/L as N
KJEL - N	0.71	mg/L as N
Total - P	0.19	mg/L as P
Total CU	7.6	µg/L***
Sol. CU	****	µg/L
Total FE	1.10	mg/L
Sol. FE	****	mg/L
Total PB	12	µg/L
Sol. PB	****	µg/L
Total Zn	36	µg/L
Sol. Zn	****	µg/L

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*micromhos per centimeter.

**milligrams per liter.

***micrograms per liter.

Table 9. Important contaminant concentrations in flow proportional composite samples of highway runoff.

	Contaminant Parameters Analyzed						
Date and Flume	TS mg/L	SS mg/L	COD mg/L	Chloride mg/L	Oil and Grease mg/L	Iron mg/L	Lead µg/L
4/29/84-4/30/84							
H-flume	285	139	40	24	3	7.0	34
Parshall flume	170	39	26	15	5.5	1.3	8
6/14/84-6/15/84							
H-flume	184	111	25	<2	<2	4.6	23
Parshall flume	122	41	22	<2	2.4	1.3	14
9/24/84-9/25/84							
H-flume	188	38	43	16	1.9	4.7	<10
10/14/84-10/15/84							
H-flume	216	23	43	13	18	1.1	12

Table 10. Summary of hydraulic data for runoff events.

Date	Flume (Terrain)	Rainfall Intensity Inches/Hour	Basin Lag Time Minutes*	Peak Flow cfs	Total Event Precip. Inches	Total Event Runoff ft^3	Runoff Inches/Acre
4/21/84	H (steep)	0.07 (9.4 hrs)	456	0.103	0.70	~2,700	0.40
	Parshall (flat)	0.07 (9.4 hrs)	264	0.16	0.70	~3,500	0.57
4/29/84 and 4/30/84	H (steep)	Overall 0.43 (3.35 hrs)			2.15 (1.60)**	~8,500 (~8,200)**	1.25 (1.21)**
		1. 0.6 (0.58 hrs)	40	0.57			
		2. 0.47 (2.10 hrs)	49	1.37			
		3. 0.28 (0.83 hrs)	38	0.26			
	Parshall (flat)	Overall 0.43 (3.35 hrs)	74	0.95	2.15 (1.60)**	~11,000 (~9,800)**	1.80 (1.59)**
5/24/84 and 5/25/84	H (steep)	1. 1.6 (~9 minutes)	73	0.085	1.33 { 0.41	435	0.07
		2. 0.45 (39 min)	51	0.526	0.92	4,632	0.68
	Parshall (flat)	Overall 0.10 (9 hrs)	110	0.32	1.33	~5,300	0.86
5/27/84 and 5/28/84		Avg. 0.21 (7.13 hrs) Max ≅ 0.4 to 0.5 inches/hr for brief periods			1.87	Not Available	Not Available
6/7/84	H (steep)	1.5 (Brief period) ~12 minutes	Not Available	0.28	0.36	Not Available	Not Available
	Parshall (flat)	1.5 (Brief period)	20	0.18	0.36	1,440	0.23
6/9/84	H (steep)	0.1 (3.87 hrs)	Not Available	Not Available	0.72	Not Available	Not Available
	Parshall (flat)	0.1 (3.87 hrs)	Not Available	Not Available	0.72	Not Available	Not Available
6/13/84	H (steep)	Avg. 0.98 (2.12 hrs) Duration Max. 1.53 (1.57 hrs)	Not Available	2.79	2.49	Not Available	Not Available
	Parshall (flat)	0.98 (2.12 hrs)	13 to 18***	2.60	2.49	~16,200***	2.63***
6/14/84	H (steep)	1.67 (1.01 hr)	39	3.87	1.83	~12,500	1.84
	Parshall (flat)	1.67 (1.01 hr)	32	2.00	1.83	~11,735	1.90
6/16/84	H (steep)	1.80 (16 min)	Not Available	0.80 cfs	0.57	Not Available	
	Parshall (flat)	1.80 (16 min)	24	0.55 cfs	0.57	3,900	0.63
6/21/84	H (steep)	0.60 (25 min)	Not Available	Not Available	0.25	Not Available	Not Available
	Parshall (flat)	0.60 (25 min)	Not Available	<0.10 cfs	0.25	Not Available	Not Available

Note: Drainage areas are ~49 percent paved surface.
TOTAL AREAS H-Flume (steep slope) ~ 1.87 acres
Parshall flume ~ 1.70 acres

*±5 minutes

**Related to precipitation between 1:45 p.m. and 5:12 p.m. on 4/29/84

***Equipment malfunction because of earthworms; therefore this is the best estimate of flow. Rain gauge clock was fast and correction was substantial for this event.

Table 10. Continued.

Date	Flume (Terrain)	Rainfall Intensity Inches/Hour	Basin Lag Time Minutes*	Peak Flow cfs	Total Event Precip. Inches	Total Event Runoff ft^3	Runoff Inches/Acre
7/10/84	Parshall (flat)	Avg. 0.31 (2.5 hrs)	60-80	0.11	0.71	392	0.06
	H-flume (steep)	Max. 0.6 to 1.2 (18 min)	47-67	0.09	0.71	196	0.03
7/14/84	Parshall (flat)	Avg. 0.13 (5 hrs) Max. 0.64 (0.55 hr)	40	0.15	0.68	1021	0.17
7/26/84	Parshall (flat)	~0.2 estimated (time discrepancy)	Not Available	0.18	0.88	1093	0.18
7/26/84	H-flume (steep)			0.33			
9/25/84	H-flume (steep)	Overall 0.19 (7.1 hrs)			1.38	3900	0.57
		1. 0.42 (1.1 hrs)	140	0.4			
		2. 0.42 (0.98 hrs)	38	0.4			
10/15/84	H-flume (steep)	Overall 0.07 (15 hrs)			1.09	2680	0.39
		1. 0.31 (2 hrs)	55	0.3			
10/16/84	H-flume (steep)	0.2 (1.67 hrs)	32	0.3	0.69	2500	0.37
10/18/84	H-flume (steep)	0.7 (0.18 hr) 0.82 hrs No Precip. 0.24 (0.67 hr)	58	0.17	0.33	1500	0.22
10/30/84	H-flume (steep)	Not Available	Not Available	0.85	0.86	5700	0.84

Table 11. Contaminant loadings in flume discharges.

Flume and Drainage Area	Date of Event	Contaminant Loadings Expressed as lbs/acre of Drainage Area/Event (lbs/acre of drainage area/inch of runoff)						
		TS	SS	COD	Chloride	Oil & Grease	Iron	Lead
H-flume	4/29/84-	80	39	11.3	6.8	0.85	2.0	0.010
	4/30/84	(64)	(31)	(9.0)	(5.4)	(0.68)	(1.6)	(0.008)
	6/14/84-	76	46	10.4	<0.8	<0.8	1.9	0.010
	6/15/84	(42)	(25)	(5.7)	(<0.5)	(<0.5)	(1.0)	(0.005)
	9/24/84-	24	5	5.6	2.1	0.25	0.6	<0.001
	9/25/84	(43)	(9)	(9.8)	(3.6)	(0.4)	(1.1)	(<0.002)
	10/14/84-	19	2	3.8	1.2	1.6	0.1	0.001
	10/15/84	(49)	(5)	(9.8)	(3.0)	(4.1)	(0.2)	(0.003)
	Average*	50	23	7.8	~2.7	~0.9	1.2	~0.005
		(50)	(18)	(8.6)	(~3.1)	(~1.4)	(1.0)	(~0.005)
Parshall Flume	4/29/84-	68	16	10.0	6	2.2	0.5	0.003
	4/30/84	(38)	(9)	(5.8)	(3)	(1.2)	(0.3)	(0.002)
	6/14/84-	52	18	9.4	<0.9	1.0	0.6	0.006
	6/15/84	(28)	(10)	(5.1)	(<0.5)	(0.6)	(0.3)	0.003
	Average*	60	17	9.7	~3.4	1.6	0.6	0.004
		(33)	(10)	(5.5)	(~1.7)	(0.9)	(0.3)	(0.003)

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*Note: The average values may be biased. The 6/14/84 to 6/15/84 event was preceded by a major runoff event on 6/13/84. The 6/13/84 event was not sampled because of mechanical malfunctions.

Table 9 summarizes the contaminant concentrations of most importance for the composited samples of June 14-15, September 24-25, and October 14-15, 1984. It also shows calculated composite contaminant concentrations for the April 29-30 runoff event derived from the discrete sample analyses of Table 3. In all cases the composited values are based on flow proportional weighting procedures.

Table 10 summarizes the hydrological data for all the runoff events monitored during the study. It contains rainfall intensity, basin lag times, peak flows, total event precipitation, and total event runoff data for both the steep and flat drainage areas.

Table 11 summarizes the contaminant loadings in the flume discharges during the runoff events sampled. Loadings are expressed as pounds of contaminant per acre of drainage area per event and also as pounds of contaminant per acre of drainage area per inch of runoff.

The authors believe that the following statements can be made regarding the data in Table 10.

1. For unsaturated topsoil conditions, the basin lag times for the two drainage areas vary with the intensity of the rainfall, the duration of the rainfall, and the slope of the drainage area.
    a) For rainfall intensities of 0.1 inch per hour (long duration) to 1.6 inches per hour (short duration) and unsaturated topsoil conditions, the basin lag time for the steeper (2 percent) slope may vary from 40 minutes to 400 minutes.

b) For rainfall intensities of 0.1 inch per hour (long duration) to 1.6 inches per hour (short duration) and unsaturated topsoil conditions, the flat (0.24 percent) grade basin lag time varies less than the basin lag time of the steep (2.0 percent) grade. For the events observed at the flat grade drainage area, an average event intensity was used to determine the basin lag time. This situation is valid because the short duration, high intensity precipitation did not cause corresponding peaks on the flat slope hydrograph that were distinguishable from the overall event peak. Typical basin lag times were from 110 minutes to 260 minutes for unsaturated conditions.

