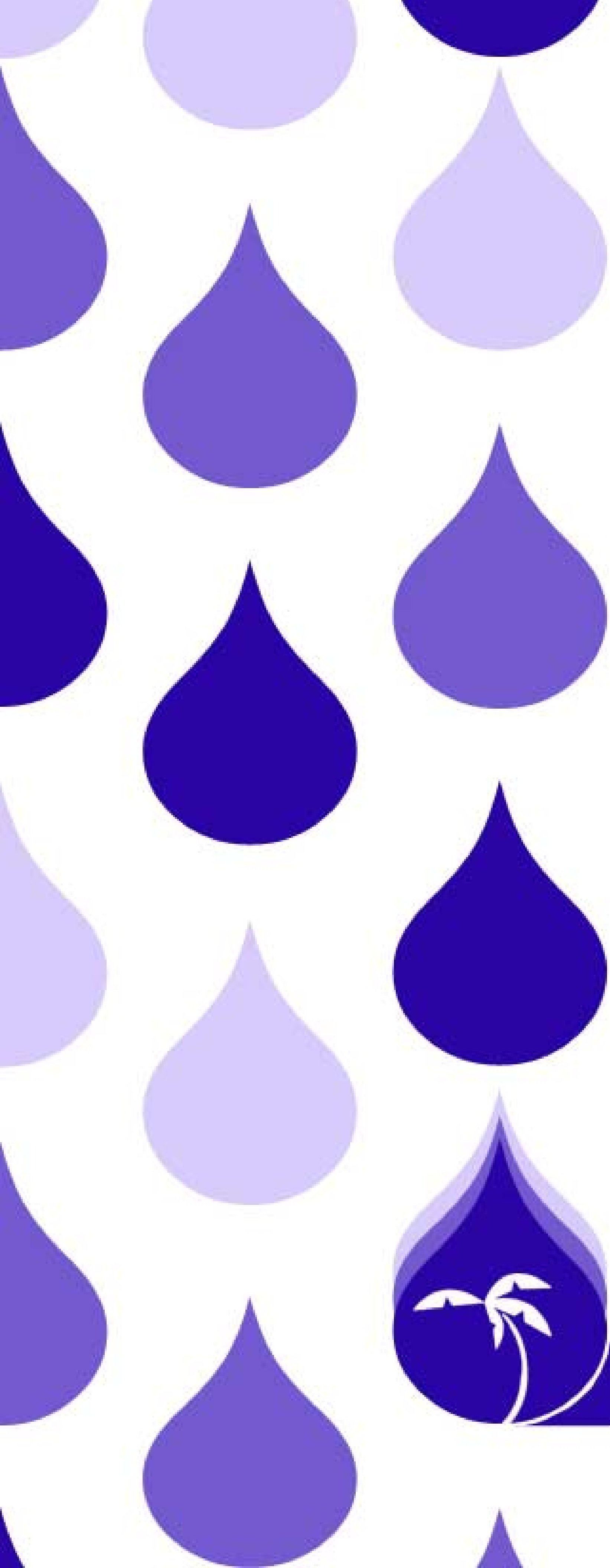

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A PRELIMINARY INVESTIGATION

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ABSTRACT

A preliminary study was undertaken to evaluate the water quality characteristics of urban runoff in Guam. The study was divided into three distinct phases. The first phase identified stormwater retention sites (sinkholes and ponding basins) in the northern half of the island. These were identified and delineated on a USGS 1:24000 quadrangle topographic map and digitized into a Geographic Information System (GIS). The second phase of the study focused on the water quality characteristics (nutrients, major ions and heavy metals) of urban runoff from several stormwater retention sites within the commercial and residential sectors of the community. Samples were manually collected from these sites on a limited number of occasions. In the third phase, a fully automated sequential sampling system was employed to collect runoff for analysis from a single storm drain that serviced the Palace Hotel in the municipality of Tamuning. Samples from this large commercial complex were collected intermittently over a three month period. The primary objective of this part of the program was to develop a fully automated model monitoring system that would: a) provide for the integration of synoptic rainfall measurements with runoff samples collected over the course of runoff events, and b) allow the autosampler to be interrogated from the laboratory to determine sampling status.

Runoff from the stormwater retention sites revealed substantial spatial and temporal variations in levels of nutrients (NO_3-N and o-PO_4-P), major ions (Ca, Mg and Na) and certain heavy metals (Ag, Cd, Cr, Cu, Fe, Mn, Ni, Pb and Zn). Several metals were found to be significantly associated with suspended solids. However, the ratios between “dissolved” and “particulate” metal fractions varied between metals both within and between sites. In contrast, the nutrients and major ions were almost exclusively confined to the dissolved fraction in the great majority of samples examined.

A comparative analysis with data previously reported for Guam’s urban runoff indicated that nutrient and heavy metal concentrations had not increased significantly over the last two decades. In fact, Cd and Pb levels appeared to have diminished somewhat, possibly reflecting current restrictions in the commercial use of these elements. Overall, there were very few exceedences of current surface and drinking water quality standards. The significance of the ponding basin water quality data is discussed with reference to published findings elsewhere in the world and includes short notes on relevant aspects related to human and environmental health. Levels were generally considered low by world standards despite the occasional indications of mild nutrient enrichment at certain sites. The maximum NO_3-N and reactive o-PO_4-P levels recorded were 3.67 mg/l (Mariana Terrace ponding basin) and 1.92 mg/l (Harmon Sink) respectively.

The water quality characteristics of runoff collected from the Palace Hotel storm drain was very different from that found in the retention ponds and was generally enriched in all detectable components. Especially noteworthy were the extraordinarily high levels of o-PO_4-P determined on several occasions (up to 482 mg/l). We determined that the autosampler was triggered by a number of storm and nonstorm events. The latter were generally higher in NO_3-N, o-PO_4-P, Na, Mg, and Cu, and were suspected of being generated by water sprinklers operating within the hotel’s landscaped areas. The major source of enrichment was concluded to be water soluble fertilizers inadvertently scattered on paths, roads and walkways adjacent to targeted lawns and gardens, and flushed into the storm drain in irrigation runoff. The possible connection between the “seaweed problem” in Tumon Bay and fertilizers used in maintaining landscaped areas of adjacent hotels is discussed with recommendation for future research.

INTRODUCTION

In recent years, we have come to realize that nonpoint sources of pollution pose far more of a threat to the health and well being of our waterways than specific point sources. This is because they come from diffuse, intermittent and often unidentifiable sources, and hence are not easily controlled or regulated (Vigon 1985). Nonpoint source pollution accounts for over half the contaminant load entering waterways in many parts of the world (Whipple *et al.* 1974, Wanielista *et al.* 1977).

Urbanized areas are particular important nonpoint sources of water pollution (Bryan 1972). In the urban environment, the largest contributor of nonpoint pollution is stormwater runoff (Hall and Anderson. 1987). According to the United States Environmental Protection Agency (U.S. EPA), urban runoff may rival and even exceed agriculture as the worst contributor of nonpoint pollution in many areas (Barton 1978). They estimated that around 30% of water quality impairments nationwide are attributable to stormwater discharges (U.S. EPA 1992).

Common contaminants in urban runoff include toxic metals (Wilber and Hunter 1979), nutrients (Bedient *et al.* 1980), major ions (Harrison and Wilson 1985a), hydrocarbons (Hunter *et al.* 1979, Hoffman 1982), synthetic organics including pesticides (Murphy and Carleo 1978) and PCBs (Gjessing *et al.* 1984), fecal bacteria (Kebabjian 1994, Matson 1996), and sediments (Whipple *et al.* 1978). Some of these are generally recognized as more important than others from an environmental health standpoint. For example, data from 51 catchment areas in the U.S. showed that the U.S. EPA organic priority pollutants posed little risk at the levels normally encountered in stormwater, based on criteria for levels considered safe to aquatic life. However, the most prominent toxic heavy metals, namely Cu, Pb and Zn, exceeded the freshwater acute toxicity criteria 50, 27, and 12% of the time respectively (Cole *et al.* 1984).

Heavy metals are a particularly troublesome group of contaminants, not only because of their potential toxicity, but also because of their persistence and tendency to bioaccumulate. Aquatic organisms frequently exhibit concentration factors (tissue - water ratios) in excess of 10^6 for several heavy metals (Denton and Heitz 1991, 1993). Thus, moderate increases in metal loadings from street runoff could result in the loss of a commercial resource, if levels laid down in edible tissues exceed those recommended for human consumption. Such events could also cause toxic thresholds to be exceeded in sensitive species resulting in their loss from the community.

The nutrients, N and P, are another very important group of urban runoff contaminants because their overabundance in receiving waters can cause accelerated eutrophication. This is characterized by large increases in the standing crop of phytoplankton and vascular plants leading to habitat modification and depleted oxygen levels. In the extreme case, there can be noxious algal “blooms”, causing a variety of water quality problems including fish kills, unpleasant tastes and odors, clogged pipelines and restricted recreational use (Freedman 1989). In 1992, the U.S. EPA reported that accelerated eutrophication was one of the leading problems facing the Nation’s lakes and reservoirs in the U.S. It is noteworthy that P is often the nutrient responsible for accelerated eutrophication in freshwater (Freedman 1989).

Guam is fortunate in having fresh and marine water resources that, by world standards, are relatively clean and free of chemical contaminants. The availability and purity of these resources has largely fostered the rapid population growth and commercial development currently underway on the island. Such major expansions, while creating jobs and improving standards of living for the people of Guam, ultimately increase risk factors for environmental pollution and deteriorating water quality. Contaminants, mobilized in stormwater runoff from developed and developing areas in northern Guam, are of particular concern in view of their potential impact upon groundwater and surface water resources.

The only studies to have looked closely at the water quality characteristics of urban runoff in Guam, are those carried out by Zolan and his co-workers back in the late 1970's and early 1980's (Zolan *et al.* 1978a, Zolan 1981). These researchers explored a range of basic physical and chemical water quality parameters in storm water collected from urban and industrial areas of the island. In summarizing their findings, Zolan (1981) called for further research to determine the extent of surface water degradation by stormwater borne contaminants. Their point is well taken in view of the considerable expansion that has taken place on the island in the last 20 or so years since their study, in addition to that planned for the immediate future. Such needs are of paramount importance if the quality of Guam's surface and ground water resources is to be protected.

In the following study we examined the water quality characteristics of urban runoff from seven major stormwater retention sites and one storm drain in northern Guam. We focused our attention specifically on nutrients (N and P) and heavy metals (Ag, Cd, Cr, Cu, Fe, Mn, Ni, Pb and Zn), in view of current land use practices and the availability of likely sources of these contaminants (commercial landscaped areas, highways, auto-shops, etc.). They were also selected for study because of their high potential for ecological disturbances as outlined above. The major ions Ca, Mg and Na were also included in the investigation primarily to assist with the categorization of runoff sources (rainwater, groundwater, saltwater).

The primary objectives of the study were as follows:

1) To identify and delineate storm water discharge and collection points in northern Guam.
2) To digitize all site locational data into WERI's ARC/INFO Geographic Information System (GIS) and make data available in hard copy format as maps.
3) To collect and analyze runoff samples, from representative stormwater retention sites (identified in objective 1 above), for a range of key chemical contaminants
4) To develop a monitoring system capable of:
    a) collecting synchronous rainfall data, thus permitting the operator to distinguish between samples collected during storm and nonstorm events
    b) sequential and/or composite sampling at predetermined intervals during runoff events
    c) being remotely interrogated to determine rainfall, runoff and sampling status
5) To identify which contaminants and sensitive areas of the environment (if any) should be monitored on a regular basis by Guam Environmental Protection Agency (GEPA)
6) To recommend a simple, reliable and easy to use system for storing and retrieving water quality data taken during the study, and later by GEPA personnel.

MATERIALS AND METHODS

PROCEDURAL OUTLINE

This project was essentially divided into three discrete phases of research. Phase I involved locating, recording and digitizing storm water discharge and collection points in Northern Guam. This work was accomplished using existing governmental agency data and staff expertise, existing topographic and geologic maps, aerial photo reconnaissance techniques and field visitations. Initially, this part of the project involved close liaison with the Department of Public Works (constructs and maintains various storm water collection and disposal systems) and GEPA (charged with monitoring various sources of pollution on the island). Agency files, plans and specifications were reviewed and key personnel interviewed to determine the location of all storm water discharge points under the purview of each agency.

Phase II and III focused exclusively on the water quality characteristics of runoff samples. The contaminants of interest were the nutrients: nitrogen (N) and phosphorus (P); the major ions: calcium (Ca), magnesium (Mg), and sodium (Na); and the potentially toxic heavy metals: silver (Ag), cadmium (Cd), chromium, (Cr) copper (Cu), iron (Fe), manganese (Mn), nickel (Ni), lead (Pb) and zinc (Zn). Phase II centered around the gathering of baseline data from representative retention sites identified during Phase 1 of the project. Seven sites were selected in all and are listed below in Table 1. Their precise locations are illustrated in Fig. 1.

Table 1: Ponding Basin and Sink-Hole Sites Monitored During Phase II

Ponding Basin/Sink-Hole	Municipality
Naval Communications Field	Barrigada
Micronesia Mall	Dededo
Calamendo Lane	Dededo
Harmon Sink (north)	Harmon
Harmon Sink (south)	Harmon
Fujita Hotel	Tamuning
Air Force Site #37	Yigo
Mariana Terrace	Yigo

Most of the retention sites were visited on two or more occasions and the water quality data, gathered from them, was primarily intended to provide a measure of the spatial and temporal variability likely to be encountered on the island.

Phase III of the study looked closely at time-dependent changes in the chemical composition of urban runoff from a single storm drain servicing the Palace Hotel in the Jonestown area of Tamuning (see Fig. 2). Runoff samples from this large commercial complex were continually collected from the storm drain outlet over a three-month period. The outlet was located underneath the police koban and discharged directly into a small ponding basin. The site was primarily chosen because it afforded the necessary security requirements to protect the automated

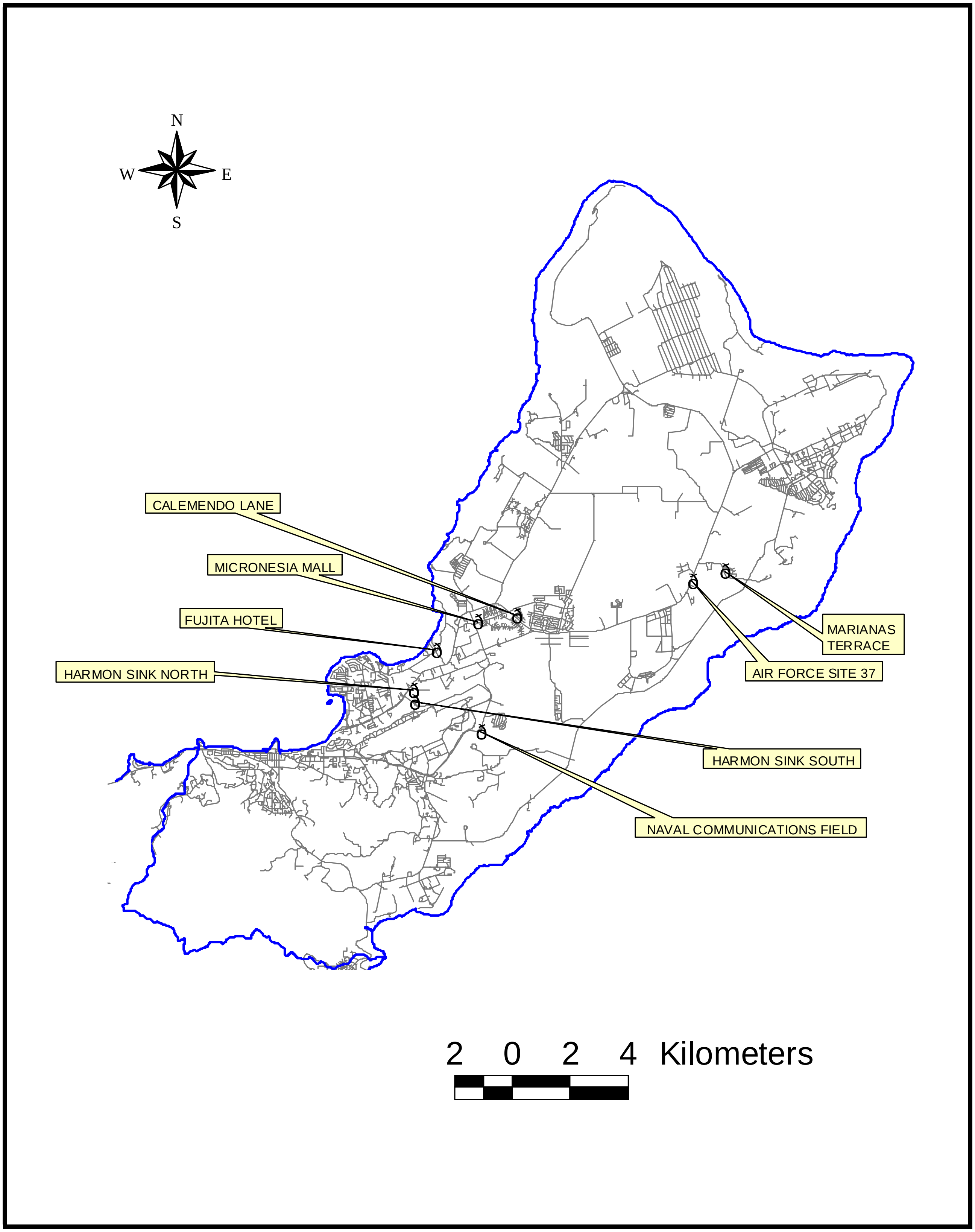

Figure 1. Location of ponding basin and sink-hole sites monitored during Phase II

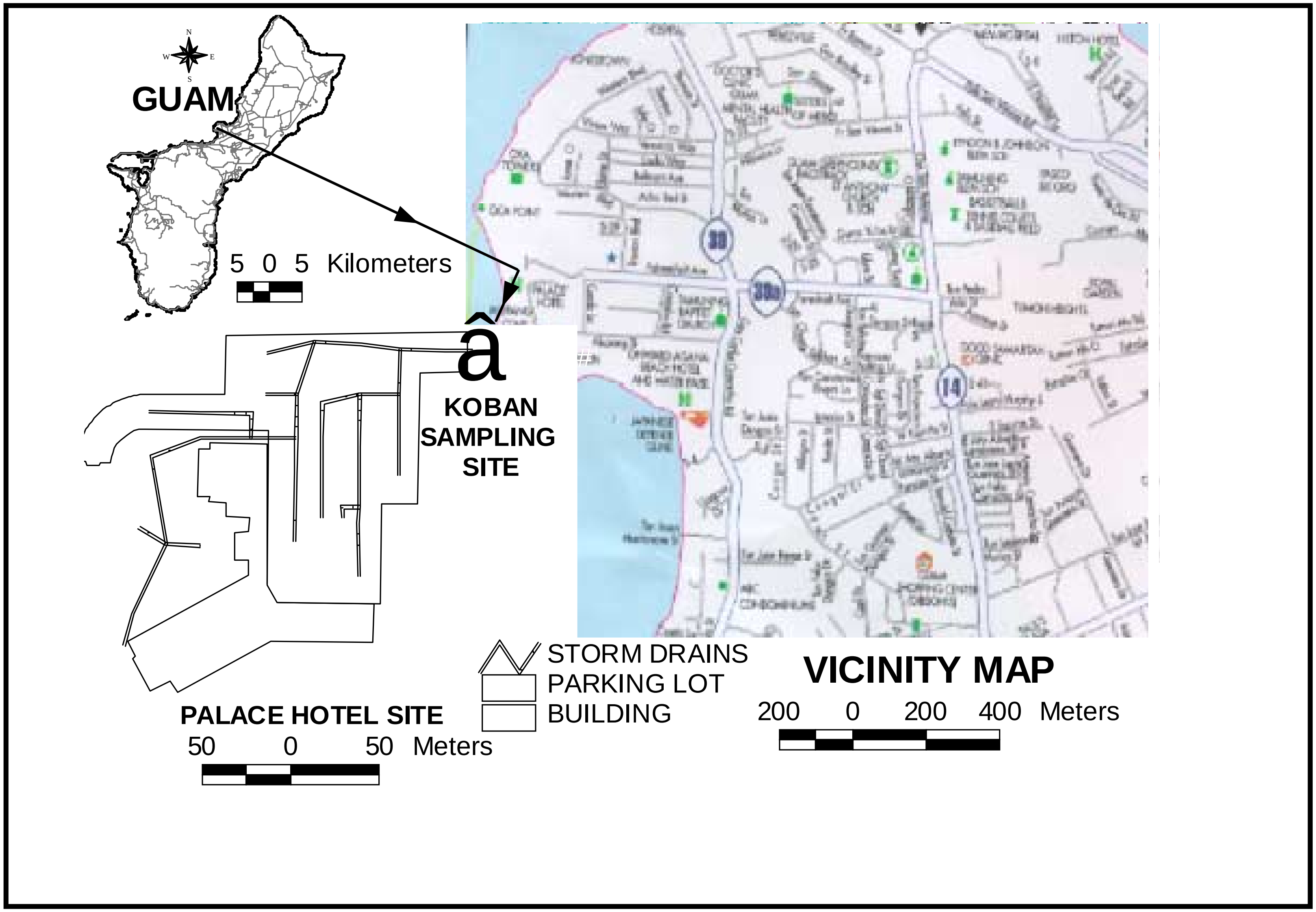

Figure 2. Location of Palace Hotel and storm drain outlet monitored during Phase III

sampling equipment from vandalism and theft. Specific sampling and analytical details associated with each segment of the study are outlined below.

SAMPLE COLLECTION

Phase II water samples were taken between July 17 and October 6, 1995. They were collected in 2.5 liter glass bottles previously used for storing concentrated acids. Field personnel were instructed to hold the sample bottles just below the water surface and walk slowly forwards while filling them. This procedure minimized the collection of surface particulates and suspended sediments stirred up during the collection process. All sample bottles were labeled, and stored on ice in the field. They were processed for analysis usually within six hours of collection. The majority of sites were visited on two or more occasions

Phase III water samples were taken between June 6 and September 8, 1995 (typically, the wettest months of the year). They were collected using an ISCO automatic water sampler (model 3700) equipped with a removable carousel of 24 low-density polyethylene bottles and Teflon sampling hose. All surfaces in contact with the sample were acid leached (10% HCl) and vigorously rinsed with deionized water prior to use.

The major components of the autosampler system are shown if Fig. 3. The control function for sampling water and measuring rainfall was driven by an ISCO 2100 flow logger. Rainfall was recorded in increments of 0.01 inch (0.25 mm), over a minimum time interval of 1 minute, using an ISCO 3333 tipping bucket rain gauge linked to the flow logger. Water sampling was triggered by using an ISCO level switch set to activate when the flow of water behind an artificial weir in the discharge channel reached a depth 3 cm. The unit's programmable sampling capability was set to the sampling interval schedule shown below in Table 2. This sampling regime was adopted to highlight and maximize differences in water quality between the initial first flush and that obtained after progressively longer periods of runoff. The sampling cycle was interrupted if the runoff depth dropped below 3 cm, and resumed at the same point when sufficient flows returned.

Table 2: Programmed Sampling Intervals Adopted During Phase III

Sample Bottle Number	Time Interval Since Last Sample (minutes)
1	0
2	5
3	5
4	5
5	10
6-24	15

The flow logger was connected by modem and cellular telephone link to WERI, and was interrogated each morning to determine the status of the sampler. If new samples were taken, a technician was dispatched to retrieve the bottles for analysis.

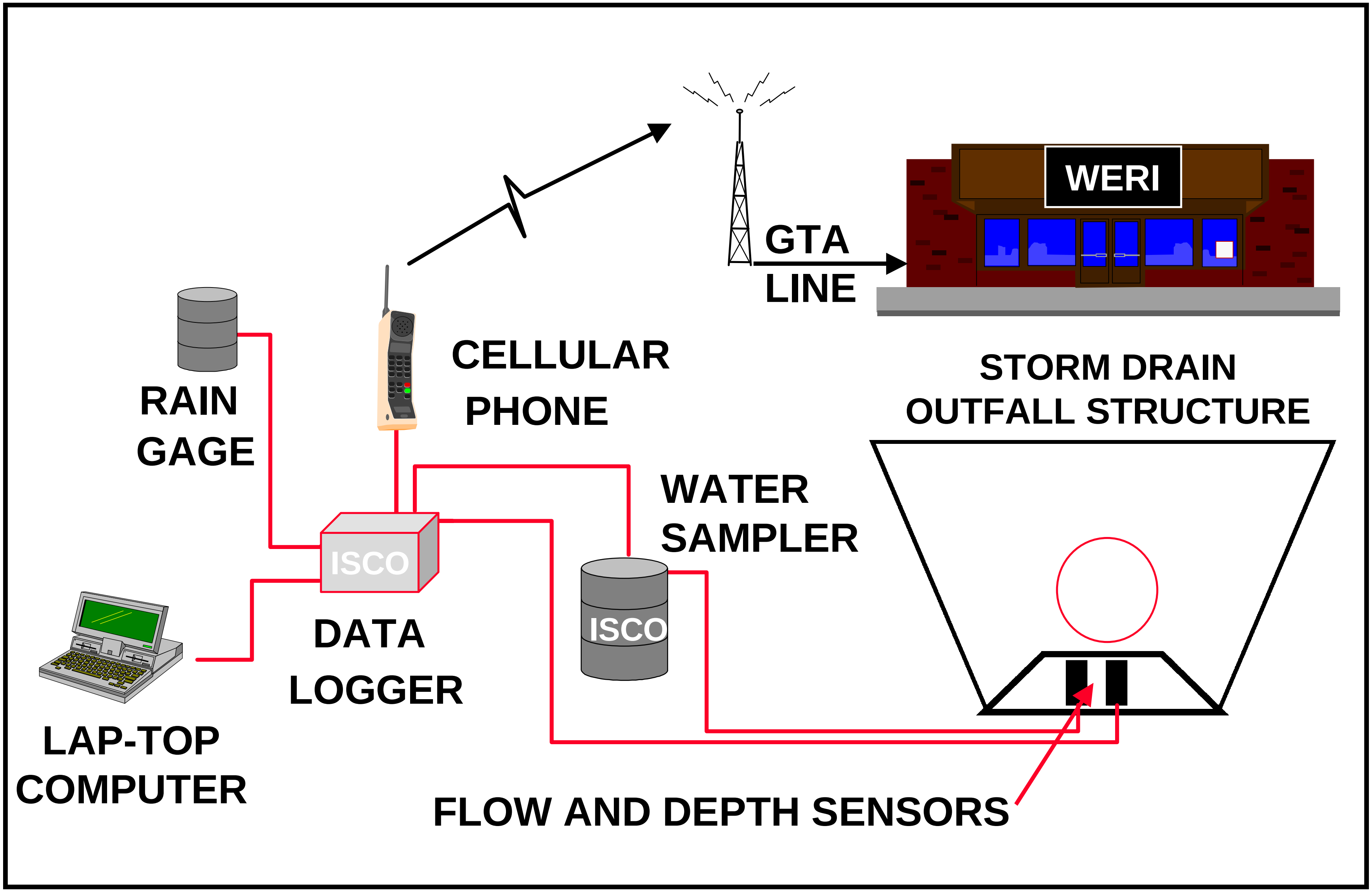

Figure 3. Components of the automated sampling system

CHEMICAL ANALYSIS

The chemical analyses of water samples were undertaken at the WERI Water Quality Laboratory, in accordance with standard QA/QC protocols. The analytical details are briefly outlined below.

Nitrate and Phosphate Determinations:

Nitrates (NO_3^-) and phosphates (PO_4^{3-}) were determined on unfiltered water samples, in accordance with the procedures described in the American Public Health Association's *Standard Methods* manual (APHA 1992). Thus, NO_3 was determined as nitrate-nitrogen (NO_3-N) on 2.5 ml of sample using the cadmium reduction, colorimetric method (*Method 4500-*NO_3^- *E.*) as modified by Jones (1984), while PO_4 was determined as orthophosphate-phosphorus (o-PO_4-P) on 5 ml of sample by the ascorbic acid colorimetric method (*Method 4500-P E.*). Both tests were run in duplicate and completed within 6 hours of samples being delivered to the laboratory. Initially, the nutrient analysis was performed on both filtered (0.45 µm) and unfiltered samples to determine contributions associated with suspended particulates. However, this practice was discontinued early on, following the discovery that differences between treatments were negligible.

It is pertinent to note that NO_3-N values reported during the present study reflect contributions from both nitrite and nitrate forms of nitrogen in all samples analyzed. However, in oxidized environments, the latter form is the more prevalent, and usually accounts for well over 90% of the sum total of both.

Elemental Analysis:

Each sample was separated into filtered (0.45 µm) and unfiltered portions to determine the relative importance of the dissolved and particulate contributions for each element. Both filtered and unfiltered samples were preserved with 0.1% analytical grade nitric acid, and stored in 60 ml, low-density, polyethylene bottles at room temperature (28 ^{o}C) prior to analysis.

Na was determined by flame emission spectroscopy while the other major elements, Ca and Mg, were analyzed by conventional flame atomic absorption spectroscopy (AAS), in the presence of 5000 mg/l lanthanum used as an ionization suppressant.

The trace elements were determined using conventional flame and furnace AAS (depending upon levels present) employing a hydrogen continuum lamp to correct for nonatomic absorption effects. All positive absorbances were calibrated against appropriate standard dilutions after corrections for field and reagent blanks.

RESULTS AND DISCUSSION

PHASE 1: LOCATION AND DELINEATION OF STORMWATER RETENTION SITES

The location data of all of the ponding basins and stormwater collection points were digitized into WERI's ARC/INFO GIS. The locations of all PUAG wells and the boundary of the designated Northern Guam groundwater protection zones have also been digitized for reference purposes. Figure 4 shows the locations of the man made ponding basins. Figure 5 shows the locations of various sink holes which serve as natural stormwater collection points. Both figures also show the locations of the boundaries of the groundwater protection zones. The total set of digitized maps make it easy to investigate the spatial relationships between the stormwater discharge points and features such as water wells, sink-holes, ponding basins and other aquifer recharge areas, as well as high use recreational areas. These maps are probably the most comprehensive list of natural and artificial stormwater collection points currently available in Guam.

PHASE II: PONDING BASIN WATER QUALITY BASELINE DATA

Levels of the 14 chemical components monitored in water from the seven ponding basins during the present study are shown in Tables 3 and 4 for unfiltered and filtered samples respectively. Previously recorded levels of some of these contaminants in Guam's urban runoff have been extracted from the earlier work of Zolan *et al.* (1978a) and Zolan (1981) and are listed in Table 5 for comparative purposes. In addition, a compilation of water quality data characterizing urban runoff in several major cities of the U.S. mainland and Canada is given in Table 6 together with data summaries derived from the Nationwide Urban Runoff Program (NURP)[1]. Finally, contaminant levels found in natural fresh and marine waters in Guam are presented in Table 7 together with levels found in the effluent streams of two of the island's wastewater treatment plants. Major findings derived from the comparative analysis of these data are highlighted below. Unless indicated otherwise, all surface water quality standards referred to relate to current U.S. EPA criteria for the protection of aquatic life against deleterious chronic effects.

Nutrients*:*

The nutrients N and P are natural components of the environment and are essential for plant growth. In uncontaminated surface waters, levels of both nutrients are low and frequently limiting. Both are important contaminants of urban runoff and can cause nuisance growth of algae and other aquatic plants when critical thresholds are exceeded. Levels of both nutrients encountered during the present study are discussed in relation to concentrations found previously in Guam and elsewhere in the world.

Nitrate (NO_3):

NO_3 in storm water is derived from a variety of natural sources including mineral deposits, the

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[1] The Nationwide Urban Runoff Program (NURP) study was undertaken by the U.S. EPA between 1978 and 1983. Its purpose was to characterize urban runoff from residential, commercial and industrial areas and is the largest study of storm water undertaken to date. Storm water samples from 81 residential and commercial properties in 22 urban/suburban areas nationwide were analyzed for eight conventional pollutants and three metals (Federal Register 1998)

decomposition of organic matter, and bacterial fixation of atmospheric nitrogen. They are

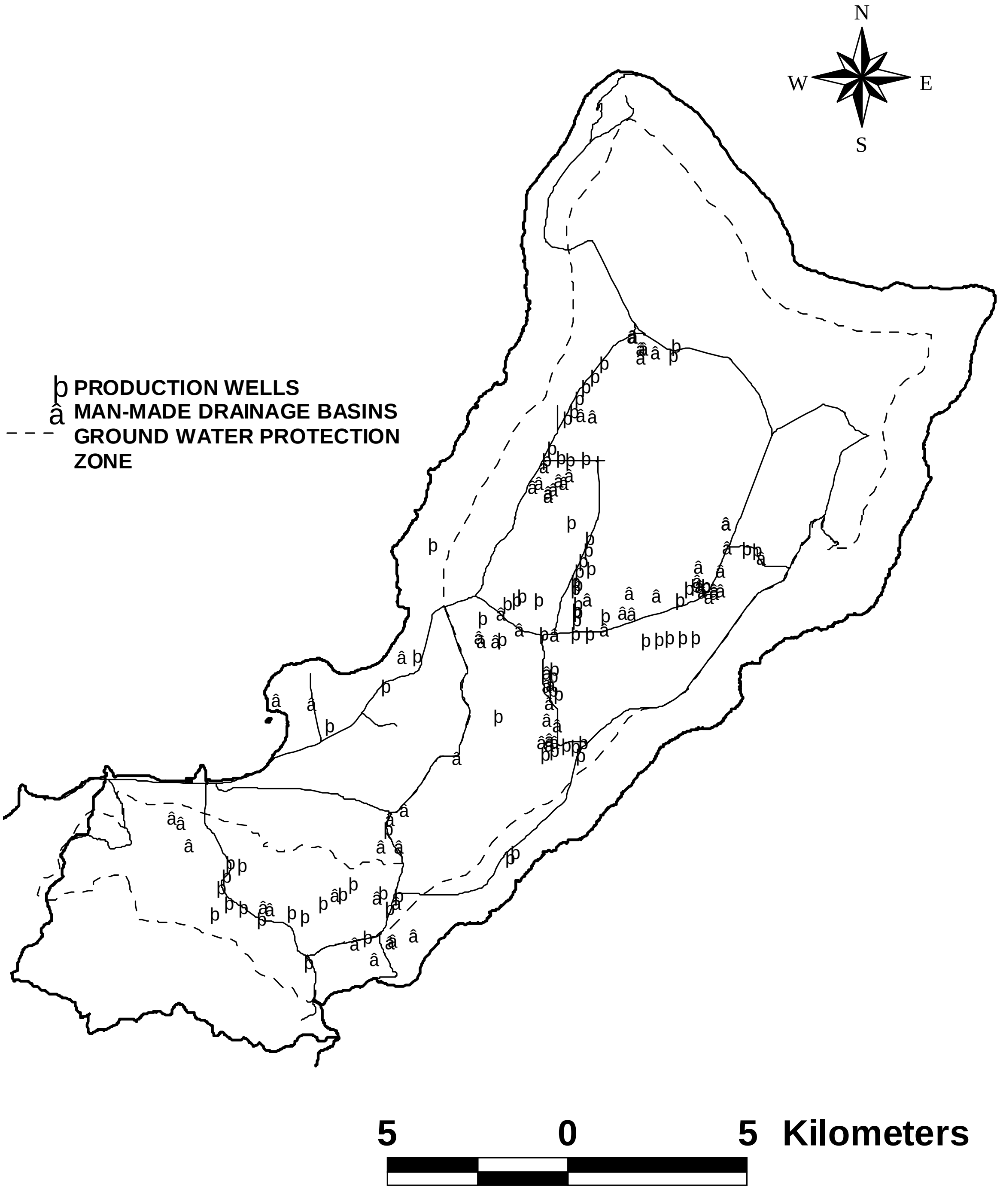


Figure 4. Stormwater ponding basins, wells and groundwater protection zone in northern Guam.

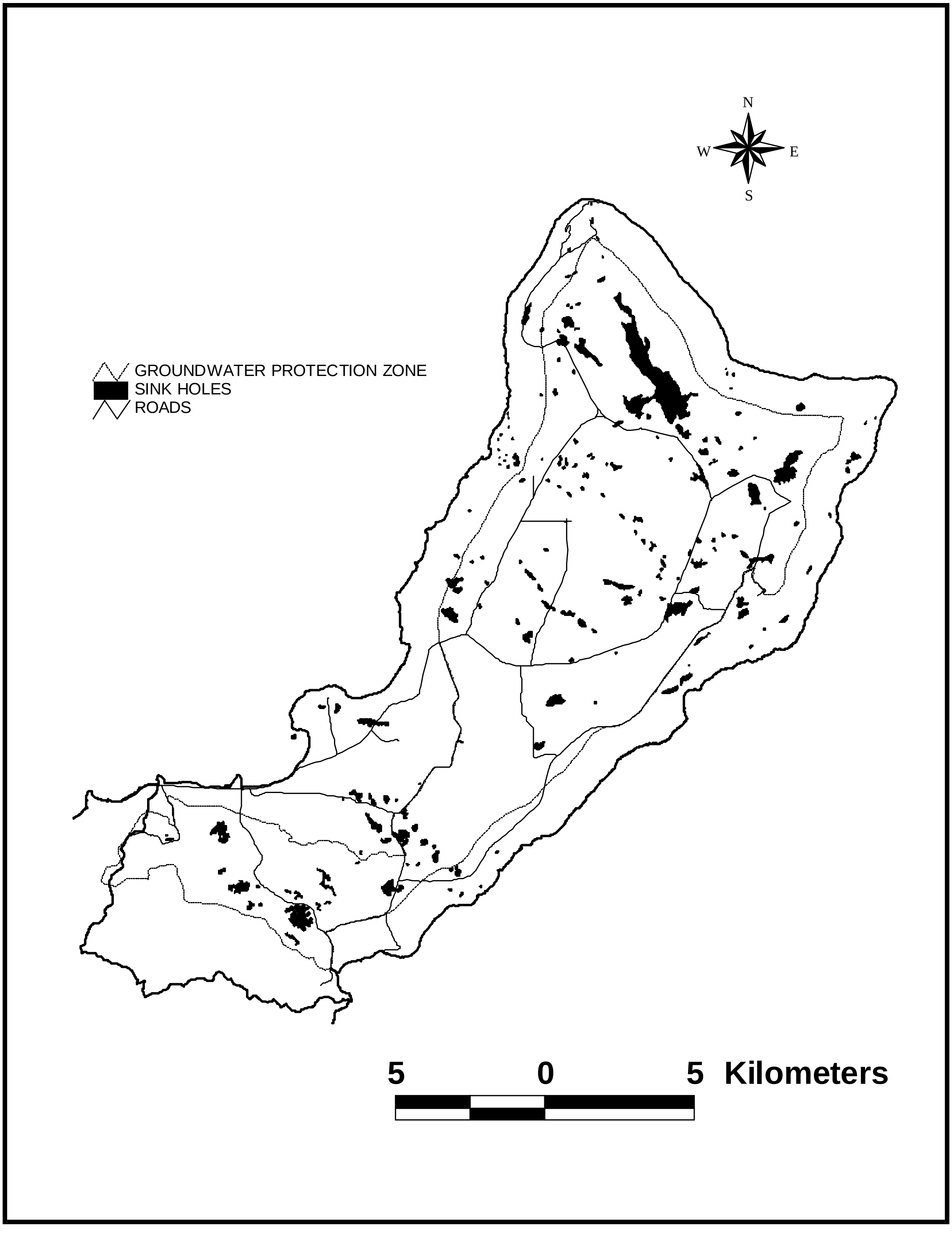


Figure 5. Sink-holes in northern Guam

Table 3

Nutrients, Major Ions and Heavy Metals in Unfiltered Urban Runoff from Various Stormwater Retention Sites in Guam

SITE	DATE	NO_3-N (mg/l)	o-PO_4-P (mg/l)	Ca (mg/l)	Mg (mg/l)	Na (mg/l)	Ag (ug/l)	Cd (ug/l)	Cr (ug/l)	Cu (ug/l)	Fe (ug/l)	Mn (ug/l)	Ni (ug/l)	Pb (ug/l)	Zn (ug/l)
Naval Commun. Fld., Barrigada,	25-Jul-95	0.01	0.16	18.1	1.04	1.83	<0.2	<0.5	<4	<7	<30	<10	<5.0	<3	2
Naval Commun. Fld., Barrigada,	28-Jul-95	0.60	0.10	384	5.54	31.9	<0.2	<0.5	<4	<7	<30	<10	<5.0	<3	4
Naval Commun. Fld., Barrigada,	16-Aug-95	2.13	0.12	26.4	0.75	11.2	<0.2	<0.5	<4	<7	73	<10	<5.0	<3	2
Calamendo Lane, Dededo	2-Aug-95	0.02	0.05	16.7	0.26	1.20	<0.2	<0.5	<4	<7	<30	<10	<5.0	<3	2
Micronesia Mall, Dededo	2-Aug-95	0.03	0.01	7.5	0.11	0.94	<0.2	<0.5	<4	<7	<30	<10	<5.0	4.2	32
Micronesia Mall, Dededo	4-Aug-95	0.01	0.02	6.01	0.11	0.08	<0.2	<0.5	<4	<7	<30	<10	<5.0	<3	7
Harmon Sink (N): site a, Harmon	6-Oct-95	0.41	0.26	92.7	0.97	1.73	<0.2	<0.5	6.7	<7	55	120	<5.0	<3	14
Harmon Sink (N): site b, Harmon	6-Oct-95	0.22	0.07	33.8	0.42	0.65	<0.2	<0.5	<4	<7	55	<10	<5.0	4.7	45
Harmon Sink (N): site c (rep. 1)	6-Oct-95	0.22	0.02	10.0	0.08	0.21	<0.2	<0.5	<4	<7	<30	<10	<5.0	<3	2
Harmon Sink (N): site c (rep. 2)	6-Oct-95	0.20	0.02	11.3	0.10	0.21	<0.2	<0.5	<4	<7	<30	<10	<5.0	<3	10
Harmon Sink (N): site d (rep. 1)	6-Oct-95	0.56	0.21	80.3	1.14	3.04	<0.2	<0.5	8.8	<7	291	70	<5.0	<3	10
Harmon Sink (N): site d (rep. 2)	6-Oct-95	0.51	0.22	84.8	1.22	3.36	<0.2	<0.5	<4	<7	236	80	<5.0	<3	10
Harmon Sink (S): site a, Harmon	28-Jul-95	0.01	1.92	377	5.23	50.6	<0.2	4.13	9.9	114	260	40	<5.0	1782	75
Harmon Sink (S): site b, Harmon	4-Aug-95	0.01	0.05	20.8	0.72	5.31	<0.2	<0.5	5.6	<7	<30	<10	<5.0	<3	32
Harmon Sink (S): site a, Harmon	8-Aug-95	0.01	0.20	21.6	1.36	8.63	<0.2	0.74	<4	<7	<30	<11	<5.0	<3	10
Harmon Sink (S): site b, Harmon	8-Aug-95	0.01	0.45	21.8	0.96	29.9	<0.2	<0.5	<4	30	<30	< 10	<5.0	<3	40
Fujita Hotel, Tumon	17-Jul-95	0.01	0.02	32.6	0.68	90.0	<0.2	<0.5	5	<7	125	<10	<5.0	<3	38
Fujita Hotel, Tumon	14-Aug-95	0.14	0.02	22.7	0.71	12.2	<0.2	<0.5	<4	<7	<30	<10	<5.0	5.3	2
A.A.F.B. Site #37, Yigo	4-Aug-95	0.02	0.02	14.3	0.81	0.94	<0.2	<0.5	<4	<7	<30	<10	<5.0	<3	2
Mariana Terrace, Yigo	17-Jul-95	1.01	0.004	172	4.07	431	<0.2	<0.5	<4	<7	350	140	<5.0	<3	38
Mariana Terrace, Yigo	8-Aug-95	3.67	0.003	126	4.59	5.91	<0.2	<0.5	<4	<7	491	126	<5.0	<3	2
	Geometric Mean	**0.08**	**0.05**	**35.09**	**0.75**	**4.04**	**<0.2**	**<0.6**	**<4.56**	**<8.57**	**<64.4**	**<18.6**	**<5**	**<4.34**	**8.96**

Table 4

Nutrients, Major Ions and Heavy Metals in Filtered Urban Runoff from Various Stormwater Retention Sites in Guam

SITE	DATE	NO_3-N (mg/l)	o-PO_4-P (mg/l)	Ca (mg/l)	Mg (mg/l)	Na (mg/l)	Ag (ug/l)	Cd (ug/l)	Cr (ug/l)	Cu (ug/l)	Fe (ug/l)	Mn (ug/l)	Ni (ug/l)	Pb (ug/l)	Zn (ug/l)
Naval Commun. Fld., Barrigada,	25-Jul-95	n.d.	n.d.	17.9	0.83	1.93	<0.2	<0.5	<4	<7	<30	<10	<5	<3	2
Naval Commun. Fld., Barrigada,	28-Jul-95	n.d.	n.d.	129	5.63	34.4	<0.2	<0.5	<4	<7	<30	<10	<5	<3	2
Naval Commun. Fld., Barrigada,	16-Aug-95	n.d.	n.d.	26.9	0.67	12.2	<0.2	<0.5	<4	<7	55	<10	<5	<3	2
Calamendo Lane, Dededo	2-Aug-95	n.d.	n.d.	16.7	0.28	1.12	<0.2	<0.5	<4	<7	<30	<10	<5	<3	2
Micronesia Mall, Dededo	2-Aug-95	n.d.	n.d.	7.50	0.15	1.63	<0.2	<0.5	<4	<7	<30	<10	<5	<3	2
Micronesia Mall, Dededo	4-Aug-95	n.d.	n.d.	6.01	0.13	0.34	<0.2	<0.5	<4	<7	<30	<10	<5	<3	2
Harmon Sink (N): site a, Harmon	6-Oct-95	n.d.	n.d.	25.7	0.54	1.73	<0.2	<0.5	<4	<7	<30	<10	<5	<3	2
Harmon Sink (N): site b, Harmon	6-Oct-95	n.d.	n.d.	18.4	0.32	0.65	<0.2	<0.5	<4	<7	<30	<10	<5	<3	14
Harmon Sink (N): site c (rep. 1)	6-Oct-95	n.d.	n.d.	9.33	0.10	0.21	<0.2	<0.5	<4	<7	<30	<10	<5	<3	2
Harmon Sink (N): site c (rep. 2)	6-Oct-95	n.d.	n.d.	10.7	0.13	0.21	<0.2	<0.5	<4	<7	<30	<10	<5	<3	2
Harmon Sink (N): site d (rep. 1)	6-Oct-95	n.d.	n.d.	33.8	0.83	3.15	<0.2	<0.5	<4	<7	55	<10	<5	<3	2
Harmon Sink (N): site d (rep. 2)	6-Oct-95	n.d.	n.d.	35.2	0.85	3.04	<0.2	<0.5	<4	<7	55	<10	<5	<3	2
Harmon Sink (S): site a, Harmon	28-Jul-95	n.d.	n.d.	100	5.53	50.6	<0.2	0.6	<4	43	<30	30	<5	33.6	50
Harmon Sink (S): site b, Harmon	4-Aug-95	n.d.	n.d.	20.8	0.72	4.82	<0.2	<0.5	<4	<7	<30	<10	<5	<3	21
Harmon Sink (S): site a, Harmon	8-Aug-95	n.d.	n.d.	19.6	1.22	8.14	<0.2	<0.5	<4	<7	<30	<10	<5	<3	2
Harmon Sink (S): site b, Harmon	8-Aug-95	n.d.	n.d.	20.8	0.75	30.2	<0.2	<0.5	<4	30	<30	<10	<5	<3	30
Fujita Hotel, Tumon	17-Jul-95	n.d.	n.d.	32.6	0.68	90	<0.2	<0.5	<4	<7	<30	<10	<5	<3	14
Fujita Hotel, Tumon	14-Aug-95	n.d.	n.d.	22.2	0.62	16.5	<0.2	<0.5	<4	<7	<30	<10	<5	<3	2
A.A.F.B. Site #37, Yigo	4-Aug-95	n.d.	n.d.	14.3	0.09	0.61	<0.2	<0.5	<4	<7	<30	<10	<5	<3	2
Mariana Terrace, Yigo	17-Jul-95	n.d.	n.d.	174.1	4.19	437	<0.2	<0.5	<4	<7	<30	50	<5	<3	24
Mariana Terrace, Yigo	8-Aug-95	n.d.	n.d.	125	4.53	5.92	<0.2	<0.5	<4	<7	<30	126	<5	<3	2
	Geometric Mean	**nc**	**nc**	**25.96**	**0.63**	**4.41**	**<0.2**	**<0.5**	**<4**	**<8.18**	**<32.7**	**<12.8**	**<5**	**<3.37**	**4.02**

n.d. = not determined; nc = geometric means not calculable;

Table 5

Previously Recorded Levels of Nutrients, Major Cations and Heavy Metals in Urban Runoff from Guam

(Compilation of data from Zolan *et al.* 1978a and Zolan 1981)

LOCATION	NO$_3$-N (mg/l)	o-PO$_4$-P (mg/l)	Ca (mg/l)	Mg (mg/l)	Na (mg/l)	Ag (µg/l)	Cd (µg/l)	Cr (µg/l)	Cu (µg/l)	Fe (µg/l)	Mn (µg/l)	Ni (µg/l)	Pb (µg/l)	Zn (µg/l)
FROM PONDING BASINS:														
Barrigada Village (#B1e)	<0.001-0.60	<0.00-0.08	26.8-32.4	0.93-1.22	-	-	-	-	-	-	-	-	-	-
Barrigada Village (#B1c)	<0.001-0.34	0.008-0.32	16.8-33.6	<0.2-1.81	-	-	-	-	-	-	-	-	-	-
Barrigada Heights (#B2d)	<0.001-0.33	0.003-0.19	12.8-30.4	0.49-1.47	-	<0.1-0.1	0.2-0.4	1-2	2.2-7.2	12-41	2.9-27	1.4-4.5	1-9	1.6-6
						(0.2)	(2.7-38)	(10)	(7-14)	(775-912)	(24)	(3.6)	(40)	(<0.4-19)
Barrigada Heights (#B2w)	<0.001-0.32	<0.001-0.14	11.2-17.6	<0.2	-	-	-	-	-	-	-	-	-	-
Barrigada Heights (#B3)	0.003-0.55	<0.001-0.27	14.4	0.24	-	-	-	-	-	-	-	-	-	-
Latte Heights (#L2)	<0.001-0.52	0.001-0.19	13.6	0.73	-	<0.1-0.6	0.1-8.4	2-4	4.4-8.9	10-50	3.6-4.6	4.3-30	1-5	4.9-53
						(2.5)	(7.1-125)	(14)	(8.1-60)	(120-775)	(<0.1)	(55)	(30-40)	(2.7-9.5)
Perez Acres	<0.001-0.50	<0.001-0.07	10.8-11.2	0.49-1.47	-	<0.1-0.1	<0.1-0.8	1-2	2.4-4.5	9-108	3.8-26	1.4-8.8	<1-2	0.4-11
						(0.6)	(0.3-1.4)	(0.8)	(0.3-8)	(200-584)	(36)	(<0.3)	(11-13)	(<1-2.3)
Mariana Terrace	<0.001-2.0	<0.001-0.37	102	<0.2	-	-	-	-	-	-	-	-	-	-
FROM STORM DRAINS:														
Airport Road	<0.001-0.35	0.02-2.06	17.2-32.4	0.73-2.19	-	0.1-0.4	0.2-2.2	4-8	8.4-95	8-220	2.6-23	10-69	<1-13	2.6-19
						(0.2)	(9.1-80)	(27)	(3.2-22)	(168-245)	(12)	(9.9)	(20-32)	(0.4-2.3)
East Agana Bay	0.01-7.40	0.003-0.47	23.2-88.0	4.64-24.4	-	-	-	-	-	-	-	-	-	-
Naval Air Station	<0.50-2.51	<0.001-0.03	116-124	26.9-28.0	-	-	-	-	-	-	-	-	-	-
West Agana Bay	0.01-4.56	<0.001-0.61	30.8-47.2	4.15-4.88	-	-	-	-	-	-	-	-	-	-
Camp Watkins Road	0.03-0.15	0.06-0.14	42.0-110	2.40-13.4	-	<0.1-0.5	0.3-5.6	12-27	11-74	72-250	41-52	5.2-32	7-52	7.8-26
						(0.5)	(4.8-28)	(5)	(59-274)	(1380-1812)	(122)	(11)	(160-330)	(6.2-122)

The heavy metal data are for dissolved (filtered through a 0.45 µm membrane filter) and suspended (values in parentheses) fractions. All other data represents total recovery from unfiltered samples. Dashes indicate no data

