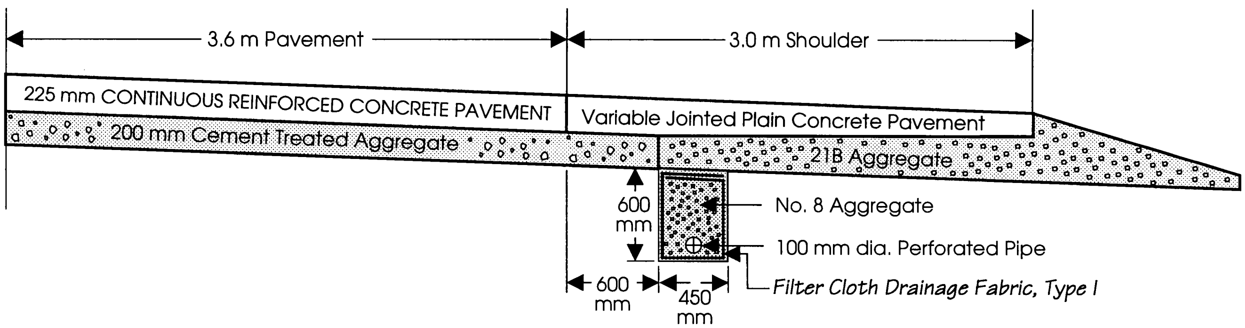
FINAL REPORT

EVALUATION OF UNDERDRAIN ON I-295



EDWARD J. HOPPE, Ph.D., P.E.
Research Scientist

DAVID C. WYANT, P.E.
Senior Research Scientist

VIRGINIA VTRC TRANSPORTATION RESEARCH COUNCIL

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16. Abstract

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Edward J. Hoppe, Ph.D., P.E.
Research Scientist

David C. Wyant, P.E.
Senior Research Scientist

Virginia Transportation Research Council
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ABSTRACT

The effectiveness of shoulder edge drains on I-295 south of Richmond was evaluated. Three adjacent outlets were monitored for outflow over a period of several months. Rainfall and outflow intensity and duration were continuously recorded using tipping bucket gages interfaced with a datalogger. The results indicated "excellent" to "good" quality of drainage, according to AASHTO criteria.

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Edward J. Hoppe, Ph.D., P.E.
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INTRODUCTION

Drainage is vital to a long term pavement performance. A properly designed and installed drainage system quickly removes water from the roadway. Water remaining in the pavement section for an extended time may cause significant structural damage under traffic loads. Rapid drainage increases the support capacity of the subgrade, thus prolonging pavement life (ERES, 1994). The AASHTO Guide for Design of Pavement Structures (1993) defines criteria for the quality of drainage as follows:

Quality of Drainage	Water Removed Within
Excellent	2 hours
Good	1 day
Fair	1 week
Poor	1 month
Very Poor	Water will not drain

Many of the newer underdrain designs consist of a flexible plastic pipe encased by an open-graded aggregate. A recent innovation widely employed in highway subdrainage is an envelope of geotextile fabric around the aggregate. Its function is to prevent infiltration by fine particles contained in subgrade soils, which reduce the effectiveness of water removal.

PURPOSE AND SCOPE

The purpose of this study was to evaluate the effectiveness of the VDOT Modified Underdrain Standard UD-1. It was decided to measure the outflow intensity and the time to drain following the rain event. AASHTO criteria for the quality of drainage were considered in the analysis.

The study was conducted on I-295 S.B.L., approximately 11 km from the merge with I-95 south of Richmond. Three adjacent outlets located on a sloping portion of a roadway were monitored. The recorded outflow was influenced by the condition of the mainline-shoulder longitudinal joint and the permeability of the overlying 21B aggregate. Furthermore, the results were affected by the permeability of subgrade soils and the ground topography at the site.

METHODS

The available instrumentation allowed a simultaneous monitoring of three outlets. It was decided to monitor three adjacent outlets with different invert elevations to assess the influence of the longitudinal roadway slope. Before selecting the test location, approximately 64 outlets were checked for obstructions with the Cues Mini Scout camera system. The objective was to find three unblocked outlets in a row, on a sloping portion of the roadway at an accessible location. Ultimately the monitoring was performed on I-295 south of Richmond, approximately 11 km from the merge with I-95. The pavement and underdrain cross section is shown in Figure 1. The longitudinal profile of the S.B.L. with outlet elevations is shown in Figure 2. Outlets labeled as #2, #3, and #4 were monitored.

Precipitation was measured with a dual tipping bucket rain gage manufactured by Texas Electronics. Each tip was equivalent to 0.25 mm of rainfall. The rain gage was factory calibrated, with an accuracy of 1%. It was labeled as #1 for data collection purposes.