2. For saturated topsoil conditions, the basin lag times for the two drainage areas were nearly identical for high intensity precipitation of substantial duration (greater than one quarter hour).

3. For high intensity precipitation exceeding one quarter hour duration and saturated topsoil conditions, the basin lag times generally ranged as follows:

   a) 0.24 percent slope--13 minutes to 35 minutes

   b) 2.0 percent slope--~35 minutes (two events 6/14/84 and 9/25/84)

4. For low to medium intensity (~0.1 inch per hour to 0.6 inch per hour, medium to long duration) precipitation and saturated topsoil conditions, the basin lag times generally ranged as follows:

a) 0.24 percent slope--40 minutes to 110 minutes

b) 2.0 percent slope--35 minutes to 70 minutes

5. For saturated topsoil conditions, runoff in inches per acre is virtually identical to precipitation in inches per acre for all but the low rainfall intensities or short duration rainfalls.

6. For unsaturated topsoil conditions, the ratio of the runoff in inches to the total event precipitation in inches was observed to range from about 0.1 to 0.8 with 0.4 to 0.7 being common ratios for overall events. For low intensity and/or short duration rainfalls and saturated topsoils, the ratio of runoff to total event precipitation was usually in the range of 0.4 to 0.7.

7. For precipitation intensities of 1.5 inches per hour to 1.8 inches per hour and saturated soil conditions, peak flows of 0.8 cfs to 3.87 cfs were observed from the steep slope. Peak flows of 0.55 cfs to 2.6 cfs were observed from the flat slope. The flat slope to steep slope peak flow ratios were generally about 0.52 to 0.69 for most storm events. However, the ratio was as high as 0.9 for the June 13, 1984, runoff event.

4.3.3. Dustbucket Analyses

Dustbuckets were installed at the site in accordance with the American Society for the Testing of Materials (ASTM) procedure ASTM D-1739-62. The dustbucket contents were periodically analyzed for total solids. Deionized water was used for the setup so that the total solids analyses results were essentially the same as suspended solids analyses. The total solids analytical results are shown in Table 12.

The authors believe that the dustbucket results are unreliable. Bird droppings and insects collecting in the dustbuckets were a continual problem. Despite attempts to remove these interferences prior to total solids analysis, it is believed that their effects were substantial. It is unlikely that a meaningful relationship between runoff contaminant loadings and dustbucket analyses can be drawn.

4.4. Groundwater

The site is underlaid by a shallow alluvial aquifer consisting primarily of fine to coarse sand and approximately 20 percent gravel. The aquifer is overlaid by 6-10 feet of lower permeability soils and topsoil. Three stainless steel monitoring wells and two lysimeters were installed at the site. The locations of these installations are shown on Fig. 2. The detailed boring logs and installation details are shown in Figs. 3, 4, 5, and 6.

Because of the flat site terrain, ponding of runoff frequently occurs just west of the highway. Thus, significant downward percolation of runoff to the aquifer occurs. The relative variability and thickness of the less permeable surface soils and the probable variation of their extent and integrity presents a substantial potential for groundwater contamination in the event of a spill or long-term accumulation of contaminated runoff.

Table 12. Dustbucket analyses.

Dates of Collection	Volume mL	Total Solids Concentration mg/L	Solids Accumulated mg/day
3/2/84-4/3/84	740	93±3 (95% confidence)	3
4/3/84-7/19/84	2290	546	12
7/19/84-9/10/84	434	346	3

The direction of groundwater migration at the site is somewhat variable depending on recent climatological conditions and water levels in surface waters (i.e., the channel reroute and the creek) located adjacent to the site. Water levels have been monitored at the three well locations and indicate a northwest to southeast migration of groundwater at the site. The range of observed flow directions with variations in time and conditions is shown on Fig. 26, page 54. The best estimate of the flow direction nearly bisects the angle included by the observed range.

After installation by the contractor, the wells were pumped at an approximate rate of five gallons per minute for approximately one half hour (until clear). Prior to sampling, but in no case more than 15 hours prior, the wells were developed by bailing. Approximately 20 gallons to 40 gallons were removed from each well during each presampling development period.

During development, water from wells NEW and SEW were observed to have substantial amounts of red (presumed iron) precipitate. The precipitate was noticeable for the first 5-10 bailer volumes (5 liters to 10 liters). Following development by bailing, however, the water was observed to be relatively clear and any suspended solids were gray in color.

Samples were obtained from the ground water wells on three occasions: December 19, 1983, April 12, 1984, and October 19, 1984. The chemical analyses of the samples are presented in Tables 13, 14, and 15, respectively. The water is a hard (contains high concentrations of calcium and magnesium) bicarbonate-type water.

ENGINEERING RESEARCH INSTITUTE
ANALYTICAL SERVICES LABORATORY
REPORT OF CHEMICAL ANALYSIS

TO: HARVEY GULLICKS
PROJECT: DOT 1219
DATE: DECEMBER 21, 1983
BY: James A. Gaunt

Table 13. Report of chemical analysis 12/21/83. Samples collected 12/19/83.

DOT 1219	NEW	NWW	SEW	FIELD BLANK	UNITS
CHLORIDE	4.2	24	2.9	.8	MG/L*
COND	1090	935	960	3	UMHO/CM**
COD	40.9	42.4	36.1	<10	MG/L
TOC	17	15	14	2.3	MG/L
OIL & GR	<0.1	14	35.0	.3	MG/L
TOT CU	44.4	28	49.3	2.7	UG/L***
SOL CU	3.1	4.1	3.4	****	UG/L
TOT FE	52.1	13.4	49.3	<0.02	MG/L
SOL FE	10.2	.10	5.12	****	MG/L
TOT PB	52	32	59	<4	UG/L
SOL PB	26	16	19	****	UG/L
TOT ZN	145	93.3	131	<2	UG/L
SOL ZN	9.9	27	8.7	****	UG/L
pH	6.6	7.0	6.9		

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*milligrams per liter.

**micromhos per centimeter.

***micrograms per liter.

ENGINEERING RESEARCH INSTITUTE
ANALYTICAL SERVICES LABORATORY
REPORT OF CHEMICAL ANALYSIS

TO: HARVEY GULLICKS
PROJECT: DOT 0412
DATE: APRIL 30, 1984
BY:

Table 14. Report of chemical analysis 4/30/84. Samples collected 4/12/84.

DOT 0412	NEW	NWW	SEW	UNITS
CHLORIDE	28.5	15.7	6.8	MG/L*
SPEC COND	900	430	780	UMHO/CM**
COD	11.2	7.3	18.6	MG/L
TOC	6	6	8	MG/L
OIL & GREASE	3.0	1.9	<1.8	MG/L
TOT CU	2.9	3.3	3.5	UG/L***
SOL CU	<0.4	<0.4	4.6	UG/L
TOT FE	9.24	.095	.52/.63	MG/L
SOL FE	8.65	.013	1.87(CONTAM)	MG/L
TOT PB	21	<9	15	UG/L
SOL PB	17	<9	18	UG/L
TOT ZN	7	5	6	UG/L
SOL ZN	15	8	9	UG/L
SULFATE	****	19.0	****	MG/L
PHENOL-ALK	****	0	****	MG/L AS CACO3
TOTAL ALK	****	160	****	MG/L AS CACO3
SOL CA	****	57.1	****	MG/L
SOL MG	****	16.1	****	MG/L
SOL NA	****	12.6	****	MG/L
SOL K	****	.61	****	MG/L
$NO_3 + NO_2 - N$		0.31 mg/L as N		

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* milligrams per liter. ** micromhos per centimeter. *** micrograms per liter.

ENGINEERING RESEARCH INSTITUTE

ANALYTICAL SERVICES LABORATORY

REPORT OF CHEMICAL ANALYSIS

TO: HARVEY GULLICKS, P.E.
PROJECT: DOT 1019
DATE: NOVEMBER 6, 1984
BY:

Table 15. Report of chemical analysis 11/6/84.

DOT 1015 & 1019	BLANK 1019	NWW 1019	SEW 1019	North-South Composite LYS 1019	UNITS
TOTAL SOLIDS	****	****	****	****	MG/L*
SUSP SOLIDS	****	****	****	****	MG/L
CHLORIDE	<0.5	20.7	<0.5	639	MG/L
SPEC COND	10	906	906	405	UMHO/CM**
COD	<5	11	59	****	MG/L
TOC	1	6	24	****	MG/L
OIL & GREASE	1	16	31	****	MG/L
NO3+NO2-N	****	****	****	****	MG/L AS N
KJEL-N	****	****	****	****	MG/L AS N
TOTAL-P	****	****	****	****	MG/L AS P
TOTAL CU	.49	6.4	28.6	20.3	UG/L***
SOL CU	****	5.7	2.6	****	UG/L
TOTAL FE	1.21	1.20	75.5	21.1	MG/L
SOL FE	****	.24	9.31	****	MG/L
TOTAL PB	<3	24	49	87	UG/L
SOL PB	****	25	18	****	UG/L
TOTAL ZN	.4	18	78	86	UG/L
SOL ZN	****	26	18	****	UG/L

*milligrams per liter. **micromhos per centimeter. ***micrograms per liter.