Table 6

Previously Recorded Levels of Nutrients, Major Ions and Heavy Metals in Urban Runoff from Elsewhere in the World

LOCATION	NO$_3$-N (mg/l)	o-PO$_4$-P (mg/l)	Ca (mg/l)	Mg (mg/l)	Na (mg/l)	Ag (µg/l)	Cd (µg/l)	Cr (µg/l)	Cu (µg/l)	Fe (µg/l)	Mn (µg/l)	Ni (µg/l)	Pb (µg/l)	Zn (µg/l)
RESIDENTIAL:														
Occoquan Watershed Virginia[a] [F]	-	-	-	-	-	0	-	46	42	1122	302	25	15	70
Des Moines, Iowa[b] [U]	-	0.06-1.4	-	-	-	-	-	-	-	-	-	-	-	-
Santa Clara County, California[c] [U]	-	0.18-0.34[1]	-	-	-	-	-	-	-	-	-	-	400	-
Tulsa, Oklahoma[d] [U]	-	0.22-0.62	-	-	-	-	-	-	-	-	-	-	-	-
COMMERCIAL/INDUSTRIAL:														
Occoquan Watershed Virginia[a] [F]	-	-	-	-	-	14	-	20	44	168	395	34	84	824
Des Moines, Iowa[b] [U]	-	0.19	-	-	-	-	-	-	-	-	-	-	-	-
Santa Clara County, California[c] [U]	-	0.14-0.29[1]	-	-	-	-	-	-	-	-	-	-	650-980	-
Tulsa, Oklahoma[d] [U]	-	0.18-1.4	-	-	-	-	-	-	-	-	-	-	-	-
North Carolina[e] [U]	0.31-2.72[3]	0.07-1.23[2]	-	-	-	0-4	0-41	38-865	39-2223	-	-	0-333	39-3223	191-10083
Sarina, Ontario[f] [F	-	0.299[1]	-	-	-	-	6.8	-	57.1	-	-	8.5	233	307
Saulte Ste. Maria, Ontario[f] [F]	-	0.309[1]	-	-	-	-	6.0	-	69.6	-	-	31.3	97	274
Winsor, Ontario[f] [F]	-	0.231[1]	-	-	-	-	5.4	-	57.1	-	-	27.8	154	234
RESIDENT./COMMERC./INDUST.:														
Seattle, Washington[g] [F]	0.76[4]	0.28[2]	-	-	-	-	-	-	-	-	-	-	-	-
Cincinnati, Ohio[h] [F]	2.75[5]	0.8[2]	-	-	-	-	-	-	-	-	-	-	-	-
Data Composite[i] [U]	0.01-12.0	0.038-3.5[2]	0.04-2114	0.02-304	0.18-660	0.2-14	0.05-13730	1-2300	0.06-1410	80-440000	7-3800	1-49000	0.57-26000	0.7-22000
MEAN RUNOFF CONCS.[j]:														
Residential [U]	1.8[3]	0.62[1]	-	-	-	-	-	-	56	-	-	-	293	254
Commercial [U]	0.8[3]	2.29[1]	-	-	-	-	-	-	50	-	-	-	203	418
Industrial [U]	0.93[3]	0.42[1]	-	-	-	-	-	-	32	-	-	-	115	1063

a = Randall *et al.* 1978; b = Davis and Borchardt 1974; c = Lager *et al.* 1977; d = AVCO 1970; e = Line *et al.* 1996; f = Area-wide mean values from Marsalek 1991; g = Municipality of Metropolitan Seattle, 1971, h = Federal Water Pollution Control Administration 1969; i = Makepeace *et al.* 1995; j = Based on the U.S. EPA Nationwide Urban Runoff Program (Whalen and Cullum 1989). 1 = as total phosphorus; 2 = as total dissolved phosphorus;

3 = as $NO_2 + NO_3$; 4 = as $NH_3 + NO_3$; 5 = as total nitrogen. [F] = filtered samples; [U] = unfiltered samples. Dashes indicate no data

Table 7

Historic Water Quality Data for Nutrients, Major Ions and Heavy Metals in Unfiltered Natural Waters and Wastewaters from Guam

LOCATION	NO_3-N (mg/l)	o-PO_4-P (mg/l)	Ca (mg/l)	Mg (mg/l)	Na (mg/l)	Ag (µg/l)	Cd (µg/l)	Cr (µg/l)	Cu (µg/l)	Fe (µg/l)	Mn (µg/l)	Ni (µg/l)	Pb (µg/l)	Zn (µg/l)
SPRING WATERS:														
Agana Spring[a]	-	-	101	6.6	26	-	-	-	-	20	-	-	-	-
Santa Rita Spring[a]	1.59	-	64.1	3.42	-	-	-	-	-	3	7	-	-	-
Tarague Spring[a]	1.53	0.1[1]	74.0	14.0	92	-	-	-	-	-	14	-	-	-
Mataquac Spring[a]	-	0.6[1]	36	5	-	-	-	-	-	50	-	-	-	-
Janum Spring[a]	3.5	0.01[1]	4.2	8.7	7.5	-	-	-	-	-	-	-	-	-
Groundwater: well D-12[b]	2.28	-	-	-	-	-	-	-	-	-	-	-	-	-
Groundwater: well A-13[b]	2.24	-	-	-	-	-	-	-	-	-	-	-	-	-
Groundwater: Island-wide[c]	0.14-4.9 (1.83)	-	7.28-117 (50.2)	<0.01-41.7 (6.93)	-	-	<0.5-1.0 -	1-27 (10.5)	-	-	-	<5	-	-
RIVERS:														
Fena Reservoir[a]	0.01	0.3[1]	24	4.8	9.6	-	-	20	20	830	60	-	20	50
Almagosa River[a]	0.01	0.013[1]	40	5.8	14	-	-	20	20	200	20	-	20	100
Imong River[a]	0.01	0.01[1]	34	5.3	15	-	-	20	20	150	20	-	20	400
Maulap River[a]	0.20	0.014[1]	43	7.7	20.5	-	-	2	2	150	20	-	20	200
Lonfit River[d]	0.03-0.6[e]	<0.001-0.01[e]	-	-	-	<0.1	<0.1	<0.3-3.3	<0.1-4.6	1-1858	3.8-130	<0.6	<0.3-4.8	<0.1-3.7
Sigua River[d]	0.02-1.8[e]	<0.001-0.01[e]	-	-	-	<0.1	<0.1	<0.3-0.8	<0.3-1.6	22.7-222	29.7-88.5	<0.6	<0.2-0.3	<0.1-0.6
Pago River[d]	0.02-1.6[e]	<0.001-0.01[e]	-	-	-	<0.1	<0.1	<0.3-0.6	<0.3-1.3	16.4-444	32.2-82.9	<0.6	0.2-1.1	0.2-1.1
Ugam River[d]	<0.01-0.7[e]	<0.001-0.07[e]	8.52[c]	4.46[c]	-	<0.1	<0.1	<0.3	3.29	444	46.9	<0.6	<0.3	0.55
COASTAL WATERS:														
Tanguisson Beach[f]	<0.001-0.27[3]	<0.001-2.62	-	-	-	-	-	-	-	-	-	-	-	-
Agana Bay[f]	<0.001-0.19[3]	<0.001-0.11	-	-	-	-	-	-	-	-	-	-	-	-
Agat Bay[f]	<0.001-0.36[3]	<0.001-1.94	-	-	-	-	-	-	-	-	-	-	-	-
Tumon Bay[f]	0.020-0.12[3]	0.004-0.018	-	-	-	-	-	-	-	-	-	-	-	-
Tipalao Bay[d]	<0.001-0.06	0.013-0.043[1]	-	840-920	-	10	-	<10	<10	<100	-	<20	<2	<20

Table 7 (cont.)
Historic Water Quality Data for Nutrients, Major Ions and Heavy Metals in Unfiltered Natural Waters and Wastewaters from Guam

LOCATION	NO_3-N (mg/l)	o-PO_4-P (mg/l)	Ca (mg/l)	Mg (mg/l)	Na (mg/l)	Ag (µg/l)	Cd (µg/l)	Cr (µg/l)	Cu (µg/l)	Fe (µg/l)	Mn (µg/l)	Ni (µg/l)	Pb (µg/l)	Zn (µg/l)
COASTAL SEEPS:														
Tumon Bay^{g}	0.742-4.14^{3}	0.037-0.056	-	-	-	-	-	-	-	-	-	-	-	-
Tumon Bay^{h}	1.38-1.64	0.007-0.007	-	-	-	-	-	-	-	-	10-20	-	-	-
WASTEWATER:														
Leachate: Ordot Landfill$^{d\ i}$	2.4-7.1	0.09-0.11^{1}	62.1-94.8	24.2-44.3	169-192	<0.1-1.9	<0.1-1.3	1.2-8.2	2.6-36.0	149-4680	283-1113	3.0-30.0	<0.1-3.4	2.3-40.4
Effluent: Tipalao STP^{b}	1.92	1.12	-	-	-	-		-	-	-	-	-	-	-
Effluent: Agana STP^{j}	-	-	-	-	-	20.9-26.0	<2	6.0-110	53-146	-	-	<50	<5-7.9	220
Effluent: Northern District STP^{j}	-	-	-	-	-	4.0-10	<2	6.2-250	46	-	-	<50	<5-5.8	108
GUAM W.Q STANDARDS^{k}:														
Fresh Waters (CCC)	0.1-0.50^{m}	0.025-0.10^{m}	none	none	none	0.12	$1.1^{\langle \circledR}$	$11^{*\circledR}$	$12^{\langle \circledR}$	3000^{k}	none	$160^{\langle \circledR}$	$3.2^{\langle \circledR}$	$110^{\langle \circledR}$
Marine Waters (CCC)	0.1-0.50^{m}	0.025-0.10^{m}	none	none	none	none	$9.3^{\circledR}$	$50^{*\circledR}$	$2.9^{\circledR}$	50^{k}	20^{k}	8.3	$8.5^{\circledR}$	$86^{\circledR}$
Safe Drinking Water Standards^{n}	10	none	none	none	none	100^{ϕ}	5	100	1000^{ϕ}	300^{ϕ}	50^{ϕ}	100	$15^{\vert}$	5000^{ϕ}
WORLD AVERAGES^{p}:														
Freshwater	<0.43-3.69^{q}	<0.01-0.05^{q}	0.2-50^{r}	0.01-10^{r}	0.1-20^{r}	0.3	0.1	1	3	500	8	0.5	3	15
Saltwater (salinity 35‰)	<0.001-0.63^{s}	<0.0001-0.1^{s}	406^{t}	942^{t}	10710^{t}	0.04	0.1	0.3	0.3	2	0.2	0.6	0.03	5
Wastewater (1st/2nd treat.)^{u}	25-25^{5}	5-15^{2}	-	-	-	-	-	-	-	-	-	-	-	-

a = Barrett Consulting Group 1992; b = Zolan *et al.* 1978a; c = Guam Waterworks Authority (unpublished data from the 1996 fourth quarter (heavy metals: 113 wells) and 1997 fourth quarter (all other parameters listed: 92 wells) groundwater monitoring (figures in parenthesis are geometric means), and surface waters impacted by the Tipalao Bay STP (July 1998); d = Denton and Wood. (unpublished 1990-1994 data); e = GEPA STORET data base
(1982-91); f = Matson 1993a; g = Matson (unpublished 1996 data); h = Fitzgerald 1976; i = GEPA 1996; j = Dueñas & Associates, Inc. 1993; k = Adopted from U.S. EPA *Quality Criteria for Water* (Federal Register 1992) and expressed as total recoverable metals; m = additional standards adopted by GEPA (GEPA1992); n = National Primary Drinking Water Standards regulated under the Safe Drinking Water Act and expressed as total recoverable metals [⎛ = secondary (non-enforceable) drinking water standards; ⎢ = as prescribed under the Lead & Copper Rule of June 1991]; p = modified from Bowen 1979; q = range of median values reported for four sub-units of the Potomac River Basin (Miller *et al.* 1997); r = anticipated natural ranges based on data reported by Stowe 1983, Watling *et al.* 1985, Talbot *et al.*1985, Miller *et al.* 1997; s = Millero and Sohn 1992; t = Stowe 1983; u = Freedman 1989. 1 = as total phosphate; 2 = as total dissolved phosphorus; 3 = as NO_2 + NO_3; 4 = as NH_3 + NO_3; 5 = as total nitrogen. Dashes indicate no data. * = Cr (IV). CCC = criteria continuous concentration (which for any of the 126 “Priority Pollutants” designated under section 307(a)(1) of the Clean Water Act, is the highest 4-day average concentration, not to be exceeded more than once every three years, that gives no discernable chronic effects). ⟨ = the freshwater aquatic life criteria for these metals are expressed as a function of total hardness (mg/l), and as a function of the pollutants water effect ration (WER) which is computed as the specific pollutant’s acute or chronic toxicity values measured in water from the site of interest, divided by the respective acute or chronic toxicity value in laboratory dilution water. Thus, the CCC for any given site = WER exp{m_c[ln(hardness)] + b_c}, where m_c = 0.7852, 0.8545, 0.8190, 1.273, 0.8460 and 0.8473 for Cd, Cu, Cr (IV), Pb, Ni and Zn respectively, and b_c = -3.490, -1465, 1.561, -4.705, 1.1645 and 0.7641 for Cd, Cu, Cr (IV), Pb, Ni and Zn respectively. The values displayed in the above table correspond to a total hardness of 100 mg/l and a WER of 1. ® = the criteria for these metals are expressed as a function of WER. Thus, CCC = the value listed above multiplied by WER.

also derived from agricultural runoff (fertilizers and animal waste), septic systems and wastewater discharges, and the combustion of fossil fuels. NO_3 levels are usually measured as NO_3-N and, in drinking water, must not exceed 10 mg/l (USEPA). Surface waters generally have NO_3-N levels of less than 2 mg/l (AWWA 1990). Stormwater NO_3-N concentrations recorded in the literature range from 0.01-12.00 mg/l (Makepeace *et al.* 1995).

Levels of NO_3-N determined in ponding basin water during the present study showed considerable inter-site variation and ranged from 0.01-3.67 mg/l with the highest value occurring at the Mariana Terrace site. Previously reported values by Zolan *et al.* (1978a) for local ponding basins were also highly variable and ranged from<0.001-2.0 mg/l (Table 5). Interestingly, their study also highlighted the Mariana Terrace ponding basin as being relatively enriched in this nutrient.

Overall geometric mean NO_3-N concentrations for this study were 0.08 mg/l, considerably lower than levels expected in urban runoff from the U.S. mainland (Table 6) and well below those normally encountered in Guam's groundwater (Table 7).

Water samples collected from three sites within Harmon Sink on October 6, 1995, showed reasonable agreement between replicates for NO_3-N. However, there was evidence of considerable temporal variability at some of the other locations. For example, NO_3-N concentrations at the Naval Communications field ponding basin, in Barrigada, increased from 0.01 to 2.13 mg/l over a 3-week period. Likewise, levels encountered at the Fujita Hotel site increased from 0.01 to 0.14 mg/l in the space of a month. In contrast, temporal variations in NO_3-N remained relatively constant at the Harmon Sink (South) and the Micronesia Mall sites. No doubt, such differences reflect discrepancies in the holding capacities and retention times of the ponding basins themselves, in addition to variations in the volume and chemical characteristics of the runoff water discharged into them.

Phosphate (PO_4):

PO_4 in uncontaminated surface waters is primarily of mineral origin, with no contributions from the atmosphere other than that associated with fallout of wind-blown dust particles. Under such conditions, levels are usually low and in the order of 0.01 mg/l or less. Anthropogenic sources of PO_4 include fertilizers, detergents, lubricants, corrosion inhibitors, and industrial and animal wastes. Total P levels in excess of 0.025 mg/l can lead to nuisance growths of algae and other aquatic plants (U.S. EPA 1986).

Various forms of PO_4 exist in natural waters and wastewaters. These are classified as ortho-PO_4, condensed-PO_4, organically bound-PO_4, and total-PO_4, and are usually expressed on a P basis. Orthophosphate-phosphorus (o-PO_4-P) was measured during this investigation. This form of P is a primary component of phosphoric fertilizers and is readily available to plants. Moreover, it is water-soluble and therefore is readily mobilized into surface waters with stormwater runoff (Csuros 1994). The Guam Water Quality Standards mandate that o-PO_4-P concentrations in clean surface waters must not exceed 0.025 mg/l (GEPA 1992). Literature values for total P and soluble P concentrations in stormwater range from 0.01-7.30 mg/l and 0.0381-3.52 mg/l (Makepeace *et al.* 1995).

The o-PO_4-P concentrations found in Guam's ponding basins during the present study were low and mostly in the 0.01-0.3 mg/l range. Only at the Harmon Sink-South site did levels exceed this upper limit reaching a high of 1.92 mg/l on July 28 and 0.45 mg/l on August 5. Zolan *et al*. (1978a) found similar concentrations of o-PO_4-P in local ponding basins with levels ranging from <0.001-0.37 mg/l. Of particular interest, here, are the relatively high o-PO_4-P concentrations that these researchers observed in the Airport Road drainage ditch (up to 2.06 mg/l with a mean of 0.384 mg/l) which discharges directly into the Harmon Sink area.

Some time-dependent variability in o-PO_4-P levels was indicated at sites visited more than once, although this was far less pronounced than observed for NO_3-N.

Major Ions:

Water channeled into ponding basins can be derived from storms as well as from irrigation and aqueous cleansing activities. In northern Guam, most, if not all, of the water used for irrigation and cleansing purposes, comes from the island's groundwater distribution system. Since the chemical signatures of these water types are very different, it seemed reasonable to assume that the dominant category of water in each ponding basin could be identified from the abundance of major cations present in solution. For example, elevated Ca and Mg levels characterize major contributions from groundwater. High levels of Na, the other hand, indicate oceanic influences and/or pollution sources depending upon the coexistence of other components such as Zn (a dominant heavy metal in contaminated storm water runoff)

Building on this rationale, and using the data presented in Table 4, the following criteria were assembled:

- High levels of Ca (>50 mg/l) and/or Mg (>5 mg/l) are considered to predominantly reflect a groundwater influence.
- Rainwater was expected to have low concentrations of all three cations unless significant amounts of sea spray were present in which case Na levels were anticipated to be relatively high (>100 mg/l).
- Samples, in which concentrations of Na and Zn exceeded 50 mg/l and 20 µg/l respectively, were considered indicative of urban pollution sources

Using these criteria to categorize the dominant water types in the ponding basins visited during the present study, it appears that the majority of samples collected were representative of storm water runoff. There were, however, some notable exceptions. For example, the high Ca (129 mg/l) and Mg (5.63 mg/l) levels determined in ponding basin water from the Naval Communications field on July 28 were indicative of groundwater runoff. The presence of relatively high NO_3-N levels in the water at that time (0.6 mg/l), and again 19 days later (2.13 mg/l), lends further support to this hypothesis.

Another example, of dominant groundwater influence was evident in the Harmon Sink-South area, also on July 28. In this particular instance, the high Ca (100 mg/l) and Mg (5.53 mg/l) levels were accompanied by high Na (50.6 mg/l) and Zn (50.0 µg/l) suggesting a nearby pollution source. The co-existence of high o-PO_4-P concentrations (1.92 mg/l - possibly from detergents) in addition to somewhat elevated levels of dissolved Cu (43 µg/l) and Pb (33.6 µg/l), gives some credence to this theory.

Finally, the high levels of Ca (125-174 mg/l) and Mg (4.19-4.53 mg/l) and NO_3-N levels (1.01-3.67 mg/l) in water samples taken from the Mariana Terrace ponding basin implied that groundwater was a major part of the water retained here. It is worth noting that several residents living slightly up gradient of the ponding basin were observed to keep pigs and poultry. The periodic hosing down of such facilities could account for the groundwater signature discovered at this site. Certainly, the elevated levels of Na (437 mg/l) and Zn (24 µg/l) determined in the July 17 sample (Table 4) imply the existence of a mild pollution source nearby.

The only evidence of stormwater contaminated with ocean spray came from the Fujita Hotel ponding basin in lower Tumon on July 17 (Table 4). On this particular occasion, the sample contained a relatively high Na concentration (90 mg/l) in the presence of low Ca (32.6 mg/l), Mg (0.68 mg/l) and Zn (14 µg/l). This seems hardly surprising in view of the close proximity of this site to the coast.

A comparison of major ion data for filtered and unfiltered samples clearly shows that Ca, Mg and Na exist largely in solution in ponding basin water. This is consistent with the findings of other workers elsewhere in the world (Harrison and Wilson 1985a). Soluble pollutants in runoff are mobilized much faster than those in solid form, and tend to be highest in the “first flush” of storm events (Harrison and Wilson 1985a). Stormwater levels reported in the literature for these three elements range from 0.04-2114 mg/l, 0.02-304 mg/l, and 0.18-660 mg/l for Ca, Mg and Na respectively (Makepeace *et al.* 1995).

Heavy Metals:

With the exception of Fe and Mn, all of the heavy metals examined during the present study are classed as “Priority Toxic Pollutants” under Section 307(a)(1) the Clean Water Act. For the protection of its aquatic life, Guam has adopted the numerical criteria established by the U.S. EPA and incorporated additional quality criteria for Fe and Mn into its Water Quality Standards (see Table 7). It is noteworthy that similar standards for limiting heavy metals (and other pollutants) in urban runoff do not exist. Efforts are underway to mitigate the impact of stormwater on receiving waters by the U.S. EPA, under their National Pollutant Discharge Elimination System (NPDES), stormwater-permitting program. However, no promulgated regulations currently apply to separate storm sewer systems serving municipalities of less than 100,000 people (Federal Register 1998).

The data gathered during the present study are discussed on a metal by metal basis below. Some general information on major uses and sources of each metal to the aquatic environment is presented together with brief notes on their important health effects to man. Levels found are measured against those determined in urban runoff and surface waters by others, and discussed in the general context of national and local water quality standards (Tables 5-7).

Silver (Ag):

Ag has no known biological function and is extremely toxic to all living organisms. Symptoms of acute toxicity in man include necrosis of the bone marrow, liver and kidney. The primary chronic effect is *argyria* the symptoms of which include: a slate gray pigmentation of the hair, skin and internal organs, a decrease in glutathione peroxidase, and a reduction in the metabolism of cyclic adenosine monophosphate (Moore 1991). The U.S. EPA classifies Ag is as a secondary drinking water contaminant in its National Drinking Water Protection Program, under the Safe Drinking Water Act (SDWA). As such, a maximum contaminant level (MCL) guideline for this element currently stands at 100 µg/l.

The principal commercial uses of Ag are in the production of photographic materials, jewelry, coinage, dental and medical supplies, some alloys, and electrical and electronic products (Moore 1990). Fortunately, Ag is relatively rare and so amounts discharged in industrial waste streams is closely controlled for economic reasons. Even so, relatively large amounts of Ag can appear in municipal wastewater and Guam appears to be no exception in this regard. For example, levels of 20.9-26.0 µg/l were recently recorded in the effluent stream of the Agana Sewage Treatment Plant (Dueñas and Associates 1993). In point of interest, around 10 metric tons of Ag were estimated to be discharged from California's four largest municipal outfall in 1988 (Schafer 1989).

Ag levels determined in ponding basin waters during this study were invariably below an analytical detection limit of 0.2 µg/l. Such low levels are consistent with the earlier findings of Zolan (1981) who reported overall averages of 0.1 and 0.2 µg/l for residential and commercial zone runoff from Guam respectively. The maximum Ag level found by this researcher was 0.6 µg/l at a ponding basin in Latte Heights. Elsewhere, Line *et al.* (1996) reported a high of 4 µg/l in urban runoff from North Carolina, while the highest Ag level found in the literature was 14 µg/l recorded by Randall *et al* (1978) for the Occoquan watershed in Virginia.

Ag levels in clean surface waters are generally less than 1 µg/l and often below 0.1 µg/l (Table 7). The world averages for Ag in marine and freshwater are 0.04 µg/l and 0.3 µg/l respectively (Bowen 1979). It would appear, then, that Ag is not a metal of immediate concern in Guam's urban runoff.

Cadmium (Cd):

Like Ag, Cd has no known biological importance and is highly toxic to many life forms. In contrast to Ag, however, it does tend to bioaccumulate in many species including man. Primary deposition sites in vertebrates are the kidney and liver tissues. Invertebrates tend to accumulate Cd in the hepatopancreas or equivalent tissue.

Clinical symptoms of severe Cd intoxication in humans include renal failure, liver injury, convulsions, shock and cardiopulmonary depression (U.S. EPA 1989). Chronic exposure may cause hypertension (elevated blood pressure), renal dysfunction (proteinuria), and increase the risk of prostate cancer (Moore 1991, Csuros 1994). Cd also interferes with Ca metabolism resulting in bone softening, fractures and skeletal deformities (Friberg *et al.* 1974). The carcinogenicity of Cd has been demonstrated in laboratory animals, following exposure by inhalation. There is no convincing evidence that this metal is carcinogenic via the oral route (U.S. EPA 1989).

The industrial uses of Cd were many and varied prior to the limiting influence of occupational health concerns, and included the production of solders, thermoplastic stabilizers, paints and pigments, and certain biocides. Nowadays, Cd is used primarily in the electroplating industry (anticorrosion coatings), and in the manufacture of glass, ceramics and storage batteries (Ni-Cd).

From a global perspective, the main anthropogenic sources of Cd relate to mine wastes, metallurgical industries, municipal effluents and sewage sludge. In the latter context, Hutton and Symon (1986) estimated that 33.3 metric tons of Cd entered UK coastal waters annually in sewage and sewage sludge. Other sources of Cd to the environment include the production and use of phosphate fertilizers, the burning of fossil fuels, the wear of automobile tires and break pads, and corrosion of galvanized materials (UNEP 1985, CCRME 1986).

From the limited data presented in Tables 5 and 6, it would appear that dissolved Cd levels in urban runoff seldom exceed 10 µg/l, whereas total recoverable amounts in unfiltered samples may be considerably higher. For example, Zolan (1981) reported a maximum dissolved and suspended Cd concentration of 8.4 µg/l and 125 µg/l respectively in urban runoff from Guam. In their review of the literature, Makepeace *et al.* (1995) found total Cd ranging from 0.05-13,730 µg/l with mean values of 0.3-11 µg/l.

It is noteworthy that we failed to find detectable quantities of Cd in all but two samples in our study. This may possibly be a reflection of the limitations imposed on the industrial use of this element over the last decade or so. The higher concentration that occurred in the Harmon Sink sample collected July 28, translated to a dissolved and suspended Cd fraction of 0.6 µg/l and 3.53 µg/l respectively. This is considerably lower than Zolan's findings during the late 70's and early 80's (Zolan 1981). In all other samples, the total recoverable Cd concentrations were below an analytical detection limit of approximately 0.5 µg/l -- an order of magnitude below the current primary drinking water standard for this element.

According to Yeates and Bewers (1987), Cd levels may be as low as 0.002 µg/l in remote open ocean waters taken far from urban and industrial growth centers. They also point out that levels in surface waters rarely exceed 0.5 µg/l, even in heavily industrialized areas. If this is correct, then one has to wonder at the utility of the surface water quality standards for Cd which currently stand at 9.3 µg/l and 1.1 µg/l for marine and freshwater respectively (Table 7).

Chromium (Cr):

Naturally occurring Cr can exist in the trivalent (Cr^{3+}) and hexavalent (Cr^{6+}) form although the former is the most stable oxidation state and predominates in nature. Cr^{3+} is nutritionally essential and relatively nontoxic. In contrast, Cr^{6+} is highly toxic affecting liver, kidney and respiratory organs with hemorrhagic effects (Moore 1991). Water-soluble Cr^{6+} chromate compounds are often mutagenic and may be carcinogenic (Langard 1988, Lanfranchi *et al.* 1988).

The primary use of Cr is in the production of ferrochromium alloys, which are used as additives in stainless steel and other specialized products (Moore 1991). It is also used extensively in the electroplating of metals, in dyes, paints and pigment, as a corrosive inhibitor in cooling waters, in fungicides, anti fouling paints and wood preservatives, in glass making and cement production, and in the tanning industry (Kroehler 1990). A major source of Cr to urban runoff is the corrosion of welded metal plating and the wear of bearings, bushings and other moving parts in automobile engines (Gupta *et al.* 1981).

Cr (Cr^{3+} plus Cr^{6+}) levels in urban runoff draining industrialized areas can be very high. For example, Line *et al.* (1996) found mean levels ranging from 38-865 µg/l in unfiltered stormwater runoff from ten industrial sites in North Carolina. In Guam, Zolan (1981) found dissolved and suspended Cr levels of 1-4 µg/l and 0.8-14µg/l respectively, in ponding basin water, and somewhat higher levels of up to 25 µg/l, for both fractions, in storm drain water. Detectable Cr levels were only found in 24% of the unfiltered samples taken during the present study and ranged from 5-9.9 µg/l, considerably lower than the current primary drinking water MCL of 100 µg/l. Levels in all other samples, including all filtered samples, were consistently below an analytical detection limit of 4 µg/l.

Cr contributions to the coastal belt from urban runoff in Guam are, thus, relatively minor, particularly in the light of amounts contributed daily from local sewage treatment plants. For example, the maximum Cr levels found in sewage effluent from the Agana and Northern District plants, by Dueñas and Associates (1993), were 110 µg/l and 250 µg/l respectively (Table 7). Fortunately, however, Cr is only moderately toxic to aquatic organisms (Moore 1991). Thus, the existing water quality standard of 50 µg/l, for the protection of aquatic life marine waters, would seem to be adequate, despite the fact that levels rarely exceed 1-2 µg/l in the most contaminated of surface waters (Beukema *et al.* 1986, U.S. EPA 1988).

Copper (Cu):

Although Cu is an essential trace element, it is highly toxic to most aquatic plants and invertebrates (Brown and Ahsanulla 1971, Denton and Burdon-Jones 1982) and is one of the most toxic heavy metals to fish (Denton and Burdon-Jones 1986, Moore 1991). In man, Cu deficiency, resulting in decreased Fe absorption, anemia, and reproductive abnormalities, is more prevalent than toxicity. According to Moore (1991), Cu poisoning is rarely reported except for individuals suffering Wilson's disease -- a congenital disorder, causing accumulation of Cu in the brain, liver and kidney, resulting in hemolytic anemia, neurological abnormalities, and corneal opacity. Cu is classified as a secondary drinking water contaminant by the U.S. EPA. The MCL guideline for this element currently stands at 100 µg/l.

Cu is used for a great diversity of purposes, and ranks second only to Fe in terms of its industrial usefulness. Major uses include electroplating, and production of electrical wiring, alloys such as bronze and brass, anti-fouling paints, fungicides and algaecides, construction and plumbing materials, to name but a few.

Primary sources of Cu to the environment include mining, smelting, domestic and industrial wastewaters, steam electrical production, incinerator emissions, and the dumping of sewage sludge (Moore 1991). Levels in stormwater runoff may also reflect contributions from automobiles (tires, brake pads, bearings and other metallic moving parts), asphalt pavement wear, the combustion of lubricating oils and the corrosion of metallic building materials (Malmqvist 1983, Revitt *et al.* 1987, Ward 1990).

Cu levels in natural waters are low and in the order 10 µg/l or less. In urban runoff, however, levels are frequently much higher, especially in unfiltered samples taken from industrial centers (see Tables 5 and 6). For example, Line *et al.* (1996) reported mean Cu levels of up to 2,223 µg/l in unfiltered runoff from a scrap metal and recycling industrial area in North Carolina for example. However, as a general rule, Cu levels in urban runoff from major US cities are in the order of 30-60 µg/l based on the results of EPA's Nationwide Urban Runoff Program (Whalen and Cullum 1989). In Guam, Zolan (1981) reported dissolved Cu levels of 8.4-95 µg/l in runoff from the commercial district and 2.2-8.9 µg/l from residential developments. Overall means were reported for each category as 37 and 8.5 µg/l respectively.

We were unable to detect Cu in the majority of our ponding basin water samples. The only exceptions were two samples collected from Harmon Sink on July 28 and August 8 when total Cu levels of 114 µg/l and 30 µg/l were respectively recorded (Table 3). In the earlier sample, about 38% of the total Cu was determined to be in the dissolved form compared with 100% in the sample taken later on (Table 4). In all other samples examined, Cu levels were consistently below an analytical detection limit of approximately 7 µg/l. While this is below the surface water standard for freshwater environments (12 µg/l) it exceeds the marine water quality standard (2.3 µg/l) by a factor of three. Therefore, it is not possible to conclude with certainty that Cu levels in Guam's urban runoff pose no immediate threat to sensitive marine species. However, in view of the rapid dilution and dispersion mechanisms operating in and around storm drain outlets and freshwater seeps, the possibility of adverse effects directly related to this element seem most unlikely.

Iron (Fe):

Fe is the fourth most abundant element in the earth's crust and is mined in greater quantities than any other element. Total amounts mined by the leading nations of the world exceed one billion metric tons (U.S. Minerals Yearbook 1988, Cordero 1988). An equivalent amount is mobilized annually within the global environment, largely by natural weathering and erosion process (Westall and Stumm 1980). Consequently, Fe is relatively abundant in all environmental compartments. The principal anthropogenic sources of Fe to stormwater runoff include the corrosion of vehicular bodies and steel building materials, the burning of coal and coke, and landfill leachate (Gupta *et al.* 1981, CCREM 1987, Denton and Wood unpublished data).

Fe levels in natural waters are extremely variable, reflecting differences in local geology, pH, redox potential, sources of contamination, and other chemical components in the water. In most well oxygenated surface waters, at normal pH, inorganic Fe exists largely as insoluble hydrated ferric (Fe^{3+}) oxides that occur as fine particulate and colloidal material. As waters become progressively acid or depleted in levels of dissolved oxygen, the insoluble Fe^{3+} salts are reduced to their respective soluble Fe^{2+} (ferrous) forms. Thus, natural concentrations of dissolve Fe may vary by several orders of magnitude from one location to another. In Guam for example, dissolved Fe levels recently found in freshwater streams ranged from a low of 0.5 µg/l, in well oxygenated waters, to a high of 138,000 µg/l in anaerobic swamp waters (Denton and Wood unpublished data, Siegrist *et al.* 1997).

Dissolved Fe levels found in ponding basin water during the present study were mostly below an analytical detection limit of 30 µg/l and reached a maximum of approximately 55 µg/l in only 14% of the samples. On the other hand, Fe concentrations were detectable in 43% of the unfiltered samples collected. In these, total Fe levels ranged from 55-491 µg/l. Thus, most of the Fe on our ponding basin samples was associated with suspended sediments. This means, of course, that total Fe concentration in urban runoff are very much dependent upon the particulate loading, i.e., the higher the loading, the greater the total Fe concentration and vice versa. Consequently, ponding basin water will generally contain lower concentrations of total Fe than storm drain water by virtue of the fact that much of the suspended sediment load has dropped out of the water column.

Total Fe concentrations previously reported for stormwater range from 80 µg/l to 440 mg/l with mean values extending from 988 µg/l to 12 mg/l (Makepeace *et al.* 1995).

Fe is biologically essential to animals and plants and of little direct toxicological significance. Consequently, the secondary drinking water standard for Fe is currently set at 300 µg/l because of aesthetic reasons (taste and laundry requirements) rather than public health considerations. Nonetheless, Fe is an important element from an environmental standpoint because it often controls the concentration and cycling of other elements, including toxic metals, in sediments and surface waters (Moore 1991).

Fe is no longer considered a priority pollutant of surface waters and the old U.S. EPA numerical standard of 1000 µg/l for freshwater no longer applies at the national level. However, Guam EPA continues to regard Fe as a potentially toxic element, undoubtedly because of its relative abundance in local soils. As a consequence, the local surface water standards for total Fe in freshwater and saltwater environments are currently set at 3000 µg/l and 50 µg/l respectively. Since dissolved Fe readily precipitates in alkaline waters, the marine standard is presumably set to protect sensitive benthic communities from the potentially toxic and/or smothering effects of settling Fe flocs (U.S. EPA 1976).

Most of the receiving waters affected by Guam urban runoff are marine and whereas some stormwater drains and culverts may discharge directly into the ocean, runoff trapped in ponding basins slowly permeates through the underlying bedrock, and possibly into the aquifer, before escaping into the sea. This provides a natural filtration mechanism that should remove much if not all of the particulate Fe present. This notwithstanding, the relatively high Fe levels reported in storm drain water by Zolan (1981) implies that amounts being discharged directly into Guam's coastal waters exceed the surface water quality standard by an order of magnitude or more on occasions (see Table 5).

Manganese (Mn):

Mn is a vital micronutrient to both plants and animals and is only slightly to moderately toxic to aquatic organisms (Moore 1991). In man, acute toxicity resulting from the inhalation of large amounts of Mn dust results in localized respiratory necrosis (Mn pneumonitis). The chronic effects of Mn inhalation and ingestion are well known in miners, mill workers and other occupationally exposed groups. Symptoms include neurological degenerative changes of the central nervous system resulting in a Parkinson-like syndrome (Mena *et al.* 1967). Interestingly, the early symptoms of chronic Mn intoxication have also been reported among people consuming Mn-tainted water or fish products (Moore 1991). This is especially relevant to the people of Guam given the naturally high background levels of Mn and the high incidence of amyotrophic lateral sclerosis and parkinsonism with dementia (ALS-PD) on the island. There is no evidence linking Mn to cancer.

Mn and its compounds are used in the manufacture of a diverse range of industrial products including steel alloys, dry-cell batteries, electrical coils, glass, dyes, welding rods; as oxidizing agents; and as animal food additives (Goyer 1991). Amounts mobilized annually into the environment from both natural and anthropogenic sources are exceeded only by Fe and Al (Moore 1991). Primary sources of Mn in urban runoff are linked with automobile tire and break pad wear, the corrosion of steel materials, the application of fertilizers, and contributions from landfill leachate (Ward 1990, Denton and Wood unpublished data)

Mn can exist in several oxidation states although Mn^{2+} (manganous) and Mn^{4+} (manganic) are the most important in aqueous systems. In oxygenated waters, at normal pH, Mn^{4+} prevails and forms insoluble oxides in the same way as Fe. In fact, redox conditions control the fate of both elements in a similar fashion. The primary differences being that Mn^{2+} oxides are reduced to soluble Mn^{2+} at higher redox potential than Fe^{3+} oxides, and that the oxidation of Mn^{2+} to Mn^{4+} occurs much more slowly than the oxidation of Fe^{2+} to Fe^{3+}. Dissolved Mn level can thus vary considerably, depending upon the proximity and mobilization rates of soluble Mn^{2+} sources. In Guam, for example, the surface waters from the mouth of the Taelayag river, a water course that drains a Mn enriched wetland area about 1000 m upstream, contained dissolved Mn levels of 60-150 µg/l. (Siegrist *et al*. 1997).

A broad concentration range that encompasses much of the published data for dissolved Mn in river water is 1-100 µg/l with a central value of around 5 µg/l (Wilson 1980). Total Mn concentrations are considerably more variable and can range from 1-2 µg/l upwards of 4000 µg/l depending on the nature and extent of the particulate loading in the water column. Typically, dissolved Mn levels account for <10% of the total Mn load in the water column (Moore 1991).

Relatively few studies have examined Mn levels in urban runoff. Randall *et al.* (1978) reported mean dissolved Mn concentrations of 302 µg/l in residential runoff from the Occoquan watershed, in Virginia. These authors also noted higher mean levels of 395 µg/l in runoff from the commercial sector of the community. Likewise, Zolan (1981) concluded that residential runoff from Guam generally contained less dissolved Mn than runoff from the island's commercial areas. However, his values were considerably lower than the aforementioned study by Randall *et al.* (1978) and averaged 11 µg/l and 28 µg/l respectively.

In the present study, Mn concentrations in the ponding basin waters examined were generally low (<10 μg/l). The highest total Mn concentration of 140 μg/l was found in the water sample collected from the Mariana Terrace ponding basin on July 17 (Table 3). At this time, 64 % of total Mn determined was present in the particulate form. The highest dissolved Mn concentration was 126 μg/l taken from the same site on August 8 some three weeks later. On this occasion there was no measurable contribution from particulate Mn. In contrast, particulate Mn accounted for >92% of the total Mn concentration (120 μg/l) determined in the October 6, Harmon Sink sample.

In their review of the available literature, Makepeace *et al.* (1995) noted that total Mn levels in stormwater ranged from 7-3800 μg/l with means extending from 110-670 μg/l.

The U.S. EPA drinking water MCL guideline for Mn is 50 μg/l and is imposed for aesthetic rather than public health purposes in the same way as for Fe. The rationale behind the setting of this secondary standard is that Mn concentrations in excess of 150 μg/l can impart an objectionable mineral taste to drinking water and cause a brownish staining of laundry (U.S. EPA 1976).

Currently, there are no national standards for Mn in surface waters, although an action level of 100 μg/l used to exist for marine waters. This standard was based on the notion that certain mollusks with a high bioaccumulation potential for this element (e.g., oysters) could pose a possible health threat to consumers. These sentiments are no longer shared by the scientific community in the wake of experimental evidence that demonstrates metabolic regulation of Mn in most molluskan tissues. This notwithstanding, the Guam EPA continues to promote its long-standing surface water standard for marine waters of 20 μg Mn/l.

Nickel (Ni):

Ni is classed as an essential element being desirable for optimum health by many animal and plant species. Although moderately toxic to many plant species, it is relatively nontoxic to aquatic invertebrates and fish (Denton and Burdon-Jones 1986, Moore 1991). In humans, the main acute effects of Ni exposure in Ni refinery workers is dermatitis and allergic sensitization while the primary issue associated with chronic exposure is respiratory cancers associated with the inhalation of Ni dust (Coogan *et al.* 1989). There is no evidence of Ni induced carcinogenesis via the ingestion of Ni contaminated food or water (Moore 1991).

Ni is used in a wide range of industrial applications because of its corrosion resistance, high strength and durability, pleasing appearance, good thermal and electrical properties, and alloying ability (Moore 1991). Major sources to the environment include municipal wastewaters and sludges, the refining of nonferrous metals, and the burning of fossil fuels (Nriagu and Pacyna 1988). Levels found in urban runoff may also reflect contributions from automobile engine and bearing wear, in addition to the corrosion of Ni alloys and electroplated metals (Gupta *et al*. 1981, CCREM 1987, Ward 1990)

Dissolved Ni levels in unpolluted surface waters typically range from 0.5-1 µg/l but may be exceed 20 µg/l in areas influenced by Ni bearing ores or receiving inputs from pollution sources. Often total Ni levels are much higher than the dissolved fractions indicating significant association of this element with suspended particulate material. Total Ni levels reported in the Mindhola Estuary (India) by Zingde *et al.* (1988), for example, ranged from 78-131 µg/l with an overall mean of 94 µg/l. In Guam, total Ni concentrations naturally occurring in ground and surface freshwater resources are in the order of 1 µg/l or less (Table 7).

In July 1992, a primary drinking water MCL of 100 µg/l was finalized for Ni, under the Phase V Rule of the SDWA (U.S.EPA 1992). This standard was incorporated into the 1995 revision of the *Guam Primary Safe Drinking Water Regulations* (GEPA 1995) and remains in effect today. However, Ni was removed from the safe drinking water contaminant list two years ago, under the SDWA amendments of 1996 (U.S. EPA 1998). The surface water Ni standards, for the protection of aquatic life in marine and freshwater environments, currently stand at 8.5 µg/l and 160 µg/l respectively.

Mean total levels of Ni in urban runoff from North Carolina industrial areas ranged from <1 µg/l from vehicle maintenance sites to 333 µg/l from scrap metal and recycling centers (Line *et al.* 1996). Such inordinately high levels are no doubt related to the presence of metallic particles in the sample. The reported means for these studies were considerably less variable and ranged from 6-150 µg/l. Other accounts in the literature report total Ni concentrations in stormwater that extend from a low of 1 µg/l to an all time high of 49 mg/l (Makepeace *et al.* 1995).

Dissolved Ni levels reported in urban runoff by Randall *et al.* 1978 for residential and commercial sectors of the Washington D.C. metropolitan area were 25 µg/l and 34 µg/l respectively. Somewhat lower mean values of 7.2 µg/l and 23 µg/l were respectively reported by Zolan (1981) for residential and commercial areas in Guam. This author also reported dissolved Ni concentration of 1.4-30 µg/l in water from residential ponding basins. In contrast, Ni levels were consistently below a detection limit of 5 µg/l in the current work. In view the above data and toxicological discussions, we conclude that Ni levels in Guam's urban runoff are of no immediate concern.

Lead (Pb):

Pb has no known biological function and is an accumulative neurotoxin. In man, short-term acute effects include, fatigue, colic anemia, renal disorders, seizures and other neurological disorders. Long-term chronic effects also include hypertension, congenital malformations, sperm count suppression and damage to the peripheral nervous system (Landrigan 1988, Assennato *et al.* 1987, Greenberg *et al.* 1986). Children are particularly sensitive to Pb and there is some evidence that exposed subjects develop cognitive and behavioral disorders (Moore 1991) and show decreased body growth and poor posture (Csuros 1994).

There is some evidence that oral ingestion of high doses of inorganic Pb can causes renal tumors although the data is far from conclusive (Moore 1991).

Pb is only moderately toxic to freshwater organisms and susceptibility usually increases with decreased hardness. In salt water, inorganic Pb is rapidly removed from the water column by particulate scavenging and precipitation mechanisms leading to its diminished toxicity (Denton and Burdon-Jones 1982, 1986). However, many invertebrate organisms, particularly mollusks, demonstrate a high capacity to accumulate Pb raising concerns over possible adverse health affects to consumers.

Pb is used in large amounts in storage batteries, ammunition and the production of various chemicals and metal products including brass. At one time, it was also used extensively in paints, pottery glaze, solders, anti-fouling paints, cable coverings, as an anti-knock additive to gasoline fuels, and as a filler material in automobile tires.

Primary sources of Pb to the environment are from mining, smelting and refining activities, manufacturing processes, domestic and industrial wastes, sewage sludge, incineration of municipal wastes, and the burning of fossil fuels especially leaded fuel combustion (Nriagu and Pacyna 1988). Major routes of Pb exposure to man include vehicular exhausts and contaminated drinking water. In the latter instance, Pb based solders and brass faucets are the primary offenders today although, historically, distribution lines were also composed of Pb in many areas. The action level for Pb in drinking water, as mandated under the U.S. EPA Lead and Copper Rule, is 15 µg/l at the tap.

Pb levels in surface waters are highly variable with particulate Pb accounting for >75% of residues in most instances. Wilson (1976) provides a global range for dissolved Pb in river water of 1-100 µg/l with a central value of 5 µg/l. This is not too far removed from Bowen's world average value of 3 µg/l (Bowen 1979). Total Pb levels reported for Canadian Prairie lakes and rivers ranged from 1-77 µg/l (Naquadat 1985). Most of the major rivers in Guam contain total Pb concentrations that rarely exceed 1 µg/l (Denton and Wood unpublished data) although reports exist that suggests otherwise (Barrett Consulting Group 1992, see Table 7).

Pb levels in marine waters tend to be lower than their freshwater counterparts with levels as low as 0.005 µg/l reported for open ocean (Burnett *et al.* 1977). Closer to shore, Pb concentrations are typically higher reaching 10-20 µg/l in grossly contaminated waters. (Halcrow *et al.* 1973, Abdullah and Royale 1974).

The current surface water standards for total Pb in fresh and saline waters are 3.2 µg/l and 8.5 µg/l respectively (U.S. EPA 1986, Federal Register 1992). These standards are frequently exceeded by levels found in urban runoff. For example, total Pb levels reported by Makepeace *et al.* (1991) in their review of the available literature ranged from 0.57 µg/l to 26 mg/l with mean values extending from 21-1,558 µg/l. Previously reported data for Guam lists a maximum total Pb concentration of 330 µg/l in storm drain water from the Camp Watkins Road area (Zolan 1981). This is close to the mean residential value of 293 µg/l that emerged from the NURP study (Whalen and Cullum 1989).

In the present study, we failed to detect Pb in water from our ponding basin sites, with the notable exception of the Harmon Sink sample taken on July 28. On this particular occasion, a total Pb concentration of 1782 µg/l was measured. Of this, 98% was estimated to be associated with suspended solids as only 33.6 µg/l were found in the filtered portion of the sample. All other samples examined contained Pb levels below an analytical detection limit of 3 µg/l. When these data are viewed against Zolan's earlier findings for local ponding basins (Zolan 1981), it seems that levels of Pb have declined in Guam's urban runoff in recent years. This is probably linked with the leaded gasoline restrictions currently in force on the island.

Zinc (Zn):

Zn is essential for the normal growth and development of plants and animals. While certain types of plants are relatively susceptible to Zn enrichment, many invertebrates, particularly mollusks and crustaceans, are fairly insensitive and seemingly flourish in relatively high concentrations of this element (Ahsanullah 1976, Burdon-Jones and Denton 1980, Denton and Burdon-Jones 1982). Fish are moderately sensitive to Zn, and 96-h LC50 values typically range between 10 and 50 mg/l (Denton and Burdon-Jones 1986).

Although Zn is not particularly toxic to man, the ingestion of excessive amounts (>2 g) may induce vomiting coupled with fever and diarrhea. The taste threshold for Zn in drinking water is approximately 15 mg/l and levels exceeding 600-700 mg/l are usually emetic. Liver and intestinal disorders can sometimes develop in occupationally exposed subjects, however, there is no evidence linking Zn with any form of human cancer (Moore 1991).

Zn has numerous industrial applications. Chief among these are its use in galvanizing, and the production of Zn based alloys, brass and bronze, batteries, paints, and rubber products, including automobile tires (Bryan 1976, Förstner and Wittman 1981, Moore 1991). Major anthropogenic source of Zn to the environment have historically included metal smelting, refining and manufacturing processes. In more recent times, however, amounts released via these sources have decreased in many parts of the world as a result of better management practices and waste control (Moore 1991). This notwithstanding, significant quantities of Zn are recycled back into the environment from the dumping and incineration of domestic and industrial wastes; the burning of fossil fuels, and the production of fertilizers and cement (Nriagu and Piacyna 1988, Nriagu 1989). Primary sources to urban runoff also include contributions from automobile tires, break pads, and exhaust emission, road and pavement wear, exterior paint, and the corrosion of metals especially galvanized materials (Gupta *et al.* 1981, Malmqvist 1983, Dannecker *et al*. 1990, Ward 1990).

Levels of Zn in rivers and streams can range from less than 1 µg/l to greater than 200 µg/l depending usually upon the proximity of anthropogenic sources of this metal (Wilson 1978, Moore 1991). However, the world average value for Zn in freshwaters is in the order of 15-20 µg/l (Wilson 1978, Bowen 1979). Zn concentrations found in a number of Guam rivers and streams by Denton and Wood (unpublished data) were considerably lower than this and ranged from <0.1-3.7 µg/l (Table 7). In contrast, Barrett Consulting Group (1992) reported elevated levels of 100-400 µg/l in three local rivers that discharge directly into Fena Lake, a major drinking water reservoir that services both military and civilian communities in central Guam. While these levels seem unusually high, they are at least an order of magnitude lower than the current secondary drinking water standard of 5 mg/l for this element.

Marine waters generally contain lower concentrations of Zn than freshwater systems although levels in coastal waters near sewage outfall or harbors can exceed 20 µg/l (Halcrow *et al.* 1973, Abdullah and Royale 1974, Zingde *et al.* 1976, Sen Gupta *et al.* 1978). In rare cases, Zn levels as high as 200-300 µg/l have been reported (Preston *et al.* 1972, Klumpp and Peterson 1979).

Zn is one of the most common trace elements in urban runoff and frequently exceeds Cu and Pb concentrations by an order of magnitude (Table 6). Concentrations of this element are closely aligned to the intensity of human activity and sources of metallic pollution. For example, total Zn concentrations derived from the EPA's NURP study for residential, commercial and industrial zones, were 254 µg/l, 418 µg/l and 1063 µg/l respectively (Whalen and Cullum 1989). Further, runoff from scrap metal recycling industrial areas in North Carolina contained total Zn concentrations that averaged 10,083 µg/l (Line *et al.* 1996).

Previously reported levels for total Zn in urban runoff from Guam were low by comparison and ranged from <0.4-19 µg/l for samples from ponding basins and 0.4-122 µg/l for those taken from storm drains. Dissolved concentrations were generally higher than those associated with suspended particulates and averaged 8.4 µg/l and 9.5 µg/l for residential and commercial areas respectively (Zolan 1981).

In the current study, Zn was consistently detected in all samples. Levels determined in filtered and unfiltered samples ranged from 2-50 µg/l and 2-75 µg/l respectively and were, therefore, below the national norm. Ratios between dissolved and particulate bound metal were highly variable although the particulate fraction generally predominated in contrast to Zolan's earlier findings. Finally, amounts found did not exceed the surface water and drinking water standards currently in force on the island (see Table 7).