Discharge from edge drains was measured concurrently with rainfall using custom built tipping buckets. The design was based on the plans obtained from the Hydrologic Instrumentation Facility (Kilpatrick and Jelinski, 1993). Some minor modifications were introduced. Three tipping buckets for measuring the discharge were fabricated at the Virginia Transportation Research Council. Each tip was sized to an equivalent of 1 liter of water. A magnetic proximity switch was used to sense bucket tips. Each device was installed in a wooden box enclosure. Laboratory calibration indicated the effective range of operation from 0 to 8 liters per minute. Tipping buckets were installed within approximately 10 meters of edge drain outlets and connected with a 100 mm diameter flexible corrugated plastic pipe. Figure 3 illustrates the field setup.

Rain gage and three outflow tipping buckets were wired to the Campbell Scientific CR10 datalogger with the 8-channel Switch Closure Input Module. A control program was developed to automatically record the number of tips in 5-minute intervals. Data were retrieved weekly with a laptop computer and processed at the office. Rain events were identified and plots of rainfall and outflow vs time were created using a spreadsheet program.

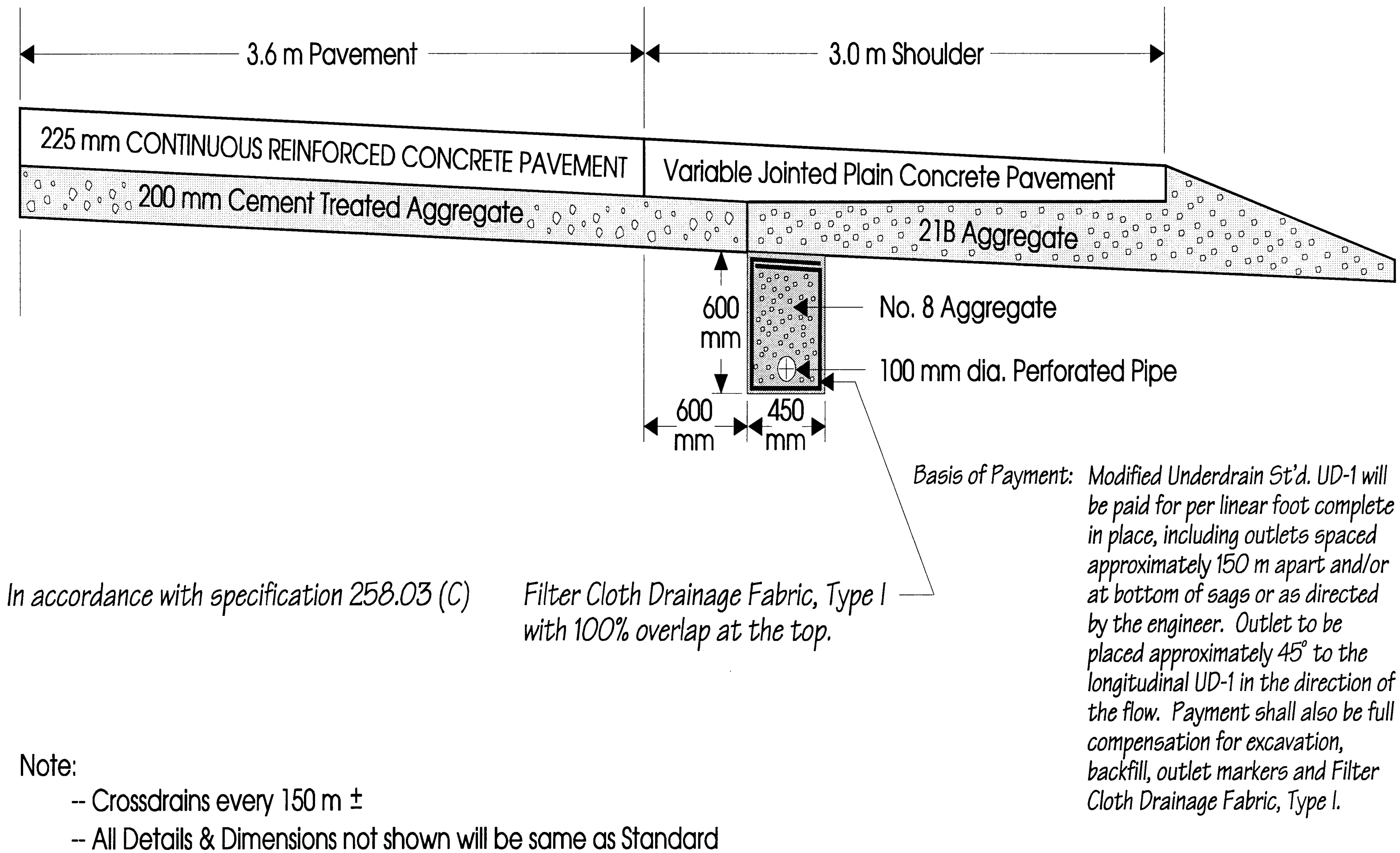

Figure 1. Cross-section of pavement and underdrain.