In addition, lysimeters, porous ceramic cups in the unsaturated soil zone, were installed in the highway median just south of the dike. The lysimeters were evacuated and discharged twice prior to sampling. The lysimeters were sampled on July 20, 1984, and October 19, 1984. The samples obtained were visibly free of sediment but were yellowish in color. The sample volumes obtained for each sampling event were small, on the order of 700 mL per lysimeter. Thus, in most cases the analyses were limited to chloride, conductivity, and metals. The chemical analyses results are shown in Tables 15 and 16.

Based on the observed lysimeter and groundwater well sampling data, it is probable that highway activities are affecting chloride, lead, iron, and oil and grease concentrations in the groundwater. The lysimeter data clearly show migration of high levels of chloride, lead, and iron downward to a depth of at least ten feet below ground level. The lysimeter data also demonstrate elevated TOC and COD levels in the unsaturated zone at a depth of five feet. The chloride, lead, and iron contaminants definitely reach the groundwater table in concentrations greater than background levels. It is probable that oil and grease also reach the groundwater table in concentrations greater than background levels based on the lysimeter TOC and COD levels observed. Despite steam cleaning and substantial bailing and pumping, it is possible that the stainless steel pipe used in construction of the wells may account for the oil and grease observations in the groundwater samples.

The observed impact of highway activities on chloride and lead levels in the groundwater down gradient of the highway is not great.

ENGINEERING RESEARCH INSTITUTE
ANALYTICAL SERVICES LABORATORY
REPORT OF CHEMICAL ANALYSIS

TO: HARVEY GULLICKS
PROJECT: DOT 0723
DATE: JULY 30, 1984
BY: J W Faust

Table 16. Report of chemical analysis 7/30/84. Samples collected 7/20/84.

DOT 0723	NORTH LYS	SOUTH LYS	UNITS
TOT CU	16	23	UG/L [*]
TOT FE	13	48	MG/L [**]
TOT PB	48	126	UG/L
TOT ZN	160	54	UG/L
CL	106	1230	MG/L
COND	1870	5300	UMHO/CM [***]
TOC	****	54	MG/L
COD	****	131	MG/L
TOTAL SOLIDS	****	****	MG/L
VOLUME	****	****	ML

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[*] micrograms per liter.

[**] milligrams per liter.

[***] micromhos per centimeter.

The soluble (0.45 μm filterable) lead concentrations were not greater than the 1975 EPA Interim Primary Drinking Water Maximum Contaminant Levels. Furthermore, despite the very high chloride concentrations in the unsaturated zone, the chloride concentrations in the groundwater down gradient of the highway were not significantly different from those in the up gradient well. Concentrations of iron in the groundwater down gradient of the highway were very high and consistently exceeded the levels in the up gradient well.

The high levels of iron in the down gradient wells, SEW and NEW, have only two possible sources. Either they are the direct result of up gradient highway activities or they are the result of localized iron precipitation in the soil interstices bordering the channel reroute. The latter mechanism is also highway related since portions of over 2,700 feet of I-35 drain directly into the channel reroute. The runoff has already been demonstrated to be high in iron. A patented in situ iron and manganese removal process makes use of the mechanisms of iron and manganese filtration of oxidized floc by periodic injection of aerated, degassed water into soils located peripherally around a groundwater supply well [2]. It is possible that the channel reroute has over its period of existence provided enough diffusion of aerated water during periods of temporary groundwater gradient reversals to the zone along its banks to develop a zone of iron filter cake on which iron precipitate continually deposits itself. In order for this mechanism to affect the monitoring wells, the zone must be of considerable lateral extent, on the order of 25 feet or more. This mechanism is less plausible than the first.

Possible sources of the high concentrations of iron are the anti-caking compound used in the deicing compound and sand mixture; the deterioration of vehicle bodies, engine, and exhaust components; the deterioration of reinforcing steel used in road construction, and the attack of the soil matrix and concrete by acids formed as combustion byproducts and by acid rain.

4.5. PCB, Herbicides, and Hydrocarbon Analyses

Water samples were obtained on September 23, 1984, from the SEW monitoring well and the lysimeters for PCB (Polychlorinated biphenyls), 2,4-D, Tordon, and hydrocarbon analysis. The SEW well sample intended for PCB analysis was lost because of a flaw in the glass sample bottle. The SEW well was resampled on October 19, 1984, to allow completion of the PCB analysis. The sample from the north lysimeter (unsaturated soil zone at 10 feet below ground surface) was analyzed for hydrocarbons. The sample from the south lysimeter (unsaturated soil zone at 5 feet below ground surface) was analyzed for PCB, 2,4-D, and Tordon.

On September 10 and 25, 1984, the first significant runoff events since July 26, 1984, occurred. Grab samples of the runoff were obtained for PCB, 2,4-D, Tordon, and hydrocarbon analysis. The total volume of flow on September 10 was about 300 cubic feet. The September 25 samples were obtained between 3:45 p.m. and 4:50 p.m.

The analytical results for PCB, 2,4-D, Tordon, and hydrocarbon contaminants are shown in Table 17. The concentrations of the above contaminants were less than the analytical detection limits in all

REPORT of CHEMICAL ANALYSIS.

Analytical Services Laboratory
Engineering Research Institute
Iowa State University
Ames, Iowa 50010
515-294-8768

Table 17. Report of chemical analysis 12/11/84.

to: Harvey Gullicks **date:** Dec. 11, 1984

project: DOT Organics 0924

SAMPLE I.D.	SEW	Grab Sample Runoff 0925	Lys.	Grab Sample Runoff 0910	Field Blank	
PCB'S	ND	ND	ND	ND	ND	
2,4-D acid	LT .8	LT 1	LT 1	LT 3	ND	
Tordon	ND	ND	ND	ND	ND	
Hydrocarbon	ND	ND	ND	ND	ND	

Note:
Results are expressed in micrograms per liter.

Detection Limits	SEW	Runoff	Lys.	0910		
PCB'S	.08	.08	.08	.3	.08	
2,4-D	.8	1	1	3	.8	
Tordon	13	21	16	48	13	
Hydrocarbons	1	3	2	4	1	

REMARKS:

Detection limits varied due to variations in sample volumes extracted.

APPROVED FOR RELEASE: James A. Gaunt cases. Based on the recorder plots, it would be acceptable to say that in many cases the contaminant concentrations were much less than the analytical detection limits. Thus, highway activities appear to contribute little, if any, of the above contaminants at the study site.

5. RESULTS FROM OTHER RUNOFF STUDIES

A study was conducted at Harrisburg, Pa., [3], on the quality of runoff from six-lane Interstate Highway 81 in a rural area with an average daily traffic count of 24,000 vehicles. Twenty-seven percent of the total 18.5 acre drainage area consisted of concrete paved surface. The highway was opened for traffic in 1975 and has a 0.5 percent grade. The Harrisburg area has an annual precipitation total of about 40 inches per year. The annual snowfall was reported to be 20-30 inches of snow. These conditions allow some comparison with the Ames site.

The average runoff coefficient at the Harrisburg site was 0.43, based on 16 nonwinter events. The range of runoff coefficients was reported to be 0.04 to 0.95. Tables 18 and 19 show the total, suspended, and volatile solids concentrations and loadings observed at the Harrisburg site and other sites [3]. Note that except for the volatile fraction data winter values typically exceed the nonwinter values in the areas where deicing operations are used.

Tables 20 and 21 show the heavy metal concentrations and loadings observed at Harrisburg and other study sites [3]. It was reported that most of the metals in the runoff were associated with the particulate fraction based on data displayed in Table 22 [3]. Table 23 presents the chloride concentrations and loadings observed at Harrisburg and other sites [3]. Winter chloride and metals levels were significantly higher than nonwinter levels. Approximately 15-30 percent of the chlorides applied were accounted for in the runoff sampled.

Table 18. Concentration of total, suspended and volatile solids in highway runoff [3].*

Total solids, mg/l

	Overall 1976-77 monitoring period		Non-winter periods[a]		Winter periods[b]	
	Avg.	Range	Avg.	Range	Avg.	Range
Milw.-Hwy. 794	1400	145-21640	378	145-1130	4594	804-21640
Milw.-Hwy. 45	2038	350-11402	992	350-2145	3750	835-11402
Milw.-Grassy site	1110	268-2401	957	268-1850	1447	651-2401
Harrisburg	791	180-3696	360	180-560	1261	301-3696
Nashville	461	223-1001	424	223-698	568	246-1001
Denver	686	295-1334	686	295-1334	--	c

Total volatile solids, mg/l

	Overall 1976-77 monitoring period		Non-winter periods[a]		Winter periods[b]
	Avg.	Range	Avg.	Range	Typical value[d]
Milw.-Hwy. 794	138	55-320	127	55-320	233
Milw.-Hwy. 45	319	80-816	323	80-816	299
Milw.-Grassy site	297	70-1522	298	70-1522	284
Harrisburg	204	52-364	177	52-364	363
Nashville	219	26-595	213	26-595	332
Denver	264	88-395	264	88-395	c

Suspended solids, mg/l

	Overall 1976-77 monitoring period		Non-winter periods[a]		Winter periods[b]	
	Avg.	Range	Avg.	Range	Avg.	Range
Milw.-Hwy. 794	268	26-1576	138	26-475	656	201-1576
Milw.-Hwy. 45	445	146-1656	396	146-1260	526	151-1656
Milw.-Grassy site	303	25-938	419	43-938	47	25-75
Harrisburg	53	4-163	47	4-136	60	4-163
Nashville	209	13-478	187	13-475	271	89-478
Denver	259	118-1029	259	118-1029	--	c

Volatile suspended solids, mg/l

	Overall 1976-77 monitoring period		Non-winter periods[a]		Winter periods[b]	
	Avg.	Range	Avg.	Range	Avg.	Range
Milw.-Hwy. 794	84	14-393	53	14-144	150	33-393
Milw.-Hwy. 45	98	27-510	101	34-510	93	27-274
Milw.-Grassy site	95	10-837	134	18-837	16	10-25
Harrisburg	14	1-48	15	3-48	13	1-23
Nashville	78	11-397	89	11-397	45	23-70
Denver	103	10-240	103	10-240	--	c

[a] Represents monitoring periods between April through October, 1976-77. Actual number of months may vary between sites.