Concluding Remarks:

From the limited information gathered during the present study, the implications are that the nutrient and elemental composition of ponding basin water in Guam exhibits appreciable spatial and temporal variability, at least for certain components. Nevertheless, levels of all components monitored were generally low by world standards and, for the most part, did not exceed local surface and drinking water quality standards. Moreover, nutrient and heavy metal levels do not appear to have increased significantly over the last two decades. On the contrary, Cd and Pb concentrations may have actually declined as a result of recent restrictions in the commercial use of these elements.

Further work is necessary to evaluate the water quality of other retention ponds not examined during the present study. In addition, the range of chemical contaminants examined should be expanded to include petroleum hydrocarbons, pesticides, and PCBs. Some insight into the complex physical, chemical and biological processes that control the accumulation and downward migration of urban runoff pollutants in ponding basin soils is also necessary, in order to fully evaluate the potential risks of groundwater contamination. Such investigations will also provide a measure of the potential adverse effects (if any) to indigenous biota, and to local people who utilize turfed retention ponds for recreational purposes during dry season conditions.

Information of this nature is important for future improvement and modification of current management practices for the retention and recharge of urban stormwater (Nightingale 1987).

A final comment is reserved here for the surface water quality standards currently in place in Guam for heavy metals (Table 7). We note that these standards represent total metal concentrations (i.e., the sum of the dissolved and particulate fractions) and are modeled on those established by the U.S. EPA (Federal Register 1992). We wish to point out, however, that total metal concentrations may be misleading with respect to toxicity because not all the metal is in a form that is available to the biological population. Free metal ions and weak inorganic complexes tend to be the most bioavailable forms and hence the most toxic to aquatic life. This is especially important with regards to stormwater runoff where, generally speaking, only a small portion of the total metal concentration is in the bioavailable form (Yousef *et al* 1985, Makepeace *et al.* 1995).

PHASE III: TEMPORAL VARIATIONS IN STORM DRAIN WATER QUALITY

Water samples were intermittently collected by autosampler from the stormwater drain outlet, beneath the police koban in the Jonestown area of Tamuning (Fig. 2), from June 30 to September 15, 1995. During this period, 20 batches of samples were removed for analysis. The number of bottles in each batch ranged from 8-24 with an overall average of 19. The elapsed times between the first and last sample bottle filled by the autosampler were mostly around 24 h. The rainfall data gathered for July, August and September are presented in Figs. 6-8. Average values for the same periods for the National Weather service rain gage at the Naval Air Station (NAS) are also provided. The July rainfall recorded at the Koban was 40% lower than normal for the same period at NAS. The August rainfall recorded at the Koban was 12% lower than normal at NAS. The September rainfall recorded at the Koban was 27% higher than normal for the same period at NAS. All rainfall and analytical data were brought together into a common Excel© spread sheet files for statistical analysis and graphical interpretation. The principal findings of this portion of the investigation are discussed below.

Overall Assessment:

All samples consistently contained detectable quantities of NO_3, PO_4, Ca, Mg, Na, Cu and Zn. The data sets for each of these components are presented as bar graphs and arranged in chronological order in Appendix A. They are summarized here in Figs. 9-15 as the geometric mean and range of concentrations determined at each sampling event. Superimposed upon these data sets are the overall geometric mean concentrations derived from all samples obtained over the entire study period. The geometric mean is the preferred measure of central tendency here because it eliminates or at least minimizes the influence of extreme values. Also, pollutant levels in storm events are generally considered to follow log-normal distributions (U.S. EPA, 1983, Harremoes 1988, Yousef *et al.* 1990).

In reviewing the overall means, we note that the values for NO_3-N, o-PO_4-P, Na, Cu and Zn are at least a factor of two higher than their respective mean estimates for unfiltered stormwater retention site waters examined during Phase II (Table 3), whereas overall mean levels for Ca and Mg were approximately the same. The greatest difference was for o-PO_4-P which had an overall mean value approximately 19 times higher than that determined for the stormwater retention sites.

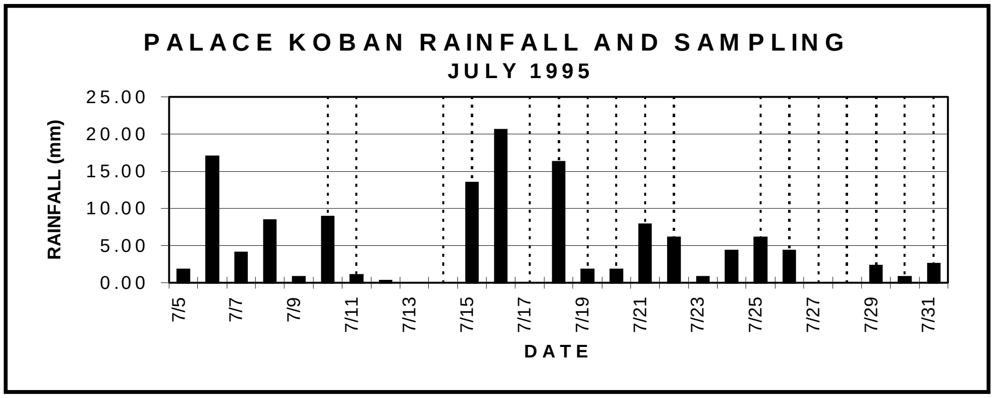


Figure 6. Daily rainfall recorded at police koban during July. Total rainfall for July 5-31 at koban site = 138 mm. Average rainfall for July 5–31 at NAS rain gage (1956-1995) = 229 mm. Dashed vertical lines indicate days on which samples were collected

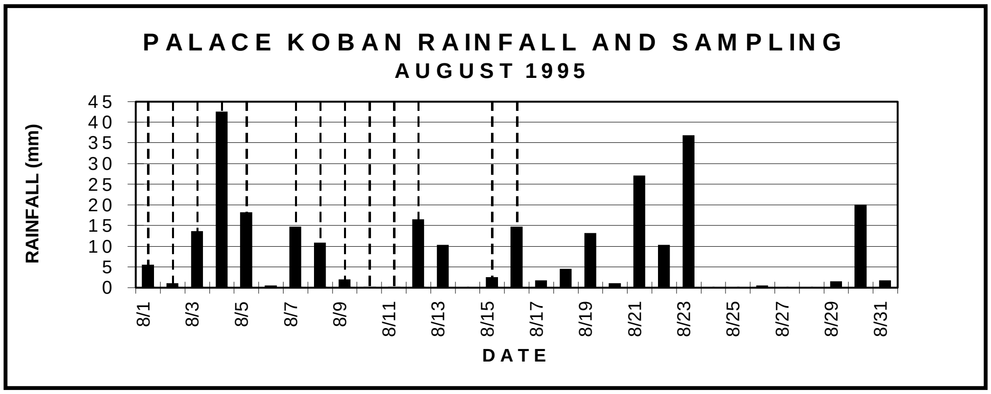


Figure 7. Daily rainfall recorded at police koban during August. Total rainfall for August at koban site = 282 mm. Average rainfall for August at NAS rain gage (1956-1995) = 323 mm. Dashed vertical lines indicate days on which samples were collected

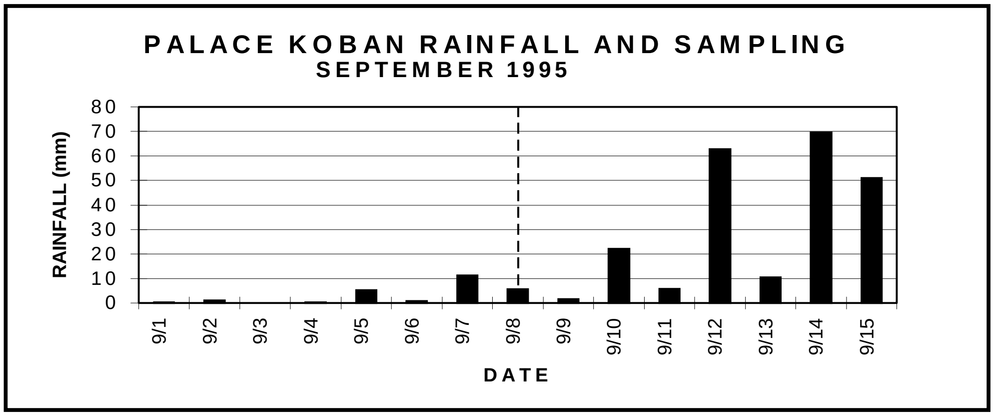
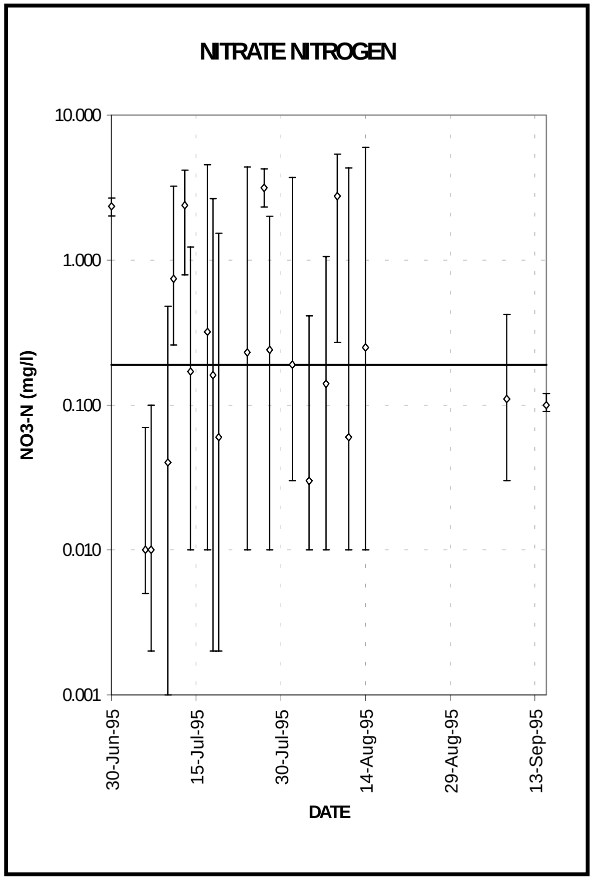


Figure 8. Daily rainfall recorded at police koban during September. Total rainfall for September 1-15 at koban site = 248 mm. Average rainfall for September 1-15 at NAS rain gage (1956-1995) = 195 mm. Dashed vertical line indicates the day on which samples were collected



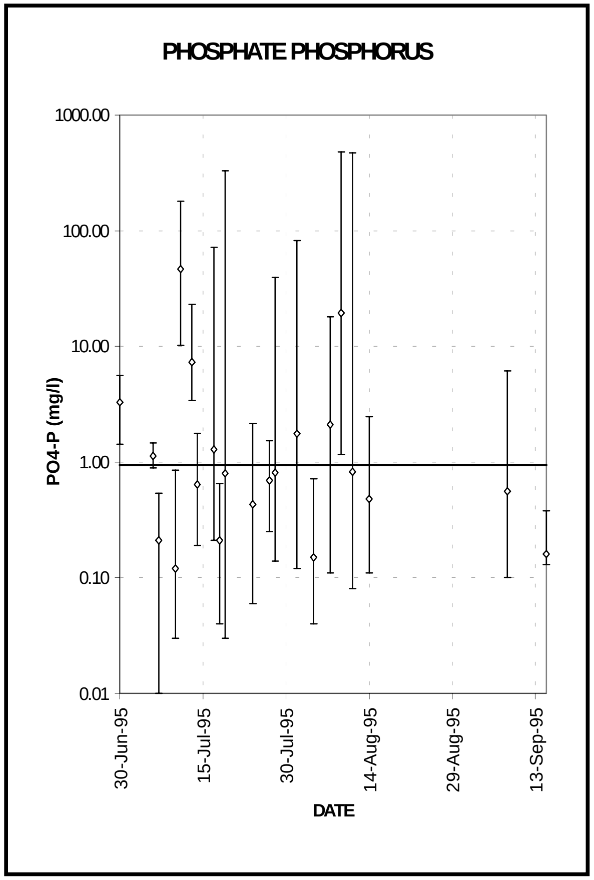


Figure 9. Nutrient levels (mg/l) recorded in unfiltered runoff samples during Phase III. The data sets are summarized as concentration ranges and geometric means superimposed upon the overall geometric mean (solid horizontal line) for the entire study period.

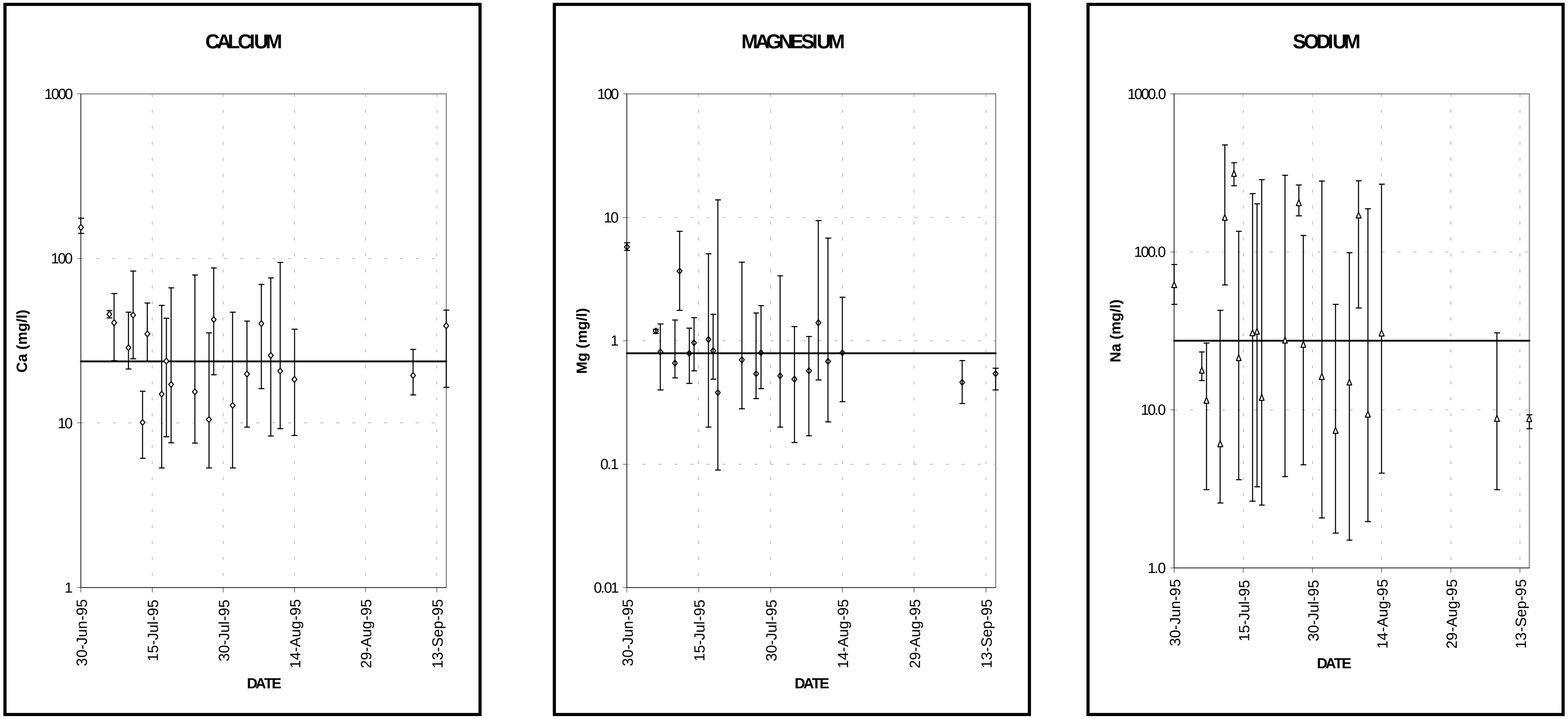
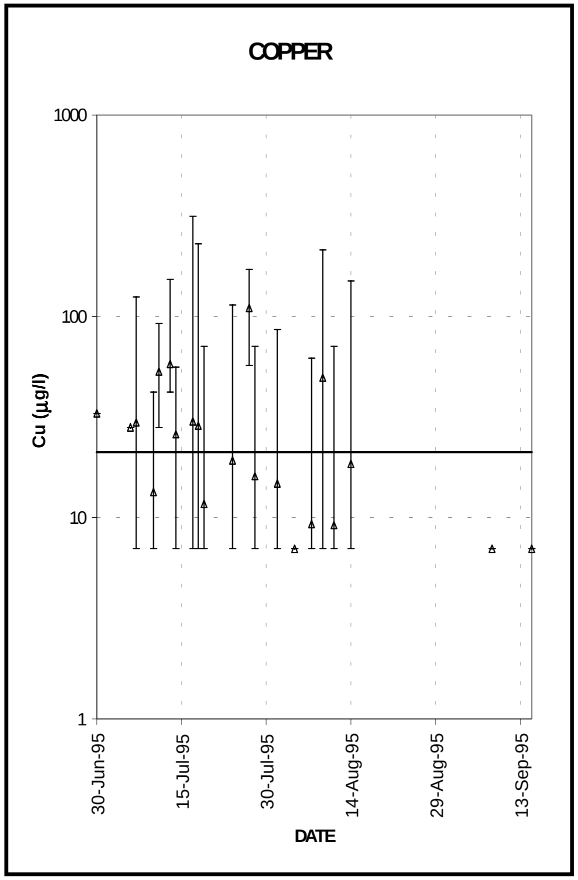


Figure 10. Major ion levels (mg/l) recorded in unfiltered runoff samples during Phase III. The data sets are summarized as concentration ranges and geometric means superimposed upon the overall geometric mean (solid horizontal line) for the entire study period.



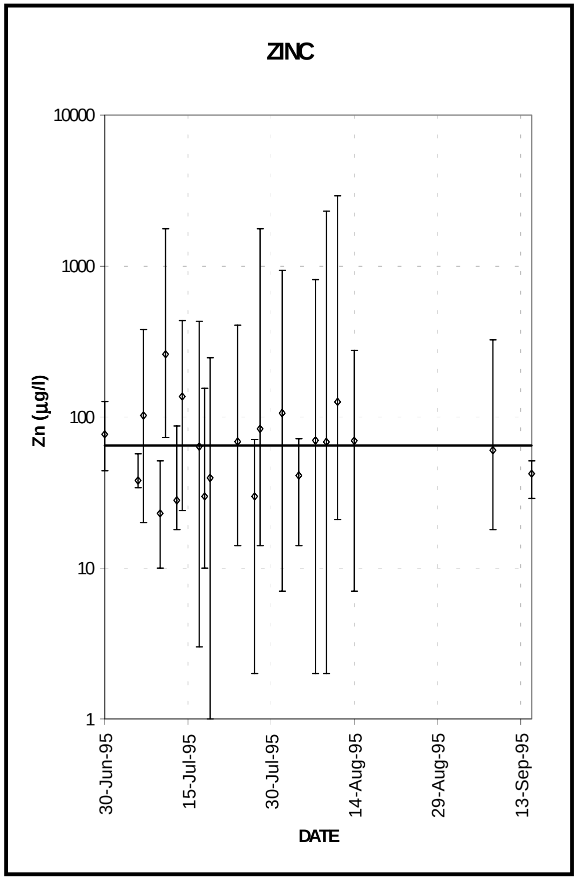


Figure 11. Heavy metal levels (µg/l) recorded in unfiltered runoff samples during Phase III. The data sets are summarized as concentration ranges and geometric means superimposed upon the overall geometric mean (solid horizontal line) for the entire study period.

Storm vs. Nonstorm Sampling Events:

One of the major benefits of an automated sampling system is that it permits the analyst to segregate or integrate samples collected over predetermined periods. In our study, emphasis was placed upon isolating "first flush" and residual samples over an approximate 5 h period of continuous rain, or longer in the event of showers of shorter duration. The collection of synchronous rainfall data also permitted us to determine the depth and duration of such storm events over the sampling period.

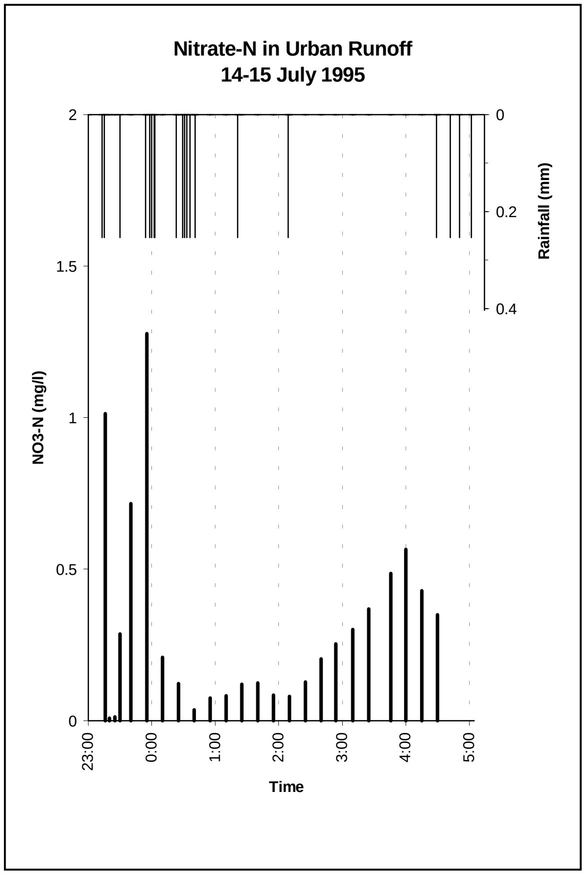
A typical example of this type of data is presented in Figs. 12-14 for samples collected during a storm event on July 14-15. In this particular instance, there is a clear distinction between the chemical composition of the first flush and subsequent samples. In most cases, levels were appreciably higher in runoff collected during the first 20-30 minutes of storm activity. The notable exception was for Zn, which did not peak until about 2 hours later. Differential mobilization rates between soluble and particulate bound contaminants, their source characteristics, and traveling distance to the point of collection are all-important factors that could possibly have accounted for this. Certainly, the temporal profiles shown for each component suggests that they were derived from multiple sources.

Occasionally, the autosampler was triggered by nonstorm events. These were readily identified by cross-referencing sampling times with rainfall data recorded by the data logger. The activities associated with these events are unknown. Likely possibilities include landscape irrigation, the washing of motor vehicles, and general cleaning operations. In point of interest, we noted that the sampling times associated with such events were not confined to normal working hours. In fact, 51% occurred between 6:00 PM and 8:00 AM. In addition, their frequency and duration of occurrence was not random, but orderly and generally happened in short bursts of an hour or so. Furthermore, 40% of such events occurred within a four-hour time slot between 10-12 midnight and 10-12 noon.

An example of this kind of data is shown in Figs. 15-17. Clearly illustrated, are three nonstorm induced sampling events of relatively short duration that occurred at regular intervals on July 13, 1995, between the hours of 12 noon and 12 midnight. In this particular instance, high levels of nutrients (especially o-PO_4) and Na are observed, together with mild enrichments of Cu and Zn.

Another example of this kind of data is shown in Figs. 18-20 for samples collected August 9-11. In this case, the temporal profiles are represented by five discrete pulses of approximately one hour duration over a 28 hour period. Extremely high concentrations of PO_4 were present in the first few samples taken. Levels of Mg, Zn were also very high initially while NO_3, Na and Cu generally showed mild to moderate enrichment in all samples collected.

Finally, Figs. 21-23 illustrate an occasion when sampling was triggered by both storm and nonstorm events. In this example, 23 samples were collected on July 29-30. Examination of the cumulative rainfall data presented shows that two of these samples were taken completely independently of any storm activity. Both showed little chemical enrichment in stark contrast to the previous examples described above. The last storm event, however, produced very high levels of PO_4 in the first sample taken.



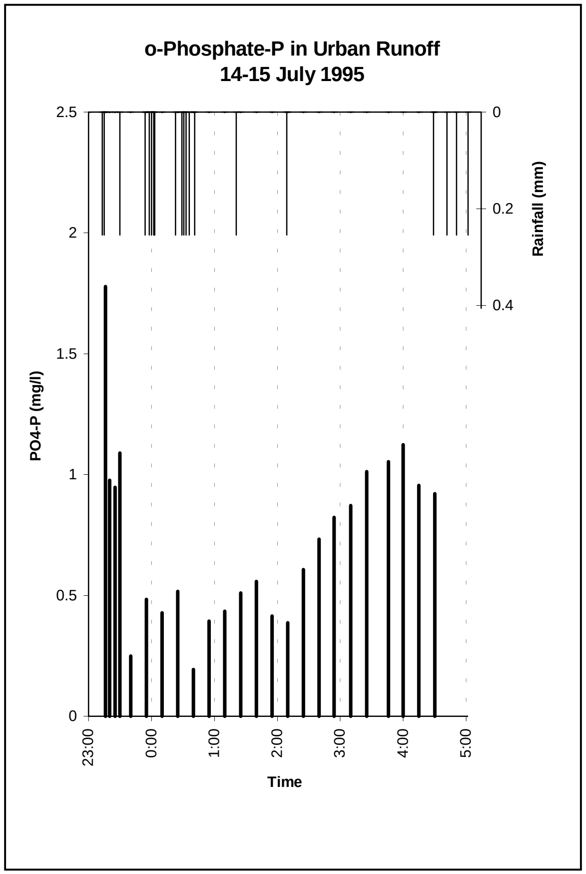


Figure 12. Nutrient levels (mg/l) recorded in unfiltered runoff samples during Phase III: July 14-15.

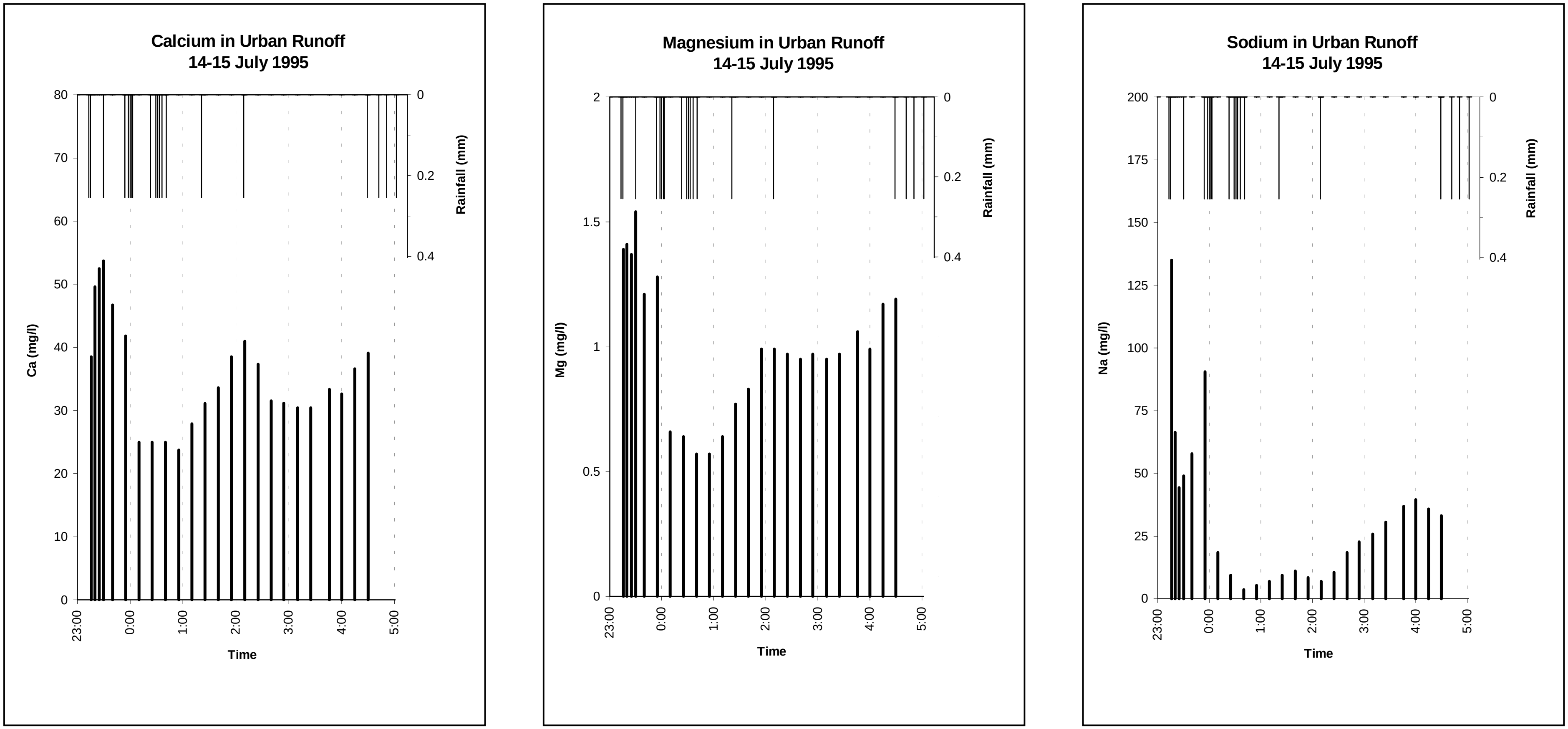
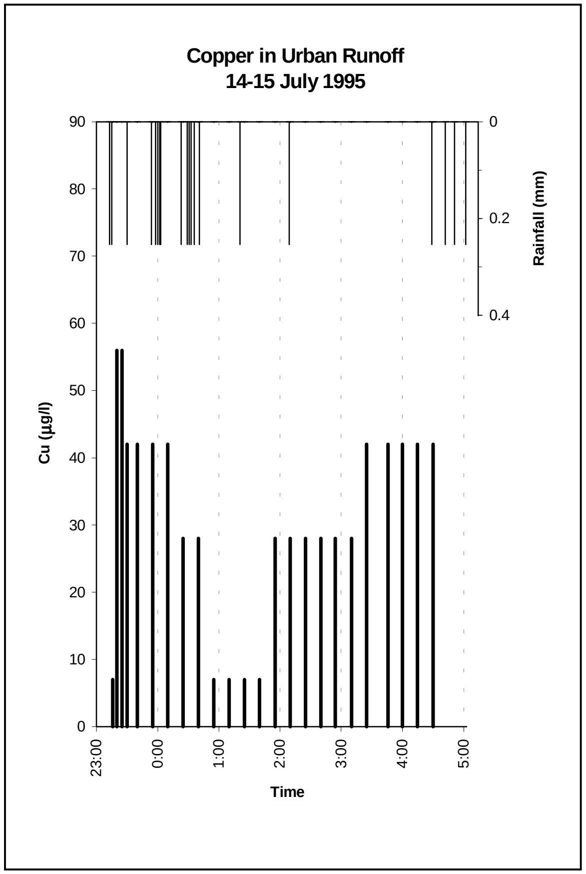


Figure 13. Major ion levels (mg/l) recorded in unfiltered runoff samples during Phase III: July 14-15.



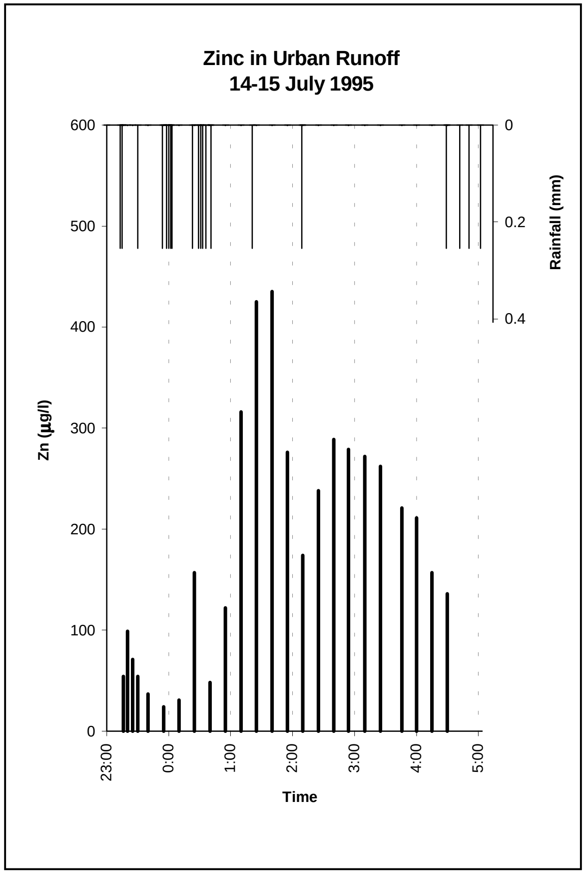


Figure 14. Heavy metal levels (µg/l) recorded in unfiltered runoff samples during Phase III: July 14-15.

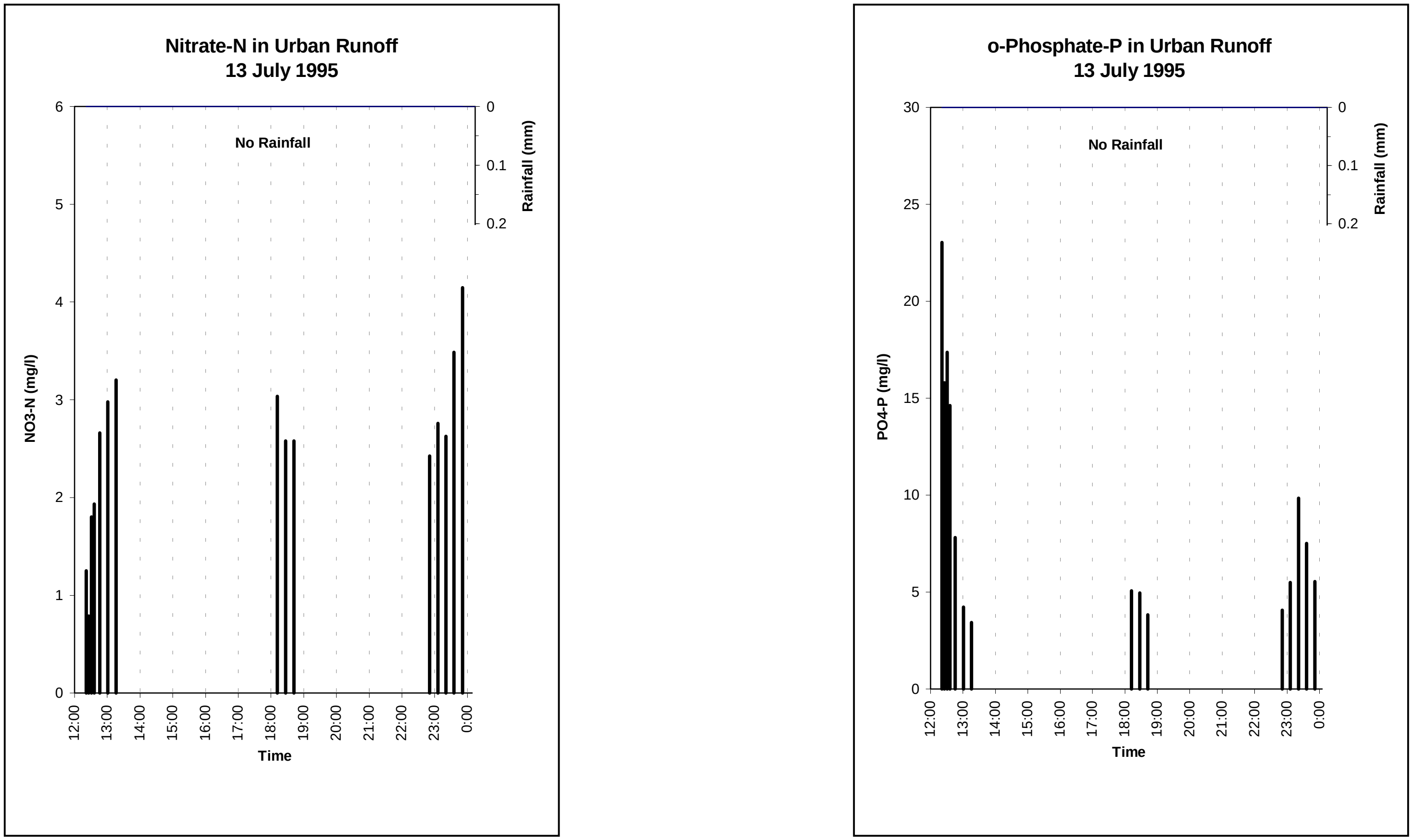


Figure 15. Nutrient levels (mg/l) recorded in unfiltered runoff samples during Phase III: July 13.

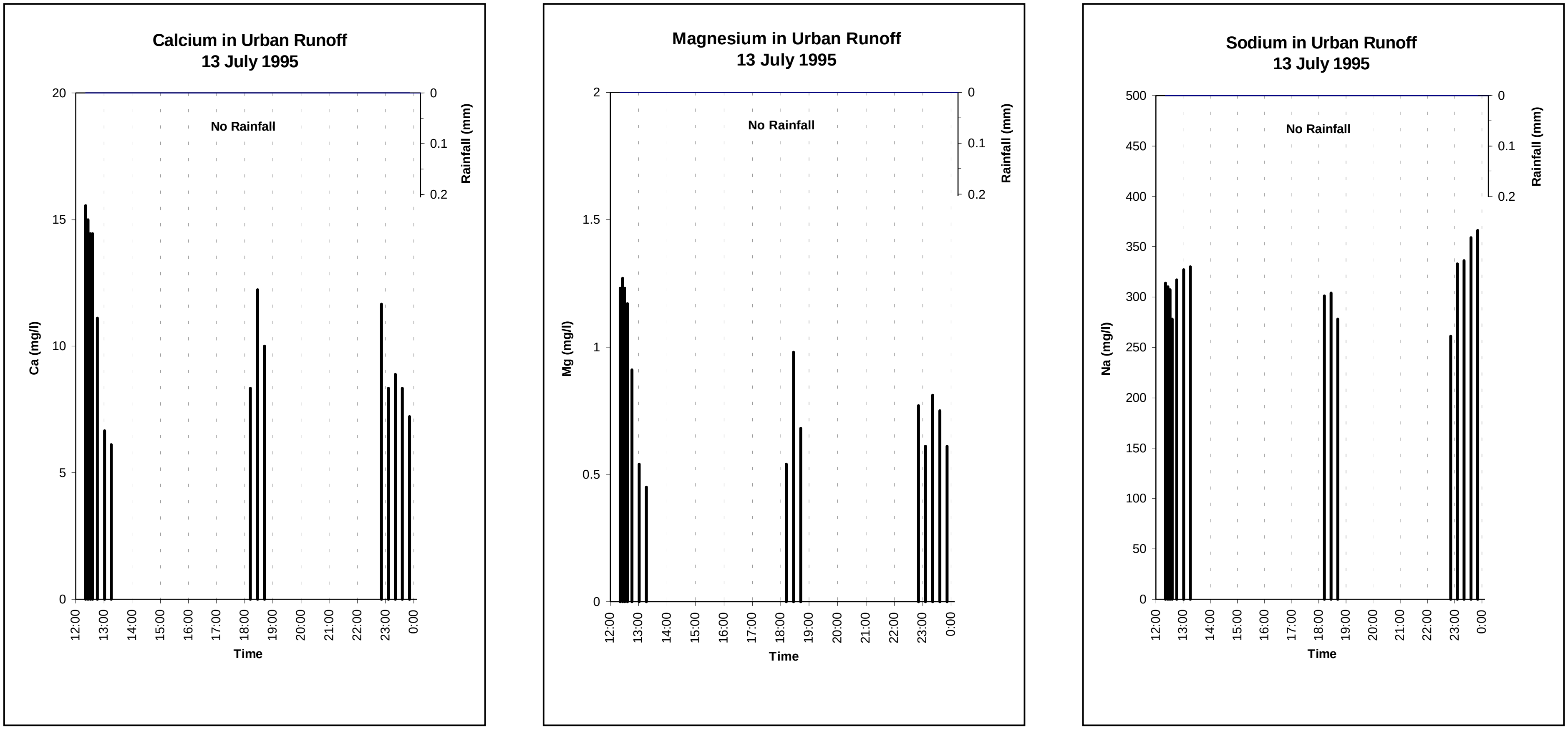


Figure 16. Major ion levels (mg/l) recorded in unfiltered runoff samples during Phase III: July 13.

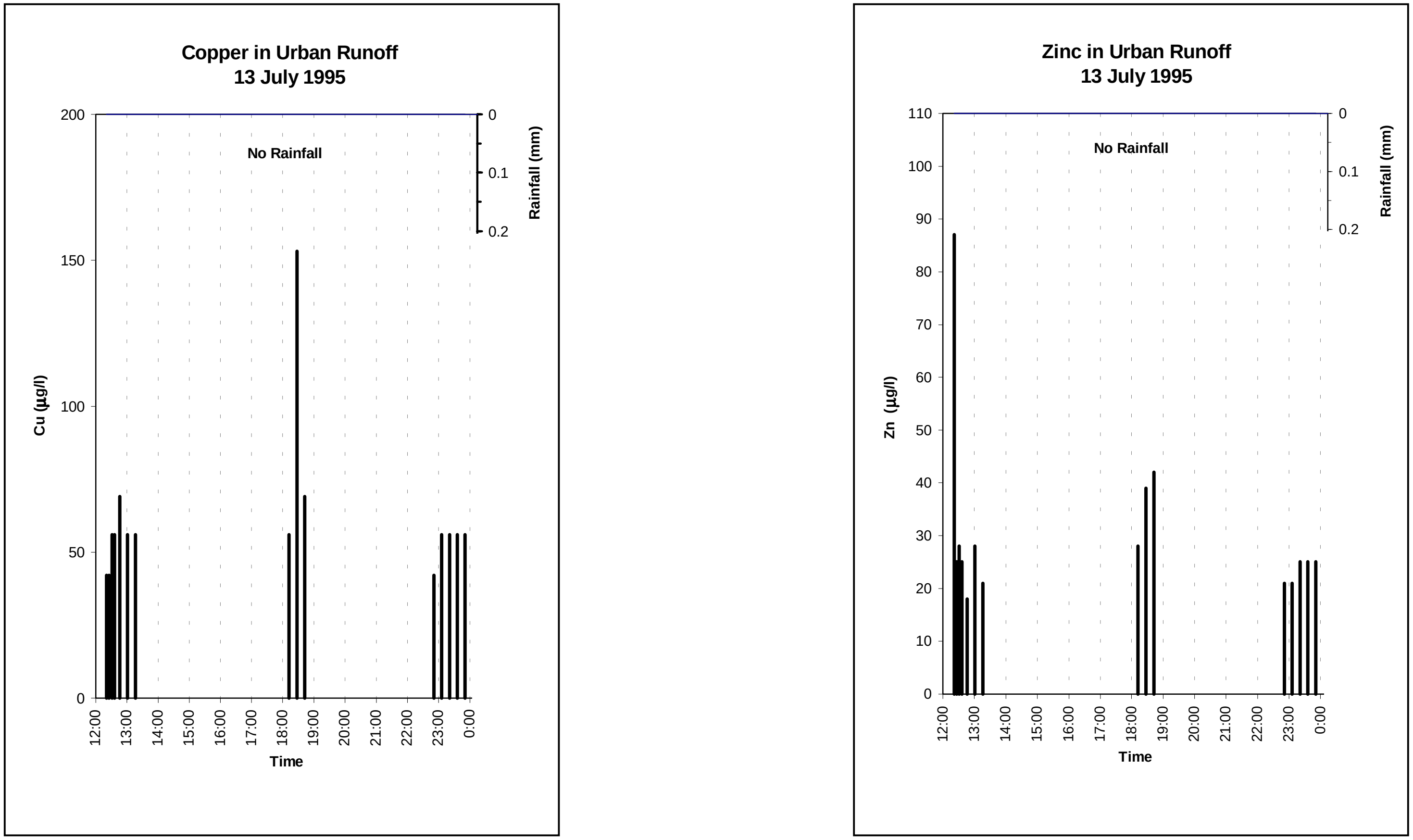


Figure 17. Heavy metal levels (µg/l) recorded in unfiltered runoff samples during Phase III: July 13.

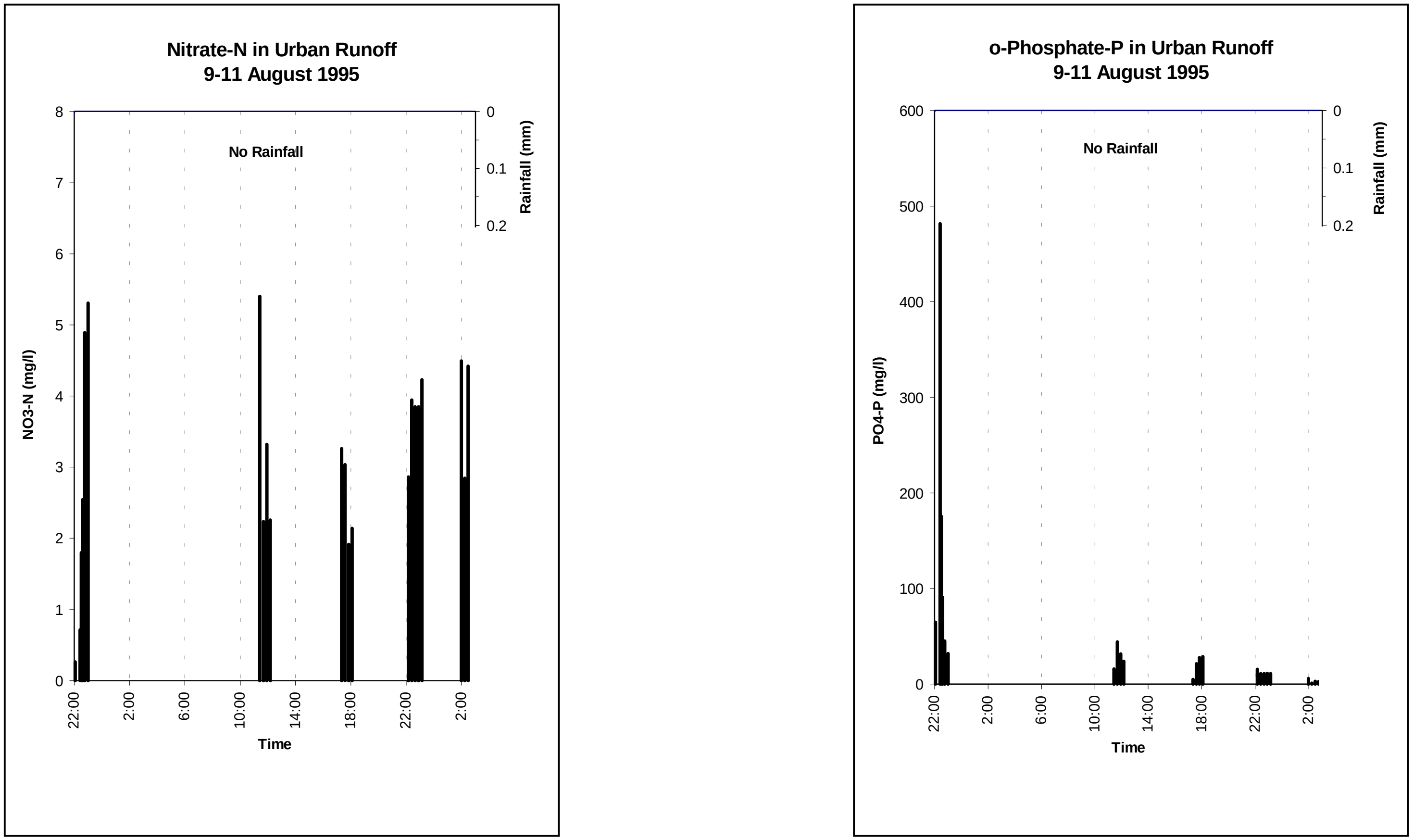


Figure 18. Nutrient levels (mg/l) recorded in unfiltered runoff samples during Phase III: August 9-11.

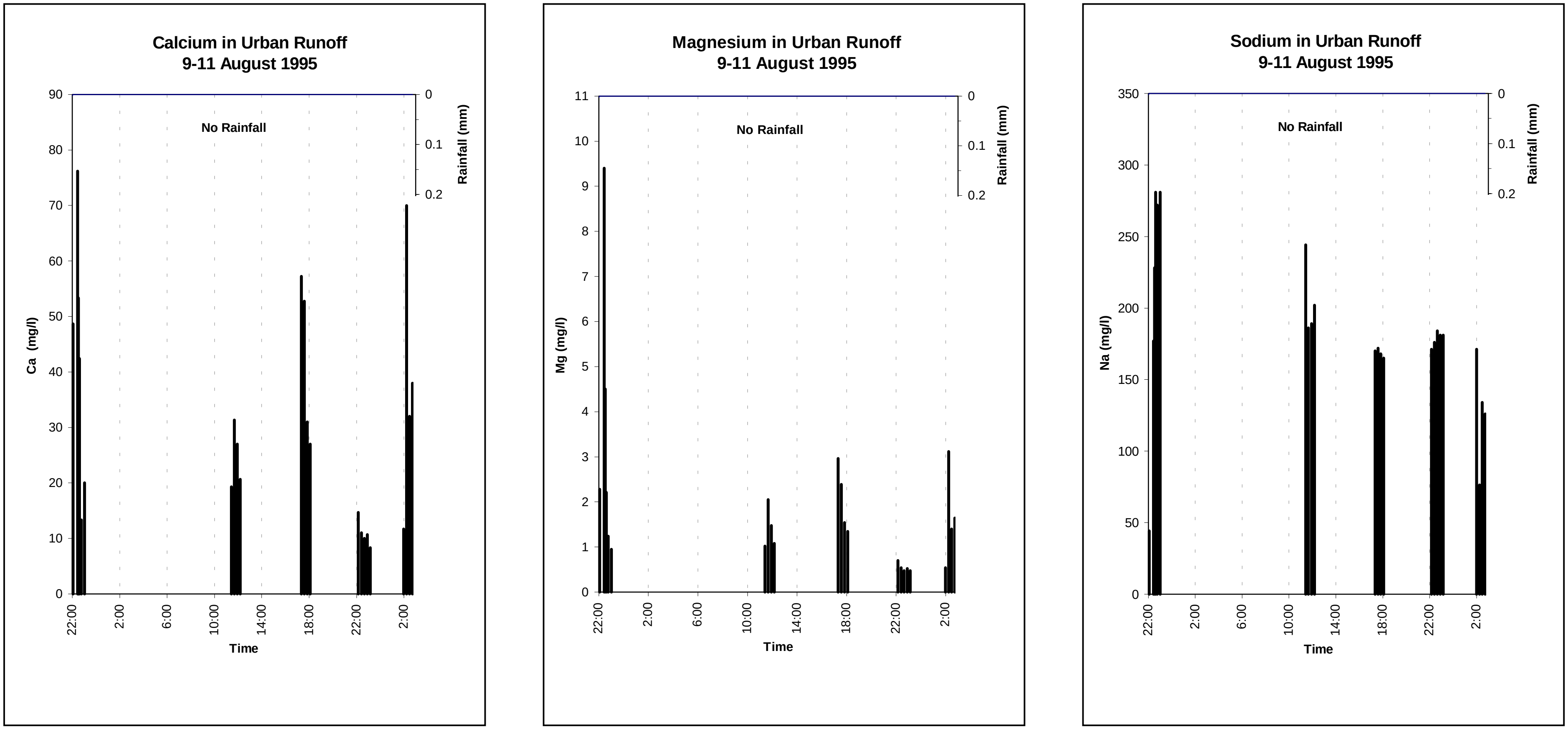


Figure 19. Major ion levels (mg/l) recorded in unfiltered runoff samples during Phase III: August 9-11.