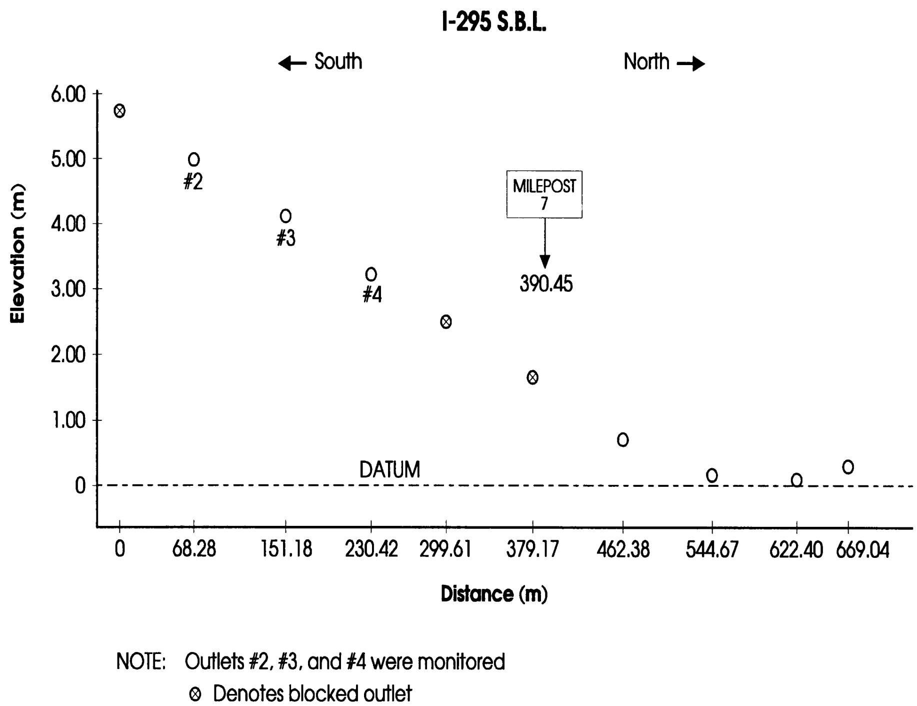

Figure 2. Profile of outlets.

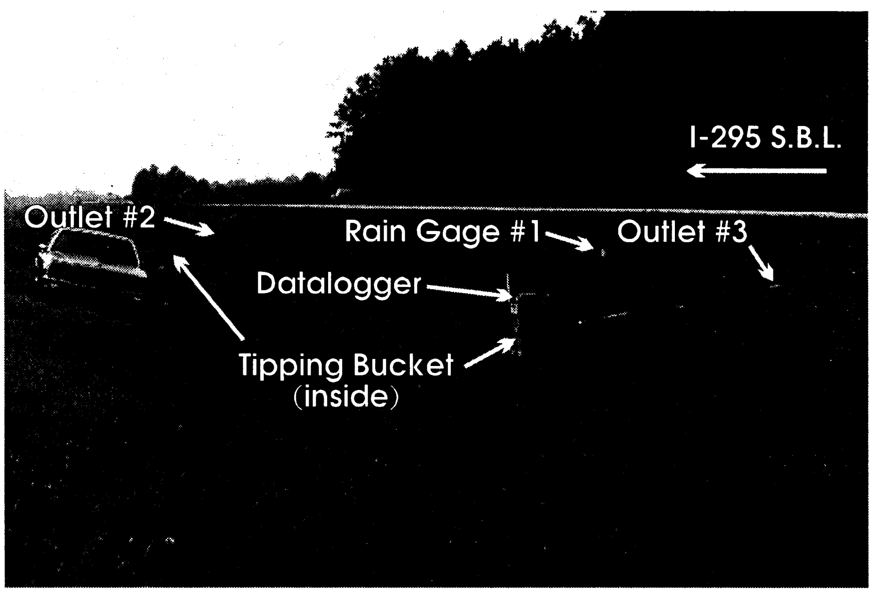

Figure 3. Field setup.

RESULTS

Field monitoring results are presented in Appendix A. Data represent cumulative flow values recorded in 5-minute segments. Various intensity rain events that occurred in the period of May 8 to October 23, 1994 are shown.