[b] Represents monitoring periods between November through March, 1976-77. Actual number of months may vary between sites.

[c] No storm events monitored during winter at Denver site due to lack of sufficient precipitation.

[d] Total volatile solids examined on a cursory basis only.

Metric units: lb/ac x 1.12 = kg/ha.

*Reproduced from page 56 of Research Report No. FHWA/RD-81/045.

Table 19. Loadings of total, suspended and volatile solids in highway runoff [3].*

Total solids, pounds per acre per event

	Overall 1976-77 monitoring period		Non-winter periods[a]		Winter periods[b]	
	Avg.	Range	Avg.	Range	Avg.	Range
Milw.-Hwy. 794	60	2-535	34	2-82	143	39.5-535
Milw.-Hwy. 45	72	4-96	29	4-82	142	9.1-384
Milw.-Grassy site	30	0.04-99	23	0.04-99	45	0.8-99
Harrisburg	78	2-191	17	2-73	144	5.8-199
Nashville	28	1-91	33	1-58	43	17.2-91
Denver	21	2-65	21	2-65	--	c

Total volatile solids, pounds per acre per event

	Overall 1976-77 monitoring period		Non-winter periods[a]		Winter periods[b]
	Avg.	Range	Avg.	Range	Typical value[d]
Milw.-Hwy. 794	15.3	1.8-44.0	16	1.8-44	9.1
Milw.-Hwy. 45	14.3	0.4-35.0	13	0.4-28	20.0
Milw.-Grassy site	7.3	0.01-22.0	6	0.01-21	22.0
Harrisburg	4.3	0.03-14.0	3	0.03-14	12.3
Nashville	9.7	0.76-43.0	10	0.8-43	6.0
Denver	4.2	0.74-10.1	4	0.7-10	c

Suspended solids, pounds per acre per event

	Overall 1976-77 monitoring period		Non-winter periods[a]		Winter periods[b]	
	Avg.	Range	Avg.	Range	Avg.	Range
Milw.-Hwy. 794	19.6	0.95-80	15	0.95-52	32.0	6.7-80.4
Milw.-Hwy. 45	18.6	0.77-96	15	0.77-58	24.0	1.7-96
Milw.-Grassy site	7.8	0.01-46	10	0.01-46	3.0	0.01-5.2
Harrisburg	4.7	0.02-32	4	0.02-28	5.9	0.04-31.5
Nashville	14.0	0.54-57	11	0.54-33	21.9	one sample
Denver	13.7	0.88-47	14	0.88-47		c

Volatile suspended solids, pounds per acre per event

	Overall 1976-77 monitoring period		Non-winter periods[a]		Winter periods[b]	
	Avg.	Range	Avg.	Range	Avg.	Range
Milw.-Hwy. 794	6.2	0.48-20	5.5	0.48-20	7.8	1.0-16.7
Milw.-Hwy. 45	4.3	0.17-24.7	4.2	0.17-25	4.6	0.4-12.9
Milw.-Grassy site	2.0	0.004-12	2.6	0.004-12	1.0	0.004-1.6
Harrisburg	1.1	0.005-5.3	0.9	0.005-5	1.2	0.01-4.1
Nashville	4.5	0.09-28.2	4.9	0.09-28	3.4	1.4-6.9
Denver	2.6	0.20-6.63	2.6	0.20-7		c

[a] Represents monitoring periods between April through October, 1976-77. Actual number of months may vary between sites.

[b] Represents monitoring periods between November through March, 1976-77. Actual number of months may vary between sites.

[c] No storm events monitored during winter at Denver site due to lack of sufficient precipitation.

[d] Total volatile solids examined on a cursory basis only.

Metric units: lb/ac x 1.12 = kg/ha.

*Reproduced from page 57 of Research Report No. FHWA/RD-81/045.

Table 20. Concentration of lead, zinc, iron and copper in highway runoff [3].*

Lead, mg/l

	Overall 1976-77 monitoring period		Non-winter periods[a]		Winter periods[b]	
	Avg.	Range	Avg.	Range	Avg.	Range
Milw.-Hwy. 794	2.90	0.80-13.1	1.50	0.80-3.10	5.53	1.8-13.1
Milw.-Hwy. 45	1.20	0.40-6.6	0.78	0.40-1.50	1.88	0.5-6.6
Milw.-Grassy site	0.21	0.05-0.70	0.26	0.10-0.70	0.11	0.05-0.20
Harrisburg	0.10	0.05-0.20	0.09	0.05-0.10	0.11	0.05-0.20
Nashville	0.50	0.02-1.70	0.50	0.02-1.70	0.50	0.30-0.70
Denver	0.45	0.30-1.80	0.45	0.03-1.80	c	

Zinc, mg/l

	Overall 1976-77 monitoring period		Non-winter periods[a]		Winter periods[b]	
	Avg.	Range	Avg.	Range	Avg.	Range
Milw.-Hwy. 794	0.69	0.14-3.40	0.35	0.14-0.86	1.32	0.47-3.40
Milw.-Hwy. 45	0.55	0.20-1.90	0.39	0.20-0.70	0.80	0.24-1.90
Milw.-Grassy site	0.18	0.07-0.34	0.21	0.10-0.34	0.12	0.07-0.15
Harrisburg	0.08	0.01-0.23	0.06	0.01-0.12	0.11	0.02-0.23
Nashville	0.28	0.10-0.61	0.28	0.10-0.61	0.29	0.11-0.41
Denver	0.72	0.33-1.50	0.72	0.33-1.50	c	

Iron, mg/l

	Overall 1976-77 monitoring period		Non-winter periods[a]		Winter periods[b]	
	Avg.	Range	Avg.	Range	Avg.	Range
Milw.-Hwy. 794	11.5	2.5-43.0	7.5	2.5-39.0	18.9	7.0-43.0
Milw.-Hwy. 45	14.6	5.6-45.0	13.3	5.6-38.6	16.8	6.5-45.0
Milw.-Grassy site	14.9	1.1-43.6	19.9	2.7-43.6	3.9	1.1-10.0
Harrisburg	2.0	0.1-6.6	1.8	0.1-6.4	2.3	0.1-6.6
Nashville	5.5	1.5-12.0	5.2	1.5-12.0	6.4	3.1-9.2
Denver	16.5	6.5-37.0	16.5	6.5-37.0	c	

Copper, mg/l

	Overall 1976-77 monitoring period		Non-winter periods[a]		Winter periods[b]	
	Avg.	Range	Avg.	Range	Avg.	Range
Milw.-Hwy. 794	0.159	0.01-0.66	0.10	0.01-0.22	0.27	0.11-0.66
Milw.-Hwy. 45	0.135	0.01-0.88	0.08	0.01-0.14	0.22	0.07-0.88
Milw.-Grassy site	0.083	0.01-0.23	0.07	0.01-0.14	0.11	0.05-0.23
Harrisburg	0.045	0.01-0.10	0.04	0.01-0.10	0.05	0.02-0.09
Nashville	0.070	0.01-0.20	0.07	0.01-0.20	0.07	0.05-0.09
Denver	0.110	0.03-0.26	0.11	0.03-0.26		

[a] Represents monitoring periods between April through October, 1976-77. Actual number of months may vary between sites.

[b] Represents monitoring periods between November through March, 1976-77. Actual number of months may vary between sites.

[c] No storm events monitored during winter at Denver site due to lack of sufficient precipitation.

*Reproduced from page 63 of Research Report No. FHWA/RD-81/045.

Table 21. Loading of lead, zinc, iron and copper in highway runoff [3].*

Lead, pounds per acre

	Overall 1976-77 monitoring period		Nonwinter periods[a]		Winter periods[b]	
	Avg.	Range	Avg. 10^{-3}	Range 10^{-3}	Avg.	Range
Milw.-Hwy. 794	0.210	0.009-0.45	180	9-480	0.260	0.080-0.48
Milw.-Hwy. 45	0.046	0.002-0.205	28	2-80	0.076	0.008-0.205
Milw.-Grassy Site	0.007	0.00001-0.28	7	0.01-230	0.006	0.00002-0.02
Harrisburg	0.007	0.001-0.33	6	1-30	0.009	0.001-0.023
Nashville	0.036	0.0016-0.10	25	2-90	0.040	0.010-0.10
Denver	0.023	0.001-0.1	23	1-100		c

Zinc, pounds per acre

	Overall 1976-77 monitoring period		Nonwinter periods[a]		Winter periods[b]	
	Avg.	Range	Avg.	Range	Avg.	Range
Milw.-Hwy. 794	0.05	0.005-0.12	40	5-110	0.060	0.02-0.12
Milw.-Hwy. 45	0.027	0.001-0.090	12	1-30	0.036	0.004-0.09
Milw.-Grassy Site	0.006	0.000001-0.02	5	0.001-20	0.007	0.00002-0.02
Harrisburg	0.006	0.00005-0.03	4	0.05-10	0.009	0.005-0.03
Nashville	0.016	0.0009-0.05	14	0.09-40	0.020	0.006-0.05
Denver	0.019	0.002-0.06	19	2-60		c