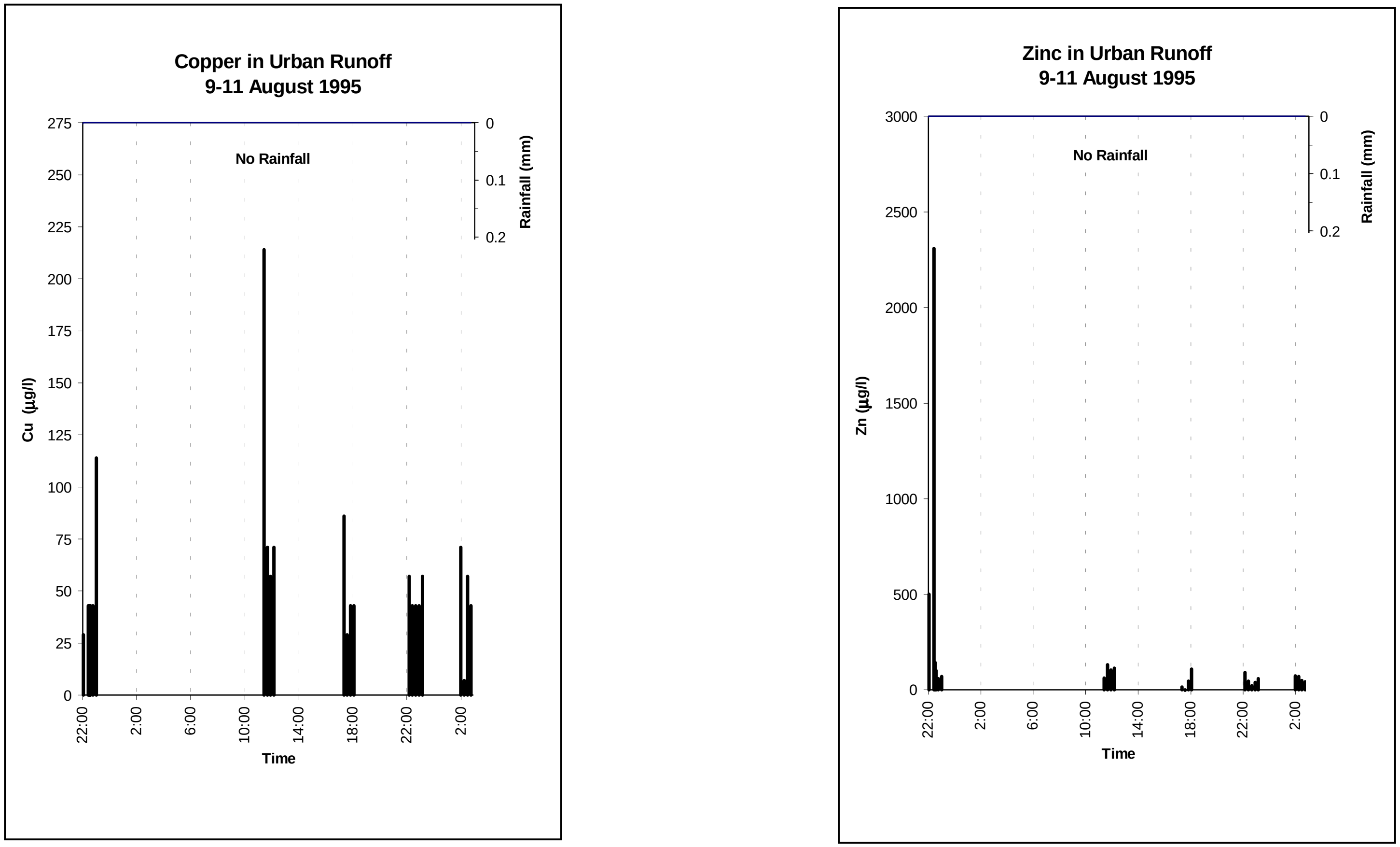


Figure 20. Heavy Metal levels (mg/l) recorded in unfiltered runoff samples during Phase III: August 9-11.

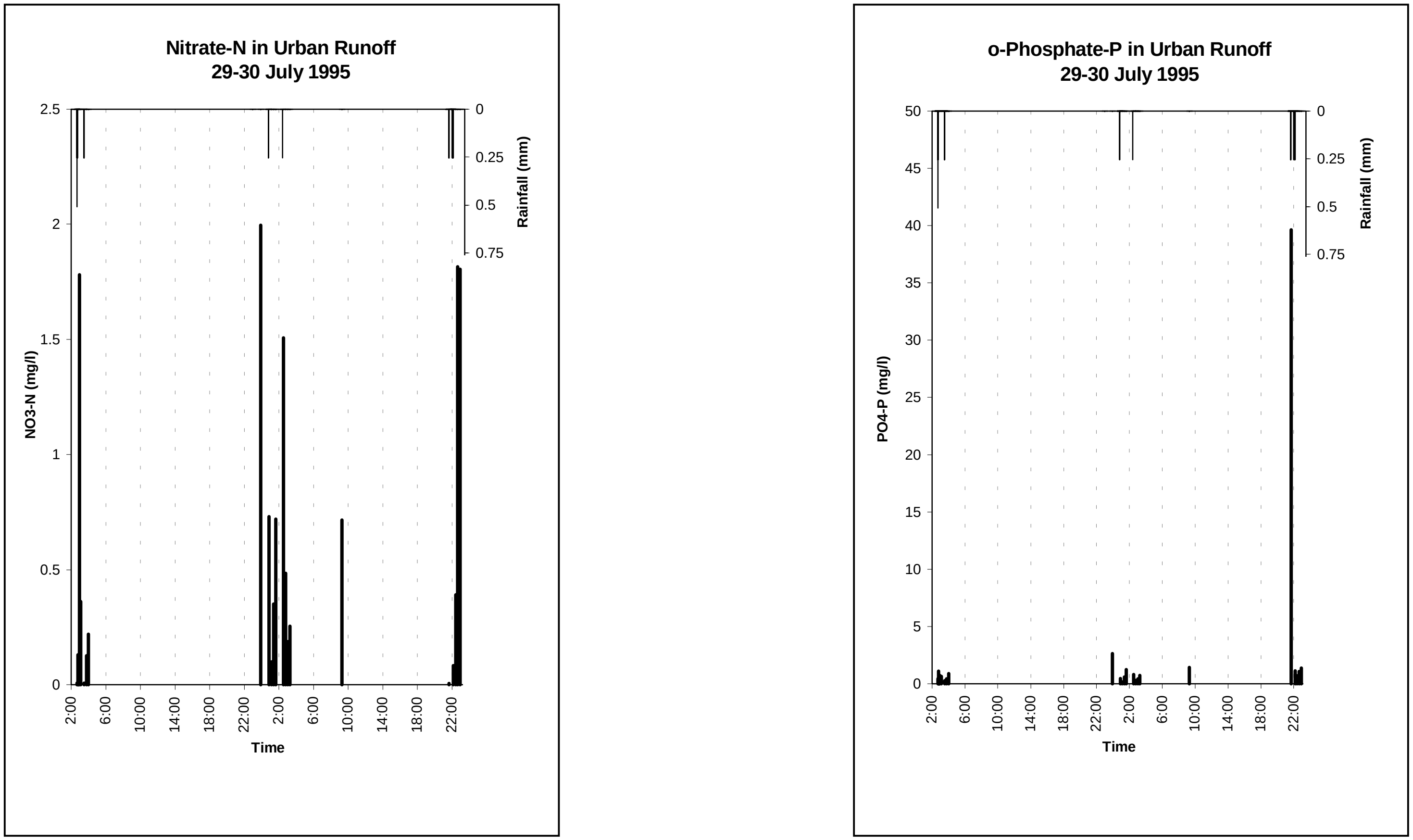


Figure 21. Nutrient levels (mg/L) recorded in unfiltered runoff samples during Phase III: July 29-30.

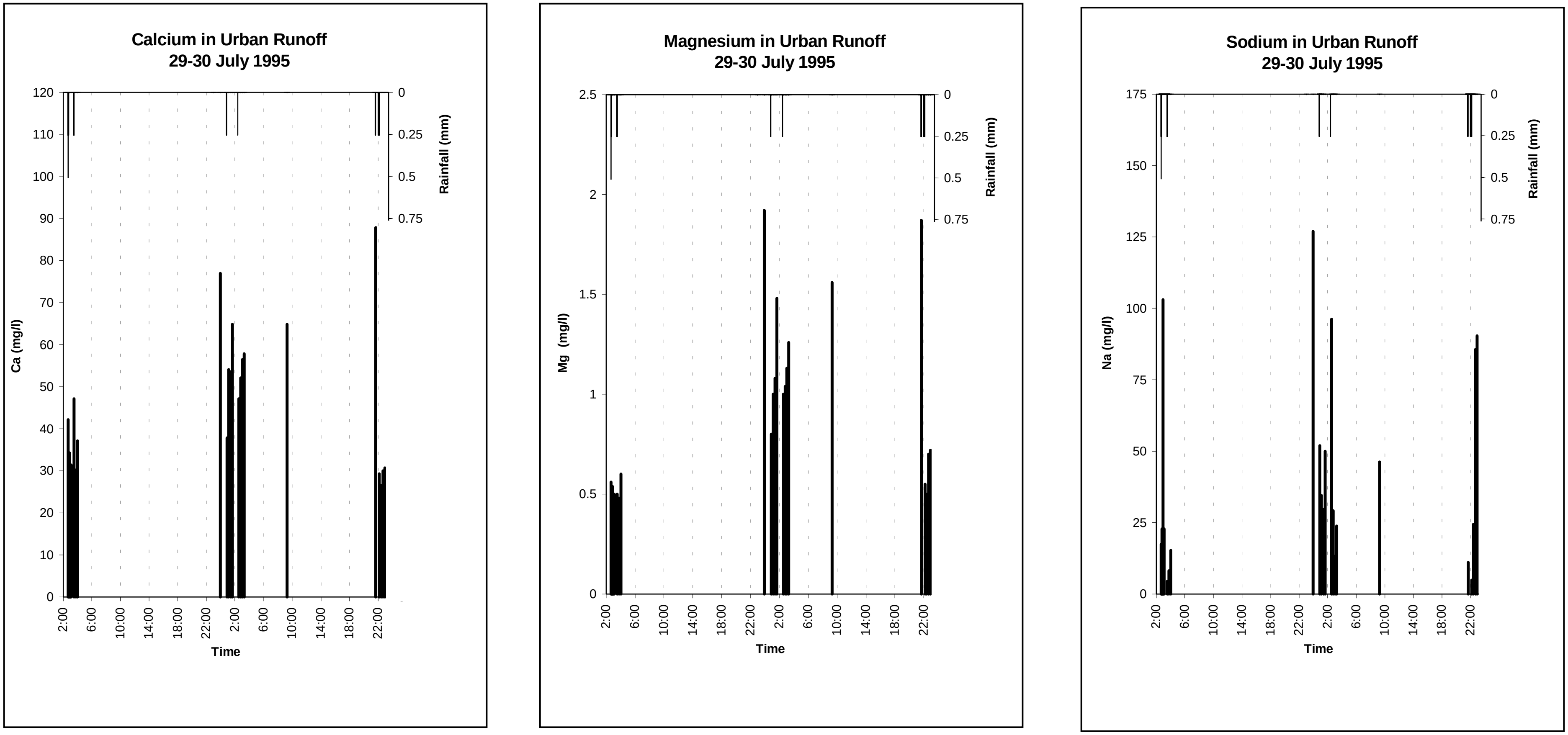


Figure 22. Major ion levels (mg/l) recorded in unfiltered runoff samples during Phase III: July 29-30.

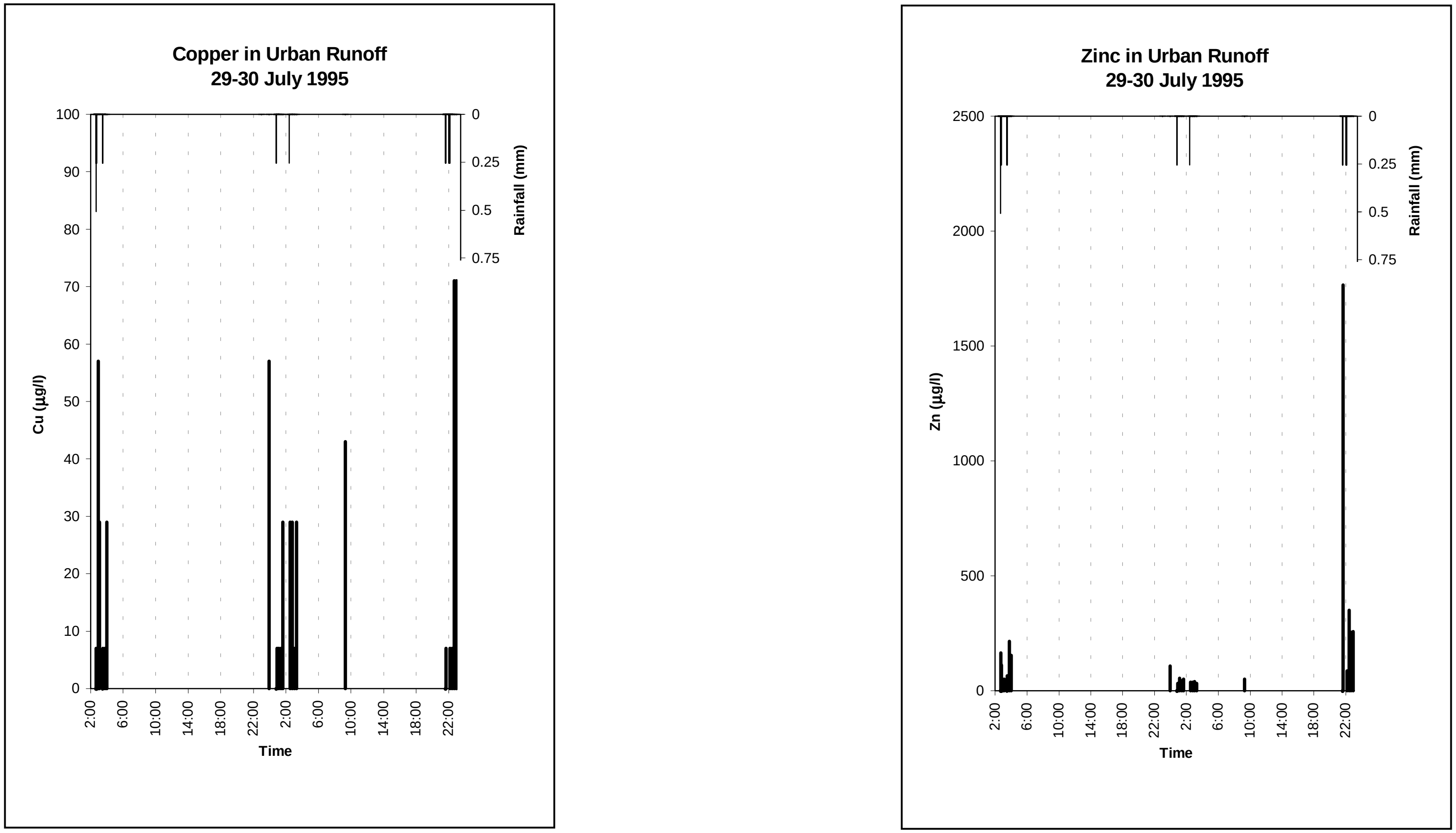


Figure 23. Heavy metal levels (mg/l) recorded in unfiltered runoff samples during Phase III: July 29-30.

The raw data sets obtained during the course of this study are included in Appendix B. They are summarized here in Tables 8 and 9 for unfiltered and filtered water samples respectively. The summarized data sets within each table are categorized into storm and obvious nonstorm induced sampling events. Also included within each category, are the overall means for the chemical components listed. It is clear from these values that NO_3, PO_4, Ca, Mg and Na were generally higher in the nonstorm induced samples, while overall levels of Ca and Zn were very similar in both categories. The high contaminant levels occasionally recorded during storm events no doubt reflects catchment washoff of residual amounts deposited during the nonstorm events.

Differences between filtered and non filtered samples indicated that >90% of the total o-PO_4-P, Ca and Mg, Ca were in the dissolved state in all samples. In contrast, the relative proportions of each fraction were much more variable for Cu and Zn although the dissolved forms of each element generally predominated. This supports the earlier findings of Morrison *et al.* (1984) that Cu and Zn generally tend to be associated with dissolved solids in urban runoff. However, under certain conditions both elements have a relatively high affinity for suspended particles and colloidal materials (Harrison and Wilson 1985b, Makepeace *et al.* 1995).

Contaminant Sources:

The primary contaminant identified during the course of this work was o-PO_4. Probable sources of this compound at the Palace Hotel were thought to be detergents (used in car washing and other cleaning operations) and fertilizers (applied to landscaped areas). The relative merits of each are discussed below.

Detergents:

Detergents are relatively complex mixtures of chemicals. Aside from the basic surfactants, they contain "builders" whose job it is to prolong the life of the surfactant by preventing its inactivation or precipitation by the elements responsible for "hardness."

Until a few years ago, the principal builders in laundry detergent were sodium tripolyphosphate ($Na_5P_3O_{10}$) and sodium pyrophosphate ($Na_4O_7P_2$). Often they accounted for almost half the weight of a detergent product (Booman *et al.* 1988). Both compounds are readily converted to o-PO_4 in the environment and were include in detergent formulations from the end of WWII until the mid to late 60's. At about this time it was discovered that wastewaters containing phosphate detergents were responsible for the nutrient enrichment and eutrophication witnessed in many lakes, rivers and streams throughout the world.

As a result of these findings, phosphate builders have largely been replaced by sodium carbonate (Na_2CO_3), sodium sulfate (Na_2SO_4) and sodium silicate (Na_2SiO_3). In fact, phosphate detergents are now banned from sale in many areas of the world including Guam. Modern day liquid and granular detergents sold locally all carry claims that P is not used during the manufacturing process and that incidental amounts total less than 0.5% of the product weight. At best then, wastewater from cleaning operations in this part of the world is unlikely to contain P levels that exceed 5 μg/l - almost two orders of magnitude lower than the maximum o-PO_4-P values determined here. It therefore seems unlikely that detergents were the primary

Table 8

Temporal Variability of Nutrients, Major Ions and Heavy Metals* in Unfiltered Urban Runoff from the Palace Hotel, Tamuning, Guam

[Data sets are expressed as geometric mean and (range)]

Date	# Samples	NO_3-N (mg/l)	o-PO_4 (mg/l)	Na (mg/l)	Ca (mg/l)	Mg (mg/l)	Zn (ug/l)	Cu (ug/l)
STORM INDUCED SAMPLING EVENTS:								
6-Jul-95 **	8	0.01 (0.005-0.07)	1.13 (0.89-1.46)	17.8 (15.3-23.3)	45.8 (43.5-48.1)	1.20 (1.15-1.24)	37.9 (34.0-57.0)	28.0 (28.0-28.0)
7-Jul-95 **	22	0.01 (0.002-0.10)	0.21 (0.01-0.54)	11.5 (3.12-26.5)	40.7 (24.0-61.1)	0.81 (0.40-1.37)	102 (20.0-378)	29.7 (7.00-125)
10-Jul-95	14	0.04 (0.001-0.48)	0.12 (0.03-0.85)	6.12 (2.58-42.6)	28.7 (21.3-47.1)	0.66 (0.50-1.47)	23.0 (10.0-51.0)	13.4 (7.00-42.0)
14-15-Jul-95	24	0.17 (0.01-1.28)	0.64 (0.19-1.78)	21.4 (3.61-135)	34.7 (23.8-53.7)	0.96 (0.57-1.54)	137 (24.0-435)	25.9 (7.00-56.0)
17-18-Jul-95	9	0.07 (0.01-0.45)	0.46 (0.21-1.02)	7.75 (2.64-35.6)	9.35 (5.33-17.1)	0.44 (0.20-1.26)	31.9 (3.00-85.0)	8.56 (7.00-43.0)
19-21-Jul-95	24	0.06 (0.002-1.53)	0.80 (0.03-330)	12.0 (2.50-286)	17.2 (7.60-66.1)	0.38 (0.09-13.8)	39.4 (1.00-247)	11.7 (7.00-71.0)
24-25-Jul-95	14	0.04 (0.01-0.51)	0.27 (0.06-2.16)	7.75 (3.77-55.1)	12.3 (7.55-21.0)	0.50 (0.28-1.08)	71.7 (14.0-407)	10.5 (7.00-29.0)
29-30-Jul-95	21	0.20 (0.01-1.82)	0.74 (0.14-39.6)	23.5 (4.48-103)	40.5 (19.7-87.8)	0.74 (0.41-1.87)	84.4 (14.0-1766)	14.5 (7.00-71.0)
1-3-Aug-95	24	0.19 (0.03-3.72)	1.76 (0.12-81.9)	16.3 (2.07-280)	12.8 (5.33-47.2)	0.52 (0.20-3.36)	106 (7.00-934)	14.8 (7.00-86.0)
4-6-Aug-95	24	0.03 (0.01-0.41)	0.15 (0.04-0.72)	7.40 (1.66-46.4)	19.8 (9.45-41.7)	0.49 (0.15-1.30)	40.9 (14.0-72.0)	7.00 (7.00-7.00)
7-9-Aug-95	14	0.13 (0.02-1.06)	1.02 (0.11-3.28)	12.0 (1.50-61.6)	33.7 (16.2-62.0)	0.44 (0.17-0.88)	44.5 (2.00-121)	8.18 (7.00-62.0)
11-12-Aug-95	20	0.04 (0.01-1.11)	0.46 (0.08-0.91)	6.53 (1.96-69.8)	19.3 (9.26-29.2)	0.58 (0.22-0.95)	111 (21.0-607)	7.00 (7.00-7.00)
14-15-Aug-95	15	0.06 (0.01-0.63)	0.23 (0.11-1.96)	11.2 (3.97-41.6)	16.8 (9.47-25.5)	0.67 (0.32-1.12)	65.8 (7.00-276)	7.00 (7.00-7.00)
8-Sep-95	11	0.11 (0.03-0.42)	0.56 (0.10-6.15)	8.85 (3.12-30.8)	19.4 (14.8-28.0)	0.46 (0.31-0.69)	60.3 (18.0-324)	7.00 (7.00-7.00)
OVERALL	**244**	**0.06 (0.001-3.72)**	**0.46 (0.01-330)**	**11.7 (1.50-286)**	**22.7 (5.33-87.8)**	**0.60 (0.09-13.8)**	**65.7 (1.00-1760)**	**12.7 (7.00-125)**
NONSTORM INDUCED SAMPLING EVENTS:								
30-Jun-95 ***	12	2.35 (2.01-2.68)	3.30 (1.43-5.58)	62.1 (46.4-83.1)	154 (142-175)	5.74 (5.38-6.22)	76.8 (44.0-127)	33.0 (33.0-33.0)
11-Jul-95 **	14	0.74 (0.26-3.24)	46.5 (10.2-180)	165 (61.7-475)	45.2 (24.6-83.9)	3.66 (1.76-7.69)	260 (73.0-1771)	53.1 (28.0-92.0)
13-Jul-95	15	2.38 (0.79-4.15)	7.31 (3.42-23.0)	313 (261-366)	10.1 (6.11-15.6)	0.79 (0.45-1.27)	28.0 (18.0-87.0)	58.1 (42.0-153)
17-18-Jul-95	7	2.18 (0.59-4.54)	4.77 (0.27-71.8)	180 (56.9-234)	27.4 (9.00-51.8)	3.00 (1.64-5.08)	154 (47.0-429)	160 (86.0-314)
18-19-Jul-95	14	0.16 (0.002-2.64)	0.21 (0.04-0.65)	31.4 (3.26-201)	23.8 (8.23-43.4)	0.83 (0.49-1.64)	29.8 (10.0-155)	28.7 (7.00-229)
26-Jul-95	10	3.07 (1.82-4.38)	0.86 (0.07-1.92)	163 (33.6-305)	21.5 (9.16-79.3)	1.14 (0.48-4.33)	64.7 (36.0-171)	45.3 (7.00-114)
27-Jul-95	24	3.14 (2.32-4.26)	0.69 (0.25-1.53)	205 (169-265)	10.5 (5.33-35.3)	0.54 (0.34-1.68)	29.8 (2.00-71.0)	110 (57.0-171)
29-30-Jul-95	2	1.19 (0.72-2.00)	1.93 (1.42-2.61)	76.6 (46.3-127)	70.6 (64.9-76.9)	1.73 (1.56-1.92)	73.1 (50.0-107)	49.5 (43.0-57.0)
7-9-Aug-95	7	0.15 (0.01-1.05)	9.00 (1.82-18.0)	23.5 (9.54-98.5)	58.3 (50.5-69.5)	0.96 (0.82-1.08)	174 (24.0-815)	12.0 (7.00-46.0)
9-11-Aug-95	23	2.75 (0.27-5.4)	19.4 (1.16-482)	171 (44.2-281)	25.7 (8.33-76.2)	1.40 (0.48-9.40)	68.0 (2.0-2308)	49.6 (7.00-214)
11-Aug-95	3	1.22 (0.49-4.30)	40.9 (6.92-470)	107 (47.9-187)	32.5 (11.6-94.3)	2.03 (0.76-6.77)	307 (45.0-2910)	55.8 (43.0-71.0)
14-15-Aug-95	9	2.56 (0.36-5.97)	1.55 (0.78-2.46)	163 (41.6-268)	21.3 (8.42-37.2)	1.07 (0.37-2.25)	76.5 (47.0-207)	94.0 (50.0-150)
OVERALL	**140**	**1.51 (0.002-5.97)**	**3.53 (0.04-482)**	**128 (3.26-475)**	**25.4 (5.33-175)**	**1.32 (0.34-9.40)**	**64.8 (2.00-2910)**	**54.5 (7.00-314)**

* Additionally, Ag, Cd and Cr were found to be below an analytical detection limit of 0.2, 0.5 and 4 ug/l respectively in all 384 unfiltered watersamples examined; Pb (dection limit: 3 ug/l) was found in only 8 samples, at concentrations ranging from 3-50 ug/l; Ni (dection limit: 5 ug/l) was found in only 12 samples, at concentrations ranging from 6-38 ug/l; Mn (detection limit: 10 ug/l) was found in only 15 samples, at concentrations ranging from 30-250 ug/l, and Fe (detection limit: 30 ug/l) was found in only 24 samples, at concentrations ranging from 40-370 ug/l

** Sampling times not recorded. *** Rainfall and sampling times not recorded

Table 9

Temporal Variability of Nutrients, Major Ions and Heavy Metals* in Filtered Urban Runoff from the Palace Hotel, Tamuning, Guam

[Data sets are expressed as geometric mean and (range)]

Date	# Samples	NO_3-N (mg/l)	o-PO_4 (mg/l)	Na (mg/l)	Ca (mg/l)	Mg (mg/l)	Zn (ug/l)	Cu (ug/l)
STORM INDUCED SAMPLING EVENTS:								
6-Jul-95 **	8	n.d.	1.14 (0.89-1.46)	16.9 (14.3-23.0)	44.8 (42.2-46.1)	1.20 (1.15-1.28)	21.7 (20.0-27.0)	28.0 (28.0-28.0)
7-Jul-95 **	22	n.d.	0.20 (0.01-0.53)	10.4 (2.91-20.2)	41.0 (25.0-62.0)	0.79 (0.40-1.36)	74.8 (17.0-314)	21.8 (7.00-28.0)
10-Jul-95	14	n.d.	0.11 (0.03-0.86)	5.80 (2.58-39.1)	28.4 (20.6-44.9)	0.66 (0.50-1.47)	10.5 (1.5-230)	31.2 (28.0-125)
14-15-Jul-95	24	n.d.	0.64 (0.19-1.77)	19.8 (3.51-121)	31.9 (20.7-47.1)	0.93 (0.52-1.48)	121 (18.0-388)	17.7 (7.00-42.0)
17-18-Jul-95	9	n.d.	n.d.	7.84 (2.64-31.3)	10.1 (6.00-26.0)	0.46 (0.23-1.29)	31.2 (7.00-135)	13.6 (7.00-31.0)
19-21-Jul-95	24	n.d.	n.d.	11.0 (2.32-286)	15.7 (6.52-59.3)	0.41 (0.09-13.5)	29.8 (3.00-189)	11.0 (7.00-71.0)
24-25-Jul-95	14	n.d.	n.d.	4.35 (0.41-39.1)	12.2 (7.60-21.4)	0.48 (0.28-1.11)	44.4 (4.00-366)	7.00 (7.00-7.00)
29-30-Jul-95	21	n.d.	n.d.	20.0 (4.05-89.4)	40.8 (25.8-89.1)	0.73 (0.48-1.85)	54.4 (14.0-1644)	11.6 (7.00-57.0)
1-3-Aug-95	24	n.d.	n.d.	14.0 (1.89-274)	12.4 (6.00-46.1)	0.52 (0.18-3.33)	69.3 (2.00-737)	13.5 (7.00-86.0)
4-6-Aug-95	24	n.d.	n.d.	6.58 (1.32-44.2)	18.7 (10.0-40.2)	0.49 (0.15-1.27)	32.6 (10.0-66.0)	7.00 (7.00-7.00)
7-9-Aug-95	14	n.d.	n.d.	12.8 (1.69-72.6)	34.8 (16.2-62.0)	0.45 (0.17-0.84)	27.1 (7.0-107)	8.18 (7.00-62.0)
11-12-Aug-95	19	n.d.	n.d.	5.84 (1.91-28.7)	20.0 (10.2-27.3)	0.52 (0.19-0.89)	96.9 (14.0-473)	7.00 (7.00-7.00)
14-15-Aug-95	15	n.d.	n.d.	11.2 (4.30-40.6)	15.0 (7.36-23.1)	0.68 (0.32-1.10)	43.7 (2.00-229)	7.00 (7.00-7.00)
8-Sep-95	11	n.d.	n.d.	8.33 (3.03-30.0)	19.0 (14.2-27.8)	0.47 (0.33-0.71)	39.2 (15.0-192)	7.00 (7.00-7.00)
OVERALL	**243**	**nc**	**0.33 (0.01-1.77)**	**10.4 (0.41-286)**	**22.1 (6.00-89.1)**	**0.60 (0.09-13.5)**	**46.3 (1.50-1644)**	**12.0 (7.00-125)**
NONSTORM INDUCED SAMPLING EVENTS:								
30-Jun-95 ***	12	n.d.	3.26 (1.43-5.54)	59.8 (29.1-82.6)	150 (140-159)	6.01 (5.42-10.2)	29.9 (22.0-36.0)	9.06 (7.00-33.0)
11-Jul-95 **	14	n.d.	45.4 (10.2-173)	157 (109-262)	41.7 (23.6-78.5)	3.38 (1.67-6.77)	23.3 (4.00-129)	29.2 (7.00-56.0)
13-Jul-95	15	n.d.	7.35 (3.42-23.0)	294 (245-346)	10.8 (7.22-15.6)	0.84 (0.50-1.27)	26.1 (21.0-42.0)	53.5 (42.0-139)
17-18-Jul-95	7	n.d.	n.d.	171 (53.4-226)	26.4 (9.00-52.4)	2.93 (1.62-5.04)	43.3 (7.00-159)	138 (62.0-308)
18-19-Jul-95	14	n.d.	n.d.	33.3 (3.46-210)	23.9 (8.82-43.9)	0.78 (0.45-1.63)	18.6 (3.0-135)	24.3 (7.00-214)
26-Jul-95	10	n.d.	n.d.	137 (23.9-286)	22.2 (9.68-79.0)	1.18 (0.52-4.39)	36.7 (7.00-139)	40.8 (7.00-100)
27-Jul-95	24	n.d.	n.d.	180 (154-225)	15.9 (7.84-47.2)	0.48 (0.27-1.66)	12.3 (2.00-36.0)	70.5 (29.0-143)
29-30-Jul-95	2	n.d.	n.d.	68.6 (46.3-102)	73.5 (69.6-77.7)	1.79 (1.69-1.89)	43.1 (29.0-64.0)	40.7 (29.0-57.0)
7-9-Aug-95	7	n.d.	n.d.	25.0 (10.4-113)	57.7 (51.1-66.1)	0.94 (0.70-1.08)	88.7 (4.00-608)	9.20 (7.00-46.0)
9-11-Aug-95	23	n.d.	n.d.	168 (37.9-263)	22.3 (8.00-60.5)	1.38 (0.48-9.62)	27.3 (2.00-2308)	49.6 (7.00-214)
11-Aug-95	3	n.d.	n.d.	107 (49.1-183)	33.0 (12.0-95.4)	1.90 (0.68-6.63)	265 (41.0-2858)	55.8 (43.0-71.0)
14-15-Aug-95	9	n.d.	n.d.	179 (40.6-354)	18.9 (6.84-43.4)	1.03 (0.32-2.25)	64.5 (36.0-189)	92.9 (67.0-150)
OVERALL	**140**	**nc**	**10.8 (1.43-173)**	**123 (3.46-354)**	**26.4 (6.84-159)**	**1.28 (0.27-10.2)**	**28.0 (2.00-2858)**	**40.3 (7.00-308)**

* Additionally, Ag, Cd, Cr and Pb were found to be below an analytical detection limit of 0.2, 0.5, 4 and 3 ug/l respectively in all 383 filtered water samples examined; Ni (dection limit: 5 ug/l) was found in only 11 samples, at concentrations ranging from 6-29 ug/l; Mn (detection limit: 10 ug/l) was found in only 14 samples, at concentrations ranging from 20-260 ug/l, and Fe (detection limit: 30 ug/l) was found in only 4 samples, at concentrations ranging from 65-109 ug/l.

** Sampling times not recorded. *** Rainfall and sampling times not recorded source of PO_4 identified during the current work although they may well have been a contributory source of Na.

Fertilizers:

Fertilizers are plant foods that come in a variety of physical forms and chemical formulations. They normally contain percentage quantities of one or more of the three macronutrients, N, P and K (potassium). Also commonly present in lower amounts, are the secondary elements, S (sulfur), Ca and Mg, incidental quantities of Na, and various essential trace elements, including Cu, Fe, Mn and Zn.

Most modern nitrogen fertilizers are commercially synthesized from N_2 and H_2 gases. The end products include aqueous ammonia (NH_3) and ammonium (NH_4^+). Under certain conditions, ammonia may be further oxidized to yield ammonium nitrate (NH_4NO_3). This was once a common solid nitrogen fertilizer, although its relative instability and potentially explosive nature has seen it largely replaced by urea [$CO(NH_2)_2$] in commercial formulations (Manahan 1994). Both NO_3^- and NH_4^+ ions are readily available to plants.

Ammonium phosphates [$(NH_4)H_2PO_4$ and $(NH_4)_2HPO_4$] are also common ingredients of modern day fertilizers and have the added advantage of supplying both N and P to the soil simultaneously. Phosphate may also be present as superphosphate [$(CaH_2PO_4)_2 \bullet H_2O$], a commercial derivative of natural rock phosphate. All of these compounds are water-soluble and provide readily available nutrients for plant growth.

Most fertilizers currently available in Guam are complete fertilizers, i.e., they contain varying proportions of all three primary nutrients. In a recent survey, we noted that the dominant chemicals in these formulations were urea, methylenediurea and methylenetriurea (slow release nitrogen compounds), monoammonium and diammonium phosphates, ammonium sulfate [$(NH_4)_2SO_4$], potassium chloride (KCl), potassium phosphate (K_3PO_4), superphosphate, and triple superphosphate. Less frequently observed were ammonium nitrate and potassium nitrate (KNO_3). We did not encounter calcium nitrate [$Ca(NO_3)_2$] or sodium nitrate ($NaNO_3$) despite their historical use as primary nitrogen sources in some fertilizers (Manahan 1994).

The secondary nutrients, Ca and Mg, were sometimes added as dolomite ($CaCO_3 \bullet MgCO_3$). Occasionally they were respectively present as calcium phosphate [$Ca_3(PO_4)_2$] and magnesium sulfate ($MgSO_4$). In water-soluble formulations, the trace elements Cu, Fe, Mn and Zn were normally supplied as oxides and sulfates and solubilized by the chelating agent, EDTA. Boron (Bo) and molybdenum (Mo) were commonly present as their respective water soluble, Na salts.

Weighing up all the evidence, there seems little doubt that fertilizers were the principal source of contaminants found in runoff samples during the present study. The extent and intensity of landscaping activities that go on within the confines of the Palace Hotel, certainly gives credence to this suggestion. Further, the timing and duration of nonstorm events recorded by data logger are generally consistent with rotational watering regimes, while the chemical composition of the samples collected are suggestive of modern water-soluble formulations. The absence of excessively high NO_3-N concentrations indicates that the ammonium ion (NH_4^+) was the dominant form of N in the products used.

According to groundsmen of the Palace Hotel, granular fertilizers are commonly applied to landscaped areas using hand-held broadcasting devices. Following application, the fertilizers are liberally watered in by sprinklers that are moved around as needed. One disadvantage of using such hand-held contraptions is the difficulty in preventing fertilizer from being scattered beyond the vegetative boundaries of targeted lawns and gardens onto adjacent roads and walkways. For this reason, it seems likely that the unusual events recorded during the present study were the direct result of fertilizer being washed into the storm drain from nonporous surfaces by irrigation runoff.

Implications of the Data:

If the water quality characteristics of runoff from the Palace Hotel are typical of other hotels in Guam, then the implications of the data are very clear and point towards continued degradation of our beaches and coastal waters. The underlying factors of primary importance here are outlined below.

Most of Guam's major hotels are within a very short distance from the beach. Many of these have extensive, well-manicured gardens that require intensive maintenance and management schedules. The regular application of fertilizer is an integral part of such operations. Runoff associated with normal fertilizing and irrigation practices will very likely be nutrient enriched. The proper disposal of such waters is therefore of paramount importance if its impact on any receiving waters is to be minimized.

The storm drain examined during the present study discharges into a small retention pond located underneath the police koban in Jonestown, and within a relatively short distance from the cliff edge. Some of the nutrient loading carried into it is undoubtedly assimilated by resident plant species. Depending upon the nutrient and its chemical form, a significant fraction may also be retained by the soil/sediment layers and underlying bedrock (Zolan *et al.* 1978b). Ultimately, however, the drainage characteristics of the retention pond will determine what proportion of the nutrient loading escapes to the sea.

The hotels situated along the shoreline in Tumon Bay do not discharge their runoff into storm water drains or storm sewers. On the contrary, runoff from the car park and garden areas is channeled underground into infiltration chambers and permeates slowly through the beach sand into the bay (Custodio, GEPA, pers. com.). By this method, the direct impact of surface runoff to the beach and the concomitant erosion effects are minimized. Unfortunately, this admirable attempt to solve one set of problems may well have created another. For example, runoff entering the bay via conventional stormwater outlets is diluted and dispersed relatively quickly. In contrast, the subterranean discharge of water from infiltration chambers greatly impedes these processes and significantly extends contaminant residence times in the intertidal zone. Moreover, such discharges will overlay the denser ocean water in this section of the beach and experience vertical displacement with each tidal cycle as they progress slowly seaward.

Consequently, nutrients carried by them will permeate into the surface layers of sand with each successive rising tide.

The net effect of nutrient enrichment in Tumon Bay is all too apparent and evidenced by the unsightly blooms of the green alga, *Enteromorpha clathrata* that extend along the intertidal zone. Personal observations indicate the nutrient enrichment problem now extends well beyond the intertidal zone into deeper waters. Further degradation seems almost inevitable in the light of continued hotel expansion in the area. The recent initiative to beautify Tumon as part of the Governor's Vision 2001, is also likely to contribute additional nutrient burdens to the coastal waters unless preventative measures are implemented.

Enteromorpha clathrata naturally occurs in Guam and its presence in Tumon Bay no doubt precedes hotel development there. However, according to local resident Vikki Gayer (pers. com.), its abundance in Tumon Bay has progressively increased in recent years at a rate that appears to be correlated with increased human activities in the area. Whether this is true or not remains to be firmly established. However, it is hard to deny that the increased growth and development that has occurred in Tumon Bay, over the last decade, has been accompanied by increased nutrient inputs into the adjacent coastal zone.

Commonly suggested sources of nutrient enrichment in Tumon Bay are sewage, stormwater runoff, and groundwater seepage. Of these three, the latter is frequently cited as the most important because it is continuous and because Guam's groundwater is naturally high in NO_3 (Matson 1991a). In fact, *E. clathrata* is frequently found growing prolifically near freshwater seeps and springs in Tumon Bay (FitzGerald 1976, 1978). However, whether N is the critical nutrient that normally limits the growth of this species in Guam is doubtful especially since seepage from the aquifer occurs at the rate of 2.2-110 m^3 (m of shoreline)$^{-1}$ d^{-1} (Matson 1993b). A more likely candidate would seem to be P based on the normal theory of supply and demand (Freedman 1989). Indeed, P is commonly the key element required by aquatic plants and usually is present in the least amount relative to need. Thus, an increase in P allows use for other already present nutrients for plant growth (U.S. EPA 1976).

Levels of o-PO_4-P normally encountered in clean coastal waters around Guam are exceedingly low (usually <10 µg/l) reflecting a natural deficiency of this element in native soils (Demeterio *et al.* 1986a and b, Siegrist *et al.* 1997). In all probability, then, a very small increase in ambient levels of available o-PO_4-P will have a dramatic effect on the primary productivity of local algae species considering that all other nutrients are nonlimiting. Noteworthy in this regard is the recent work of Matson (1996) who found o-PO_4-P levels of 37-56 µg/l in water from a shallow pit in the intertidal zone of Tumon Bay, directly in front of the Tahiti Rama Hotel. These values were an order of magnitude higher than levels found subtidally in the same vicinity. More importantly, however, they are almost double mean levels found in Tumon Bay in the late 1980's (Matson 1991a and b, 1993a) and 5-8 times higher than levels determined at approximately the same location in the mid 1970's (FitzGerald 1976). The question as to whether this steady increase reflects fertilizer use in the area remains unanswered at this time. Matson contends that street runoff and leaky sewer pipes are the primary sources of bacterial and nutrient enrichment in Tumon Bay and draws attention to a number of beach bars in the area that are not adequately sewered (Matson 1996). It seems likely, then, that multiple sources of nutrient enrichment exist in this area and most, if not all, are controllable.

The importance of P in triggering phytoplankton blooms in Tumon Bay was discussed earlier by Marsh (1977) who cited hotel storm drains as significant sources of this nutrient. Marsh noted that the blooms occurred at the beginning of the wet season and reasoned that nutrients (especially P) accumulated within the watershed during the dry season, and were flushed into the bay with the first heavy rains. In support of this, he produced data showing that mean o-PO_4-P levels roughly doubled in the bay during bloom conditions (i.e., from 7 μg/l to 18 μg/l). Incidentally, the highest o-PO_4-P level recorded by Marsh in runoff from a hotel storm drain was 388 μg/l (unpublished data, cited in FitzGerald 1976).

It may be argued that o-PO_4 is not especially mobile in calcareous materials, at least under aerobic conditions. In fact, from a purely thermodynamic standpoint one would expect the o-PO_4^{3-} ion to react with calcium carbonate to form the relatively insoluble compound, hydroxyapatite [$Ca_5(PO_4)_3(OH)$] (Stumm and Morgan 1996). That this does indeed happen, is implied by the work of Zolan and coworkers who found that 90-98% of o-PO_4-P in runoff samples was removed after passage through a column of crushed Mariana limestone (Zolan *et al.* 1978b). However, even if 99% of o-PO_4 discharged into Tumon Bay were precipitated as calcium phosphate, residual levels emerging from infiltration chambers may still be more than adequate to increase the standing crop of *E. clathratus* in the immediate vicinity. This may be illustrated by comparing the highest o-PO_4-P level encountered during the present study (482 mg/l) with the optimum o-PO_4-P requirement of *E. clathratus* (1.22 mg/l) as estimated by FitzGerald (1976).

Worth mentioning here is the fact that liquid ammonium polyphosphate fertilizers are becoming very popular in other parts of the world. A major advantage of the polyphosphate fertilizers over conventional phosphatic formulations is their ability to chelate Fe and other essential trace metals, thus rendering them more available to plants (Manahan 1994). Points to remember, however, are that polyphosphates are relatively mobile in soils and do not react with calcareous materials forming insoluble calcium phosphates. Therefore, their use in Guam could exacerbate the nutrient enrichment problem of our coastal waters unless applied under very carefully controlled conditions.

Concluding Remarks:

There is little doubt that the seaweed problem that currently plagues the recreational beaches of Tumon Bay is reflective of nutrient enrichment. To what extent this represents anthropogenic activity, is currently unknown. Obviously, the export of fertilizer nutrients from the adjacent hotel gardens into the bay area is a very real possibility based on the findings of the current study. Inputs of o-PO_4 are of particular concern here because of the suspected limiting nature of P under normal conditions in Guam. Thus, relatively small inputs of this nutrient will substantially alter N:P ratios in Tumon Bay. In fact, there is enough P in four cans of Coca-Cola (as phosphoric acid) to approximately double the ambient o-PO_4-P concentrations of Tumon Bay waters according to Matson (pers. com.).

Clearly then, every attempt should be made to eliminate the scattering of solid fertilizer formulations beyond landscaped areas onto impervious catchment surfaces. Amounts supplied should be based upon the immediate needs of the plants and should not be watered in to excess. Ideally, all runoff from hotel gardens should be directed into retention ponds with impervious plastic liners. These could be carefully landscaped into the hotel grounds so as not to detract from the natural beauty of the surrounding gardens. They would contain a variety of plants whose primary purpose would be to trap and assimilate the excess nutrients. Periodically these plants would be harvested for composting and nutrient recycling back into the gardens.

GENERAL CONCLUSIONS

The overall program is seen as an initial first step towards updating and expanding the rather limited urban runoff, water quality data base that currently exists for the island of Guam. It has identified and delineated a number of hitherto uncharted stormwater retention sites (sinkholes and ponding basins) in northern Guam. The precise locations of these are now available for the first time in map form having been digitized into a P.C. ARC/INFO map coverage. It has also produced important water quality baseline data for nutrients, major ions, and heavy metals in stormwater runoff from a number of strategic locations in Guam. These data provide a useful reference point with which future levels may be compared and evaluated. They are also of value to GEPA during the formulation of future guidelines for an ongoing monitoring program insofar as revealing key contaminants and sensitive areas of the environment. For example, the threat of nutrient enrichment and continued deterioration of water quality in Tumon Bay has been identified with a call for better management practices and improved ways of dealing with runoff from hotel catchment areas. The need for increased vigilance in this area is highlighted and GEPA is urged to incorporate the regular nutrient analysis of freshwater seeps from hotel infiltration chamber outlets into future monitoring programs for the island.

The project also demonstrates the advantages of utilizing a fully automated sampling system to monitor the “first flush” for contaminants during a storm event. if so desired The incorporation of a rain gauge into the system enables the operator to differentiate between storm and nonstorm induced sampling events and is a critical component, if illicit discharge sources are to be tracked and identified. The modem/phone link-up to the laboratory is a labor saving device that allows the progress of the autosampler to be monitored without having to visit the site.

On a final note, it is imperative that complete sets of historical water quality data be readily available to planners, regulators, water quality managers, researchers and the public at large. Modern computerized data storage and retrieval systems readily facilitate this. Of several commercial data management systems that are currently available, we recommend P.C. ArcView© and Hydroshpere’s© CD ROM based water quality data system (Hydrodata) for the following reasons:

1. ArcView is one of the most widely accepted and easy to use P.C. based geographic information systems on the market.

2. Map coverages in ArcInfo format are readily available for all aspects of the geography, geology and infrastructure of Guam.

3. Hydrodata uses CD ROMs that are downloaded directly from USEPA’s STORET water quality data files.

4. Hydrodata is highly compatible with the ArcView program. Therefore, users can readily identify sampling locations and view the data, and analyze short- and long-term spatial and temporal trends. The data can also be readily exported into various formats for further analysis and presentation as required.

5. WERI researchers have facilitated and refined the interactions between these two programs as part of the 1998 Guam Hydrologic Survey project. As a result we now have far more sophisticated access to Guam’s water quality data directly from reference maps of Guam. In addition we have also added the capability of accessing streamflow and climatological data in the same manner.

To derive maximum benefit from the above-mentioned system, it is absolutely vital that all available data, past, present, and future, be archived to the STORET system as soon as possible after collection.

RECOMMENDATION FOR FUTURE RESEARCH

The following recommendations for future research emerge from the studies described herein:

- Characterize urban runoff from a wider representation of local retention ponds and stormwater drains in order to: a) fully evaluate its potential as a significant contributor to water quality deterioration in receiving waters and b) reassess (if necessary) selected control measures. Sampling programs should be designed to characterize both spatial and temporal variability.

- Expand the urban runoff pollutant data base for Guam to include other toxic substances commonly found in urban runoff, e.g., mercury, arsenic, selenium, polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), and certain house and garden biocides (selection based on toxicity and persistence). The data base should also include the more conventional water quality parameters like solids, substances exerting oxygen demand, and bacteria.

- Delineate catchment areas serviced by ponding basins and stormwater drains especially in the commercial and more densely populated residential areas on island. Provide realistic estimates of runoff volumes and annual loadings for cumulative pollutants (e.g., toxic metals and nutrients) within each catchment. Ensure that total pollutant loading estimates take into account both dissolved and sediment bound fractions for each contaminant of interest. Event loading estimates may be derived from composite grab (manual) or automatic sampling techniques. Choosing between the two is really a matter of weighing capital outlay for equipment acquisition and maintenance against the increased labor costs for grab sampling (Marsalek 1991). The product of the mean concentration and runoff volume is the simplest method of calculating contaminant loadings from nonpoint sources (see Marsalek and Schroeter 1988).

- Establish correlations between runoff event volumes and event mean concentrations. Develop regression load equations from observed data to obtain load predictions from unmonitored sites. Derive linear regression models for estimating storm runoff event volumes, event pollutant loads, event mean pollutant concentrations, and mean seasonal or annual pollutant loads (see Tasker and Driver 1988). The independent variables of importance here include antecedent dry periods, street cleaning practices, volume of runoff, storm duration, volume of rainfall, average rainfall and average runoff (Marsalek 1991).

- Determine pollutant retention and vertical migration in ponding basin soils with emphasis on soil chelating properties, cation exchange capacity, pH and redox potential, likelihood of Fe and Al hydrous oxide formation, and microbial activity. Considerably more work along these lines needs to be done in the Harmon Sink area. In all probability, this faulted structure acts as a direct conduit for transport of water-soluble contaminants from the airport and Harmon industrial park area into Tumon Bay.

- Initiate studies to monitor nutrient loading in runoff from Tumon Bay hotels. Such studies should be preceded by an accurate assessment of the total land area servicing each storm drainage system and the extent of the lawns and gardens belonging to each hotel. The location of each infiltration chamber should be precisely known in order to facilitate the regular collection of discharged water for nutrient analysis. Studies should focus on establishing unit area pollutant loads (pollutant mass export from the unit area over one year) from each hotel (see Geiger *et al*. 1987).

- Provide educational seminars to hotel management and staff explaining the possible connection between fertilizer use and the "seaweed" problem. Outline project objectives and long-term benefits to hotel and tourism businesses in Guam. Encourage groundsmen to keep chronological records of all fertilizer applications and watering regimes. Install secured automated devices, complete with flow logger, rainfall recorder, and modem/cellular telephone link-up to the laboratory, at the mouth of a storm drainage system in one or two of the larger hotels.

- Establish a continuous monitoring program to measure nutrient levels in pore waters from freshwater seeps down gradient from storm drainage discharge points within the intertidal zone of Tumon Bay. Particular attention should be paid to areas of the beach exhibiting profuse growth of the green alga, *Enteromorpha clathrata.* Set up laboratory experiments to determine the mobility of nutrients in the calcareous marine sand deposits of Tumon Bay under aerobic and anaerobic conditions.

- Examine N:P ratios in the tissues of *E. clathrata* from Tumon Bay and nutrient unenriched control sights. P is stored to excess in the tissues of plants growing under luxury conditions. Thus, N:P ratios should be significantly lower in Tumon Bay alga compared with control sites if o-PO_4-P enrichment is indeed occurring.

BIBLIOGRAPHY

Abdullah and Royale (1974). A Study of the Dissolved and Particulate Trace Elements in the Bristol Channel. . *Journal of the Marine Biological Association, U.K.,* 54: 581-597.

Ahsanullah, M. (1976). Acute Toxicity of Cadmium and Zinc to Seven Invertebrate Species from Western Port, Victoria. *Australian Journal of Marine and Freshwater Research,* 27: 187-196.

APHA (1992). *Standard Methods for the Examination of Water and Wastewater,* American Public Health Association, American Water Works Association, and Water Environment Federation (APHA-AWWA-WPCF). 18th ed. (L.S. Clesceri, A.E. Greenberg, R.R. Trussell (eds.)). American public Health Association, Washington DC.

Assennato, G., C. Paci, M.E. Baser, R. Molinini, R.G. Candela, B.M. Altamura and R. Giogino (1987). Sperm Count Suppression Without Endocrine Dysfunction in Lead-Exposed Men. *Archives of Environmental Health,* 42: 124-127.

Athayde, D.N., P.E. Shelly, E.D. Driscol, D. Gaboury and G. Boyd (1983). *Results of the Nationwide Urban Runoff Program, Volume I. Final Report,* NTIS PB84-185552, U.S. Environmental Protection Agency.

AVCO Economic Systems Corporation (1970). Storm Water from Urban Land Activity. *Report 11034FKL,* . U. S. Environmental Protection Agency, Washington DC.

AWWA (1990). *Water Quality and Treatment. A Handbook of Community Water Supplies. Fourth Edition.* American Water Works Association, McGraw-Hill, Inc. 1194 pp.

Barrett Consulting Group (1992). Guam Water Facilities Master Plan Update. Final Report Prepared by Barrett Consulting Group, Agana, Guam, for the Public Utility Agency of Guam. February 1992.

Barton, K. (1978). The Other Water Pollution. *Environment,* 20: 12-20.

Beukema, A.A., G.P. Hekstra and C. Venema (1986). The Netherlands' Environmental Policy for the North Sea and Wadden Sea. *Environmental Monitoring and Assessment,* 7: 117-155.