DISCUSSION

Data represent the performance of outlets spaced at 89 and 79 meters apart on a longitudinal roadway slope of approximately 1%. It can be seen that tipping buckets measuring the edge drain outflow frequently exceeded their measuring range, as evidenced by the flattening of the outflow graph (Appendix 1). Drainage times were found to increase with decreasing outlet elevation. It is evident that the outflow starts first and finishes last at the lowermost outlet. The following lag times after the end of the rain event were calculated:

Date of Rain Event	Maximum Rainfall (mm/min)	LAG AFTER THE END OF THE RAIN EVENT (hr) #2	#3	#4
May 8,'94	0.36	0.6	4.4	8.8
July 4	0.30	0.5	2.5	5.2
July 17-18	1.80	0.6	3.4	6.6
Sept. 17-18	0.87	0.7	2.3	5.0
Sept. 25-26	1.62	0.6	3.2	7.5
Oct. 23	0.42	0.5	3.2	7.6

Based on the AASHTO criteria for evaluating the quality of drainage, outlet #2 can be classified as "excellent," and the others as "good." A general trend of worsening quality of drainage (increasing drainage time) with the decrease in elevation is seen. Outlets located below #4, as shown in Figure 3, may be expected to drain significantly longer following the rain event.

Field data do not indicate a trend of increasing time to drain with an increased rainfall intensity. This observation is consistent with the findings contained in the study on pavement drainage performed by the Purdue University (Ahmed et al., 1993).

In the initial stages of site selection numerous problems were noted with the edge drain operation. A significant number of outlets were found to be defective. Approximately 30% of the outlets probed with the camera were either fully or partially blocked. Most of the blockages were found at the outlet "Y" connector, and some occurred between the "Y" and the end of the outlet. At the test location some neighboring outlets were also blocked. The results are probably affected by this condition.

CONCLUSIONS AND RECOMMENDATIONS

The performance of the Modified Type UD-1 edge drains on I-295 around Richmond was found to be satisfactory. Field measurements indicated good to excellent quality of drainage, according to AASHTO standards. A progressive deterioration of drainage effectiveness was detected at lower elevations of a sloping roadway.

Various steps may be taken to improve the edge drain effectiveness, especially in the sag portion of the roadway. Consideration should be given to increasing the number of outlets at critical locations, such as a bottom of a vertical curve, to enhance the quality of subsurface drainage. Construction of underdrains should be closely monitored to minimize the occurrence of blocked outlets. It is recommended that VDOT use a portable TV inspection camera to check drainage outlets for obstructions before accepting edge drain installation work. It is also recommended that pavement distress and outlet blockage be periodically monitored in order to correlate the pavement condition with edge drain performance. Finally, some redundancy should be incorporated in the drainage design, so a minimum level of performance will be assured despite a limited number of defective outlets.

ACKNOWLEDGMENTS

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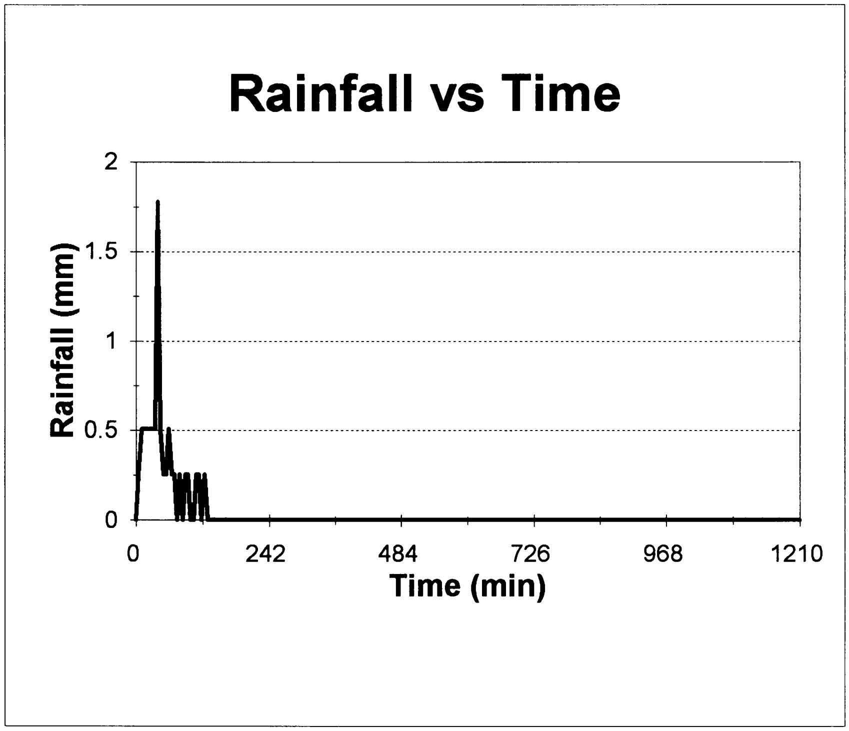
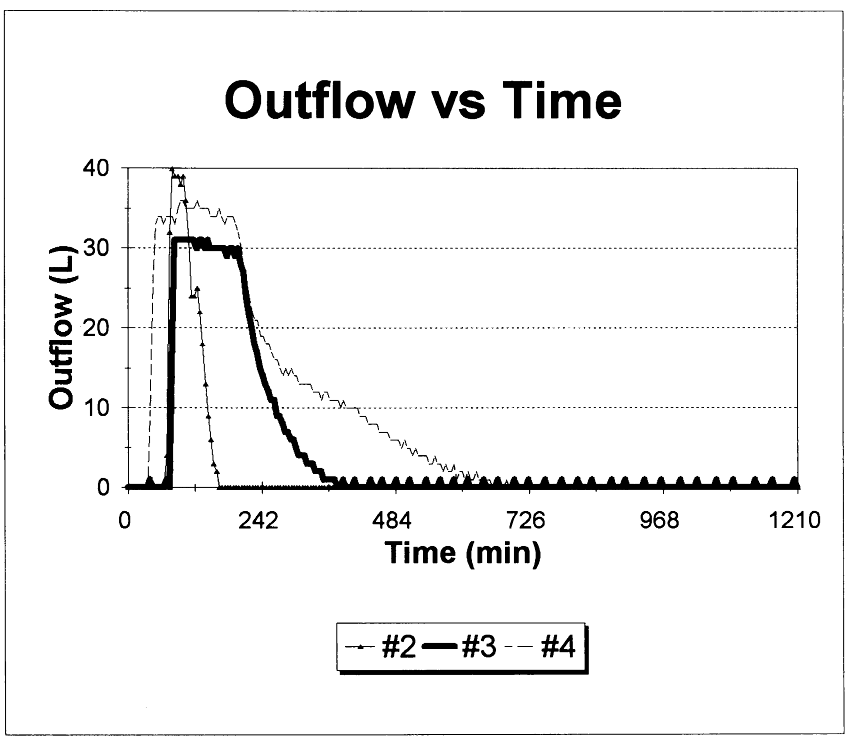
APPENDIX A