Iron, pounds per acre

	Overall 1976-77 monitoring period		Nonwinter periods[a]		Winter periods[b]	
	Avg.	Range	Avg.x10^{-3}	Range x 10^{-3}	Avg.	Range
Milw.-Hwy. 794	0.83	0.024-2.44	780	24-2440	0.93	0.25-2.12
Milw.-Hwy. 45	0.653	0.037-3.50	490	37-1770	0.92	0.06-3.50
Milw.-Grassy Site	0.444	0.0000004-2.42	510	0.0004-2420	0.30	0.0002-0.77
Harrisburg	0.193	0.001-1.28	150	1-1130	0.24	0.002-1.28
Nashville	0.380	0.0097-2.05	300	10-840	0.61	0.12-2.05
Denver	0.48	0.04-1.76	480	40-1760		c

Copper, pounds per acre

	Overall 1976-77 monitoring period		Nonwinter periods[a]		Winter periods[b]	
	Avg.	Range	Avg.x10^{-3}	Range x 10^{-3}	Avg.	Range
Milw.-Hwy. 794	0.011	0.001-0.29	10	1-29	0.012	0.005-0.024
Milw.-Hwy. 45	0.006	0.000018-0.029	3	0.02-9	0.010	0.001-0.029
Milw.-Grassy Site	0.003	0.000003-0.008	2	0.003-8	0.004	0.00001-0.008
Harrisburg	0.003	0.0004-0.016	2	0.04-6	0.005	0.0002-0.016
Nashville	0.005	0.0004-0.02	5	0.04-20	0.006	0.001-0.02
Denver	0.004	0.0006-0.017	4	0.06-17		c

[a] Represents monitoring periods between April through October, 1976-77. Actual numbers may vary between sites.

[b] Represents monitoring periods between November through March, 1976-77. Actual numbers may vary between sites.

[c] No storm events monitored during winter at Denver due to lack of sufficient precipitation.

Metric units: pounds per acre x 1.12 = kg/ha.

*Reproduced from page 66 of Research Report No. FHWA/RD-81/045.

Table 22. Total and dissolved analysis for lead, zinc and iron at various sites [3].*

Site	Storm no.	Storm date	Type of sample	Lead, mg/l		Zinc, mg/l		Iron, mg/l	
				Total	Dissolved	Total	Dissolved	Total	Dissolved
I-794 Milwaukee	11	3/8/77	Composite	13.1	<0.05	3.4	0.21	43.0	0.03
			Discrete	160.0	<0.05	25.0	0.58	39.0	0.48
			Discrete	17.0	<0.05	3.3	0.20	52.0	0.09
			Discrete	2.5	<0.05	0.8	0.31	10.0	0.08
			Discrete	0.2	<0.05	0.1	0.09	0.4	0.07
Hwy. 45 Milwaukee	17	3/8/77	Composite	6.6	<0.05	1.9	0.36	35.0	0.11
			Discrete	8.6	<0.05	2.8	0.25	43.0	0.12
			Discrete	9.3	<0.05	3.0	0.29	51.0	0.14
			Discrete	2.3	<0.05	1.2	0.48	14.0	0.20
	18	3/11/77	Composite	2.2	<0.05	0.94	0.39	15.0	0.23
			Discrete	6.5	<0.05	2.35	0.33	39.0	0.13
			Discrete	6.4	<0.05	2.00	0.37	34.0	0.24
			Discrete	0.1	<0.05	0.35	0.34	1.1	0.16
Grassy Site Milwaukee	01	2/23/77	Composite	<0.05	<0.05	0.14	0.08	2.9	0.25
			Discrete	0.20	<0.10	0.16	0.08	3.6	0.19
			Discrete	0.40	<0.10	-	-	2.1	0.20
			Discrete	<0.10	<0.10	-	-	1.5	0.15
I-81 Harrisburg	15	2/24/77	Composite	<0.05	<0.05	0.15	0.02	6.6	0.13
			Discrete	<0.05	<0.05	0.09	0.08	1.9	0.05
I-40 Nashville	03	2/23/77	Discrete	2.0	<0.05	1.10	0.20	27.0	0.05
	04	2/26/77	Composite	0.5	<0.05	0.36	0.03	6.3	0.34
			Discrete	2.2	<0.10	1.30	0.16	32.0	0.43
			Discrete	0.8	<0.10	0.40	0.14	7.9	0.04
			Discrete	0.3	<0.10	0.19	0.01	3.7	0.05

*Reproduced from page 70 of Research Report No. FHWA/RD-81/045.

Table 23. Concentration and loadings of chloride in highway runoff [3].*

	Chloride, mg/l					
	Overall 1976-77 monitoring period		Nonwinter periods[a]		Winter periods[b]	
	Avg.	Range	Avg.	Range	Avg.	Range
Milw.-Hwy. 794	856	10-13300	63	10-118	2343	62-13300
Milw.-Hwy. 45	645	40-3413	229	40-828	1327	150-3413
Milw.-Grassy site	315	40-1165	168	40-366	610	219-1165
Harrisburg	195	20-800	56	20-110	347	20-800
Nashville	21	5-55	17	5-45	28	7-55
Denver	36	8-90	36	8-90		c

	Chloride, pounds per acre per event					
	Overall 1976-77 monitoring period		Nonwinter periods[a]		Winter periods[b]	
	Avg.	Range	Avg.	Range	Avg.	Range
Milw.-Hwy. 794	23.0	0.95-329	2.7	0.95-76	61	10-329
Milw.-Hwy. 45	24.8	0.91-188	4.6	0.91-15.2	58	3-188
Milw.-Grassy site	6.3	0.008-34.4	2.4	0.008-7.6	14	0.3-34
Harrisburg	11.2	0.32-82.8	2.6	0.32-8.6	21	1-83
Nashville	1.2	0.054-4.55	0.8	0.05-1.6	2	0.6-5
Denver	0.8	0.11-2.38	0.8	0.11-2.4		c

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[a] Represents monitoring periods between April through October, 1976-77. Actual number of months may vary between sites.

[b] Represents monitoring periods between November through March, 1976-77. Actual number of months may vary between sites.

[c] No storm events monitored during winter at Denver site due to lack of sufficient precipitation.

Metric units: pounds per acre x 1.12 = kg/ha

*Reproduced from page 71 of Research Report No. FHWA/RD-81/045.

The data accumulated at Harrisburg and other sites also indicated that pathogenic bacteria were from nonhuman sources. Furthermore, levels of PCB's, herbicides, and pesticides were very low. Tables 24 and 25 show the oil and grease concentrations and loadings observed at Harrisburg and other sites [3].

The Ames study site runoff contaminant loadings in Table 11 are generally similar to those of the Harrisburg study. The total solids, suspended solids, and chloride loading differences are likely the result of the method of deicing material application. The Iowa DOT practice of using a 50/50 mixture of sand and salt increases the suspended solid loading but lowers the chloride and total solids loadings for most runoff events. The iron loading differences may be the result of the length of highway service time, deicing compound additives, and basic native soil composition. The oil and grease loading differences cannot be explained easily. The higher oil and grease loadings at the Ames site may be the result of the percentage of paved drainage area, shoulder construction, length of service time, and maintenance practices.

A French study [4] indicated that up to 30 percent of the total annual pollution load from motorway runoff waters may occur in a few runoff events. The Ames site data shown in Tables 9 and 11 seem to bear that prediction out. The French study site was characterized by a semi-continental climate, a 2.1 percent grade, a bituminous-paved, 1,470 square meter drainage area, and 5,500 vehicles per day traffic. The average pollutant concentrations and annual loads are shown in Table 26.

Table 24. Summary of composite O&G data for monitored sites [3].*

Site	Nonwinter[a] O&G concentrations, mg/l				Winter[b] O&G concentrations, mg/l				Overall 1976-77 O&G concentration, mg/l			
	Avg.	Max.	Min.	Number of events sampled	Avg.	Max.	Min.	Number of events sampled	Avg.	Max.	Min.	Number of events sampled
I-794; Milw.	8	12	3	6	43	104	9	3	20	104	4	9
Hwy. 45; Milw.	6	17	2	5	6	15	2	5	6	17	1	10
Grassy site; Milw.	1	2	1	4	<1			1	1	2	<1	5
Harrisburg	3	6	1	9	3	10	1	10	3	10	1	19
Nashville	4	9	2	4	27	57	11	4	16	57	1	8
Denver[c]	14	55	3	15				0	14	55	3	15
All 6 sites	6	55	1	43	16	104	<1	23	10	104	<1	66

[a] Nonwinter: April through October periods (1976-77).

[b] Winter: November through March periods (1976-77).

[c] No storm events monitored during winter at Denver due to lack of sufficient precipitation.

*Reproduced from page 119 of Research Report No. FHWA/RD-81/045.

Table 25. Monitored oil and grease loadings in highway runoff [3].*

	Overall 1976 - 1977 loadings, lb/acre/event				Nonwinter[a] loadings, lb/acre/in. runoff			
Monitoring sites	Events monitored	Avg.	Min.	Max.	Events monitored	Avg.	Min.	Max.
I-794, Milw.	9	1.04	0.08	2.62	6	1.96	0.82	3.00
Hwy. 45, Milw.	10	0.24	0.01	0.84	5	1.53	0.42	3.87
Grassy site, Milw.	5	0.03	0.00007	0.06	4	0.34	0.22	0.46
Harrisburg	19	0.16	0.002	0.55	9	0.46	0.02	1.15
Nashville	8	0.52	0.13	1.82	4	1.02	0.45	2.16
Denver	15	0.35[b]	0.02	1.55	15	3.12	0.72	12.40

Metric units: To convert lb/acre/event to kg/ha/event multiply by 1.12.