Bedient,, P.B., J.L. Lambert, and N.K. Springer (1980). Stormwater pollutant Load - Runoff Relationships. *Journal of the Water Pollution Control Federation,* 52: 2396-2404.

Booman, B., T.M. Cascieri and J. Demetrulias (1988). In Vitro Methods for Estimating Eye Irritancy of Cleaning Products. Phase I: Preliminary Assessment. *Journal of Toxicology,* 7: 173.

Bowen, H.J.M. (1979). *The Environmental Chemistry of Elements.* Academic Press, London.

Brown, B. and M. Ahsanulla (1971). Effects of Heavy Metals on Mortality and Growth. *Marine Pollution Bulletin,* 2: 182-187.

Burdon-Jones, C. and G.R.W. Denton (1980). *Metal in Marine Organisms. Part 3: Influence of Environmental Variables on Toxicity, Uptake and Depuration.* Unpublished Final Report prepared under contract to the Water Quality Council of Queensland, Australia. 99 pp.

Bryan, E.H. (1972). Quality of Storm Water Drainage from Urban Land. *Water Reources Bulletin,* 8: 578-588.

Bryan, G.W. (1976). Heavy Metal Contamination in the Sea. In: *Marine Pollution* (R. Johnston (ed.)). Academic Press: London : New York : San Francisco. Pp. 187-302.

Burnett, M., A. Settle, D. Ng, and C.C Patterson (1977). Impact of Man on Coastal Marine Ecosystems. In: *Lead in the Environment,* (M. Branica, Z. Konrad (eds.)), Pergamon Press, Oxford, New York, Toronto, Sydney, Paris, Frankfurt, 1980. Pp. 7-13.

CCRME (1987). Canadian Council of Resource and Environment Ministers, *Canadian Water Quality Guidelines,* Health and Welfare Canada.

Cole, R.H., R.E. Frederick, R.P. Healy and R.G. Rolan (1984). Preliminary Findings of the Priority Pollutant Monitoring Project of the Nationwide Urban Runoff Program. *Journal of the Water Pollution Control Federation,* 56: 898-908.

Coogan, T.P., D.M. Latta, E.T. Snow and M. Costa (1989). Toxicity and Carcinogenicity of Nickel Compounds. *Critical Reviews in Toxicology,* 19: 341-384.

Cordero, R. (1988). *Metal Bulletin Prices and Data 1988*. Metal Bulletin Books, Surrey, England. 375 pp. Cited in Cutter, G.A. 1989. Freshwater Systems. In: *Occurrence and Distribution of Selenium* (M. Ihnat (ed.)) CRC Press, Boca Raton, Florida. 243-262.

Csuros, M. (1994). Environmental Sampling and Analysis for Technicians. Lewis Publishers, Boca Raton • Boston • New York • Washington, D.C. • London. 320 pp.

Davis, P.L. and T. Borchardt (1974). Combined Sewer Overflow Abatement Plan, Des Moines, Iowa, *Environmental Protection Technology Series, EPA-R2-73-170,* U.S. Environmental Protection Agency, Cincinnati.

Danneker, W., M Au and H Stechmann (1990). Substance Load in Rainwater Runoff from different Streets in Hamburg. *Science of the Total Environment,* 93: 385.

Demeterio, J.L., D.D. Ventura and F.J. Young (1986a). Some Physical and Chemical Properties of the Agricultural Soils of Guam. *Technical Report, Guam Agriculture Experiment Station Publication # 56,* University of Guam, Mangilao, Guam. 15 pp.

Demeterio, J.L., F.J. Young and M.B. Yamanaka (1986b). Guam Soil Test Summary, 1975-84 *Technical Report, Guam Agriculture Experiment Station Publication # 58,* University of Guam, Mangilao, Guam. 18 pp.

Denton, G.R.W. and L.F. Heitz (1993). Heavy Metal Uptake and Loss in the Burrowing Clam *Tridacna crocea:* Implications from a Public Health and Mariculture Viewpoint. In: *Biology and Mariculture of Giant Clams.* (W.K. Fritt (ed.)). ACIAR Monograph Series No. 47. Pirie Printers, Canberra, Australia. Pp. 119-132.

Denton, G.R.W. and L.F. Heitz (1991). *Tridacna:* Sentinels of Heavy Metal Pollution in Torres Strait – A Critical Evaluation. In: *Sustainable Development for Traditional Inhabitants of the Torres Strait Region.* (D. Lawrence and T. Cansfield-Smith (eds.)). Great Barrier Reef Marine Park Authority Workshop Series No. 16. Australian Government Publishing Service, Canberra, Australia. Pp. 311-331.

Denton, G.R.W. and C. Burdon-Jones (1986). Environmental Effects on Toxicity of Heavy Metals to Two Species of Tropical Marine Fish from Northern Australia. *Chemistry in Ecology,* 2: 233-249.

Denton, G.R.W. and C. Burdon-Jones (1982). The Influence of Temperature and Salinity Upon the Acute Toxicity of Heavy Metals to the Banana Prawn (*Penaeus murguiensis* de Man). *Chemistry in Ecology,* 1: 131-143.

Dueñas and Associates 1993. Guam Islandwide Wastewater Facilities Plan. Interim Report No 3. Prepared by Dueñas and Associates, Inc./CH2M Hill, P.O. Box 8900, Tamuning, Guam 96931, for the Public Utility Agency of Guam.

Federal Water Pollution Control Administration (1969). *Water Quality Studies Training Manual,* U.S. Department of the Interior, Washington, D.C.

Federal Register (1998). Part II Environmental Protection Agency. (40 CFR Parts 122 and 123). *National Pollution Discharge Elimination System - Proposed Regulations for Revision of the Water Pollution Control Program Addressing Storm Water Discharges; Proposed Rule.* Vol. 63, No. 6, Friday, January 9, 1998

Federal Register (1992). Part II Environmental Protection Agency. (40 CFR Part 131; 48 FR 51405; Revised through July 1, 1991; amended at 56 FR 64893, Dec. 12, 1991; 57 FR 60910, Dec.22, 1992). *Appendix A - Water Quality Standards Regulation (9/14/93).*

FitzGerald, W.J. (1976). Environmental Parameters Influencing the Growth of *Enteromorpha clathrata* (Roth) J. Ag. in the Intertidal Zone of Guam. *Botanica Marina,* 21: 207-220.

FitzGerald, W.J. (1976). Environmental Parameters Influencing the Growth of *Enteromorpha clathrata* (Roth) J. Ag. in the Intertidal Zone of Guam. M.S. Thesis, University of Guam, 43 pp.

Förstner, U. and G.T.W. Wittmann (1981). *Metal Pollution in the Aquatic Environment.* 2nd Ed., Springer Verlag. 486 pp.

Freedman, W. (1989). *Environmental Ecology. The Impacts of Pollution and Other Stresses on Ecosystem Structure and Function*. Academic Press. Inc. 424 pp.

Friberg, L., M. Piscator and T. Kjellstrom (1974). Cadmium in the Environment. CRC Press, Cleveland Ohio.

Geiger, W.F., J. Marsalek, W.J. Rawls and F.C. Zuidema (1987). Manual on Drainage in Urbanized Areas, Vol. I, Planning and Design of Drainage Systems. *Studies and Reports in Hydrology No. 43,* UNESCO Press, Paris, France. 203 pp.

GEPA (1995). *Guam Primary Safe Drinking Water Regulations*. Amended October 5, 1995. Guam Environmental Protection Agency. 288 pp.

GEPA (1992). *Revised Water Quality Standards*. Approved January 1992. Guam Environmental Protection Agency. 84 pp.

Gjessing, E. E. Lygren, S. Andersen, L. Berglind, G. Carlberg, H. Efraimsen, T. Kallqvist and K. Martinsen (1984). Acute Toxicity and Chemical Characteristics of Moderately Polluted Runoff from Highways. *The Science of the Total Environment,* 33: 225-232.

Goyer, R. (1991). Toxic Effects of Metals. In: Casarett and Doull's Toxicology. The Basic Science of Poisons. Fourth Edition. (M.O Amdur, J. Doull and C.D. Klaassen (eds.)). Pergamon Press. Pp. 623-680.

Gupta, N.K., R.W. Agnew and N.B. Kobriger (1981). Constituents of Highway Runoff, I State-of-the Art Report. U.S. Federal Highway Administration, Office of Research and Development, *Report No. FHWA/RD-81/042.*

Greenberg, A., D.K. Parkinson, D.E.Fetterolf, J.B. Puschett, K.J. Ellis, L.Wielopolski, A.N. Vaswani, S.H. Cohn and P. Landrigan (1986). Effects of Elevated Lead and Cadmium Burdens on Renal Function and Calcium Metabolism. *Archives of Environmental Health,* 41: 69-76.

Halcrow, W., D.W. Mackay and I. Thornton (1973). The Distribution of Trace Metals and Fauna in the Firth of Clyde in Relation to the Disposal of Sewage Sludge. *Journal of the Marine Biological Association, U.K.,* 53: 721-739.

Hall, K.J. and B.C. Anderson (1988). The Toxicity and Chemical Composition of Urban Stormwater Runoff. *Canadian Journal of Civil Engineering,* 15: 98-106.

Harrimoes, P. (1988). Stochastic Models for Estimations of Extreme Pollution from Urban Runoff. *Water Research,* 22: 1017-1026.

Harrison, R.M. and S.J. Wilson (1985a). The Chemical Composition of Highway Drainage Waters. I. Major Ions and Selected Trace Metals. *Science of the Total Environment,* 43: 63-77.

Harrison, R.M. and S.J. Wilson (1985b). The Chemical Composition of Highway Drainage Waters. II. Chemical Associations of Metals in Suspended Sediments. *Science of the Total Environment,* 43: 79-97.

Hoffman, E.J., J.S. Latimer, G.L. Mills and J.G. Quinn (1982). Petroleum Hydrocarbons in Urban Runoff from a Commercial Land Use Area. *Journal of the Water Pollution Control Federation,* 54: 1517-1525

Hunter, J.V., T. Sabatino, R. Gomperts, M.J. McKenzie (1979). Contribution of Urban Runoff to Hydrocarbon Pollution. *Journal of the Water Pollution Control Federation,* 51: 2129-2138.

Hutton, M. and C. Symon (1986). The Quantities of Cadmium, Lead, Mercury and Arsenic Entering the U.K. Environment from Human Activities. *Science of the Total Environment,* 57: 129-150.

Jones, M.N. (1984). Nitrate Reduction by Shaking with Cadmium: Alternative to Cadmium Columns. *Water Research,* 18: 643-646.

Kababjian, R. (1994). Monitoring the Effects of Urban Runoff on Recreational Waters. *Journal of Environmental Health,* 56: 15-18

Klumpp, D.W. and P.J. Peterson (1979). Arsenic and Other Trace Elements in the Waters and Organisms of an Estuary in S.W. England. *Environmental Pollution,* 19, 11-20.

Kroehler, C.J. (1990). What Do the Standards Mean? A Citizens’ Guide to Drinking Water Contaminants. *Virginia Water Resources Research Center Occasional Publication 8-90-2M.* Virginia Polytechnic Institute and State University, Blacksburg, VA. 88 pp.

Lager, J.A.., W. Smith, R. Lynard, R. Finn and J. Finnmore (1977). Urban Stormwater Management and Technology: Update and User’s Guide, *EPA-600/8-77-014,* U.S. Environmental Protection Agency, Cincinnati.

Landrigan, P.J. (1988). Lead: Assessing Its Health Hazards. *Health and Environment Digest,* 2: 1-5.

Lanfranchi, G., S. Paglialunga and A.G. Levis (1988). Mammalian Cell Transformation Induced By Chromium (VI) Compounds in the Presence of Nitrilotriacetic Acid. *Journal of Toxicology and Environmental Health*, 24: 251-260.

Langard, S. (1988). Chromium Carcinogenicity: A Review. *Water, Air, and Soil Pollution*, 40: 223-250.

Line, D.E., J.A. Arnold, G.D. Jennings and J. Wu (1996). Water Quality of Stormwater Runoff from Ten Industrial Sites. *Water Resources Bulletin*, 32: 807-816.

Makepeace, D.K., D.W. Smith and S.J. Stanley (1995). Urban Stormwater Quality: Summary of Contaminated Data. *Critical Reviews in Environmental Science and Technology*, 25: 93-139.

Malmqvist, P.A. (1983). *Urban Stormwater Pollutant Sources*. Chalmers University of Technology, Gothenburg

Manahan, S.E. (1994) *Environmental Chemistry*. CRC Press Inc., Boca Raton, Florida. 811 pp.

Marsalek, J. (1991). Pollutant Loads in Urban Stormwater: Review of Methods for Planning-Level Estimates. *Water Resources Bulletin*, 27: 283-291.

Marsalek, J. and H Schroeter (1988). Annual Loadings of Toxic Contaminants in Urban Runoff from the Canadian Great Lakes Basin. *Water Pollution Research Journal of Canada*, 23: 360-378.

Marsh, J.A. Jr. (1977). Terrestrial Inputs of Nitrogen and Phosphorous on Fringing Reefs on Guam. *Proceedings: Third International Coral Reef Symposium*, Miami, Florida. Pp. 331-336.

Matson, E.A. (1996). Terrestrial Groundwater Sources of Fecal Indicator Bacteria in Guam. A Comparison of Densities of Pollution Indicator Microorganisms in Recreational Coastal Waters and their Contaminated Influent Groundwaters of Guam. In: Phase II of Project Completion Report WRRC-96-03 entitled *Applicability of New Marine Water Quality Standards in Guam* (Principal Investigator: R.S Fujioka. Co-investigators: C. Sian-Denton and M. Borja). Pp. 1-20. Prepared for U.S. EPA under Cooperative Agreement # CR820809-01-0, August 1996. Available from the Water Resources Research Center, Honolulu, Hawaii.

Matson, E.A. (1993a). Fecal Pollution in Guam's Coastal Waters and Sediments. *Micronesica*, 26: 155-175.

Matson E.A. (1993b). Nutrient Flux Through Soils and Aquifers to the Coastal Zone of Guam (Mariana Islands). *Limnology and Oceanography*, 38: 361-371.

Matson, E.A. (1991a). Nutrient Chemistry of the Coastal Waters of Guam. *Micronesica,* 24: 109-135

Matson, E.A. (1991b). Water Chemistry and Hydrology of the "Blood of Sanvitores", A Micronesian Red Tide. *Micronesica,* 24: 95-108.

Mena, I., O. Neurin, S. Feunzobda and G. Cotzias (1967). Chronic Manganese Poisoning. Clinical Picture and Manganese Turnover. *Neurology,* 17: 128-136.

Miller, C.V., J.M. Denis, S.W. Ator and J.W. Brakebill (1997). Nutrients in Streams During Baseflow in Selected Environmental Settings of the Potomac River Basin. *Journal of the American Water Resources Association,* 33: 1155-1171.

Millero, F.J. and M.L. Sohn (1992). *Chemical Oceanography.* CRC Press, Boca Raton Ann Arbor London. 531 pp.

Moore, J.W. (1991). *Inorganic Contaminants of Surface Waters. Research and Monitoring Priorities.* Springer-Verlag: New York • Berlin • Heidelberg • London • Paris • Tokyo • Hong Kong • Barcelona. 334 pp.

Morrison, G.M.P., D.M. Revitt, J.B. Ellis, G. Svensson and P. Balmer (1984). Variations of Dissolved and Suspended Solid Heavy Metals Through an Urban Hydrograph. *Environmental Technology Letters,* 7: 313.

Municipality of Metropolitan Seattle (1971). Maximizing Storage in Combined Sewer Systems. *Water Pollution Control Series, 11022 ELK 12/71.* U.S. Environmental Protection Agency, Washington, D.C.

Murphy, C.B. Jr. and P.J. Carleo (19780. The Contribution of Mercury and Chlorinated Organics from Urban Runoff. *Water Research,* 12: 531-533.

Naquadat (1985). National Water Quality Data Bank. Environment, Canada, Ottawa.

Nightingale, H. I. (1987). Accumulation of AS, NI, CU, and PB in Retention and Recharge basins Soils from Urban Runoff. *Water Resources Bulletin,* 23: 663-672.

Nriagu, J.O. (1989). A Global Assessment of Natural Sources of Atmospheric Trace Metals. *Nature (London),* 338: 47-49.

Nriagu, J.O. and J.M. Pacyna (1988). Quantitative Assessment of Worldwide Contamination of Air, Water and Soil By Trace Metals, *Nature,* 333: 134-139.

Preston, A., D.F. Jeffries, J.W.R. Dutton, B.R. Harvey and A.K. Steele (1972). British Isles Coastal Waters: The Concentration of Selected Heavy Metals in Sea Water, Suspended Matter and Biological Indicators – A Pilot Survey. *Environmental Pollution,* 3: 69-82

Randall, C.W., T.S. Grizzard and R.C. Hoeln (1978). Impact of Urban Runoff on Water Quality in the Occoquow Watershed. Water Resources Research Center Bulletin, 80: Virginia Poly. Tech. And State University. 77 pp.

Revitt, D.M. and G.M. Morrison (1987). Metal Speciation Variations Within Separate Storm Water Systems. *Environment and Technology Letters,* 8: 373.

Sen Gupta, R., S.Y.S. Singbal and S. Sanzgiri (1978). Atomic-Absorption Analysis of a Few Trace Metals in Arabian Sea Waters. *Indian Journal of Marine Science,* 7: 295-299.

Schafer, H. (1989). Improving Southern California's Coastal Waters*.* *Journal of the Water Pollution Control Federation*, 61: 1395-1401.

Siegrist, H.G., G.R.W. Denton, H.R. Wood, L. P. Concepcion and R.R. Lewis (1997). Aqueous Chemistry of a Perennial Wetland in Southern Guam. Water and Environmental Research Institute (WERI) of the Western Pacific *Technical Report No. 79.* 58 pp.

Smith, Roger (1992). *A Primer of Environmental Toxicology.* Lea & Febiger, Malvern, Pennsylvania, U.S.A. 300 pp.

Stowe, K. (1979). *Ocean Science*. Second Edition, John Wiley and Sons, Inc. 671 pp.

Stumm, W. and J.J. Morgan (1996). *Aquatic Chemistry (Third Edition).* John Wiley and Sons, New York. 780 pp.

Talbot, M.M.J-F., E.B. Branch, S.A. Marsland and R.J. Watling (1985). Metal Surveys in South African Estuaries X. Blind, Ihlanza, Nahoon and Quinera Rivers. *Water SA,* 11: 65-68.

Tasker, G.D. and N. Driver (1988). Nationwide Regression Models for Predicting Urban Runoff Water Quality at Unmonitored Sites. *Water Resources Bulletin,* 24: 1091-1101

UNEP (1985). GESAMP: Cadmium, Lead and Tin in the Marine Environment*.* *United Nations Environment Program: Regional Seas Reports and Studies* No. 56. 90 pp.

U. S. Environmental Protection Agency (1998). Safe Drinking Water Is In Our Hands: Existing Standards and Future Priorities. United States Environmental Protection Agency, Office of Water (4607). EPA 815-F-98-007, June 1998. 24 pp.

U. S. Environmental Protection Agency (1992). Phase V Rule. United States Environmental Protection Agency, Office of Water WH-550A. EPA 811-F-92-001, May 1992. 5 pp.

U. S. Environmental Protection Agency (1989). NPDES Storm Water Sampling Guidance Document. *EPA 833-B-92-001*, Office of Water, Washington, D.C. 123 pp..

U. S. Environmental Protection Agency (1989). Drinking Water Health Advisories. *Reviews of Environmental Contamination and Toxicology,* 107: 1-184.

U. S. Environmental Protection Agency (1988). Distribution of Contaminants in Waters of Monroe Harbor (River Basin) Michigan and Adjacent Lake Erie. U. S. Environmental Protection Agency, *EPA/600/3-88/002*, Duluth, MN. 153 pp.

U. S. Environmental Protection Agency (1986). Quality Criteria for Water 1986. U. S. Environmental Protection Agency, *EPA 440/5-86-001,* Office of Water Regulations and Standards Washington, DC 20460

U. S. Environmental Protection Agency (1983). Results of the Nationwide Urban Runoff Program, Volume I, Final Report. Water Planning Division, U.S. Environmental Protection Agency, NTIS No PB84-185552, Washington, D.C.

U. S. Environmental Protection Agency (1976). Quality Criteria for Water 1976 (The "Red Book"). U. S. Environmental Protection Agency, Washington, DC 20460. 256 pp.

U.S. Minerals Yearbook (1930-1989). Bureau of Mines, U.S. Department of the Interior, Washington, D.C.

Vigon, B.W. (1985). The Status of Nonpoint Source Pollution. *Water Resources Bulletin,* 21: 179-184.

Wanielista, M.P. Y.A. Yousef, W.L. McLellon (1977). Nonpoint Source Effects of Water Quality. *Journal of the Water Pollution Control Federation,* 49: 441-451.

Ward, N.I. (1990). Multielement Contamination of British Motorway Environments. *Science and the Total Environment*, 93: 393.

Watling, R.J., M.M.J-F Talbot, E.B. Branch and S.A. Marsland (1985). Metal Surveys in South African Estuaries IX. Buffalo River. *Water SA*, 11: 61-68

Westall, J. and W. Stumm (1980). The Hydrosphere. In: The Handbook of Environmental Chemistry. (O. Hutzinger (ed.)). Springer-Verlag, New York. Pp. 17-49.

Whalen, P.J. and M.G. Cullum (1989). An Assessment of Urban Land Use/Stormwater Runoff Quality Relationships and Treatment Efficiencies of Selected Stormwater Management Systems. South Florida Water Management District Resources Planning Department, Water Quality Division, *Technical Publication No. 88*-9.

Whipple, W. Jr., B.B. Berger, C.D. Gates, R.M. Ragan and C.W. Randall (1978). *Water Resources Bulletin,* 14: 370

Whipple, W., J.V. Hunter and S.L. Yu (1974). Unrecorded Pollution from Urban Runoff. *Journal of the Water Pollution Control Federation,* 46: 873-885.

Wilber, W.G. and J.V. Hunter (1977). Aquatic Transport of Heavy Metals in the Urban Environment. *Water Resources Bulletin,* 13: 721-734.

Wilson, A.L. (1980). Trace metals in Waters. In: *Environmental Geochemistry and Health,* (S.H.U. Bowie and J.S. Webb (eds.)). Royal Society of London, pp. 24-40.

Yeats, P.A. and J.M. Bewers (1987). Evidence for Anthropogenic Modifications of Global Transport of Cadmium. In: Cadmium in the Aquatic Environment (J.O. Nriagu and J.B. Sprague (eds.)). Wiley, New York. Pp. 19-34.

Yousef, Y.A., T. Hvitved-Jacobsen, H.H. Harper and L.Y. Lin (1990). Heavy Metal Accumulation and Transport Through Detention Ponds Receiving Highway Runoff. *The Science of the Total Environment*, 93: 433-440.

Yousef, Y.A., H.H. Harper, L.P. Wiseman and J.M. Bateman (1985). Consequential Species of Heavy Metals in Urban Runoff. *Transportation Research Record,* 1017: 56-62.

Zingde, M.D., M.A. Rokade and A.V. Mandalia (1988). Heavy Metals in Mindhola River Estuary, India. *Marine Pollution Bulletin* 19: 538-540.

Zingde, M.D., S.Y.S. Singbal, C.F. Moraes and C.F. G. Reddy (1976). Arsenic, Copper, Zinc and Manganese in the Flora and Fauna of Coastal and Estuarine Waters Around Goa. *Indian Journal of Marine Science,* 5: 212-217.

Zolan, W.J. (1981). Metal Concentrations in Guam Urban Runoff. *Water and Energy Research Institute (WERI) of the Western Pacific Technical Report* No. 25.27 pp.

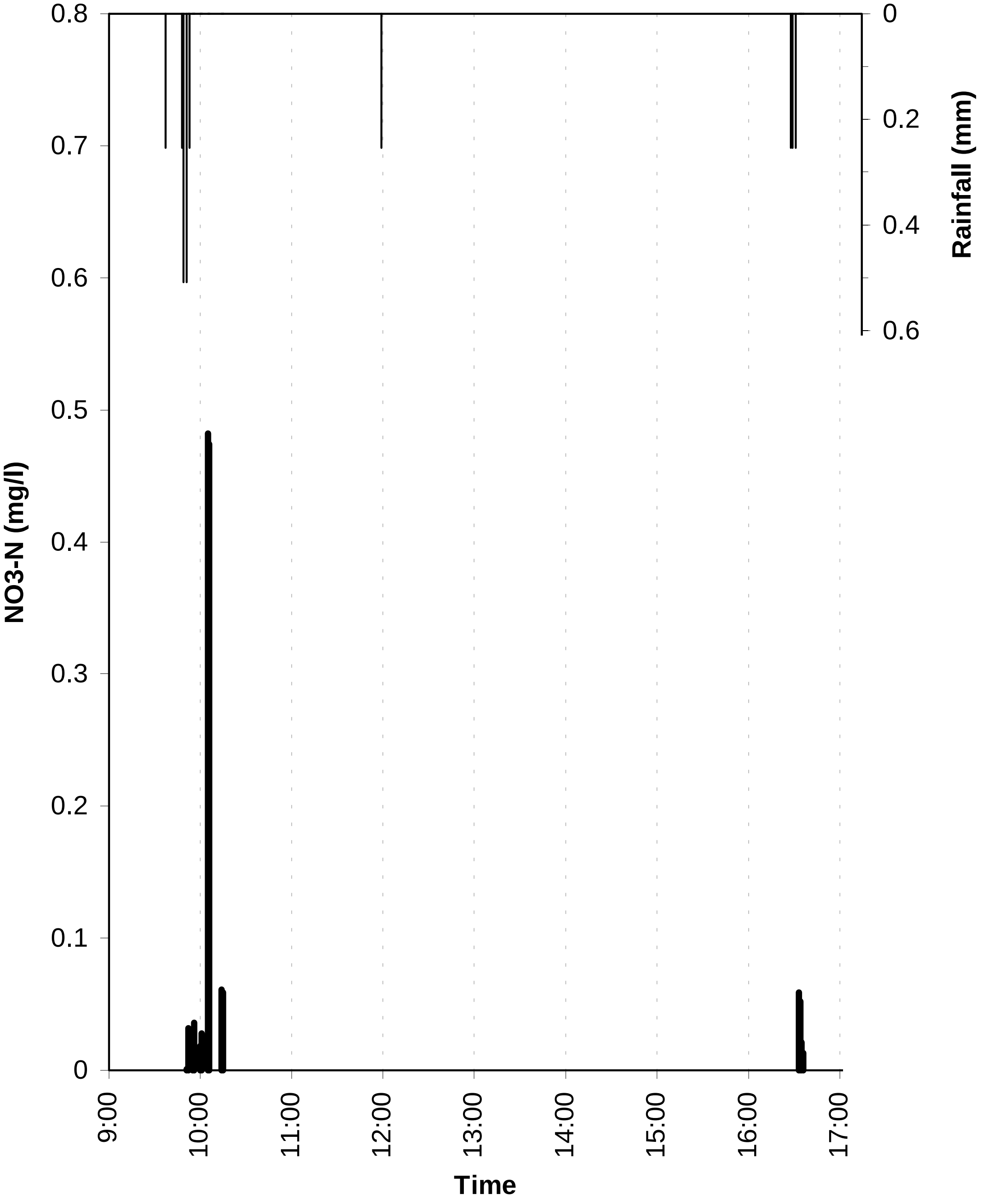
Zolan, W.J., R.N. Clayshulte, S.J. Winter, J.A. Marsh, Jr. and R.H.F. Young (1978a). Urban Runoff Quality in Northern Guam. *Water and Energy Research Institute (WERI) of the Western Pacific Technical Report* No. 5 168 pp.

Zolan, W.J., R.N. Clayshulte, S.J. Winter (1978b). Urban Runoff Pollutant Adsorption and Filtering by Selected Northern Guam Soils and Limestone. *Water and Energy Research Institute (WERI) of the Western Pacific Technical Report* No. 6. 39 pp.

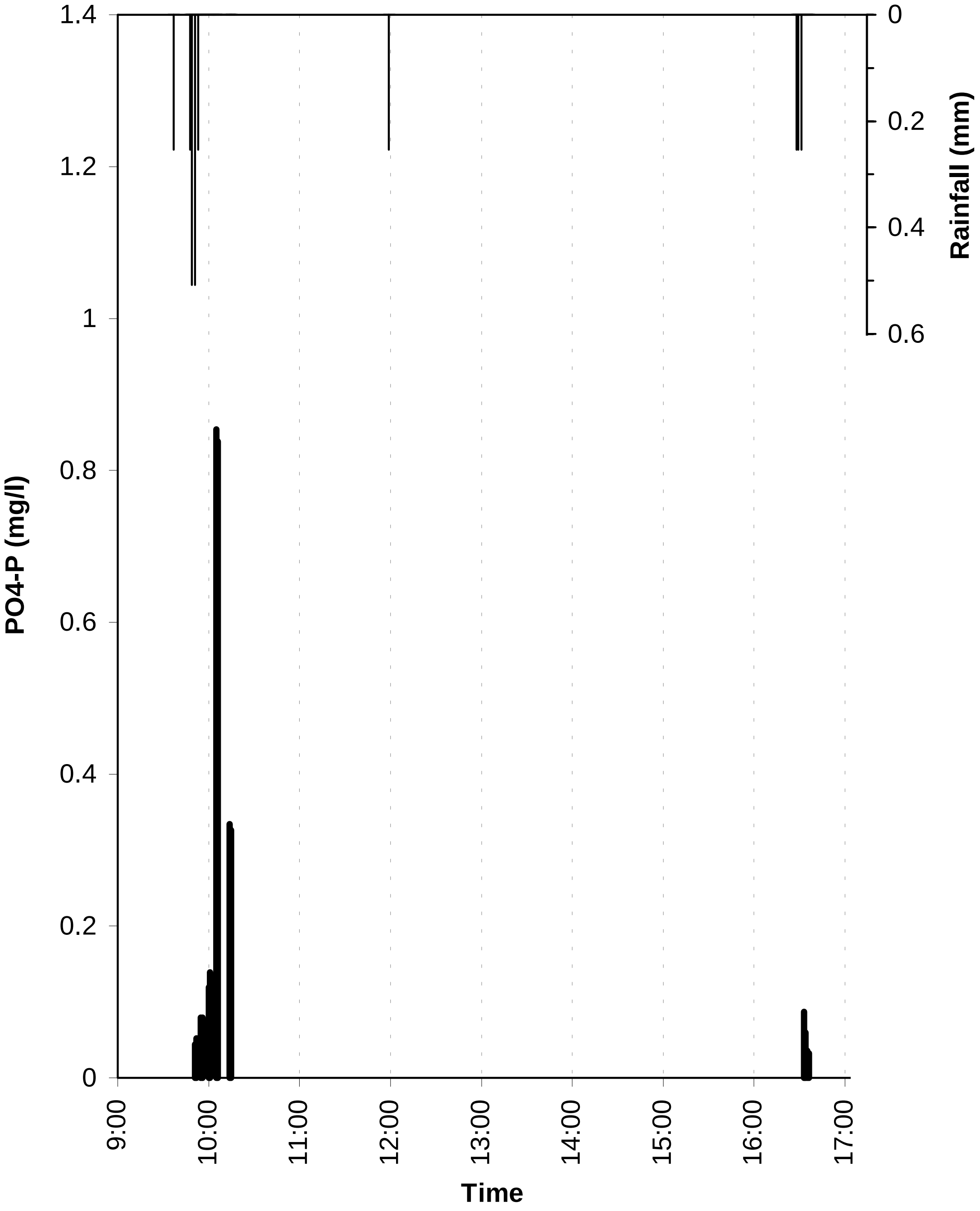
APPENDIX A

Graphical Presentations of Data Sets Obtained During Phase III Arranged in Chronological Order (Unfiltered Samples Only).

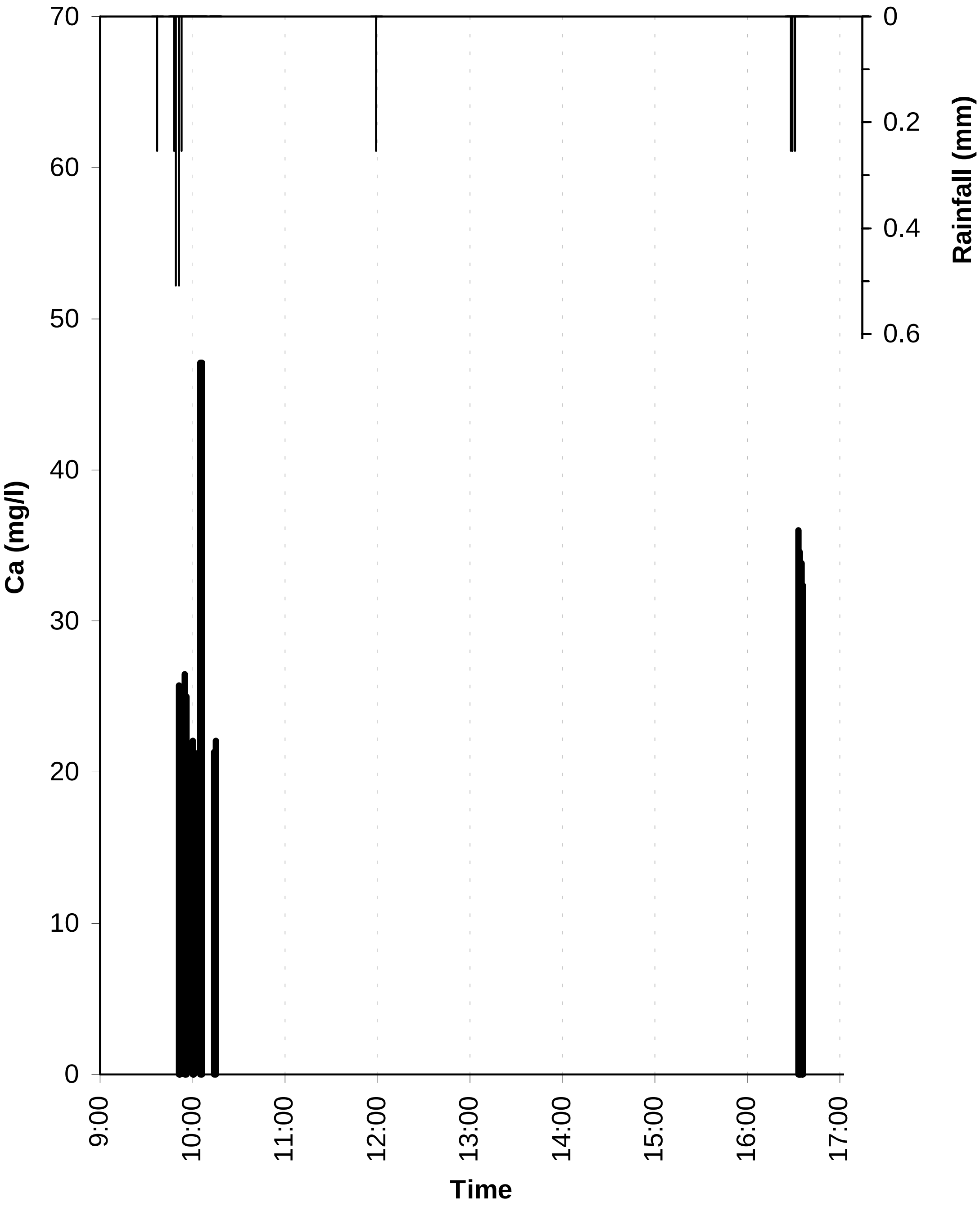
Nitrate-N in Urban Runoff
10 July 1995

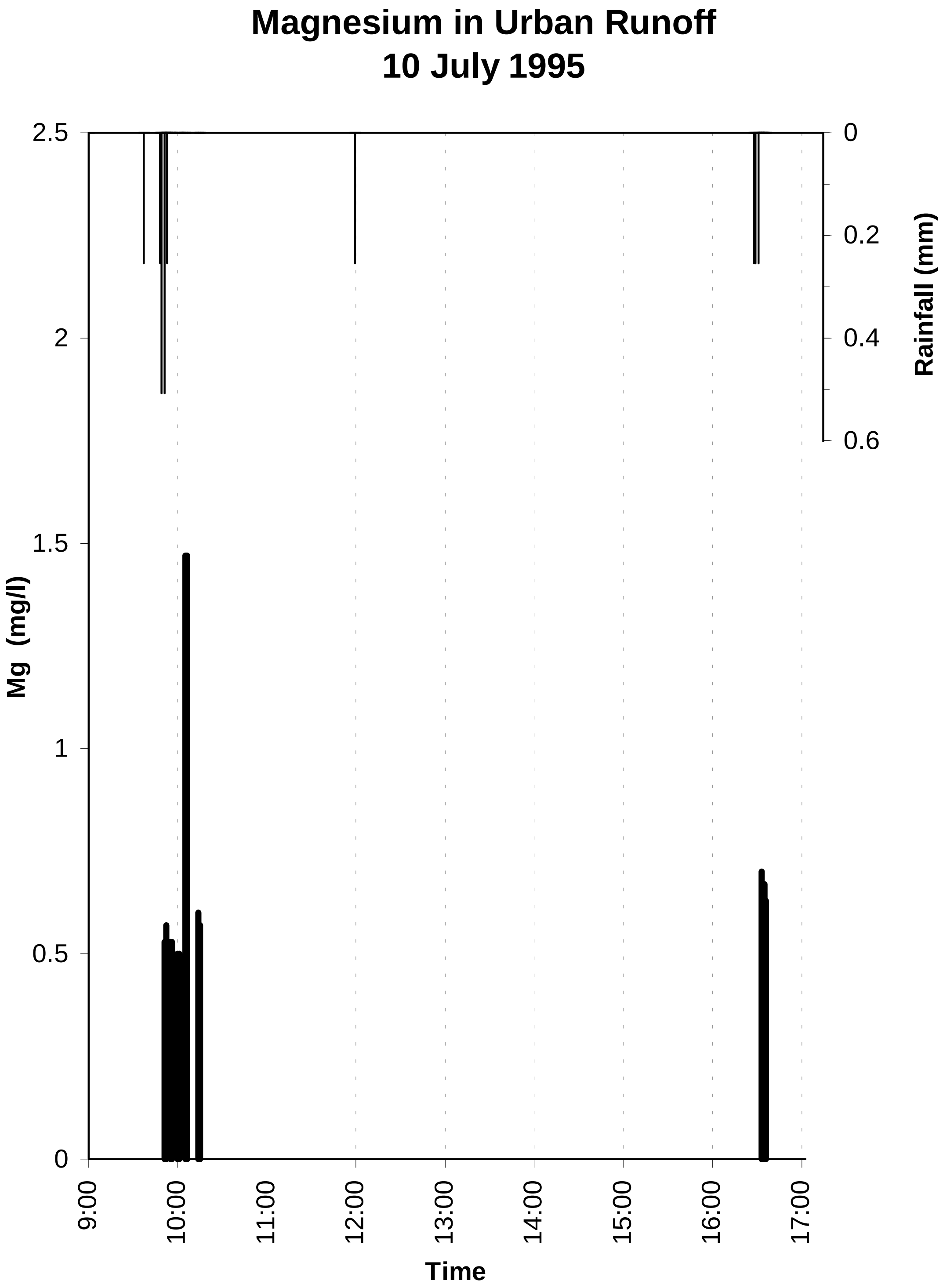


o-Phosphate-P in Urban Runoff
10 July 1995



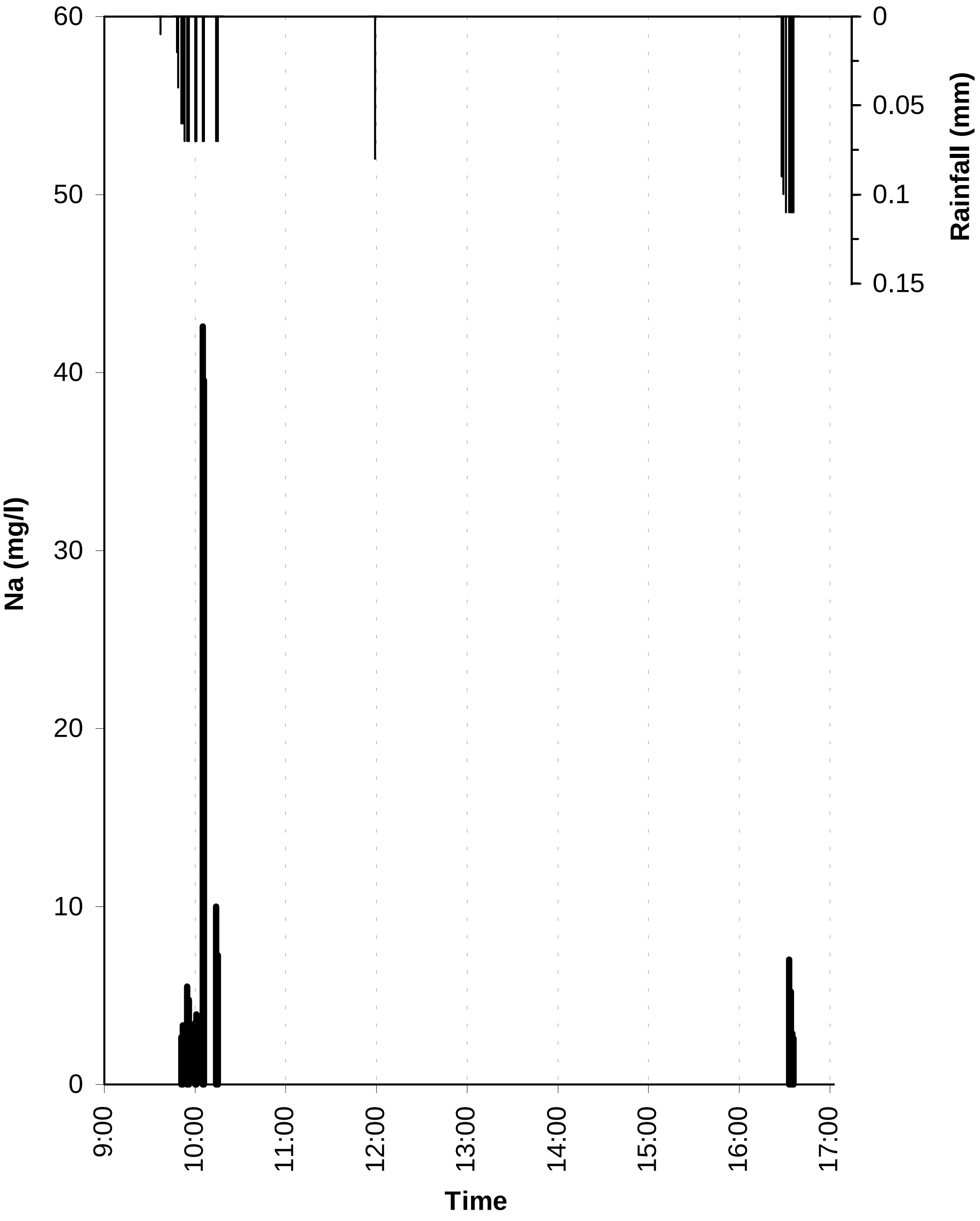
Calcium in Urban Runoff
10 July 1995

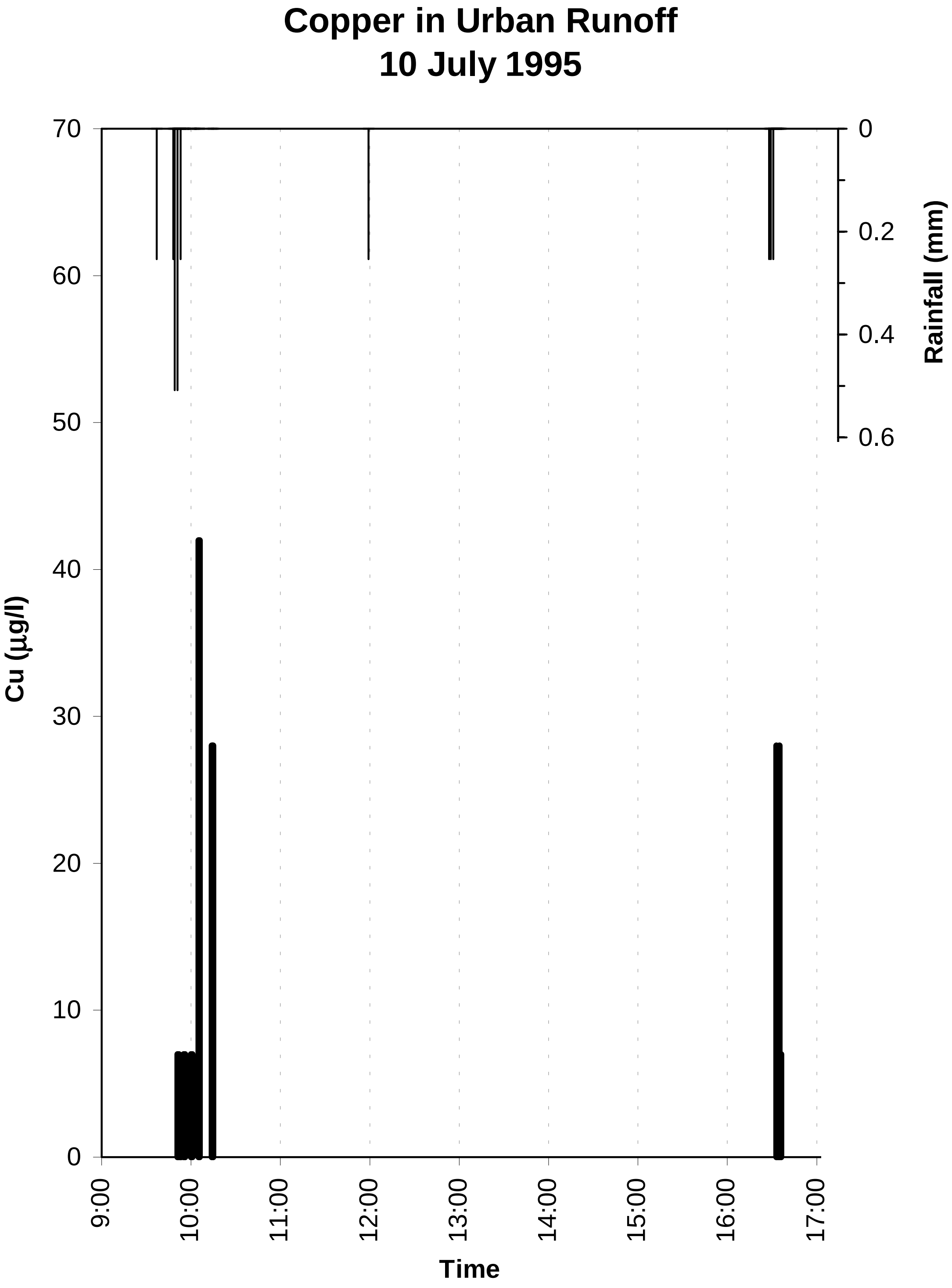




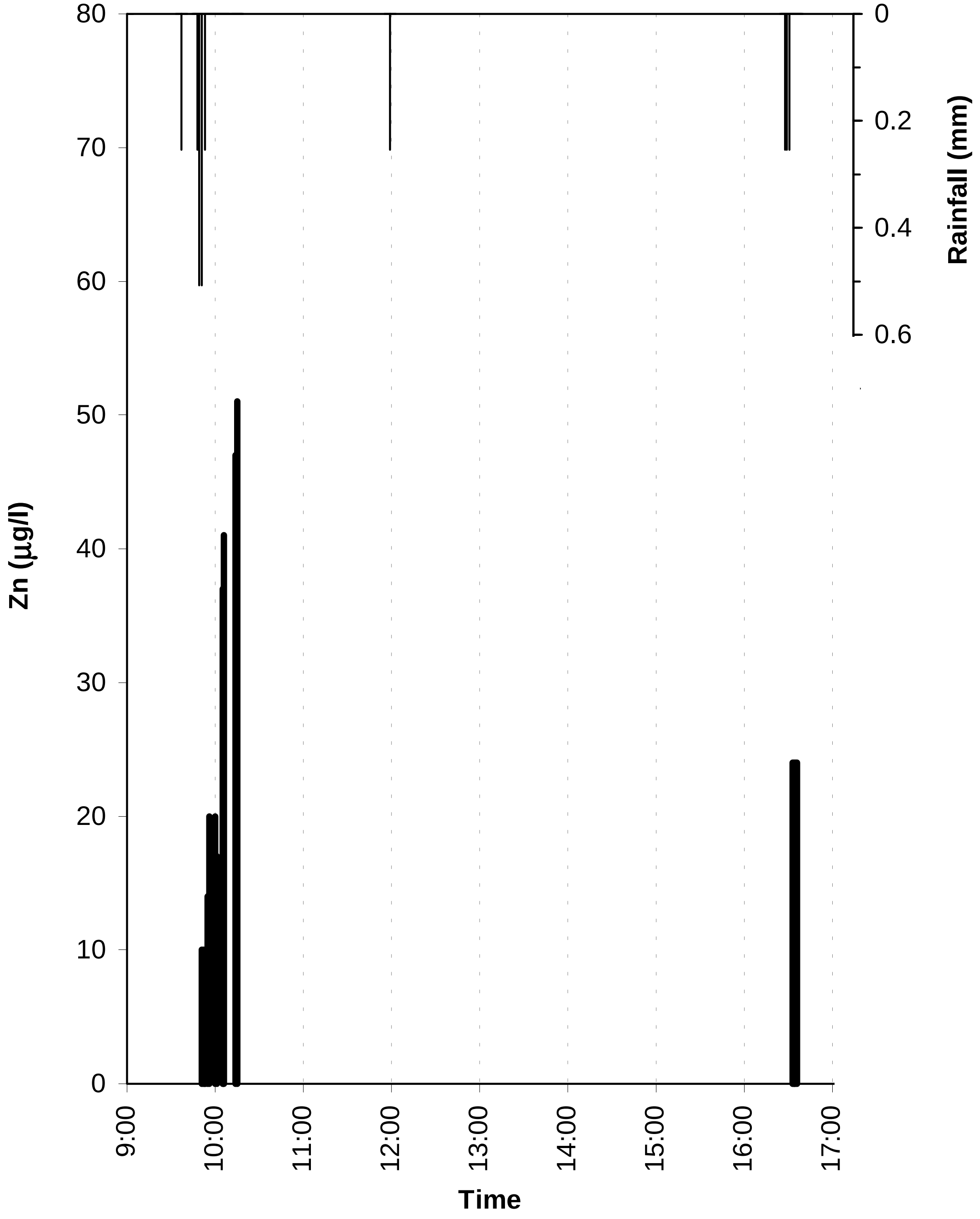
Magnesium in Urban Runoff
10 July 1995
Mg (mg/l)
0
0.5
1
1.5
2
2.5
Rainfall (mm)
0
0.2
0.4
0.6
9:00
10:00
11:00
12:00
13:00
14:00
15:00
16:00
17:00
Time