Field Monitoring Results

May 8, 1994

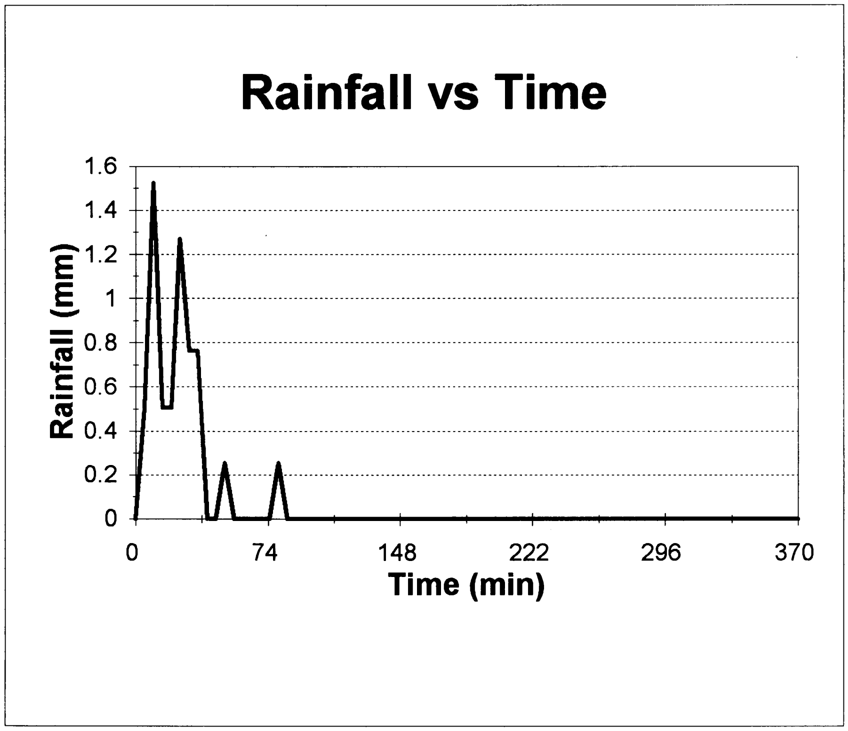


Rainfall vs Time
2
1.5
1
0.5
0
Rainfall (mm)
0
242
484
726
968
1210
Time (min)