[a] Nonwinter: April through October periods (1976-77).

[b] No storm events monitored during winter at Denver due to lack of sufficient precipitation.

*Reproduced from page 121 of Research Report No. FHWA/RD-81/045.

Table 26. Pollutant concentrations and annual loads for the A4 motorway in France [4].

Pollutant	Mean Conc. mg/L	Mean Annual Load grams/kilometer of 2-Lane Highway
COD	208	4714
SS	182	6550
Zn	0.85	51
Pb	0.18	5.9
Hydrocarbons	2.2	69

6. ENVIRONMENTAL IMPLICATIONS

Based on examination of the runoff data, the authors have drawn the following conclusions.

1. The primary contaminants contributed to surface waters by the I-35 runoff are suspended solids, metals, chloride, oil and grease, and an elevated oxygen-demand.
2. The metals concentrations are directly proportional to the suspended sediment load in the highway median runoff based on a plot of metal concentrations versus suspended solids. Chloride, oil and grease, and oxygen demand values may also be affected by suspended solids loading but do not exhibit a direct correlation with suspended solids.
3. Reduction of highway runoff impacts depends to a large extent on suspended solids reduction. This may be accomplished by the following means:
   - maintaining vegetative cover
   - reducing median and right-of-way mowing activities
   - repairing turf damage from vehicular and construction activities
   - maintaining strict sediment retention procedures at construction sites
   - evaluating the quantity and gradation of deicing materials used

- considering median and right-of-way grading (dikes and terracing slopes) or retarding (low, narrow rip rap strips on intervals) structures in some cases.

The Skunk River has a typical flow range of 4-8 million gallons per day (500,000-1,000,000 cubic feet per day) at Ames based on limited examination of flow records for 1982 and 1983. The total recorded runoff from the I-35 sites (3.57 acres) between April 21, 1984, and October 31, 1984, was about 163,000 cubic feet. Between the dates of November 1, 1983, and April 21, 1984, when the flow monitoring equipment was icebound or nonoperational, the authors estimate the runoff to have been on the order of 6.7 inches or 86,000 cubic feet. Thus, the annual runoff volume per acre of highway drainage area was about 70,000 cubic feet (19.2 inches). Of this volume, a significant fraction infiltrated into the soil in the flat land located west of the monitoring station and did not flow into the receiving surface water. This would not be the case in many drainage areas.

Total solids, suspended solids, ammonia-nitrogen, nitrite plus nitrate nitrogen, and total phosphorus data for the Skunk River at Ames indicate concentrations in the river consistently equal to or greater than those observed in the highway runoff. Based on the contaminant concentrations observed in runoff at the site and in the Skunk River and on their relative flow volumes, it is the authors' opinion that the environmental impact of the I-35 site on surface waters is minimal.

The highway runoff suspended solids and total lead data can be manipulated to obtain an estimate of the lead concentration in the highway right-of-way soils if it is assumed that all lead in the runoff is associated with the solids. The authors have made this assumption in preparation of Table 27. Lead levels in the highway right-of-way soils were estimated to be about 300 parts per million.

Based on the October 1983 Environmental Protection Agency (EPA) Process Design Manual for Land Application of Municipal Sludge, the majority of crops do not accumulate lead [5]. The concern is that animals ingesting the grasses from highway right of ways might indirectly ingest lead via dust and dirt that might adhere to and contaminate the grasses. For application to fruit and vegetable production lands, the EPA restricts high-quality municipal sludge to a maximum lead concentration of 1000 mg/Kg (1000 parts per million) and a maximum accumulated application of 800 kilograms of lead per hectare [5]. For agricultural cropland, the EPA recommends a cumulative limit for lead application of 560-2240 kilograms per hectare, depending on the cation exchange capacity of the native soils [5]. The higher cumulative application limits apply to silt and clay type soils, such as those at the site.

On this basis, it is the authors' opinion that cutting the right-of-way grasses at the site or similar sites for use as livestock feed probably does not present a health concern. However, at sites where traffic volumes are higher or solids accumulation is high, the cutting of right-of-way grasses for use as livestock feed probably should not be encouraged as evidenced by data in Tables 18, 20, and 26.

Based on the vadose zone and groundwater monitoring data accumulated at the site, the ponding and infiltration of highway runoff can

Table 27. Estimated lead concentrations in the sediment carried in the runoff at the Ames site.

SS mg/L	Total Lead mg/L	Ratio of Lead/SS	Approx. Lead Conc. of Solids Assuming all Lead to be Associated with Suspended Solids
139	0.034	2.45×10^{-4}	245 ppm
39	0.008	2.05×10^{-4}	205 ppm
111	0.023	2.07×10^{-4}	207 ppm
41	0.014	3.41×10^{-4}	341 ppm
38	<0.010	$<2.6 \times 10^{-4}$	260 ppm
23	0.012	5.2×10^{-4}	520 ppm
		Avg.	296 ppm

cause migration of contaminants to the groundwater table. This is particularly true in areas where the surficial soils overlaying a shallow aquifer are thin and/or sandy. Where shallow potable water supply wells may be located immediately down gradient of such infiltration points, periodic water quality testing for iron, lead, chloride, and oil and grease may be desirable, particularly for high traffic volume highways.

7. SUMMARY

The highway runoff project results to date indicate that highway activities do contribute suspended solids, chloride, oil and grease, metals, and oxygen demand to runoff waters and groundwater. However, the contaminant contributions observed at the study site have not degraded the quality of the receiving stream or the groundwater, with the possible exceptions of spring snowmelt runoff, the first spring rainfall event, and the first runoff following a long dry period. Even at those times, it is the authors' opinion that the environmental impact on the receiving stream and groundwater is minimal.

The runoff volume from the flat (0.24 percent) median with saturated soil conditions frequently exceeds that of the steep (2 percent) median with unsaturated soil conditions (i.e., when the flat slope soils are relatively more saturated than the steep soil slopes). However, for most storm events the peak flows for the flat area are generally 52-69 percent of the steep area peak flows. The flat area to steep area peak flow ratio approached 0.9 for the June 13, 1984, precipitation event with an approximate intensity of 1.0 inch per hour for a two-hour duration.

When saturated soil conditions existed, the total runoff for medium to heavy precipitation events nearly equaled and in some cases slightly exceeded total precipitation. This is due to both lateral precipitation variation and highway traffic effects. For unsaturated soil conditions and for low intensity and/or short duration rainfalls on saturated soil, the runoff was generally 40-70 percent of the precipitation.

Basin lag times were observed to be highly dependent on the basin slope, the degree of soil saturation, and the rainfall intensity. However, for the worst observed conditions, i.e., saturated soils and 1.0-1.6 inches per hour rainfall intensity, basin lag times for both the flat and the steep slopes were observed to be on the order of 13-35 minutes.

While the environmental impact at the study site was found to be minimal, the environmental impacts at other sites with higher traffic loadings or with differing maintenance, construction, and drainage may not be minimal. The reduction of highway runoff environmental impacts depends to a large extent on suspended solids reduction. Recommendations regarding methods for suspended solids control are given in the report text. Chloride, another contaminant in highway runoff, is highly soluble and not strongly adsorbed in soil matrices. Therefore, the control of chloride reverts to stringent application control. It is probable that some of the recommendations for suspended solids control would redistribute the final impacts of soluble contaminants. The recommendations would increase basin lag times for most storm events and encourage infiltration over larger land surfaces. Thus, runoff volumes to streams would be reduced, infiltration in isolated ponding areas would be reduced, and the soil bulk available for adsorption of contaminants would be maximized.

Where shallow potable water supply wells may be located immediately down gradient of runoff infiltration basins or ponding areas for high traffic volume highways, periodic water quality testing for iron, lead, chloride, and oil and grease may be desirable based on the data accumulated in this study, depending on the type and thickness of soils overlaying the aquifer and the depth of the down gradient supply well.

Table 27 showed the estimated lead concentration in the sediment carried by runoff at the site to be about 300 parts per million. These lead levels in right-of-way soils probably do not exclude right-of-way grasses from cutting and use in feeding livestock. However, lead levels in soils in higher traffic volume highway right of ways could be higher as evidenced by the data in Tables 18, 20, and 26. Therefore, traffic volume should be considered when evaluating the use of right-of-way grasses for livestock feed.

8. ACKNOWLEDGMENTS

The authors wish to express their appreciation to the Federal Highway Administration for funding the Iowa Department of Transportation participation in FHWA Demonstration Project No. 56. The participation of FHWA personnel in a demonstration workshop at the Iowa DOT facility in June 1983 and their continued interest in the study progress and results were very helpful and greatly appreciated.

The assistance, support, and continued interest of Mr. John Whited, Transportation Planner with the Iowa DOT Transportation Research Division, was instrumental in successful installation of the site equipment and successful completion of the monitoring program. Other Iowa DOT personnel who contributed to the program were Hector Hogue, Environmental Analyst; Steve Tritsch, Special Assignment Engineer; and the maintenance personnel who provided equipment and manpower for installation of the monitoring equipment and recorded highway maintenance data throughout the project.

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10. APPENDIX:

SPRING 1985 HIGHWAY RUNOFF SUMMARY

Information accumulated during the period of November 1, 1984, to April 24, 1985 is presented and discussed in this appendix. Based on the recommendations of ISU personnel, the Iowa DOT elected to extend the collection of runoff data from the steep (2.0 percent) grade beyond the first year of data collection originally contracted to provide a better snowmelt and early spring runoff data base. Iowa DOT personnel were to collect on-site precipitation data and sample spring snowmelt and rainfall runoff. ISU personnel were to set up the automated sampling equipment for the rainfall runoff data collection.