Sodium in Urban Runoff
10 July 1995

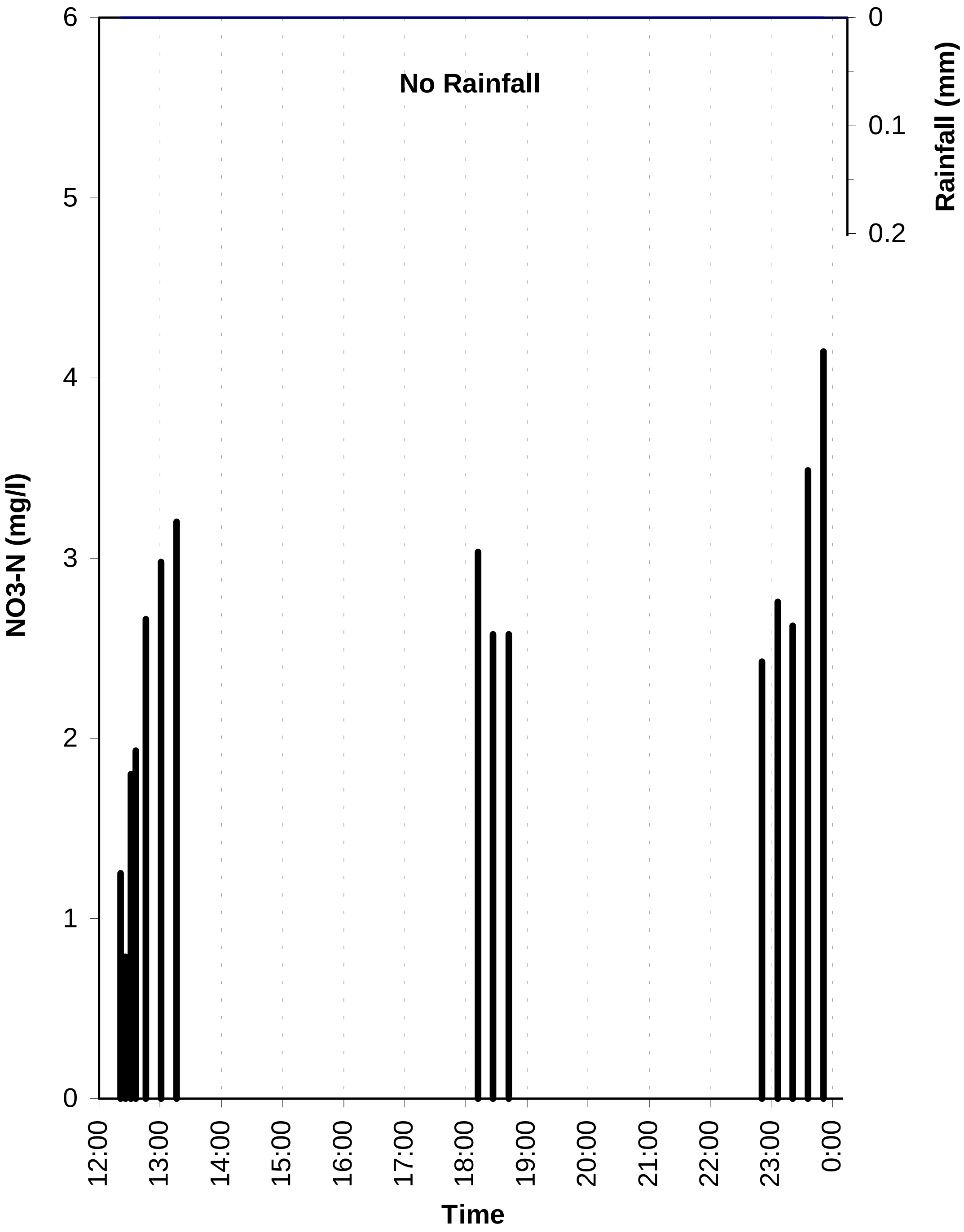



Copper in Urban Runoff
10 July 1995
Cu (µg/l)
0
10
20
30
40
50
60
70
Rainfall (mm)
0
0.2
0.4
0.6
9:00
10:00
11:00
12:00
13:00
14:00
15:00
16:00
17:00
Time

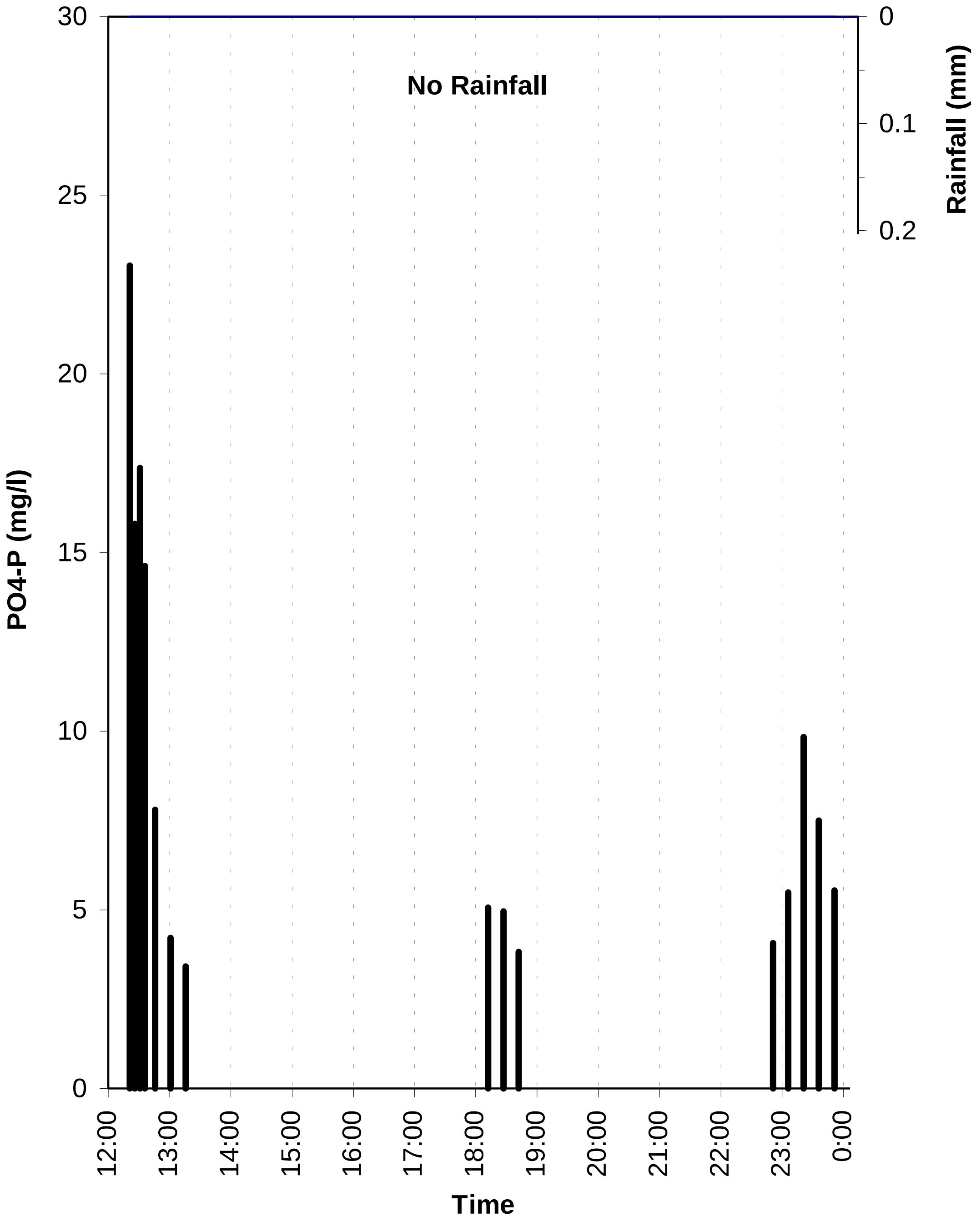
Zinc in Urban Runoff
10 July 1995



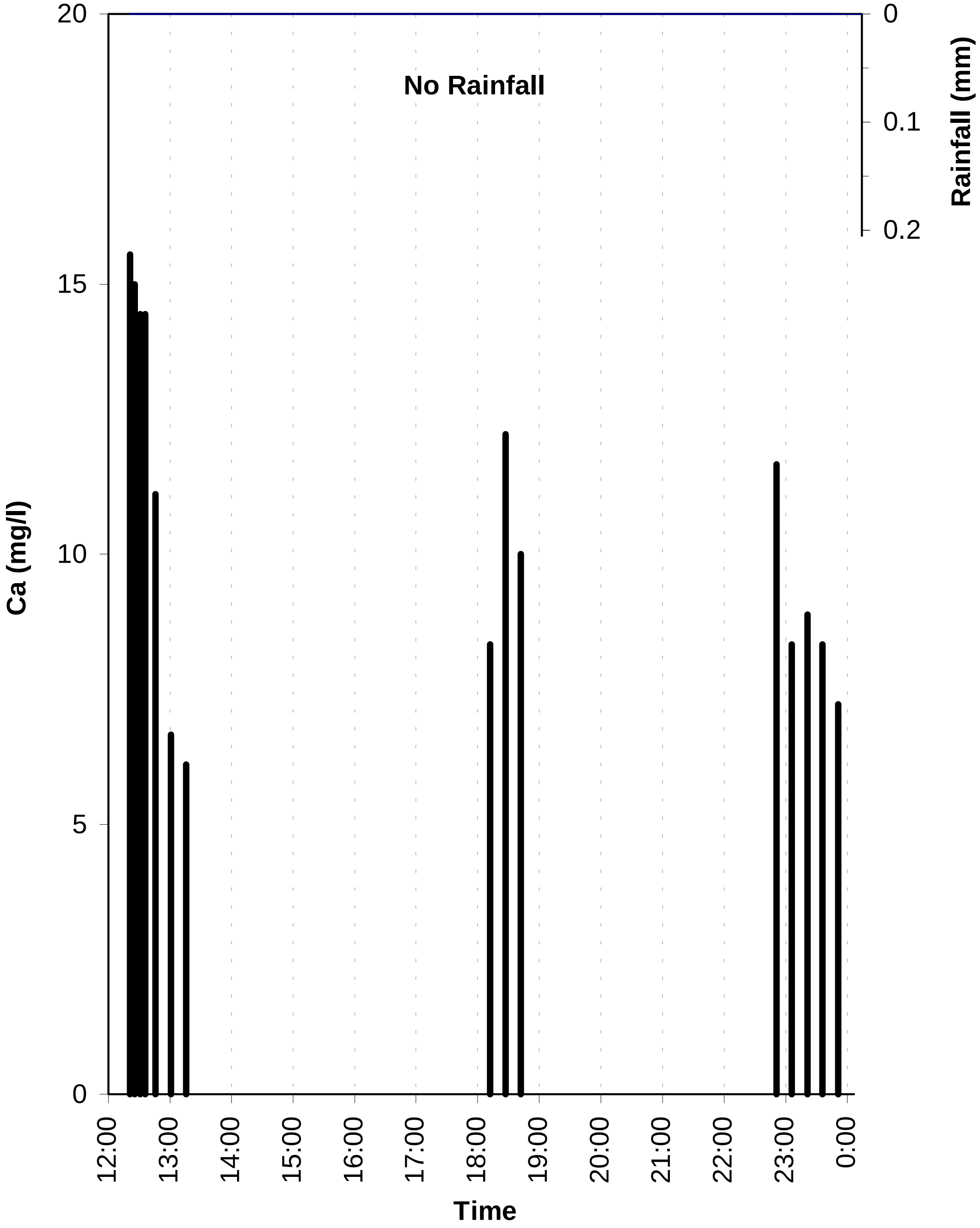
Nitrate-N in Urban Runoff
13 July 1995



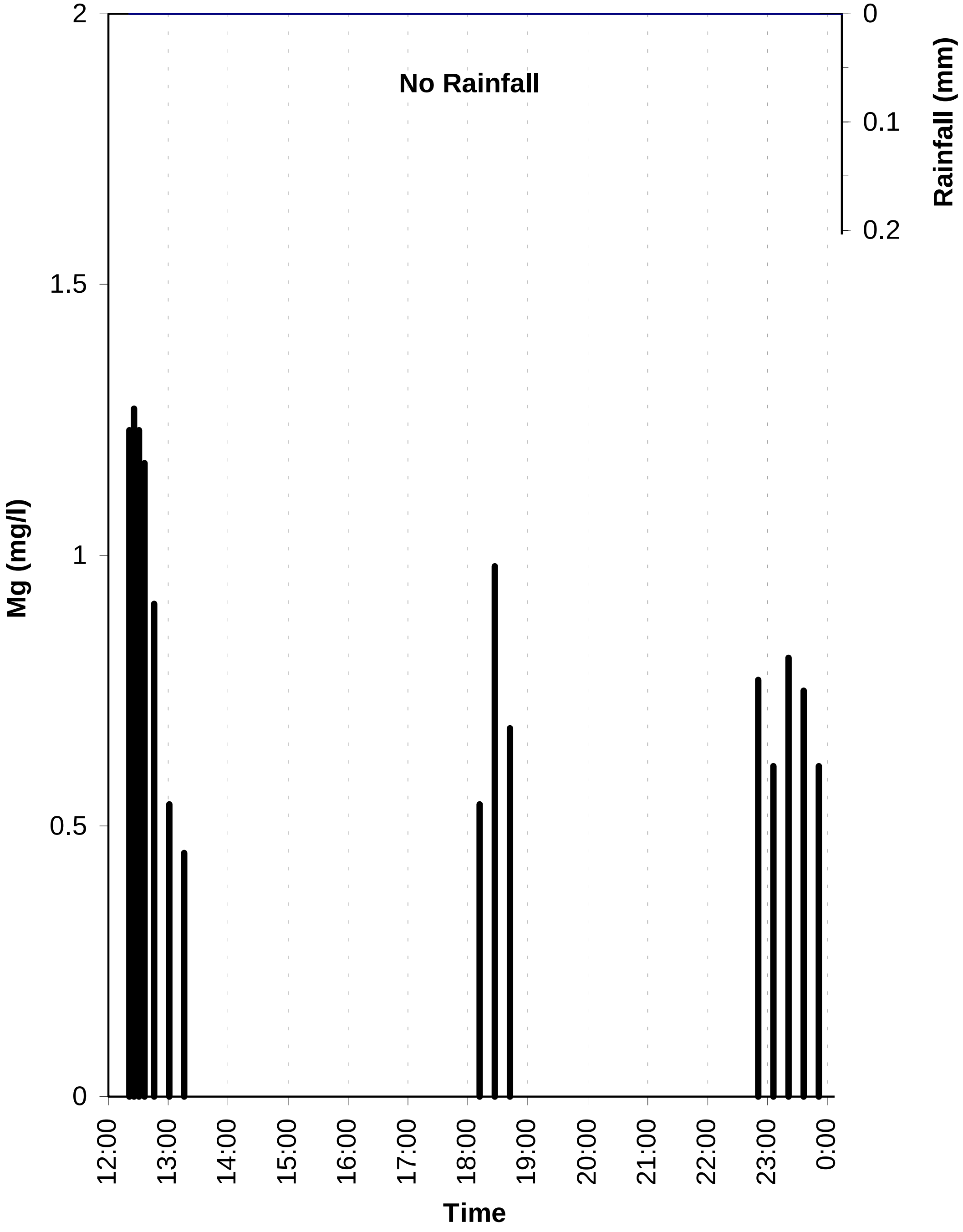
o-Phosphate-P in Urban Runoff
13 July 1995



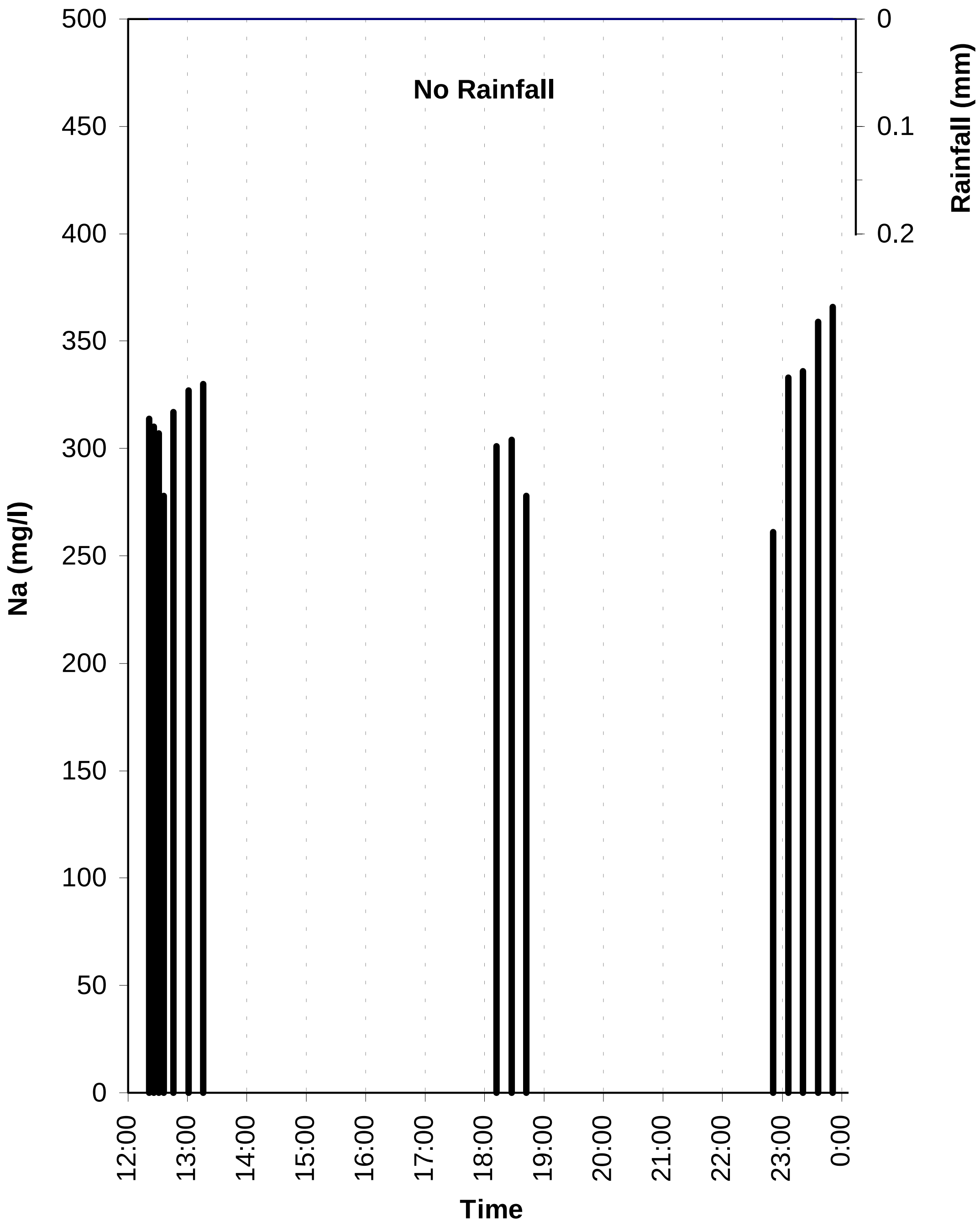
Calcium in Urban Runoff
13 July 1995

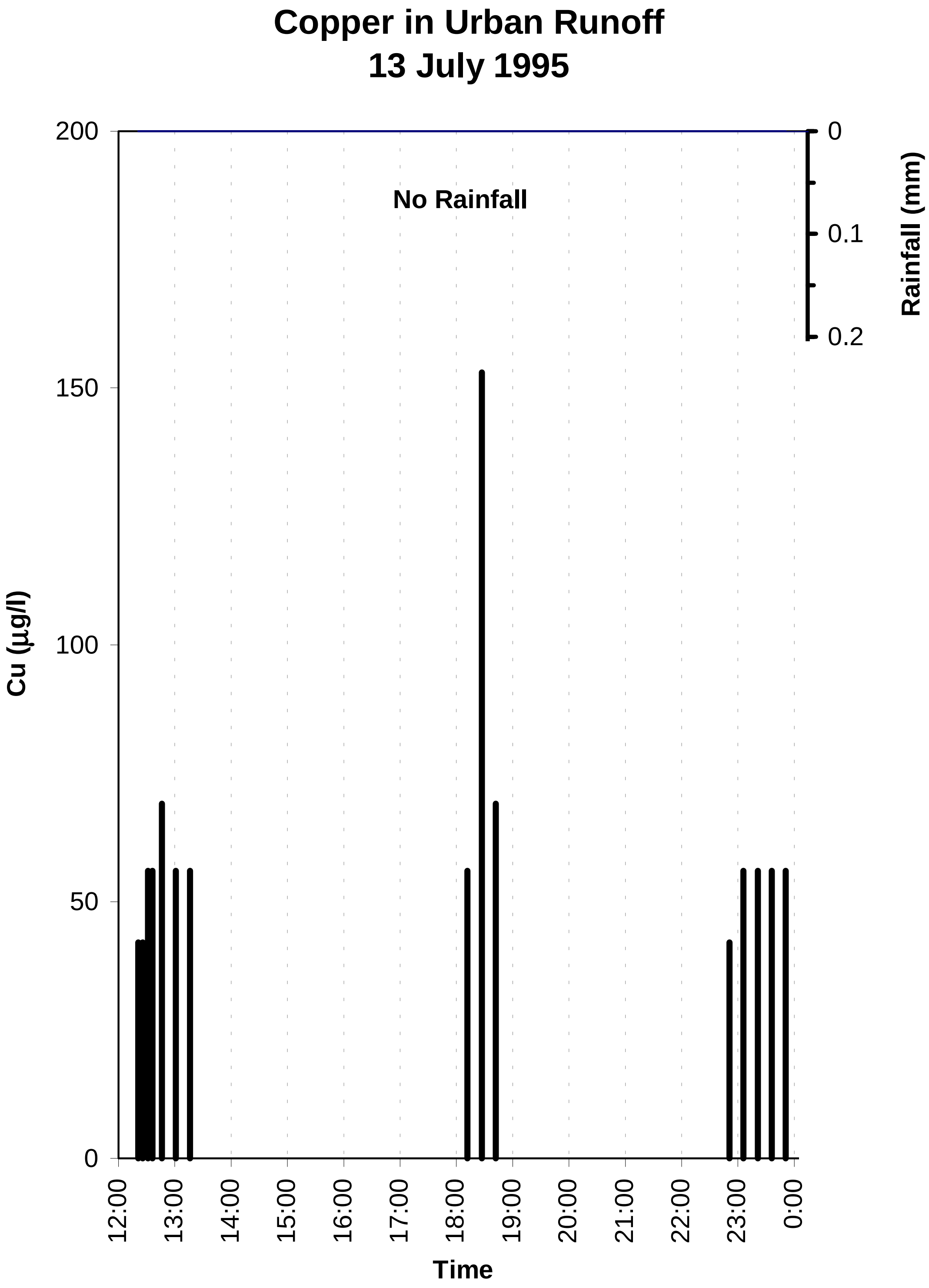


Magnesium in Urban Runoff
13 July 1995

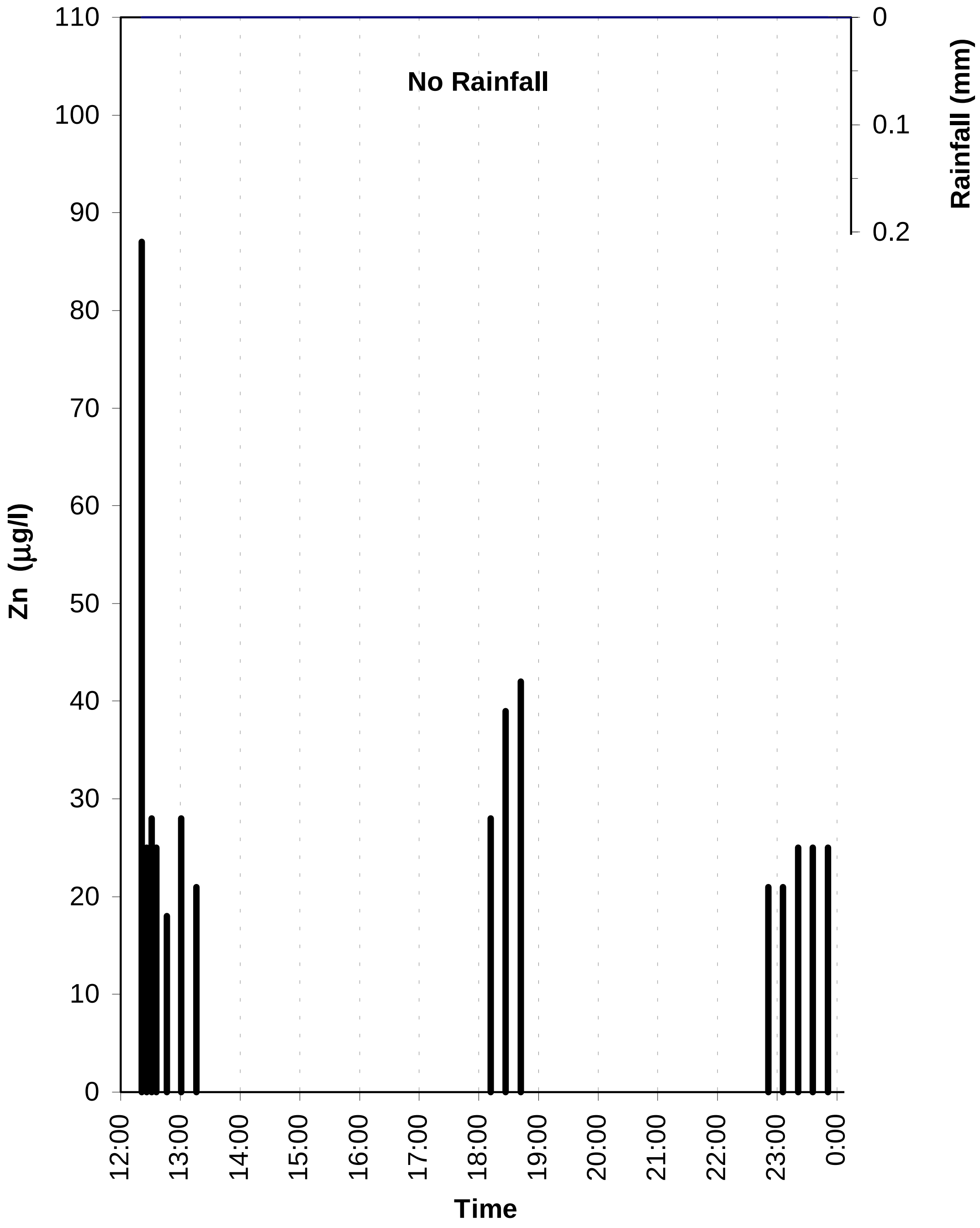


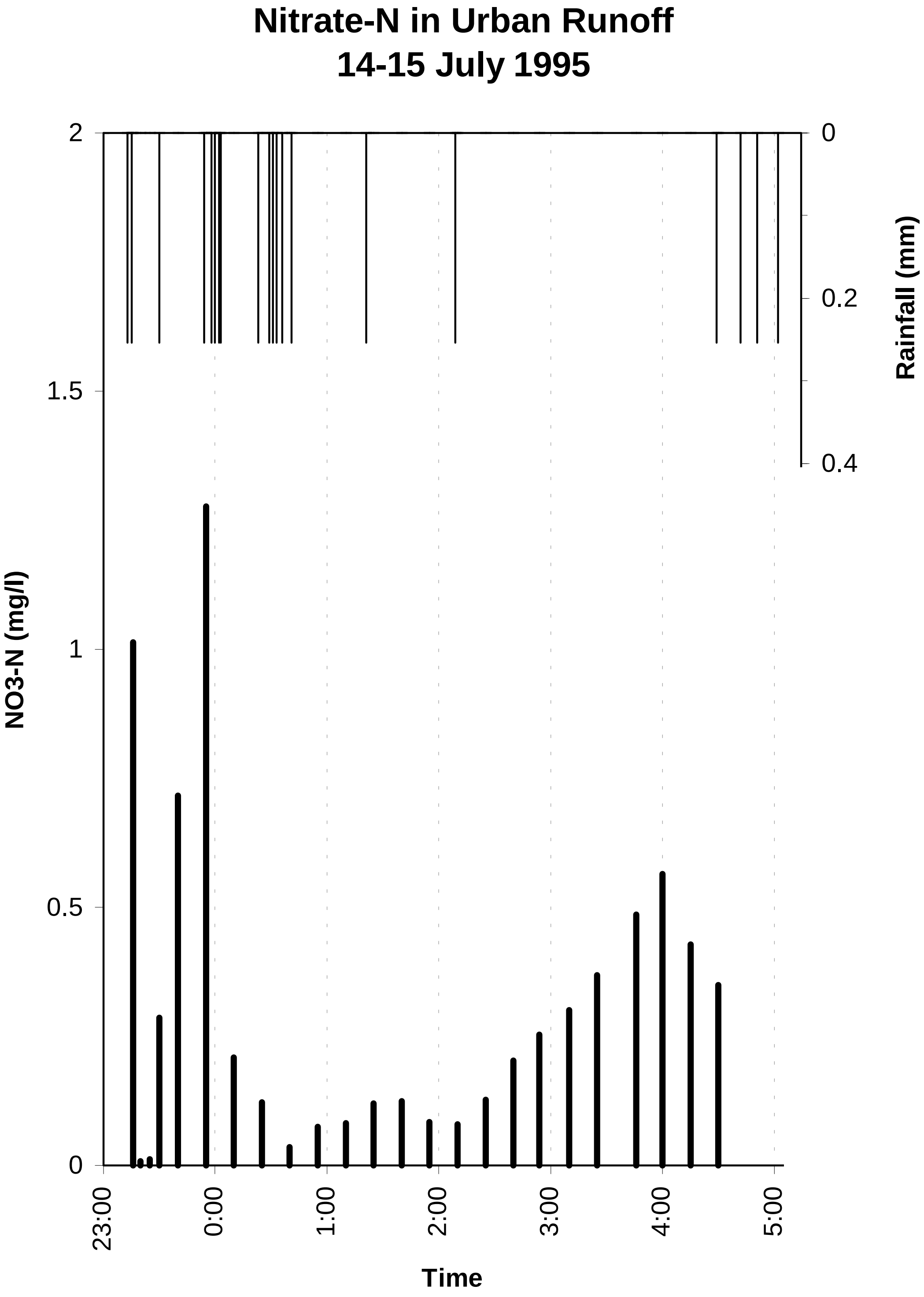
Sodium in Urban Runoff
13 July 1995



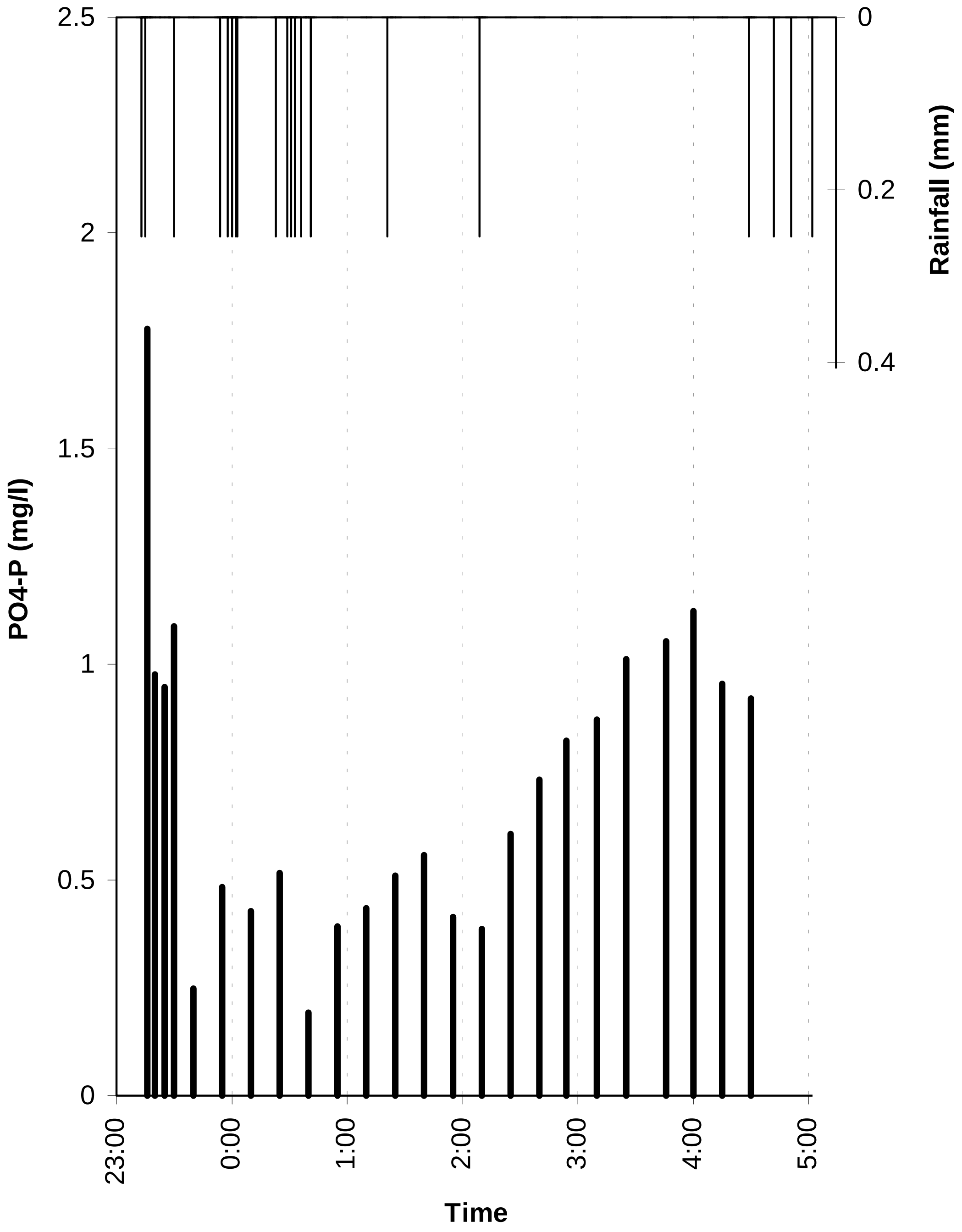

Copper in Urban Runoff
13 July 1995
No Rainfall
Cu (µg/l)
200
150
100
50
0
Rainfall (mm)
0
0.1
0.2
12:00
13:00
14:00
15:00
16:00
17:00
18:00
19:00
20:00
21:00
22:00
23:00
0:00
Time

Zinc in Urban Runoff
13 July 1995

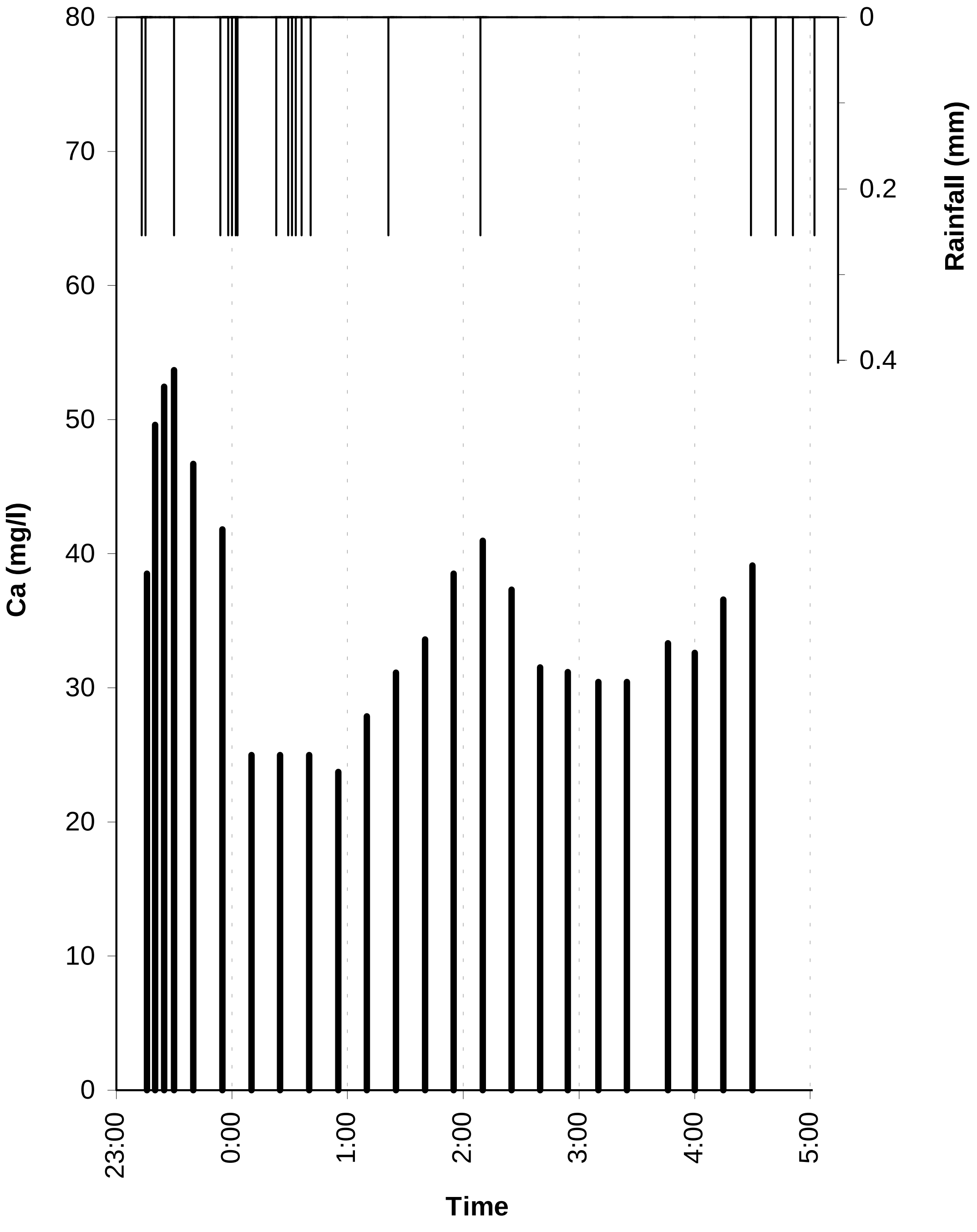



Nitrate-N in Urban Runoff
14-15 July 1995
NO3-N (mg/l)
2
1.5
1
0.5
0
Rainfall (mm)
0
0.2
0.4
23:00
0:00
1:00
2:00
3:00
4:00
5:00
Time

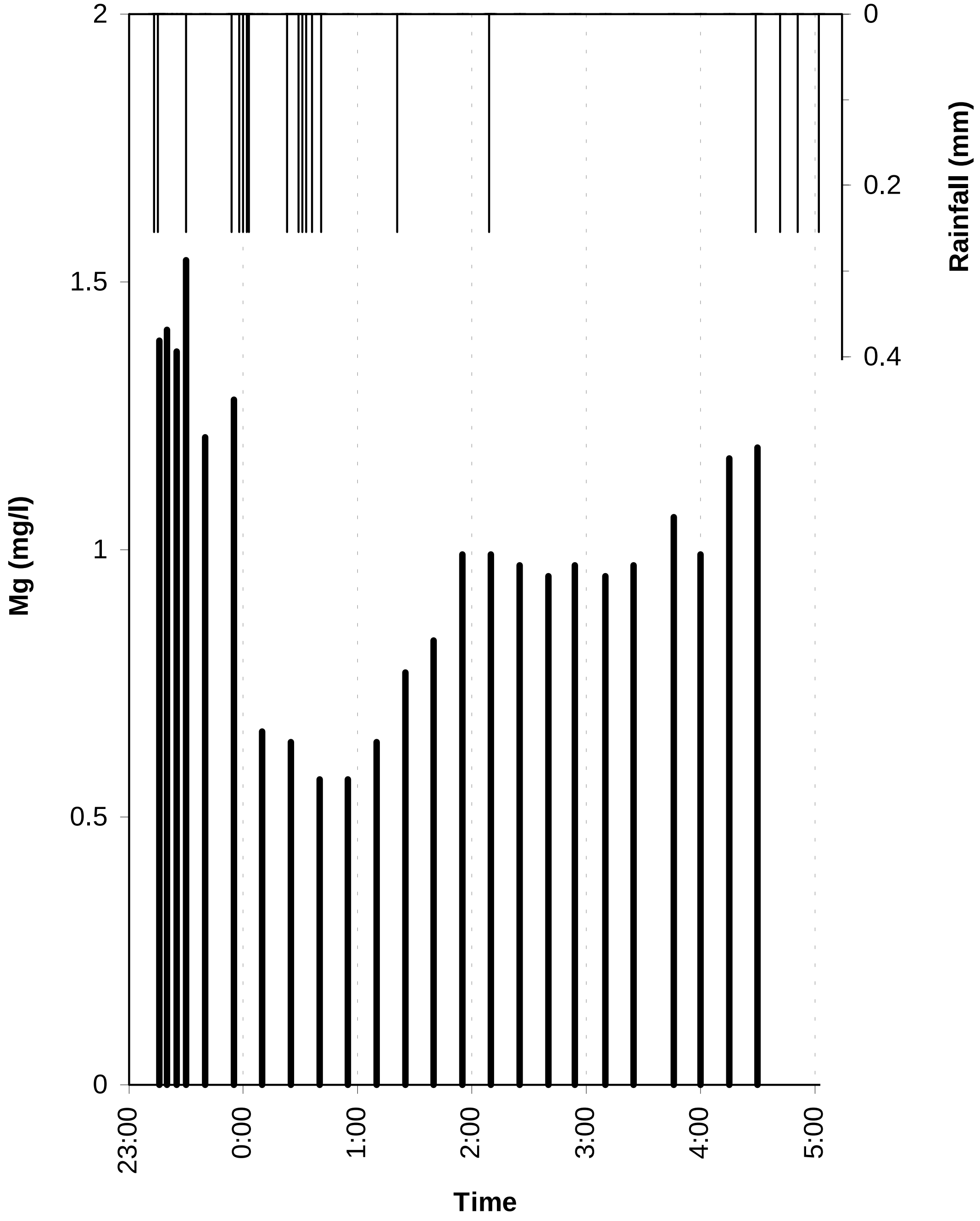
o-Phosphate-P in Urban Runoff
14-15 July 1995



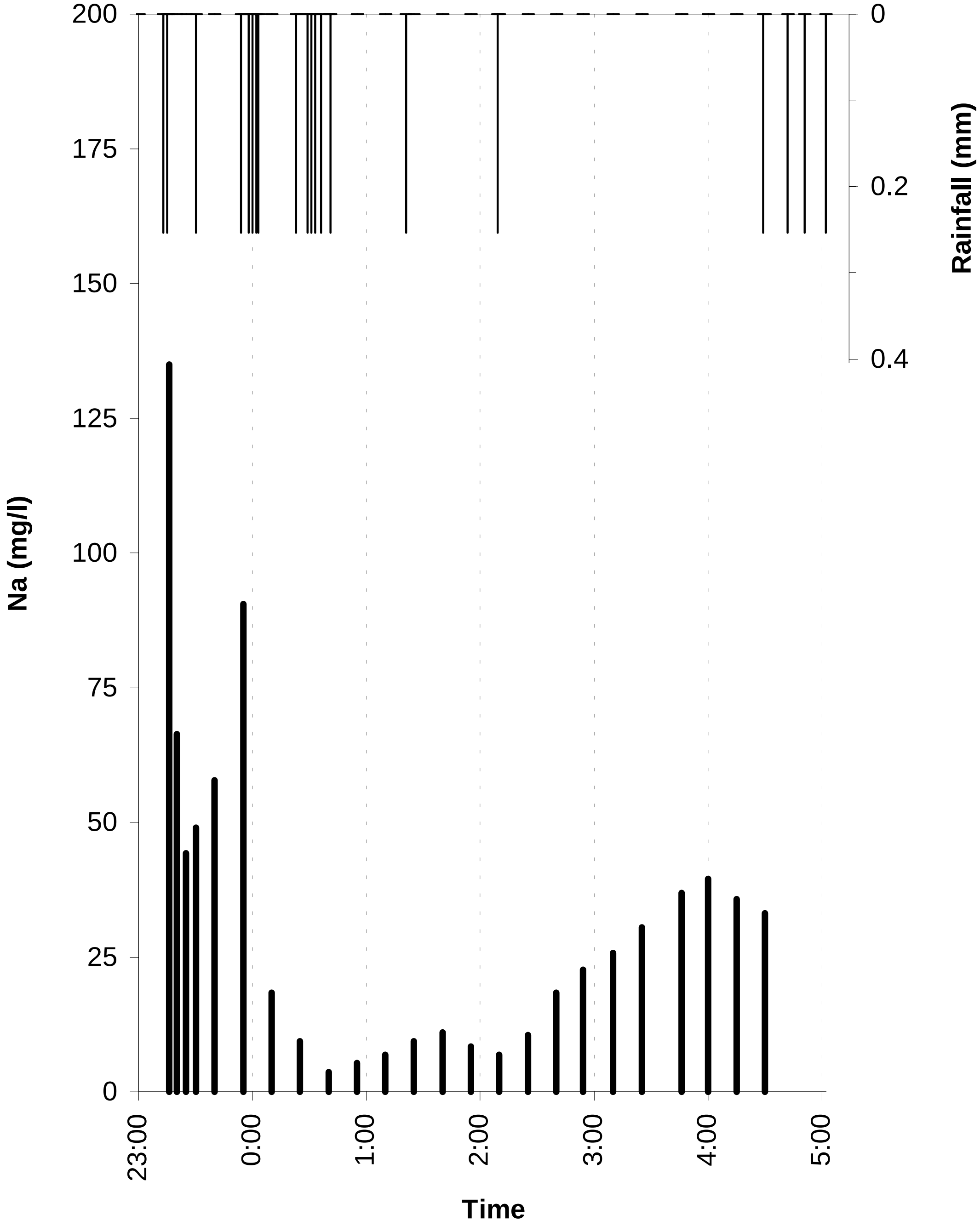
Calcium in Urban Runoff
14-15 July 1995



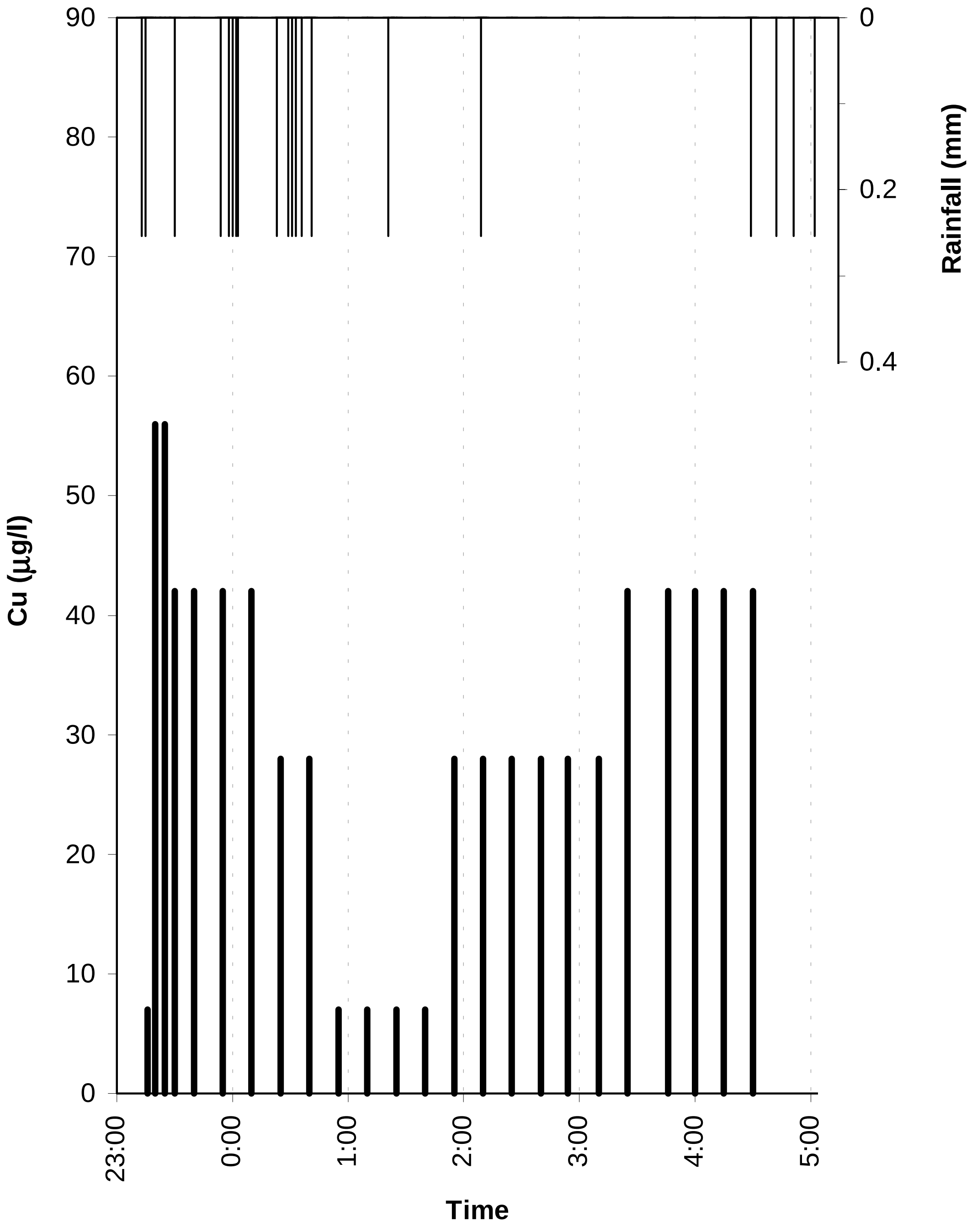
Magnesium in Urban Runoff
14-15 July 1995