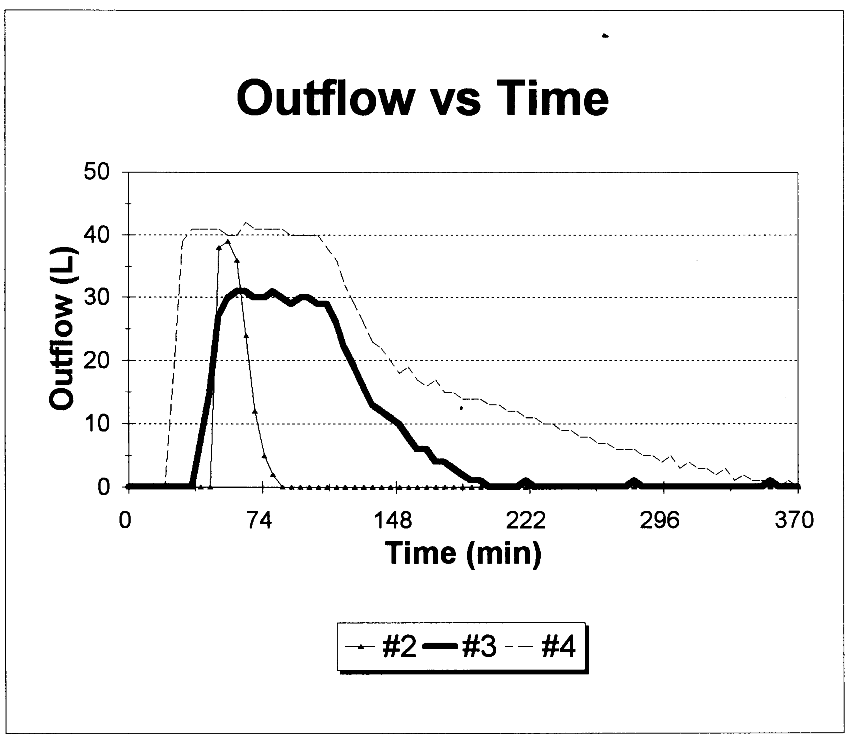


Outflow vs Time
40
30
20
10
0
Outflow (L)
0
242
484
726
968
1210
Time (min)
#2
#3
#4

July 4, 1994

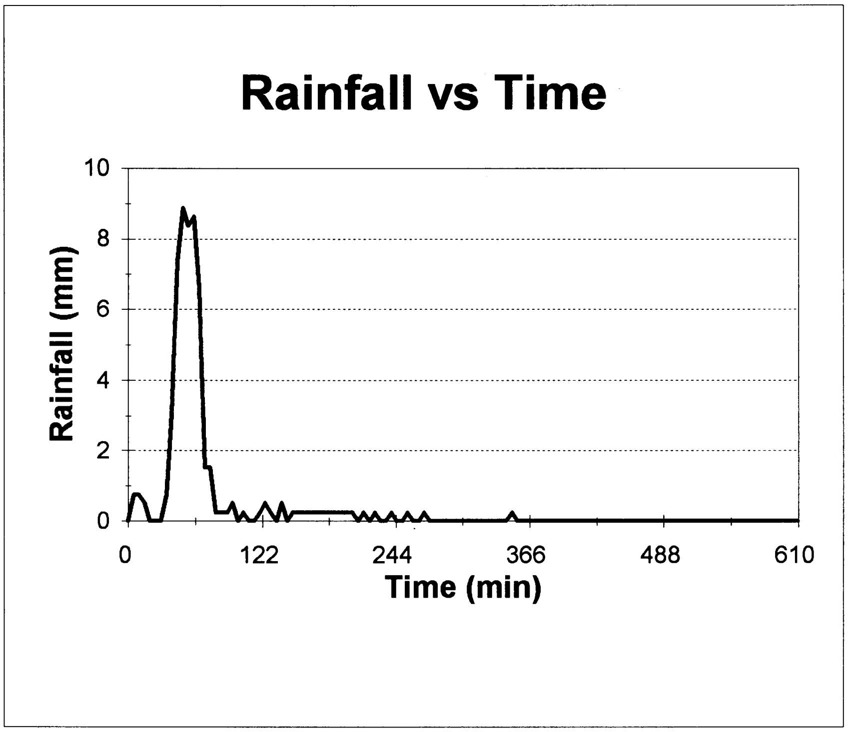


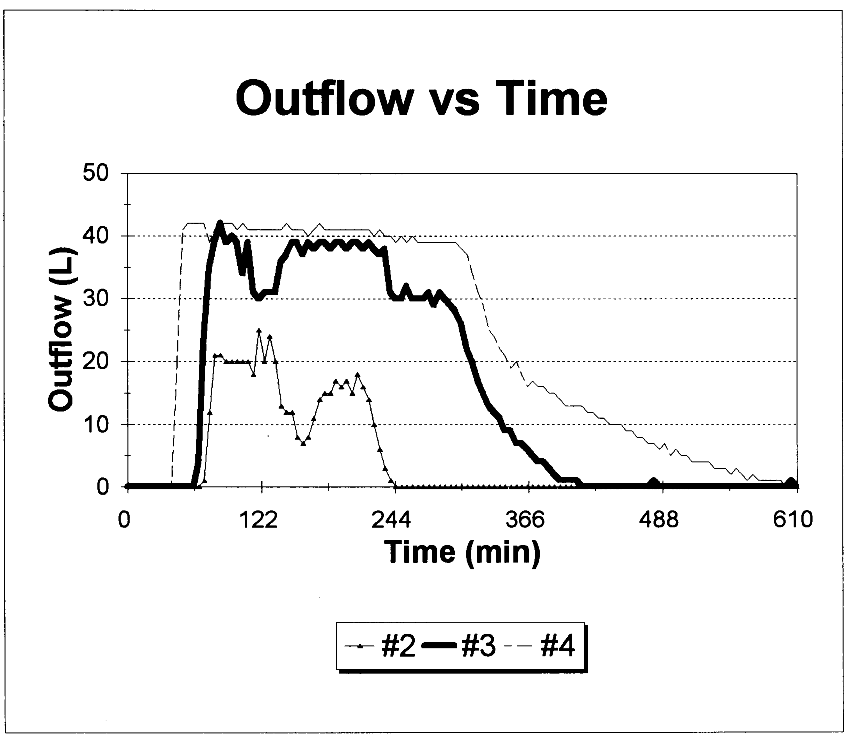
Rainfall vs Time
Rainfall (mm)
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
0
74
148
222
296
370
Time (min)