The precipitation record for the time period of November 1, 1984, to April 24, 1985, is contained in Table A.1. The data are mostly those from the Ames and Des Moines weather stations. The total precipitation in this period was 7.94 inches. Snowfall accounted for 3.8 inches of the total.

Weather records show that snowfall prior to January 1985 did not accumulate appreciably because of occasional unseasonably warm weather. The surface soils in the Ames area remained frozen from December 4, 1984, to about February 23, 1985. Thus, any snowmelt or rainfall during that period would have resulted in little, if any, infiltration. Rainfall and snowmelt prior to December 4, 1984, and subsequent to February 23, 1985, would have contributed both to infiltration and runoff.

Snowmelt occurred several times during the winter, but flow rates and quantities for each event were very small. The largest snowmelt

Table A.1. Precipitation from 11/1/84 to 4/24/85.

Date	Nov. 1984	Dec. 1984	Jan. 1985	Feb. 1985	Mar. 1985	Apr. 1985
1	1.31 R	0	0.05 S	0	0	0.07 R-S
2	0	Tr	0	0	0	0
3	0	Tr	0	0	0.55 R	0
4	0	0	0	0.06 S	0.08 R	0.06 R
5	Tr	0	0	0.08 S	0	0
6	0	Tr	Tr	0	0	0
7	0	0	Tr	0	0	0
8	0	0	0	0	0	0
9	0.05 R	0	0.07 S	Tr	0	0
10	0.43 S	0	0.15 S	0.02 S	0	0
11	0.17 S	0	0.03 S	0.08 S	Tr	0
12	0	0	0	0	0	0
13	0	Tr	0	0	~0.1 S*	Tr
14	0	0.84 S	0	0	0	Tr
15	0	Tr	0	0	0	0
16	0	0.17 R-S	0	0	0	0
17	0	0.05 S	0	0	0	0
18	0.01 S	Tr	0	0	0	0
19	0	Tr	0	0	0	0
20	0	0	0	Tr	0	Tr
21	0	0.40 S	0	0.31 R	0	~0.18 R
22	0	0.29 S	0	0	Tr*	~0.05 R
23	0	0	0	0.33 R-S	~0.34 R*	Tr
24	0	0.01 S	Tr	0.05 R-S	Tr*	0
25	0	Tr	Tr	0	0	
26	0.02 R	Tr	0	0	0	
27	0.02 R	0.33 R	0	0	0.20 R	
28	0.24 S	Tr	0	0	0	
29	Tr	Tr	Tr		0	
30	0.01 S	0	0.05 S		0.09 R	
31		Tr	0		0.44 S	
Total	2.26 (Ames data) 2 mi. SE	2.09 (Ames data) 2 mi. SE	0.35 (Ames data) 8 mi. WSW	0.93 (Ames data) 8 mi. WSW	1.80 (site data) *Supplemented with Ames data 8 mi. WSW	0.36 (site data) last day of record 4/24/85
		Frozen soil on 12/4/84	0.64 Des Moines	Soil no longer frozen ~2/23/85		

Note: Precipitation in inches.
R = rain, S = snow, Tr = trace.

runoff occurred February 16-18 and 23-28, 1985. As a result of the above conditions, Iowa DOT personnel collected no snowmelt data in 1985.

The automated equipment was set up by ISU and Iowa DOT personnel on March 1, 1985. On that day a grab sample of runoff from the H-flume (~0.001 cfs flow) was obtained from the ponded runoff at the flume by ISU personnel. The runoff was likely representative of the latter stages of the snowmelt runoff. ISU and Iowa DOT personnel also sampled the lysimeters (composited) in the median and groundwater monitoring wells NWW and SEW on March 1. The analytical data for these samples are shown in Table A.2. Based on the H-flume grab sample analysis, it appears that in the majority of the snowmelt chloride concentrations were on the order of 250-300 mg/L.

The first precipitation following spring snowmelt was the rainfall event of March 3. The cumulative precipitation versus time plot for the event is shown in Fig. A.1. The runoff hydrograph for the event is shown in Fig. A.2. A total of 0.63 inch of rain occurred, resulting in a total flow of 3,500 cubic feet (0.52 inch) from the 1.87 acre south (steep slope) drainage area. The ratio of runoff to precipitation was 0.83.

The peak flow rate was 0.22 cfs, and the observed basin lag time was 58 minutes. The maximum rainfall intensity was 0.34 inch/hour. Five samples (S-1 to S-5) were collected from the H-flume by the flow proportional sampler, and samples T-1 to T-21 were collected by the liquid level actuated H-flume sampler. The analyses performed on discrete runoff samples from the event are shown in Table A.3.

ENGINEERING RESEARCH INSTITUTE
ANALYTICAL SERVICES LABORATORY
REPORT OF CHEMICAL ANALYSIS

TO: HARVEY GULLICKS
PROJECT: DOT 0301
DATE: MARCH 8, 1985
BY: D. Schueller

Table A.2. Analysis of samples obtained 3/1/85.

DOT 0301	COMPOSITED LYSIMETERS	GRAB SAMPLE H-FLUME	NWW	SEW	UNITS
PH	8.14	7.98	7.18	6.81	-LOG H+
CHLORIDE	714	289	1	13	MG/L*
SPEC COND	4330	1640	979	957	UMHO/CM**
OIL & GREASE	****	****	3	6	MG/L
TOC	****	****	8	11	MG/L
COD	****	****	26.4	29.5	MG/L
TOT FE	****	****	8.17	28.7	MG/L
SOL FE	****	****	****	18.7	MG/L
TOT PB	****	****	47.2	34.9	UG/L***
SOL PB	****	****	****	28.0	UG/L

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*milligrams per liter.

**micromhos per centimeter.

***micrograms per liter.

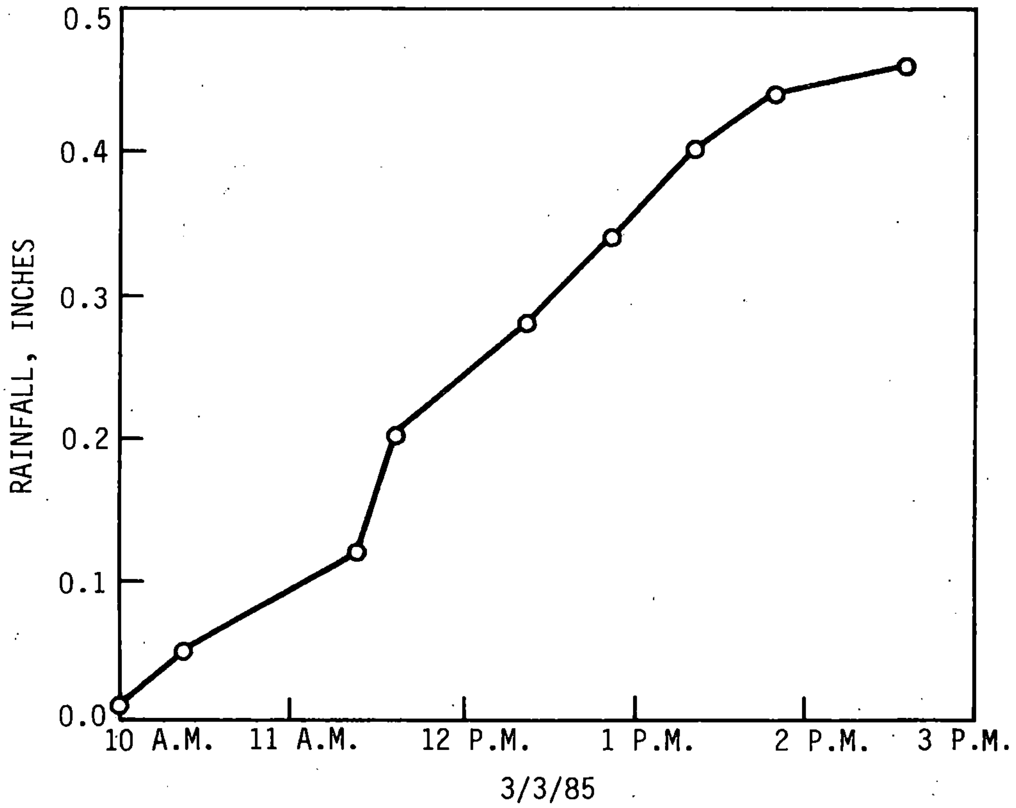

Fig. A.1. Cumulative rainfall versus time 3/3/85 rainfall event.

Note: Light precipitation continued between 2:35 p.m. and 1:33 a.m. of 3/4/85 adding 0.17 inch precipitation for a total event precipitation of 0.63 inch.