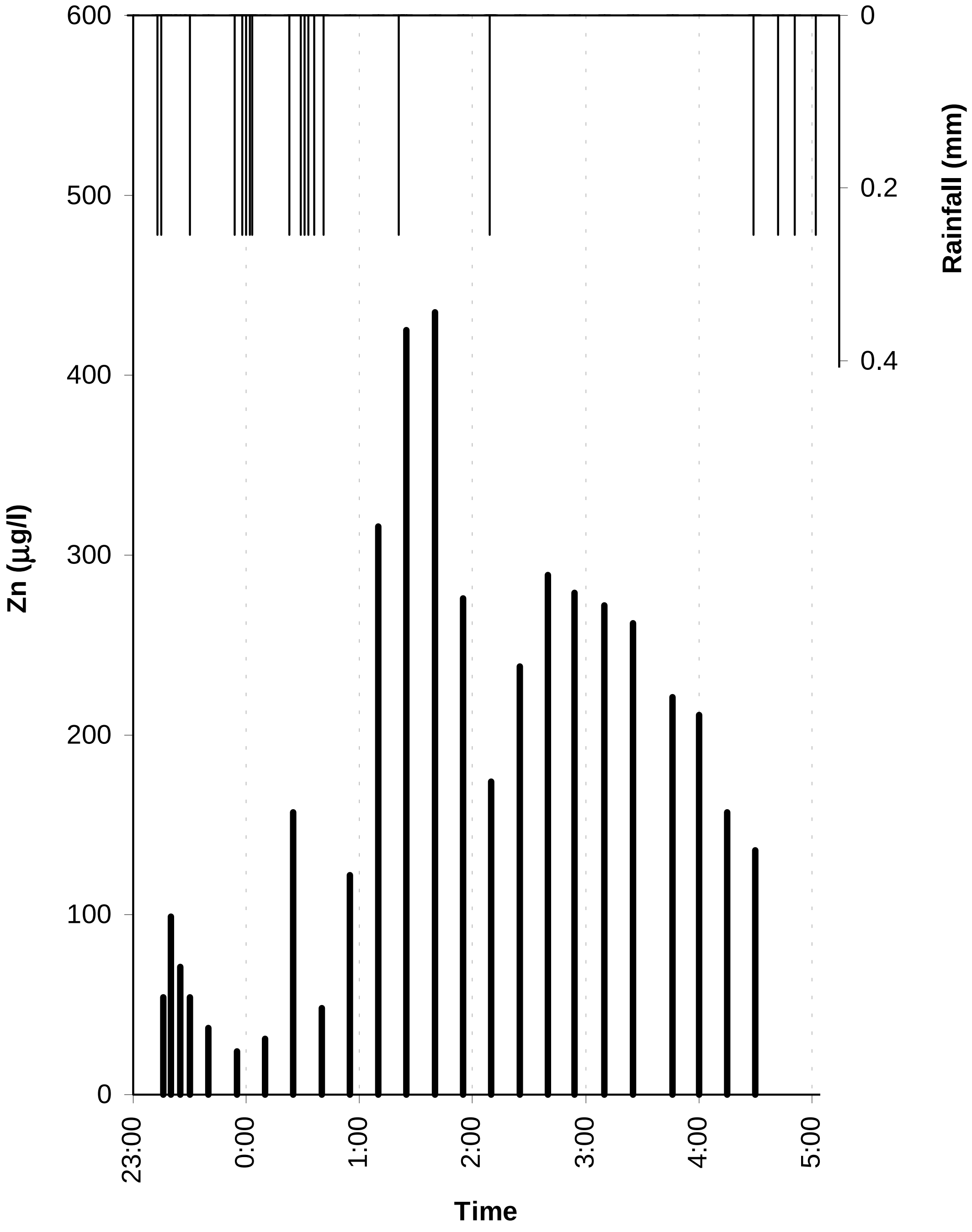
Sodium in Urban Runoff
14-15 July 1995



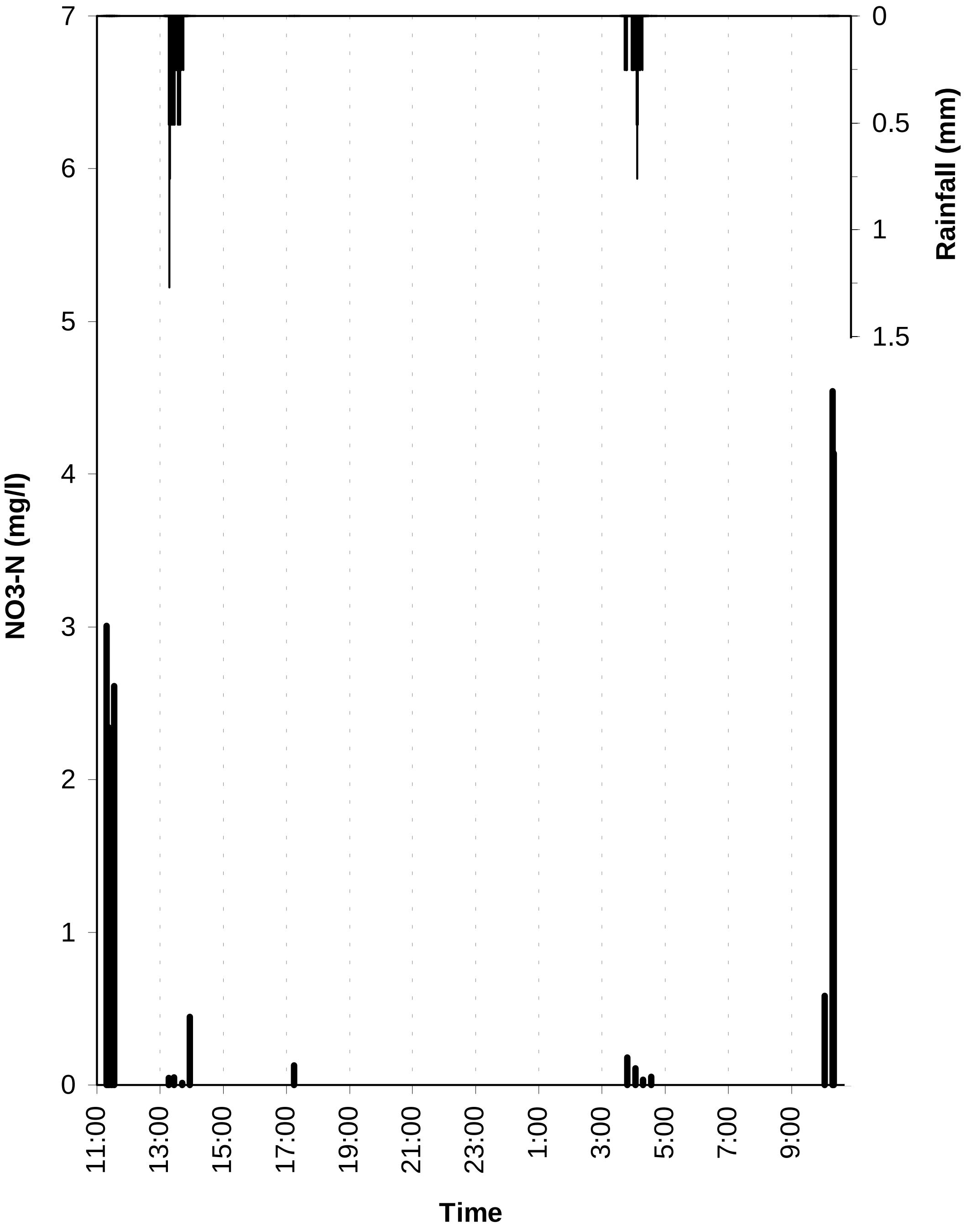
Copper in Urban Runoff
14-15 July 1995



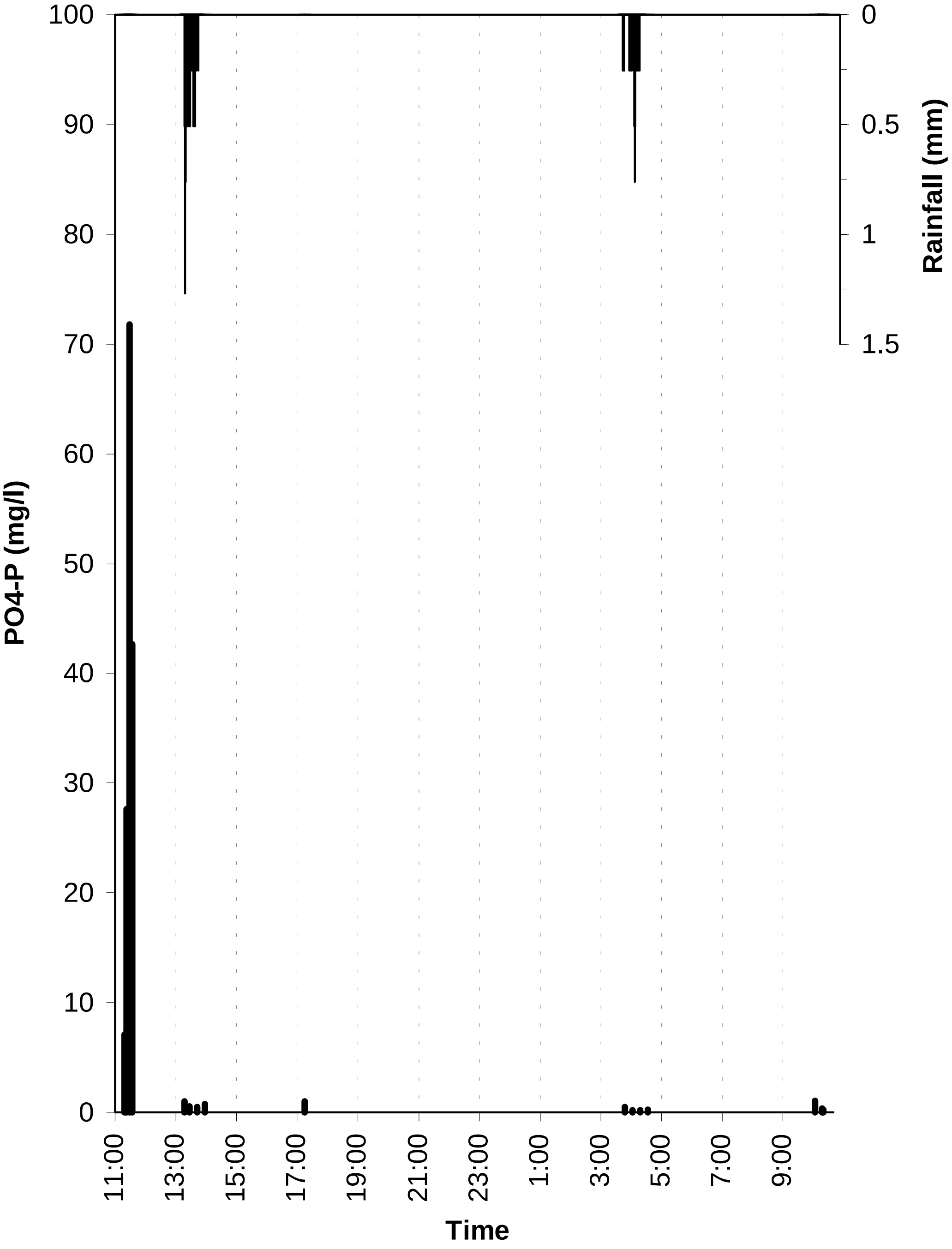
Zinc in Urban Runoff
14-15 July 1995



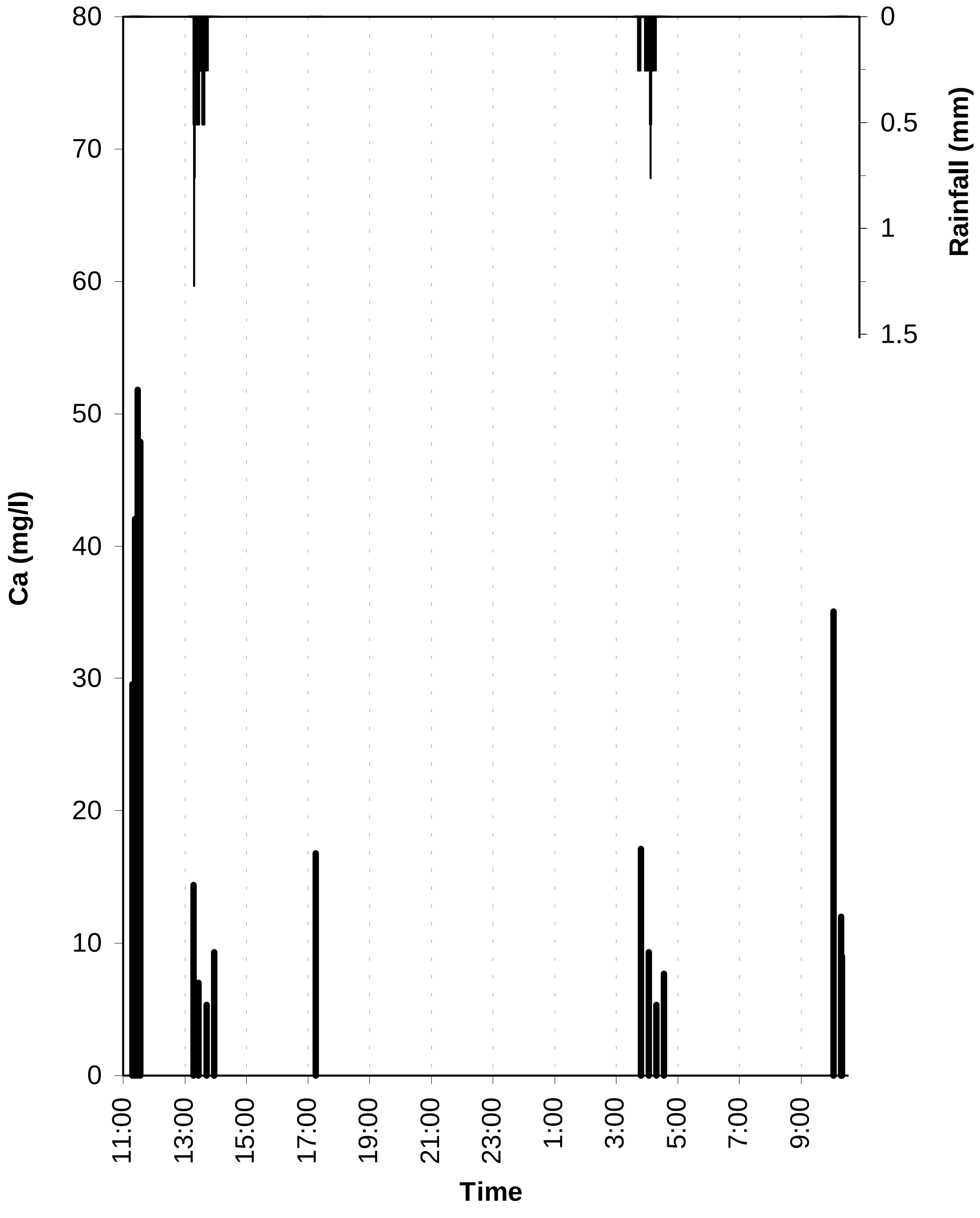
Nitrate-N in Urban Runoff
17-18 July 1995



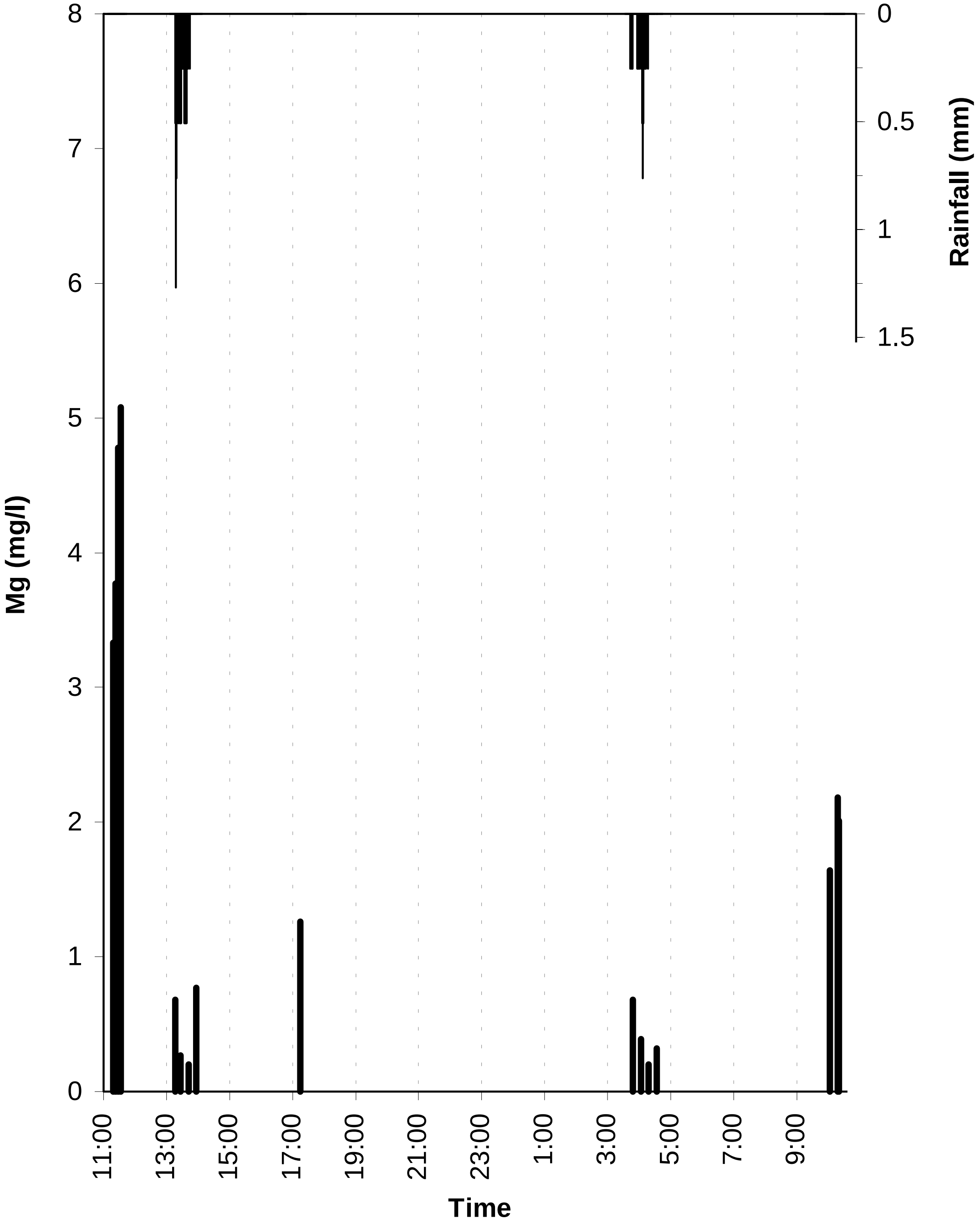
o-Phosphate-P in Urban Runoff
17-18 July 1995



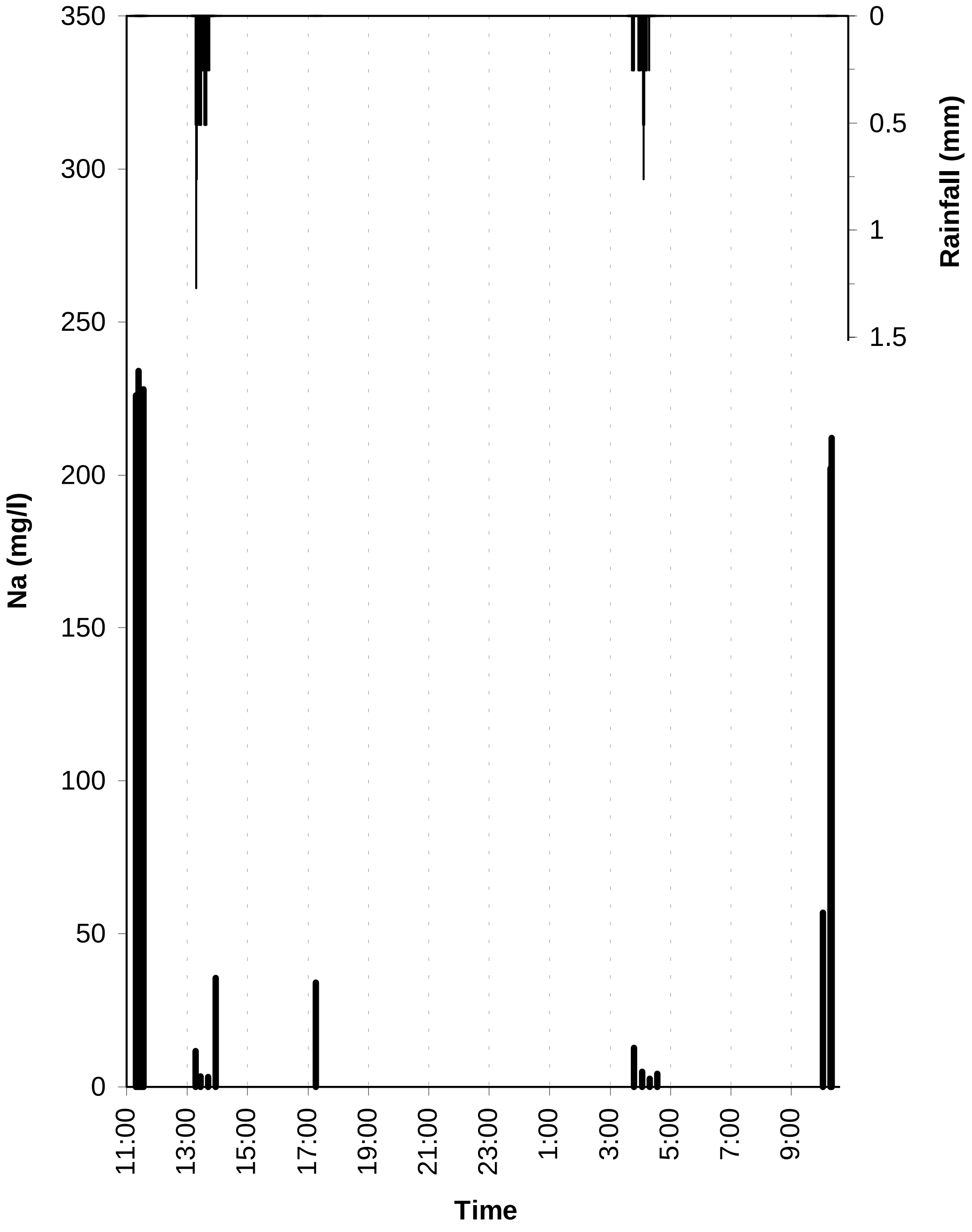
Calcium in Urban Runoff
17-18 July 1995



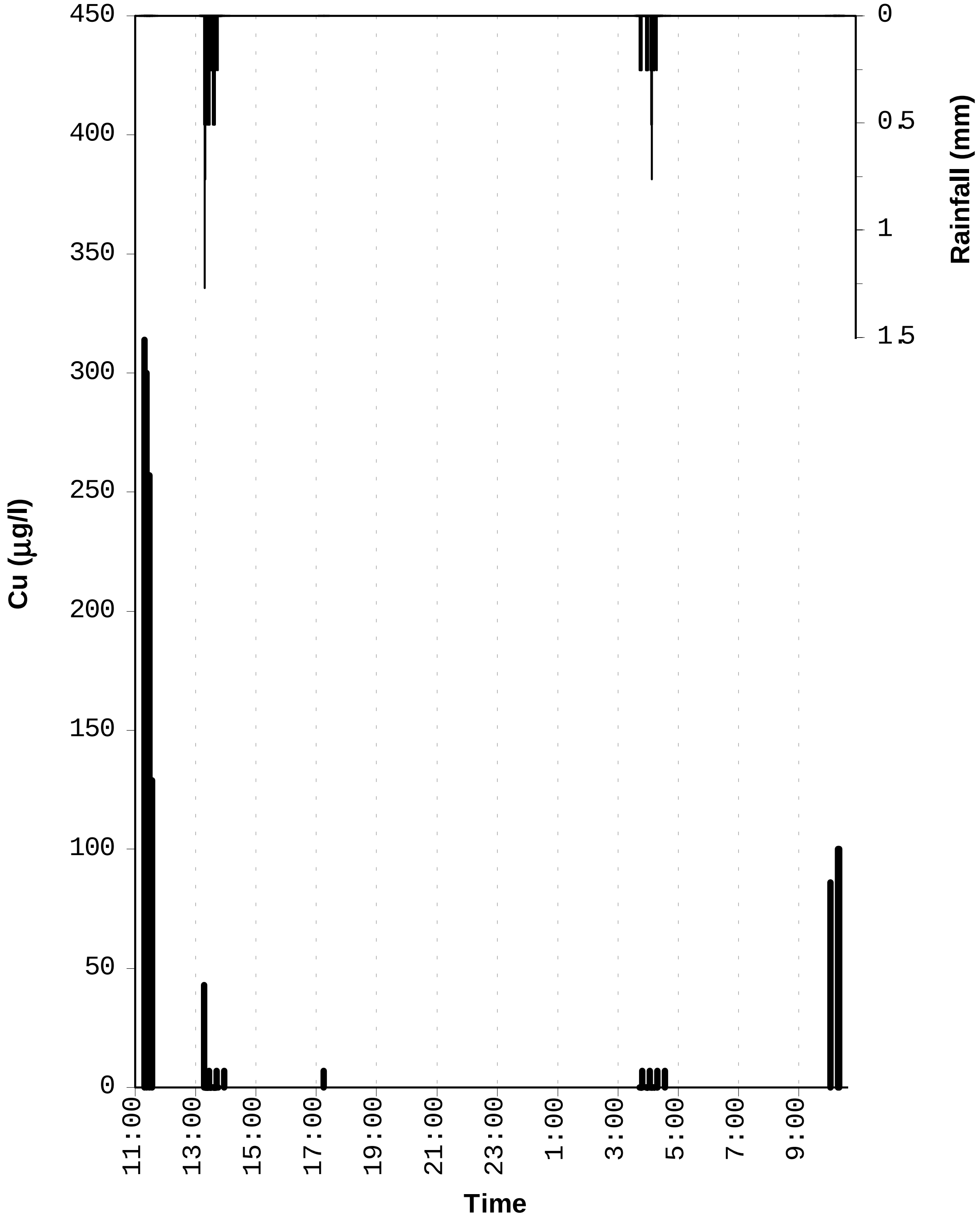
Magnesium in Urban Runoff
17-18 July 1995



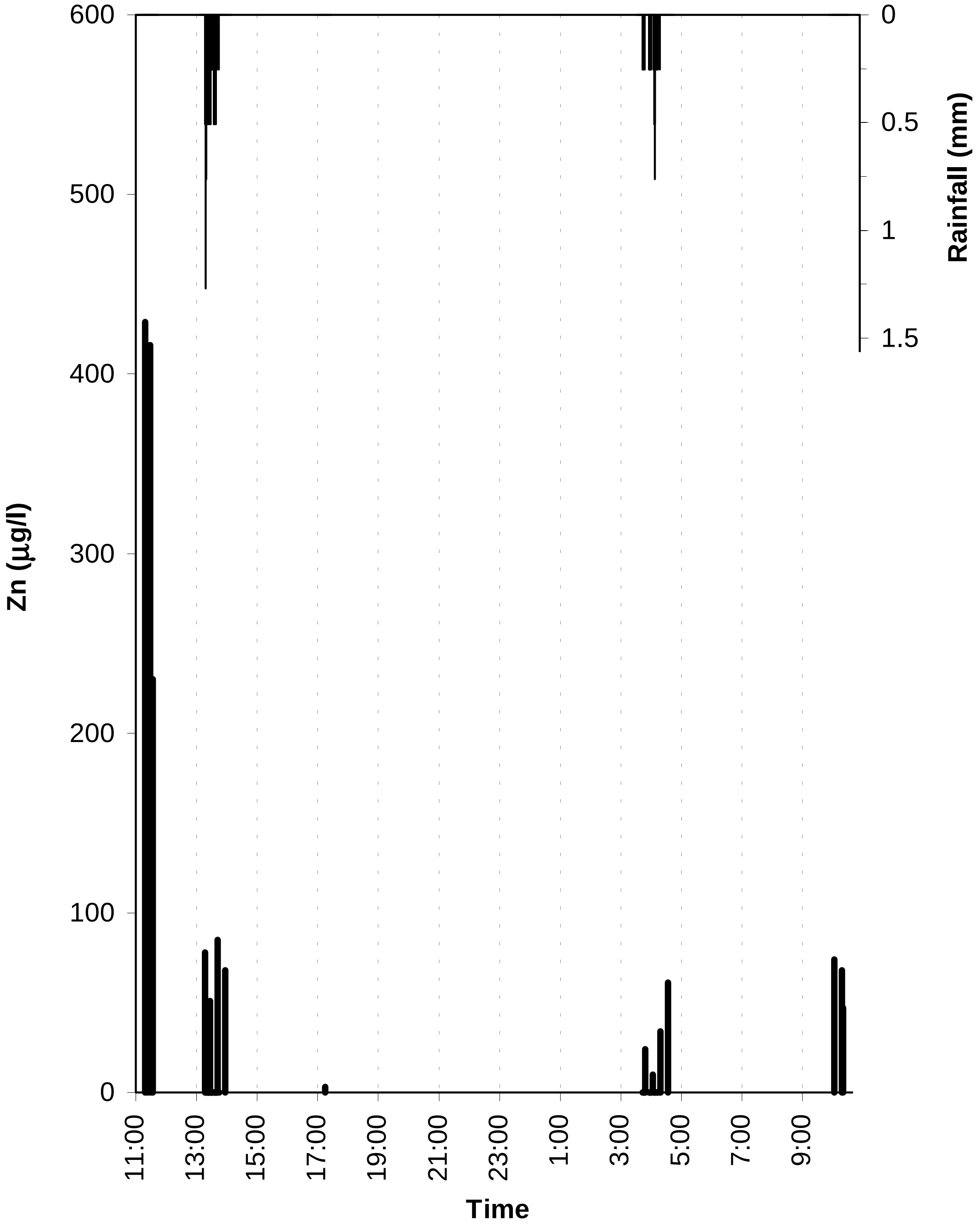
Sodium in Urban Runoff 17-18 July 1995



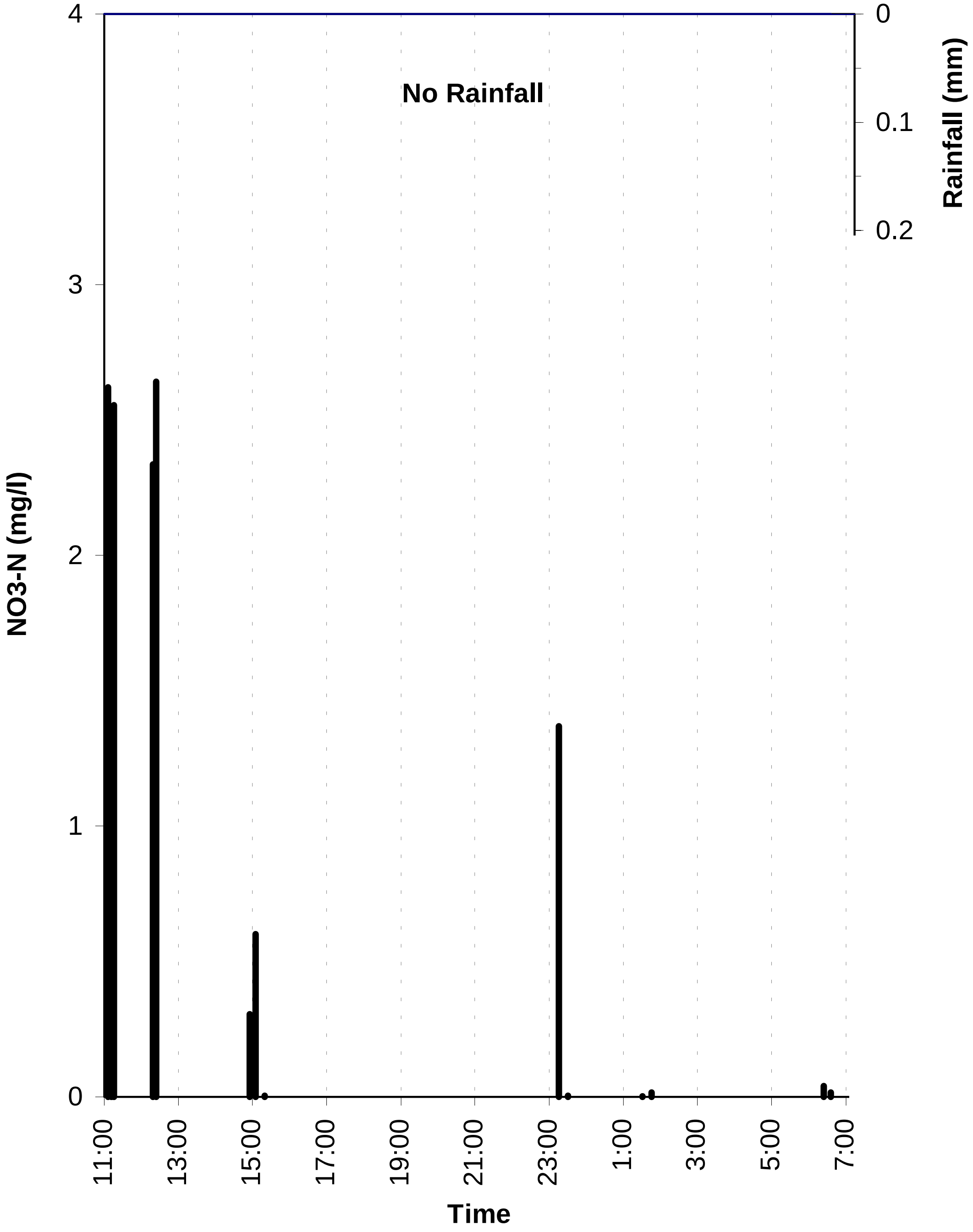
Copper in Urban Runoff
17-18 July 1995



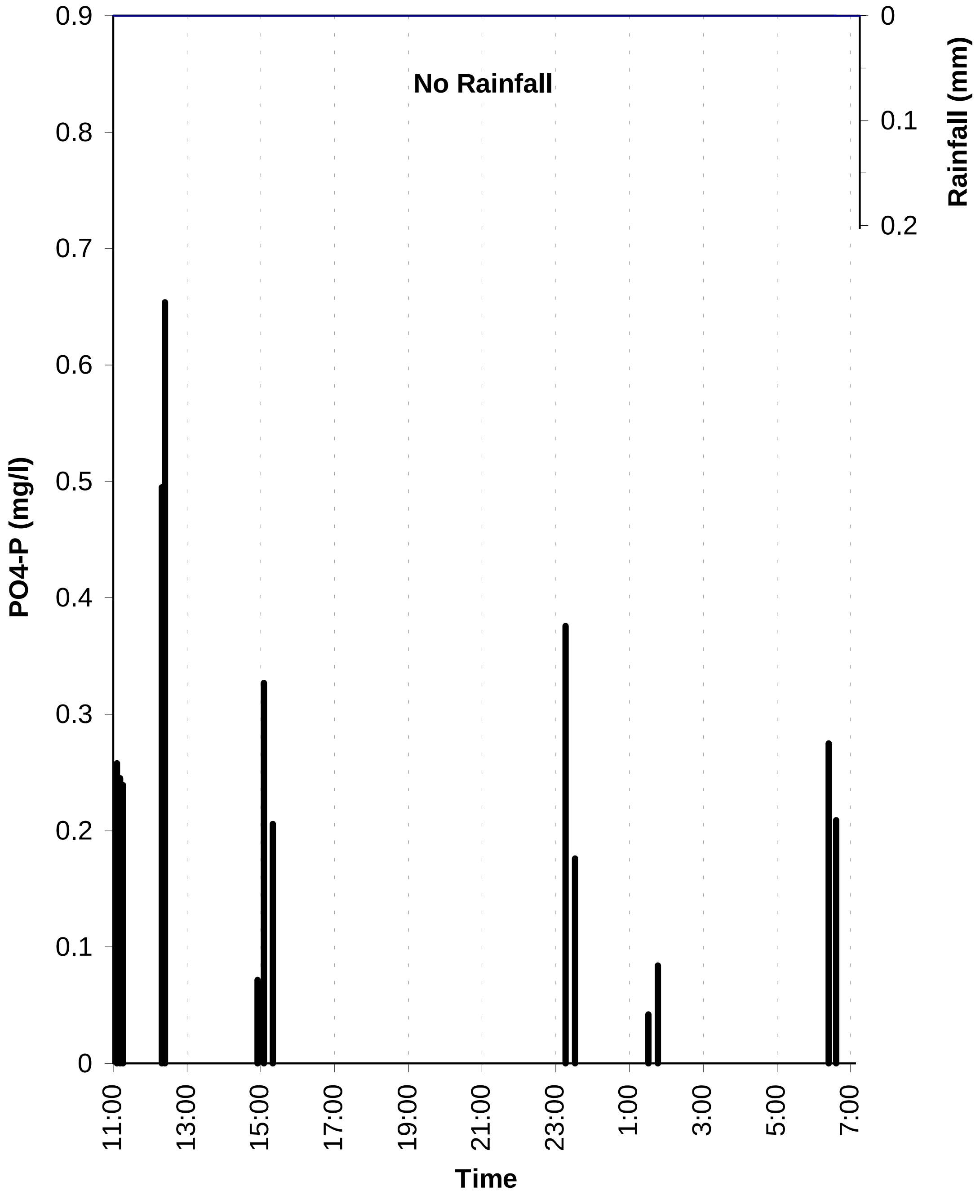
Zinc in Urban Runoff
17-18 July 1995



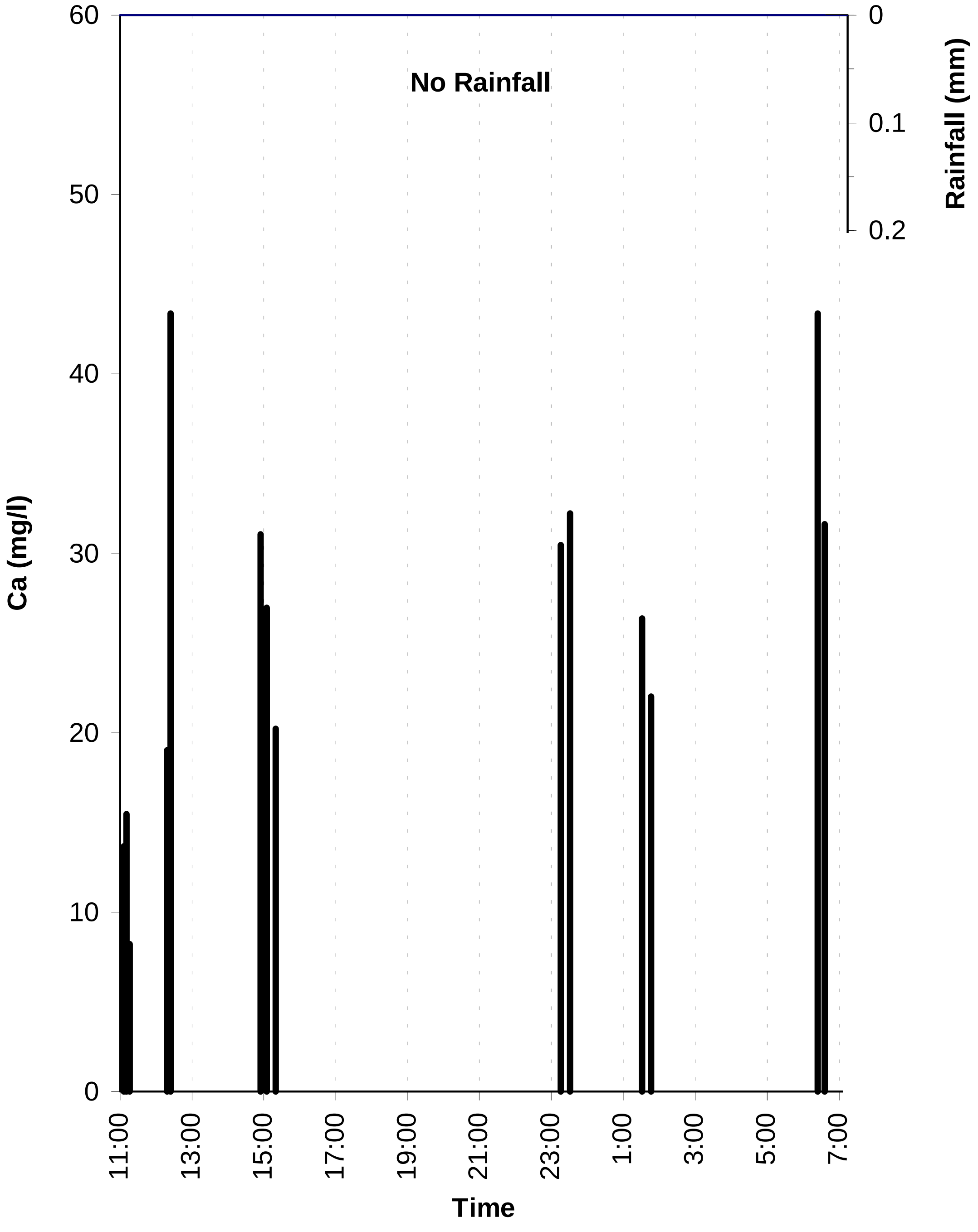
Nitrate-N in Urban Runoff
18-19 July 1995

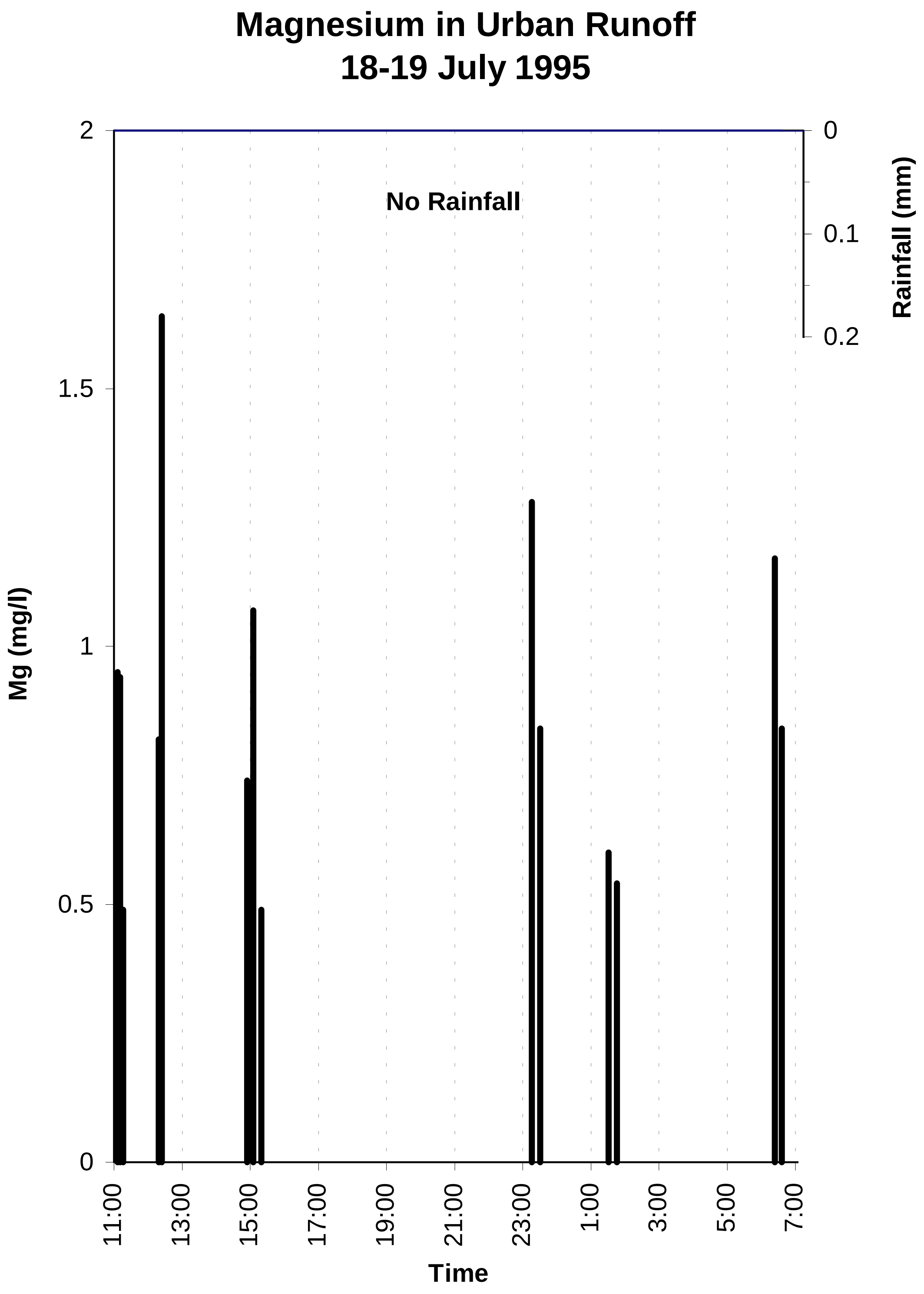


o-Phosphate-P in Urban Runoff
18-19 July 1995

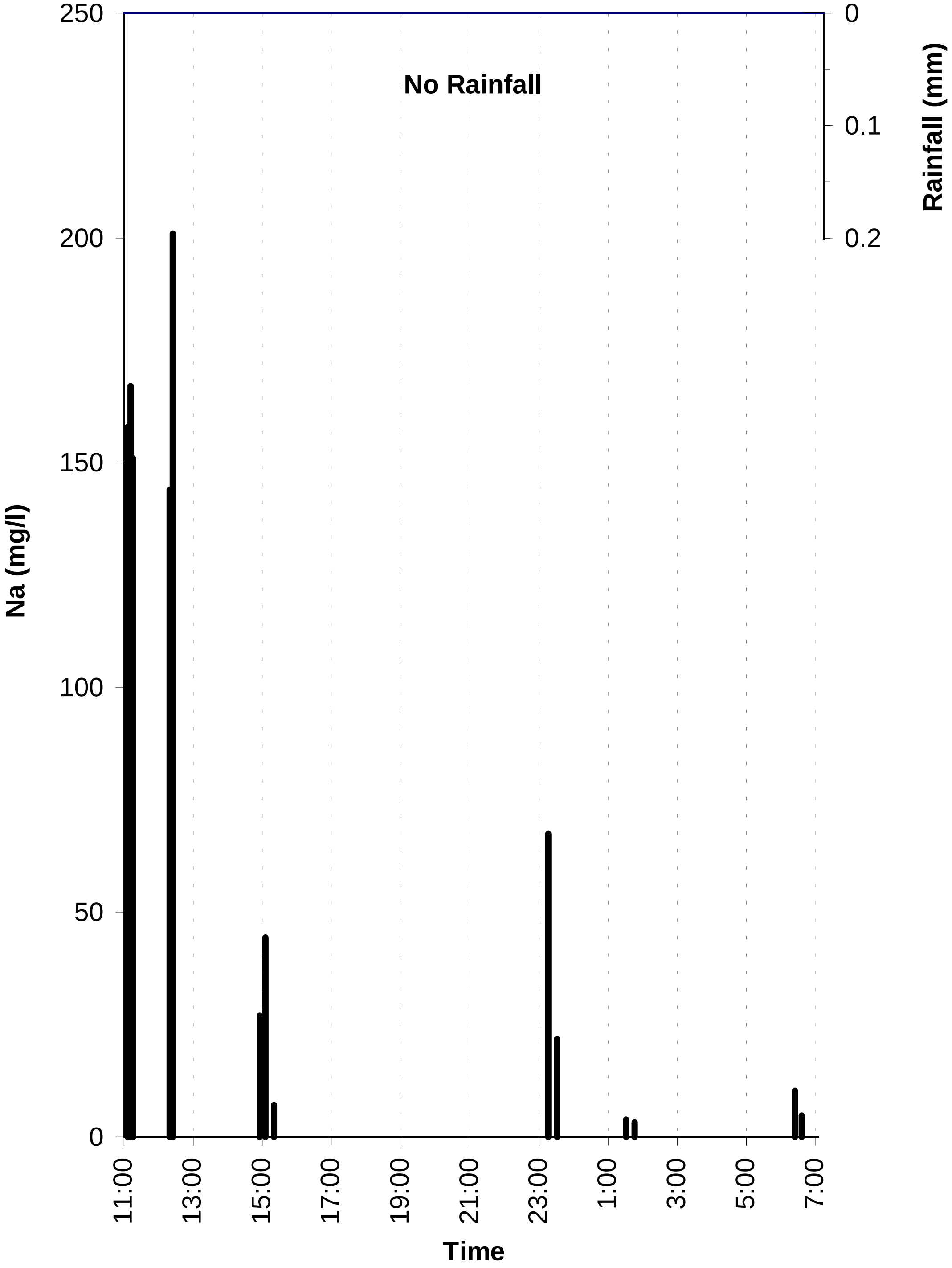


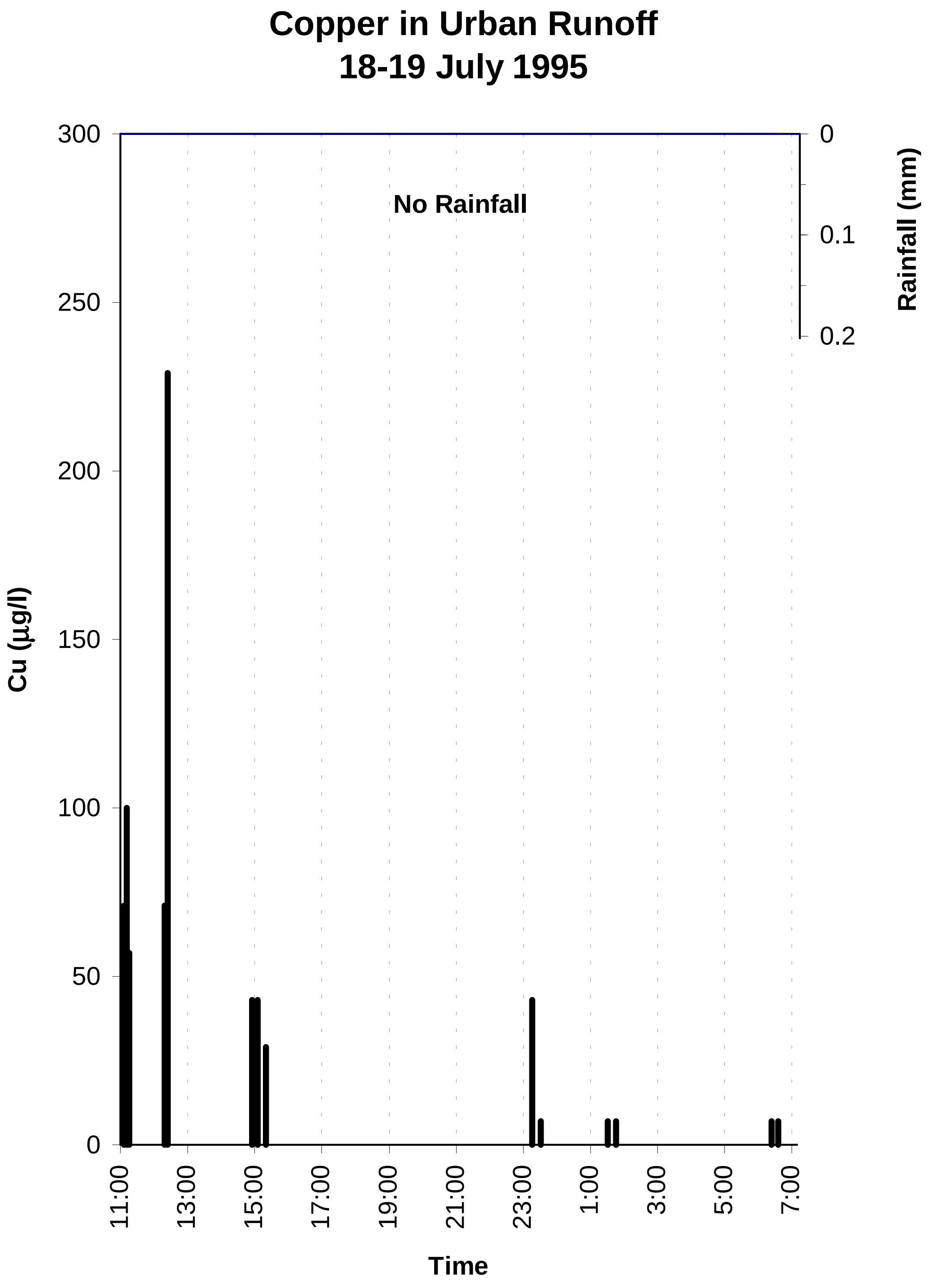
Calcium in Urban Runoff
18-19 July 1995



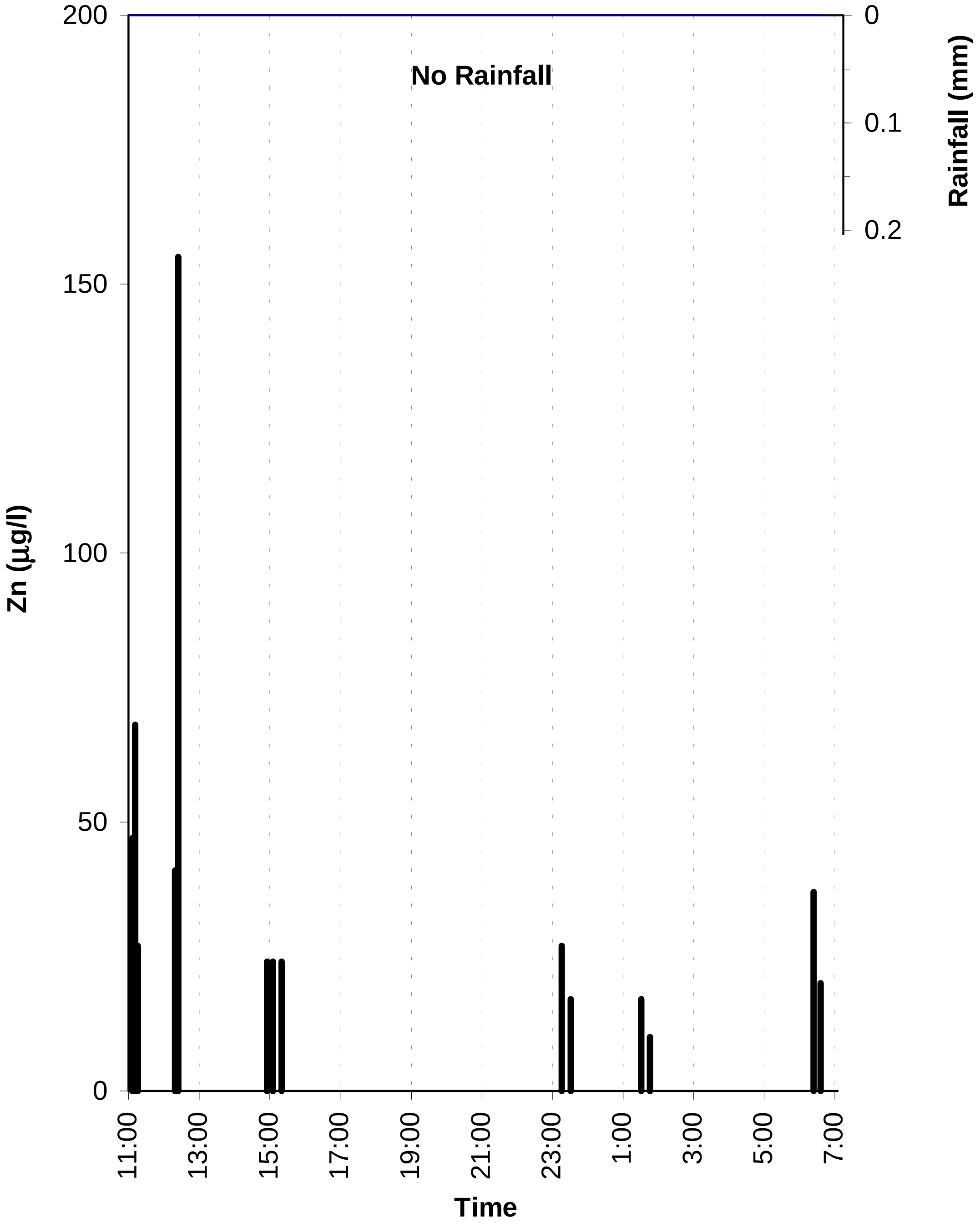

Magnesium in Urban Runoff
18-19 July 1995
No Rainfall
Mg (mg/l)
2
1.5
1
0.5
0
Rainfall (mm)
0
0.1
0.2
11:00
13:00
15:00
17:00
19:00
21:00
23:00
1:00
3:00
5:00
7:00
Time