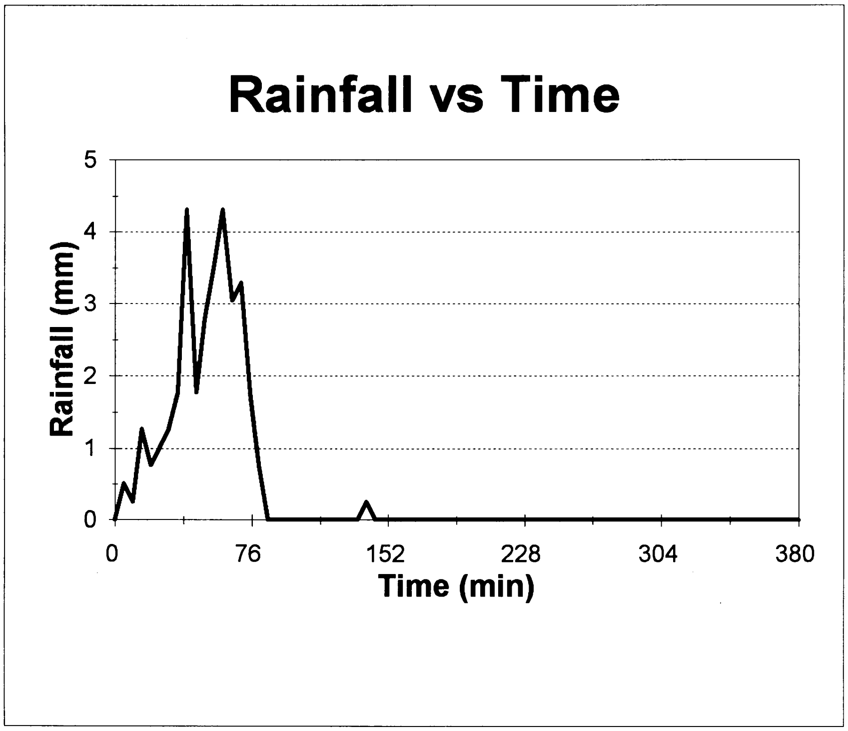
Outflow vs Time
Outflow (L)
50
40
30
20
10
0
0
74
148
222
296
370
Time (min)
#2
#3
#4