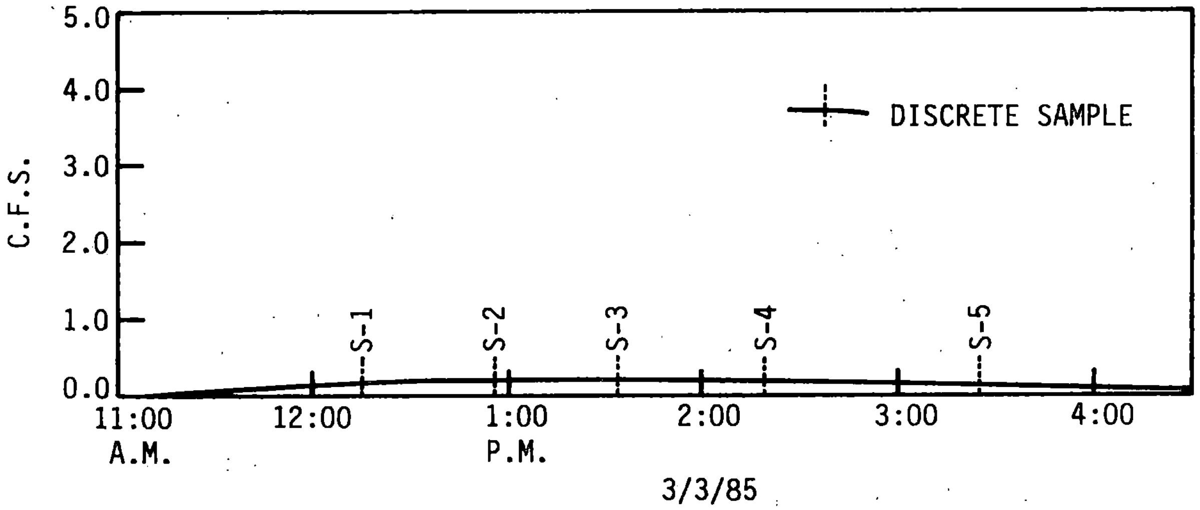

Fig. A.2. H-flume hydrograph 3/3/85 event. Samples S-1 to S-5 were taken at 500 cubic feet flow intervals. Basin lag time = 11:28 to 12:25 = 58 minutes. Maximum rainfall intensity = 0.34 inch/hour.

3/3/85 H-FLUME RUNOFF
DISCRETE SAMPLES FROM THE LIQUID-LEVEL ACTUATED SAMPLER.

Sample	Time Taken p.m. 3/3/85
T-1	12:25
T-2	12:27
T-3	12:29
T-4	12:32
T-5	12:35
T-6	12:39
T-7	12:43
T-8	12:48
T-9	12:53
T-10	12:58
T-11	1:03
T-12	1:08
T-13	1:13
T-14	1:18
T-15	1:23
T-16	1:33
T-17	1:43
T-18	1:53
T-19	2:03
T-20	2:13
T-21	2:23

ENGINEERING RESEARCH INSTITUTE
ANALYTICAL SERVICES LABORATORY
REPORT OF CHEMICAL ANALYSIS

TO: HARVEY GULLICKS
PROJECT: DOT 0304
DATE: MARCH 13, 1985
BY: JoGaunt

Table A.3. Discrete samples from H-flume during 3/3/85 runoff event.

DOT 0304	PH	COND	CL	FE	PB	T.SOL.	S.SOL.	COD	TOC	OIL&GR
S1	7.91	1097	250	760	22.9	653	15	****	****	****
S2	7.96	1286	296	1360	31.0	733	50	****	****	****
S4	7.91	1352	291	2480	34.9	856	92	****	****	****
S5	7.94	1113	252	1150	17.6	630	28	****	****	****
T1	7.82	1365	304	2740	33.6	855	95	****	****	****
T2	****	****	****	****	****	****	****	40.1	11	2
T3	7.91	1322	299	1830	33.0	813	66	****	****	****
T4	****	****	****	****	****	****	****	44.6	11	LT .2
T5	7.89	1293	296	1520	31.3	866	45	****	****	****
T6	****	****	****	****	****	****	****	40.5	12	2
T7	7.93	1337	297	1080	28.3	808	29	****	****	****
T10	****	****	****	****	****	****	****	34.8	10	4.9
T11	8.00	1159	262	3350	31.3	894	98	****	****	****
T14	****	****	****	****	****	****	****	34.9	11	2.2
T15	7.96	1076	253	1180	28.8	816	28	****	****	****
T18	****	****	****	****	****	****	****	42.1	9	5.7
T19	7.87	1076	242	830	25.7	656	16	****	****	****
UNITS	-LOG H+	UMHO/CM*	MG/L**	UG/L***	UG/L	MG/L	MG/L	MG/L	MG/L	MG/L

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*micromhos per centimeter. **milligrams per liter. ***micrograms per liter.

The chloride concentrations remained very uniform throughout the runoff event, ranging from 242 to 304 mg/L. Iron concentrations ranged from 0.76 to 3.35 mg/L. Lead concentrations ranged from 17 to 35 μg/L, below the EPA maximum contaminant levels. The total and suspended solids concentrations ranged from 653 to 894 mg/L and 15 to 98 mg/L, respectively. COD and TOC were relatively uniform throughout the event. The oil and grease concentrations, however, fluctuated between <0.2 and 5.7 mg/L.

Runoff after March 3 was caused only by low intensity, small quantity precipitation events and by snowmelt (3/30/85 to 4/1/85). Table A.4 clearly shows that once the surficial soils of the two percent median slope were saturated, the ratio of runoff to precipitation is high even for low intensity precipitation.

Table A.4. Runoff subsequent to 3/3/85 from low intensity rainfall and snowmelt.

Date	Precipitation (inches)	Runoff Associated with Precipitation (inches)
3/27/85	0.20 Rain	0.07
3/30/85 to 4/1/85	0.60 Mostly Snow	0.52
4/4/85	0.06 Rain	0.06

Deicing operations were not required for the snowfall event of 3/30/85 to 4/1/85.

The data collected in 1985 substantially reinforce the conclusions that were drawn by the authors based on the data collected in 1984. Those conclusions are given in the main body of this report.

The 1985 data confirm that chloride concentrations in snowmelt and initial rainfall-induced runoff will exceed the EPA drinking water maximum contaminant chloride concentrations. High total solids concentrations parallel high chloride concentrations in snowmelt and early spring rainfall-induced runoff. Lead concentrations in the runoff were a function of the suspended solids concentrations, but the lead concentrations were below the EPA drinking water maximum contaminant levels.

The Iowa DOT applied 1,510 pounds of deicing salt (3,020 pounds of 50/50 sand/salt mix) to the south (steep) drainage area between November 10, 1984, and April 2, 1985. Assuming that the salt was either sodium chloride or calcium choride, the salt contained 61-64 percent chloride by weight. Thus, 930 pounds of chloride were applied to 1.87 acres of drainage area during this time period. Six and one-half percent of the chloride applied was in the runoff associated with the March 3, 1985, runoff event. The authors estimate that snowmelt and precipitation between November 10, 1984, and March 1, 1985, accounted for a total steep slope runoff quantity of 27,000 cubic feet. Assuming that this volume had an average chloride concentration of 275 mg/L (as did the 3/3/85 runoff), the chloride in runoff for this time period was an additional 460 pounds. Thus, the total chloride in runoff through March 3, 1985, was about 56 percent of the total 930 pounds applied.

From November 1, 1983, to March 31, 1984, the Iowa DOT applied 900 pounds of deicing salt per acre of drainage area. Assuming that the salt was either sodium chloride or calcium chloride, the salt contained 61-64 percent chloride by weight. This amounts to 560 pounds of chloride applied per acre of drainage area. The chloride in runoff actually collected and sampled in 1984 accounted for 39 pounds of chloride per acre of drainage area. The authors estimate that the snowmelt and early spring rainfall runoff volume not measured and sampled was ~24,000 cubic feet per acre. Assuming that this volume had an average chloride concentration of 125 mg/L as observed in a 1984 grab sample of snowmelt runoff, an additional 190 pounds of chloride per acre of drainage area was accounted for. Thus, the total chloride load in 1984 runoff was about 40 percent of the total 560 pounds applied per acre of drainage area.

Based on two years of limited snowmelt and early spring rainfall runoff monitoring and sampling, it appears that about 40-56 percent of the total chloride applied in deicing operations left the highway median in surface water runoff. The remainder infiltrated into the soils in the median. Most of the chloride loading that leaves the highway right of way occurs in low flow rate runoff resulting from snowmelt and/or very low to low intensity spring rainfall. The chloride loadings are often undetected because the low flows (often less than 0.01 cfs) do not represent "significant runoff events" and are, therefore, not sampled.

Evapotranspiration appears to concentrate the chlorides in the upper soil zones as evidenced by the lysimeter analyses to date.

However, no significant chloride difference appeared in the monitoring wells located up and down gradient of the site.

The 1985 groundwater data (Table A.2) indicate that the pH of the up gradient (NWW) well water is higher than that of the down gradient (SEW) well water. The iron concentrations in the down gradient wells (NEW and SEW) have been consistently higher than those of the up gradient well (NWW). The relative pH and iron concentrations in the up and down gradient well locations are related. The elevated iron concentration down gradient of the highway is the result of a combination of the following sources:

- Acid attack of soils and concrete in the highway right of way (Acids are emitted by automobiles, particularly those with catalytic converters, as a byproduct of the combustion process.)
- Iron compounds used in the Iowa DOT deicing operation as anti-caking compounds
- Iron deposition from vehicular engine and body deterioration
- Iron from deterioration of reinforcement used in the construction of concrete pavement.

The anticaking compounds (ferrocyanide and ferric ferrocyanide) are quite stable, do not dissociate appreciably, and are not materially toxic.* Exposure of dilute iron-cyanide complex ion solutions to extensive direct sunlight causes photolysis to yield toxic HCN. However, photodecomposition yielding HCN is very slow in deep, shaded, or turbid

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*Standard Methods for the Examination of Water and Wastewater, 15th Ed., pages 313-314.

receiving waters. Furthermore, HCN is lost to the atmosphere and biological and chemical destruction so that harmful levels are not likely to occur.*

Comments in the main body of this report related to the overall environmental impact of highway activities at the study site are still valid. However, it is important to recognize that runoff at this site does not discharge directly into a surface water body. Rather, the majority of the runoff generated at the study site eventually infiltrated the soils adjacent to the site and entered the groundwater regime. Areas with higher traffic, different construction, and more direct discharge into surface waters may have a greater environmental impact.

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*Standard Methods for the Examination of Water and Wastewater, 15th Ed., pages 313-314.