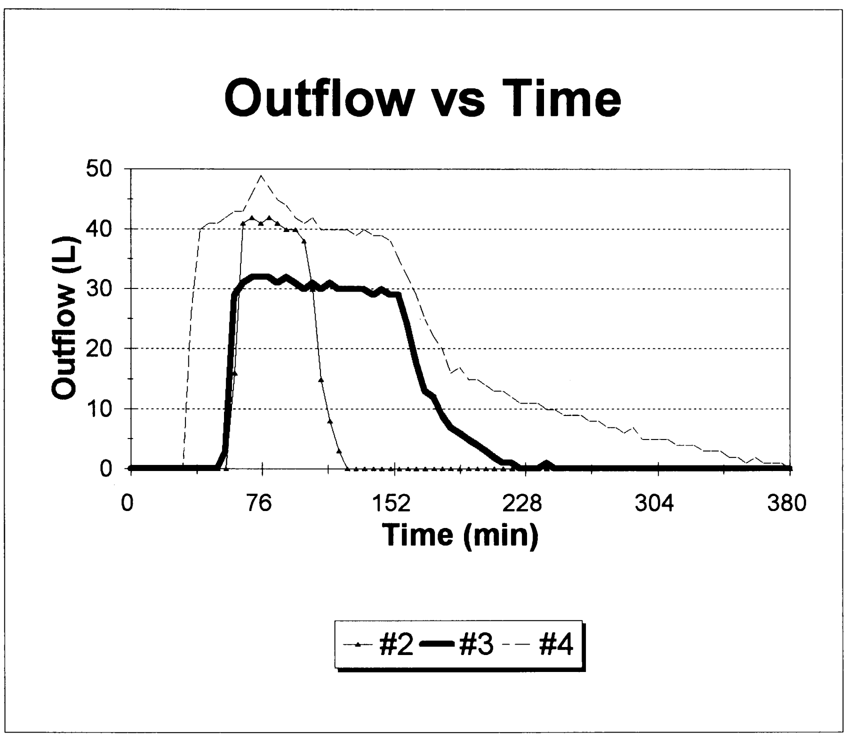
July 17 - 18, 1994





September 17 - 18, 1994





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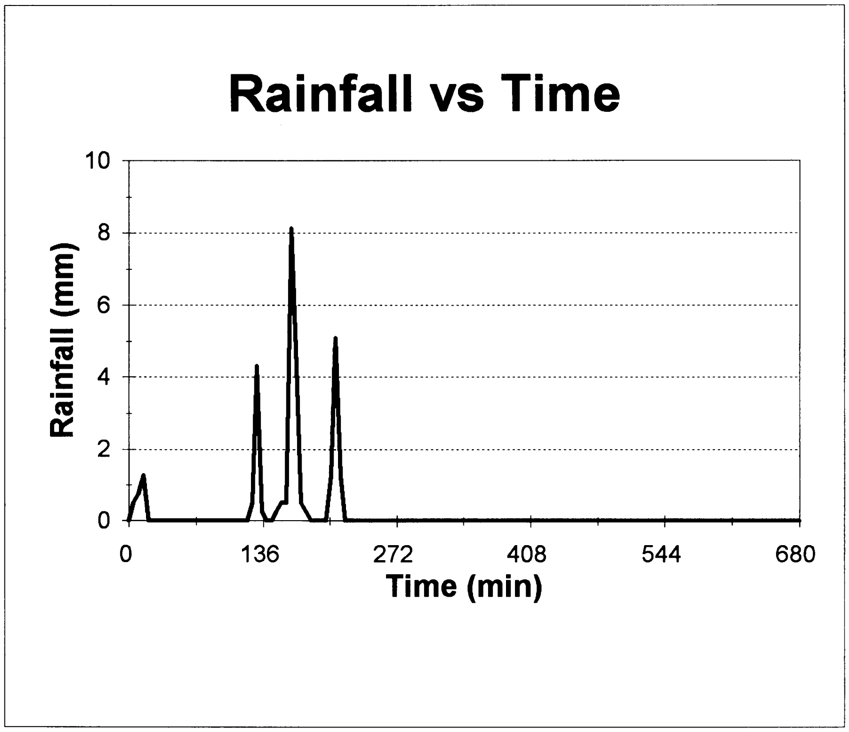

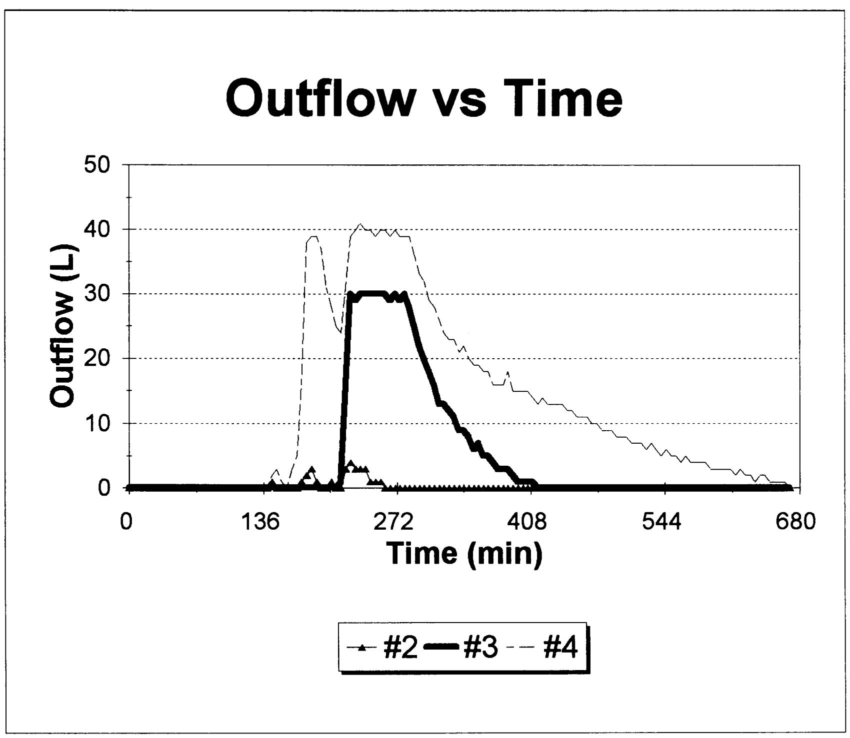

October 23, 1994