Sodium in Urban Runoff
18-19 July 1995

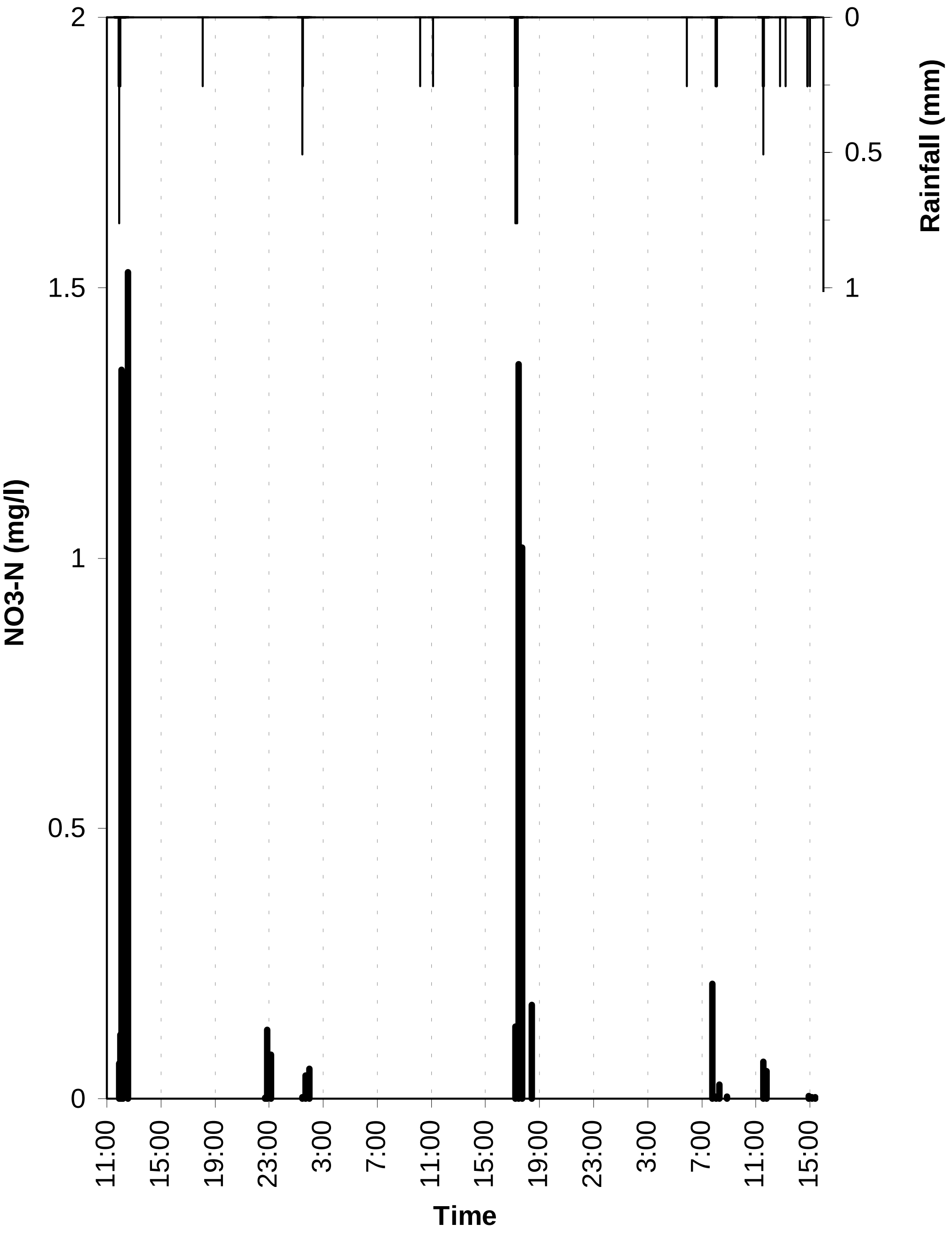



Copper in Urban Runoff
18-19 July 1995
No Rainfall
Cu (µg/l)
300
250
200
150
100
50
0
Rainfall (mm)
0
0.1
0.2
11:00
13:00
15:00
17:00
19:00
21:00
23:00
1:00
3:00
5:00
7:00
Time

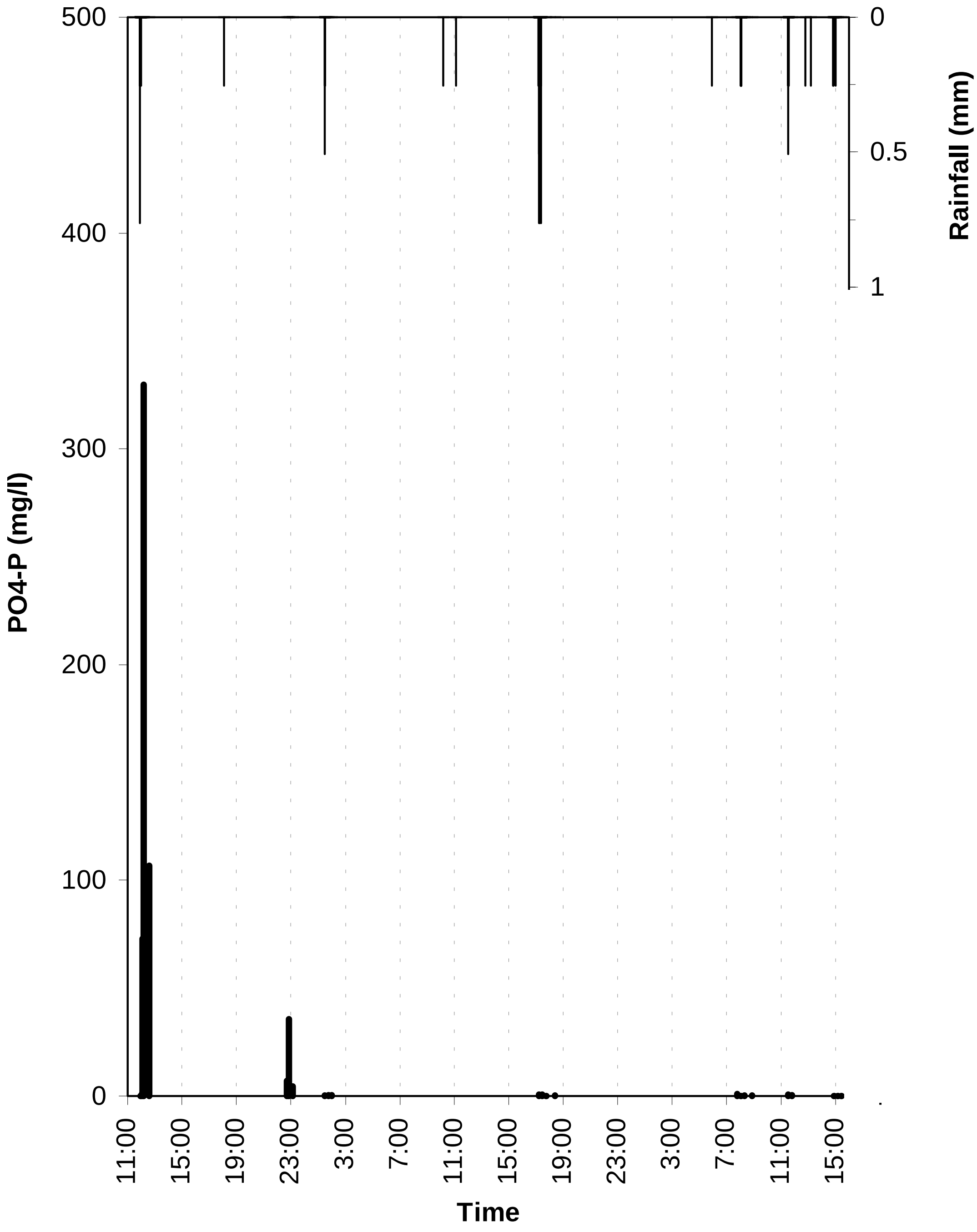
Zinc in Urban Runoff
18-19 July 1995



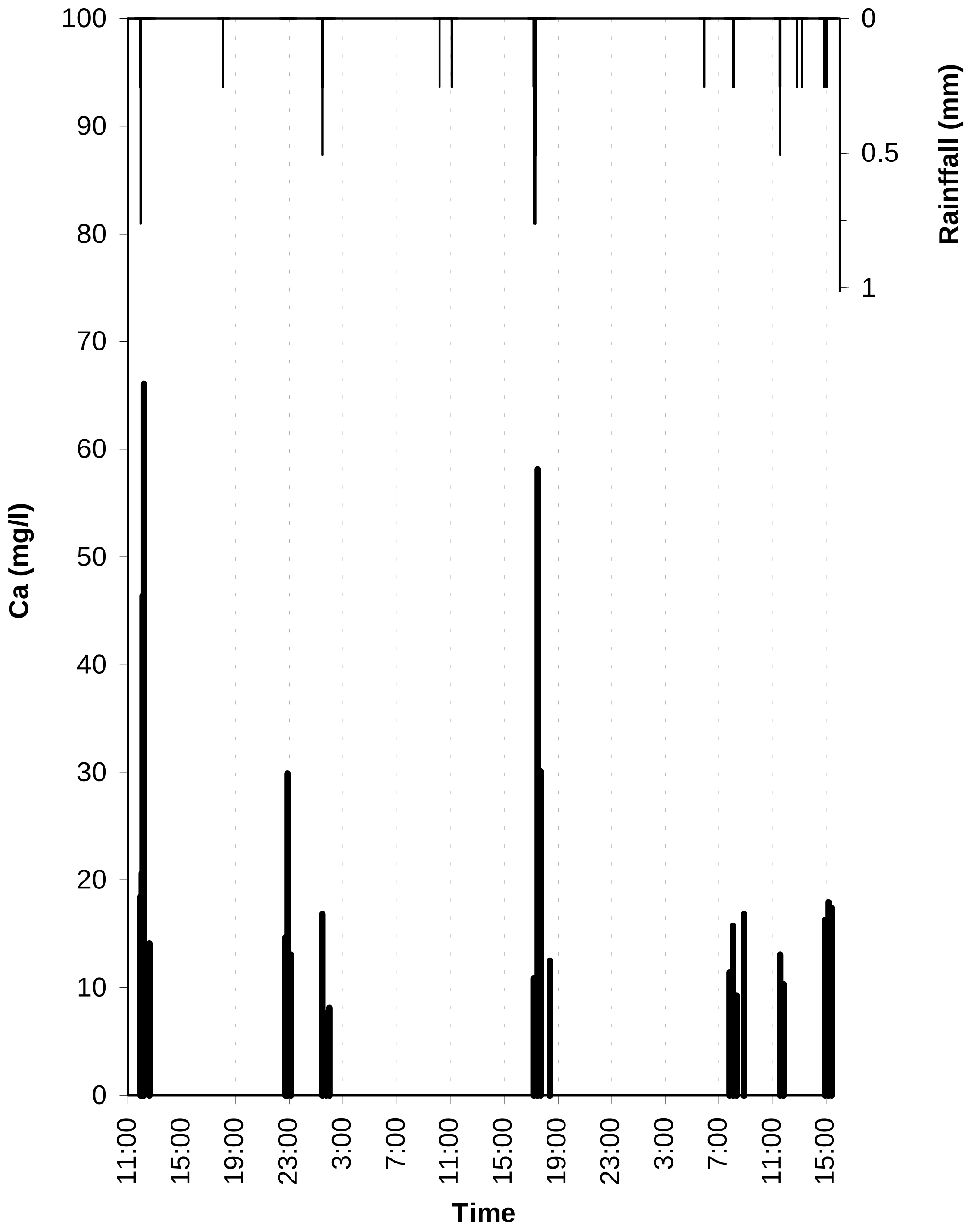
Nitrate-N in Urban Runoff
19-21 July 1995



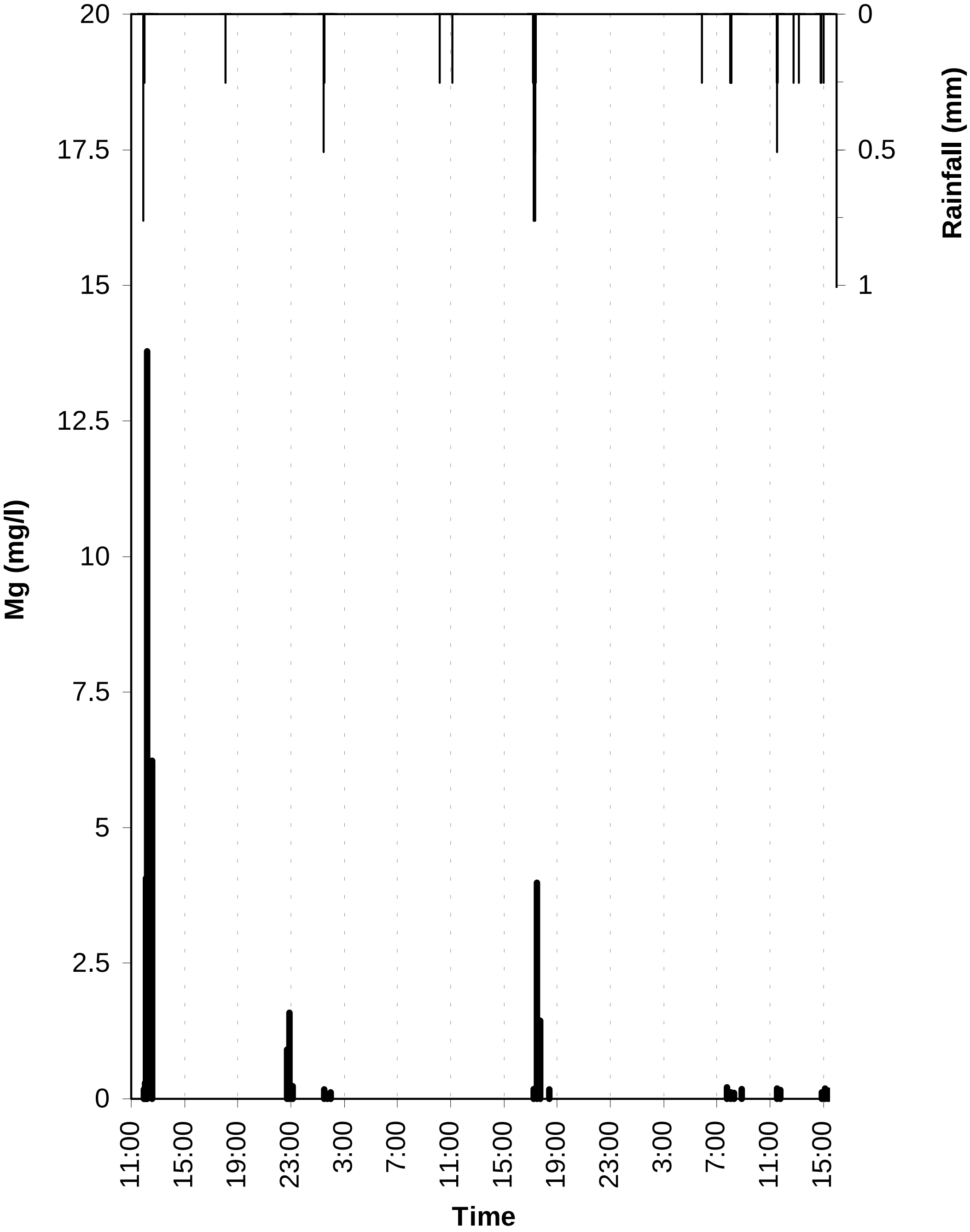
o-Phosphate-P in Urban Runoff
19-21 July 1995



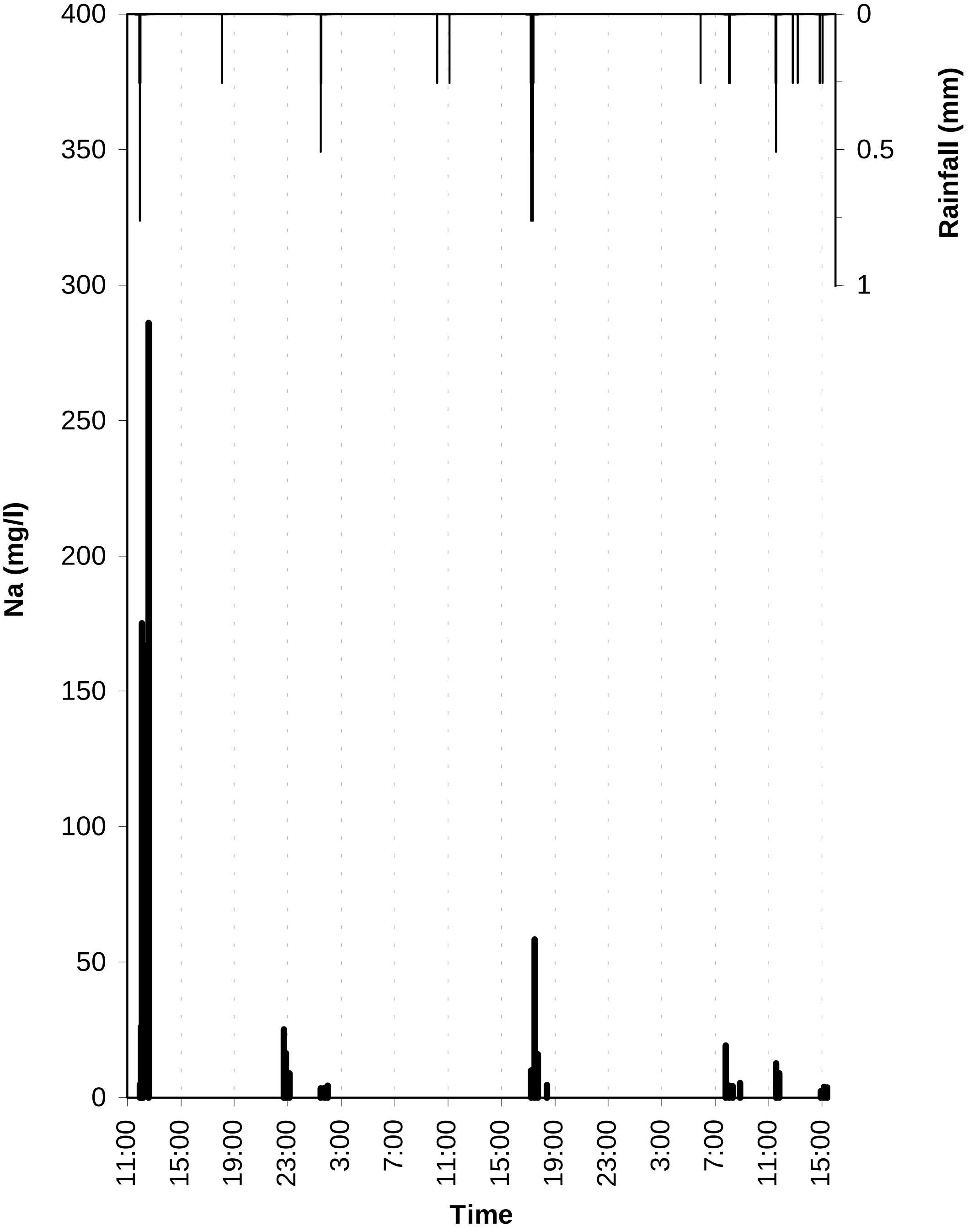
Calcium in Urban Runoff
19-21 July 1995

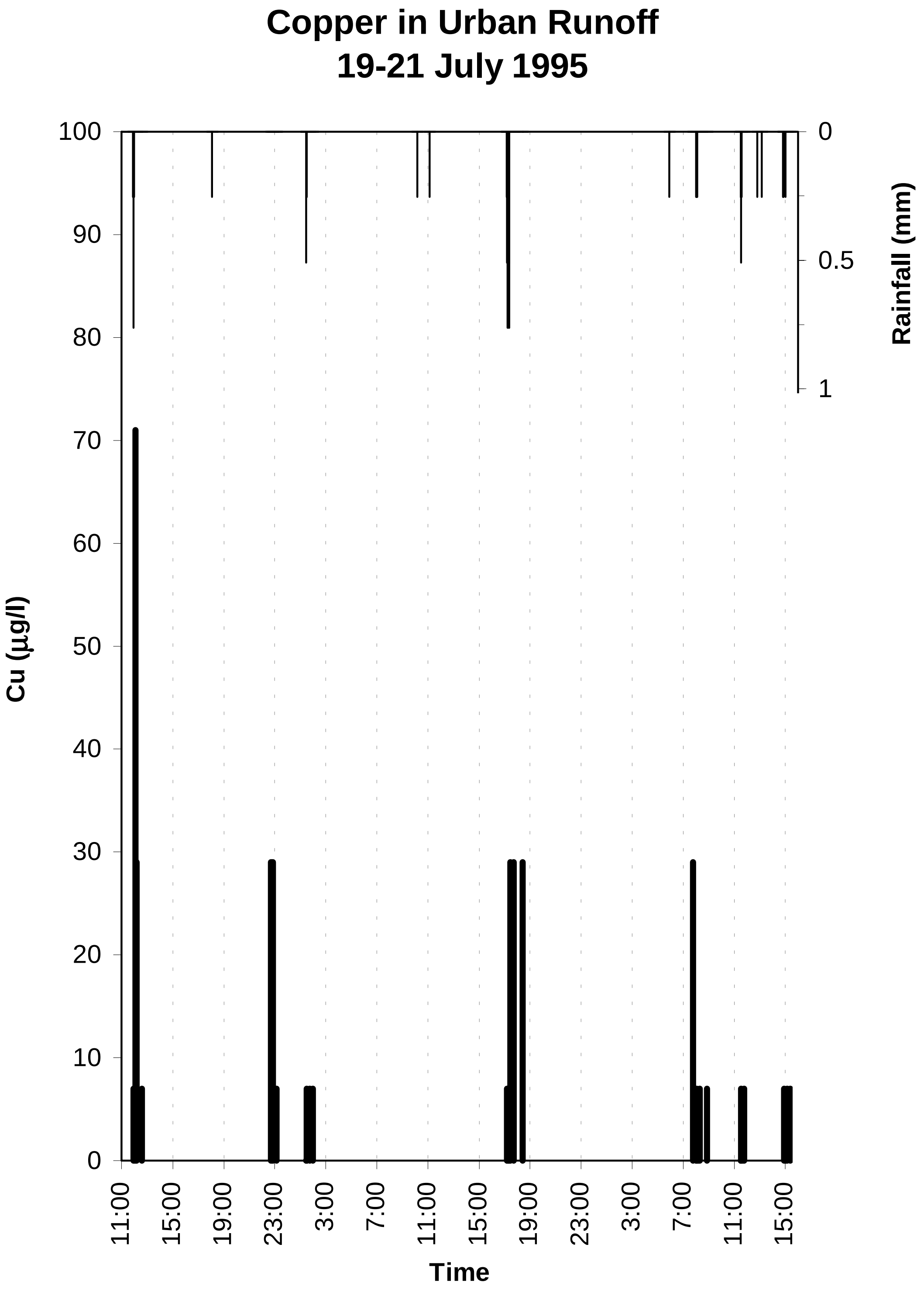


Magnesium in Urban Runoff
19-21 July 1995

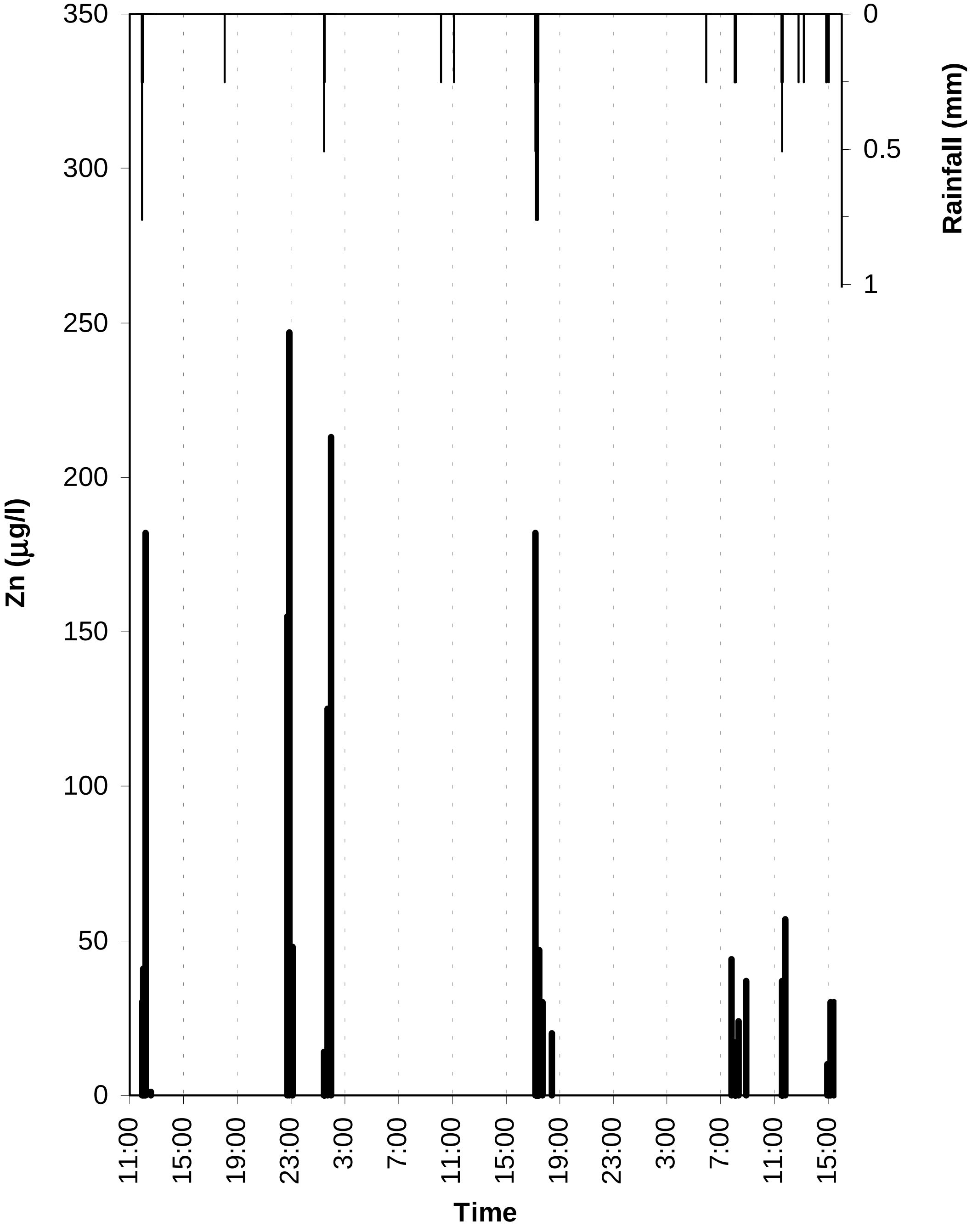


Sodium in Urban Runoff
19-21 July 1995

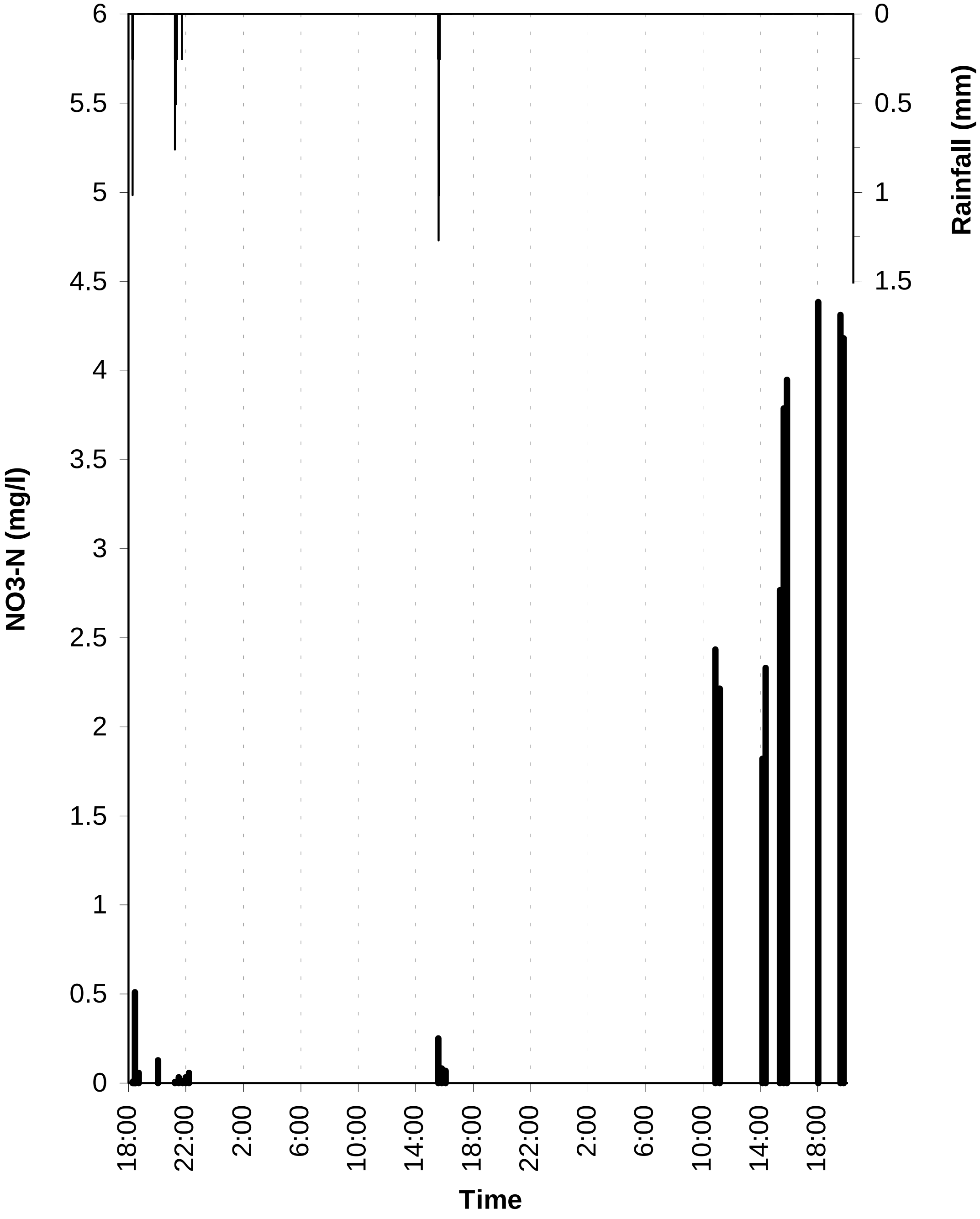



Copper in Urban Runoff
19-21 July 1995
Cu (µg/l)
100
90
80
70
60
50
40
30
20
10
0
Rainfall (mm)
0
0.5
1
11:00
15:00
19:00
23:00
3:00
7:00
11:00
15:00
19:00
23:00
3:00
7:00
11:00
15:00
Time

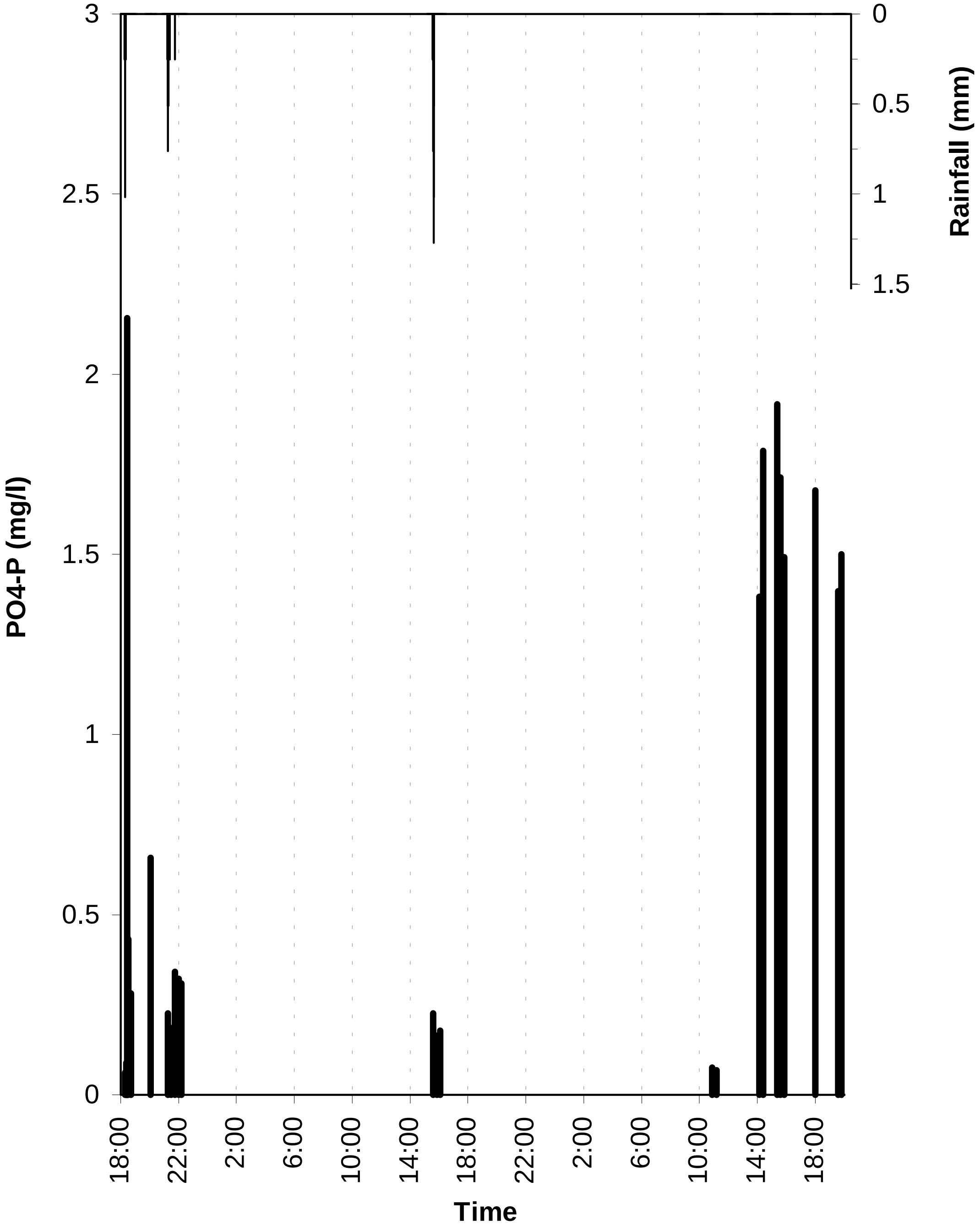
Zinc in Urban Runoff
19-21 July 1995



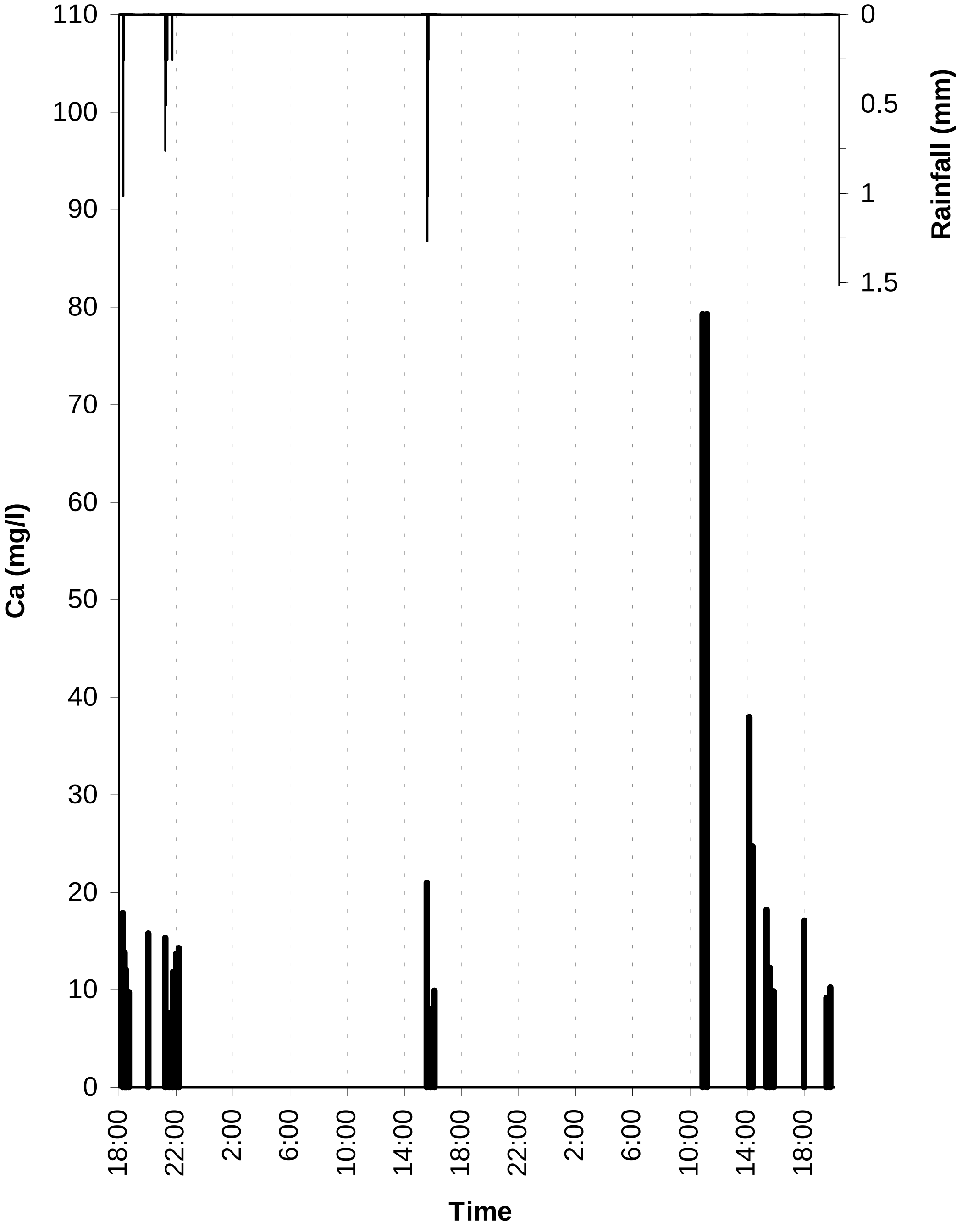
Nitrate-N in Urban Runoff
24-26 July 1995



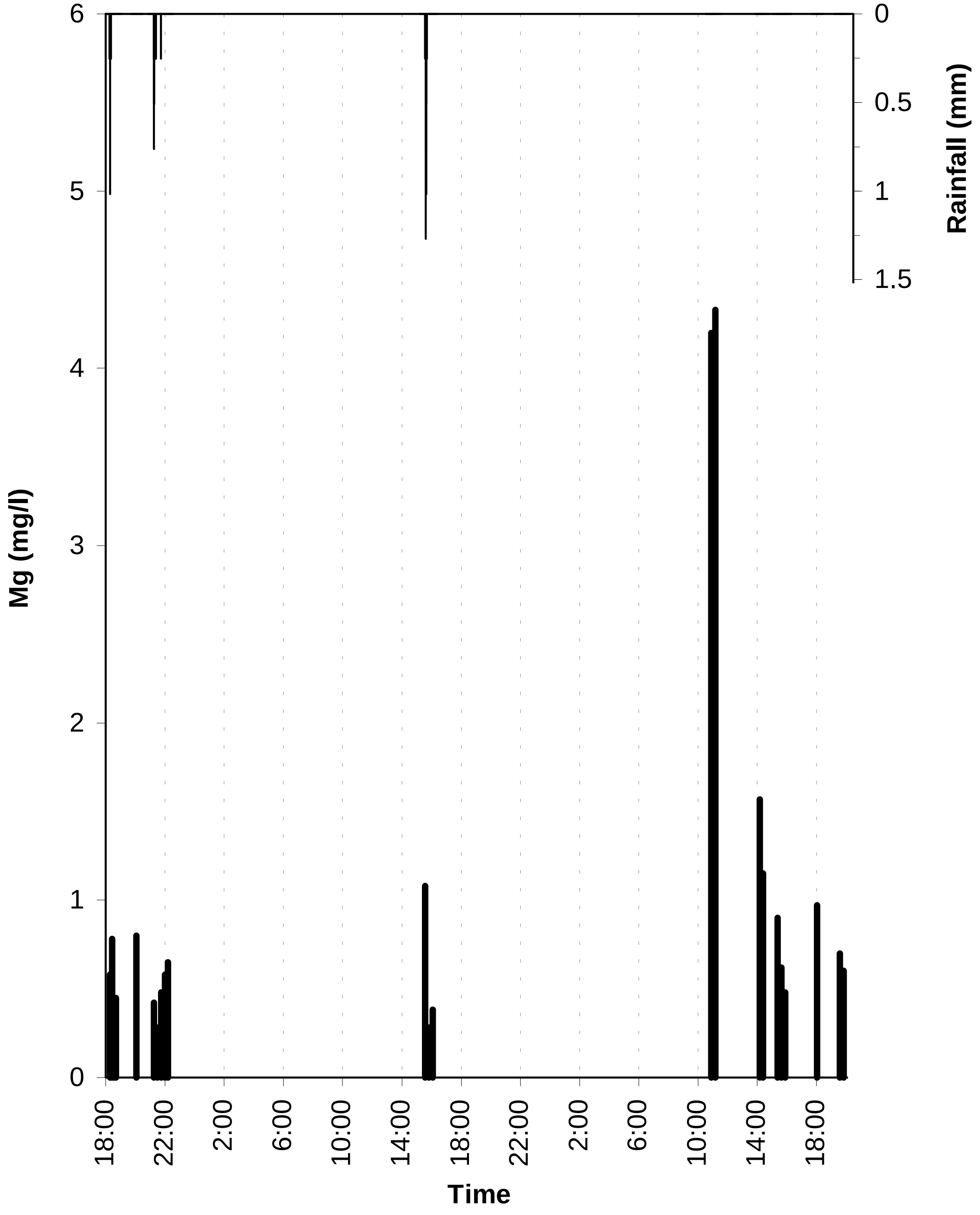
o-Phosphate-P in Urban Runoff
24-26 July 1995

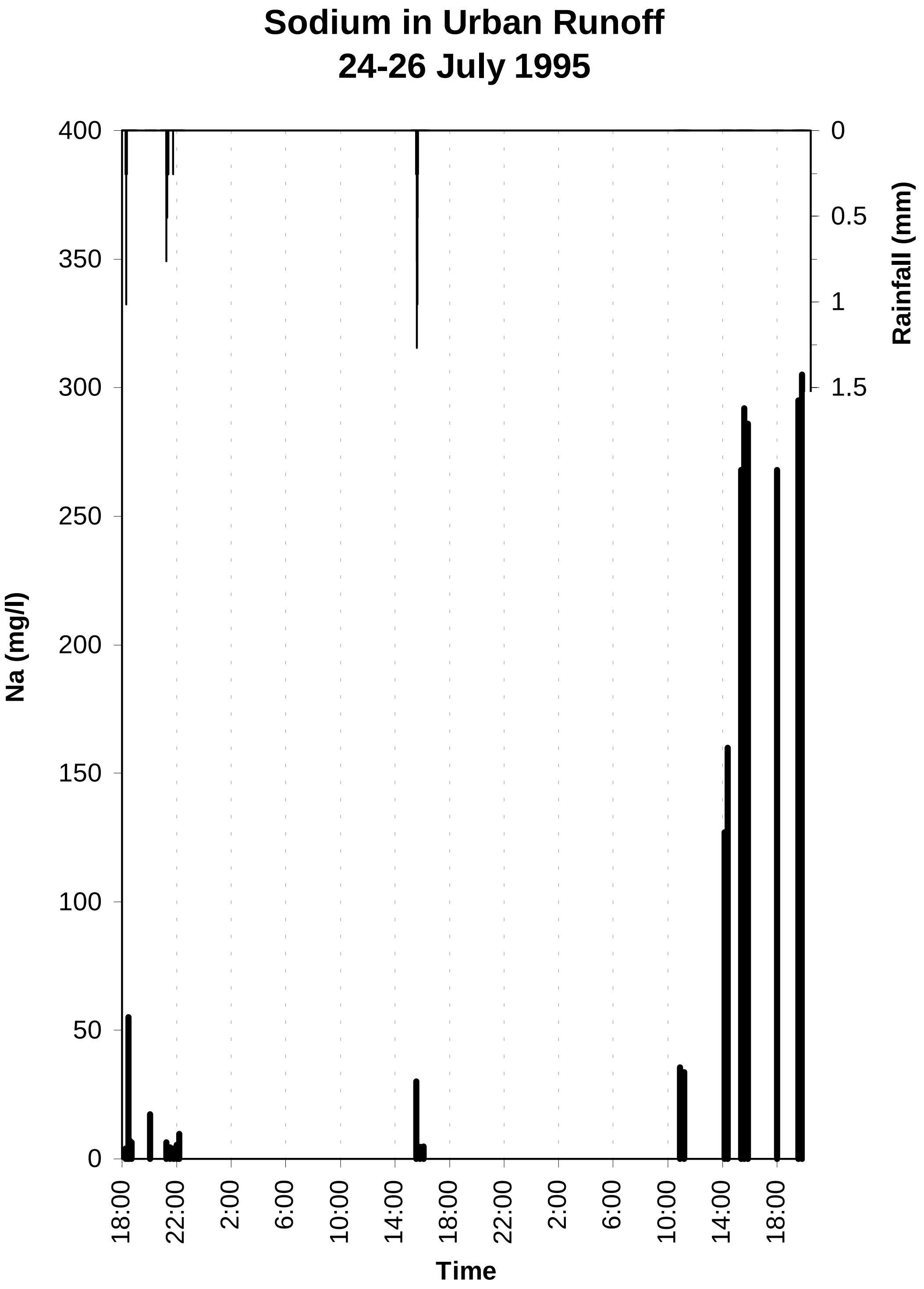


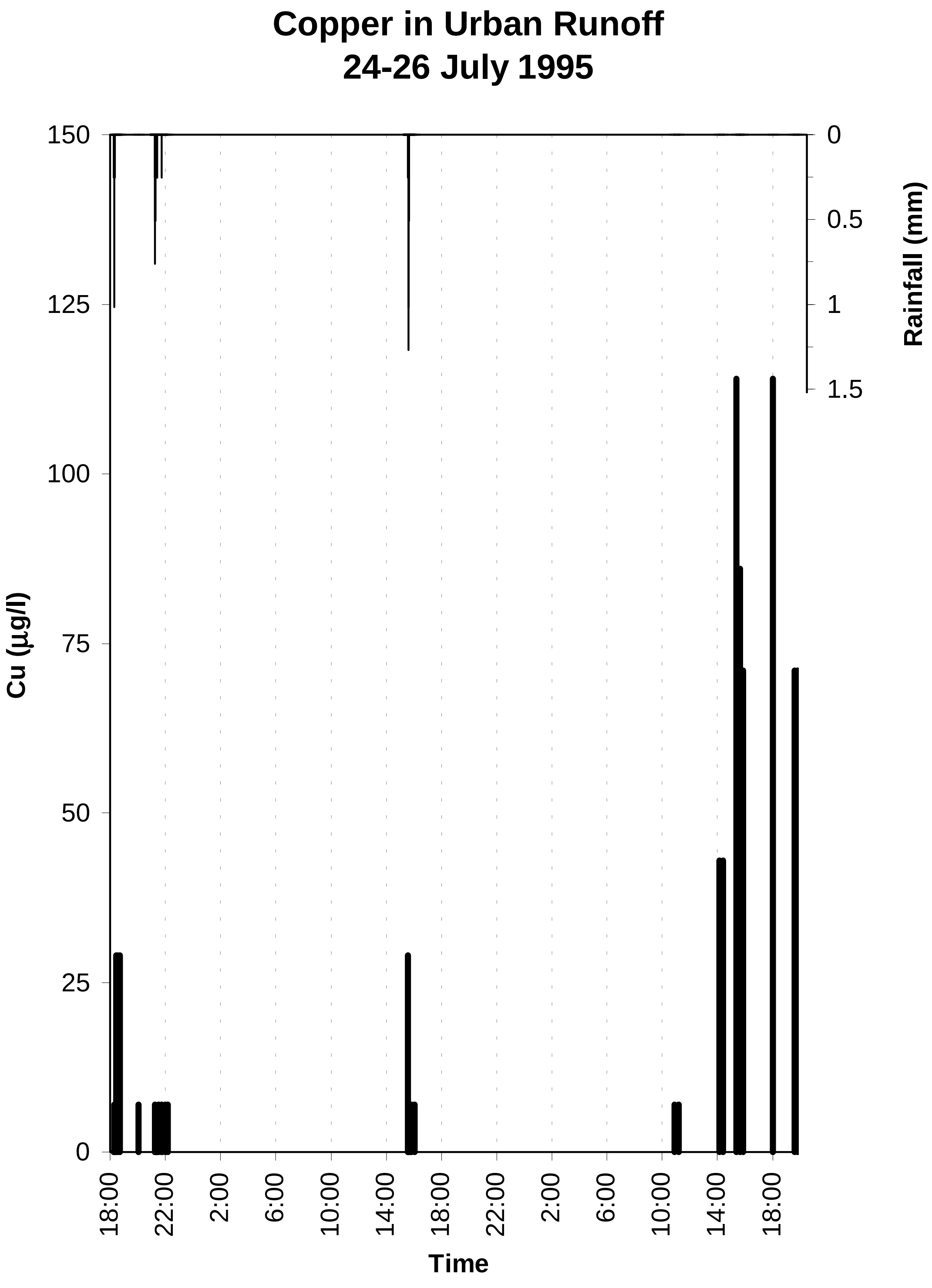
Calcium in Urban Runoff
24-26 July 1995

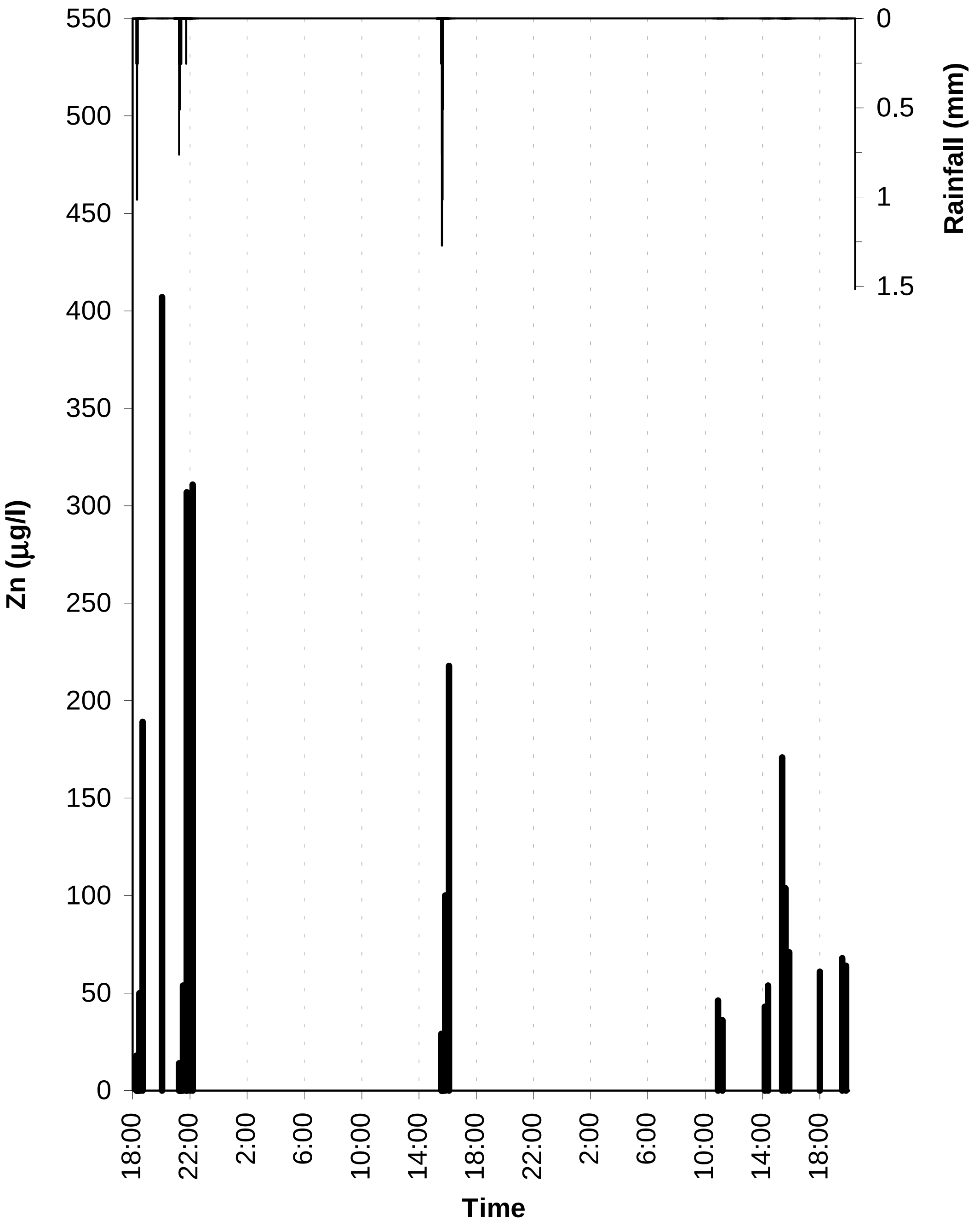


Magnesium in Urban Runoff
24-26 July 1995



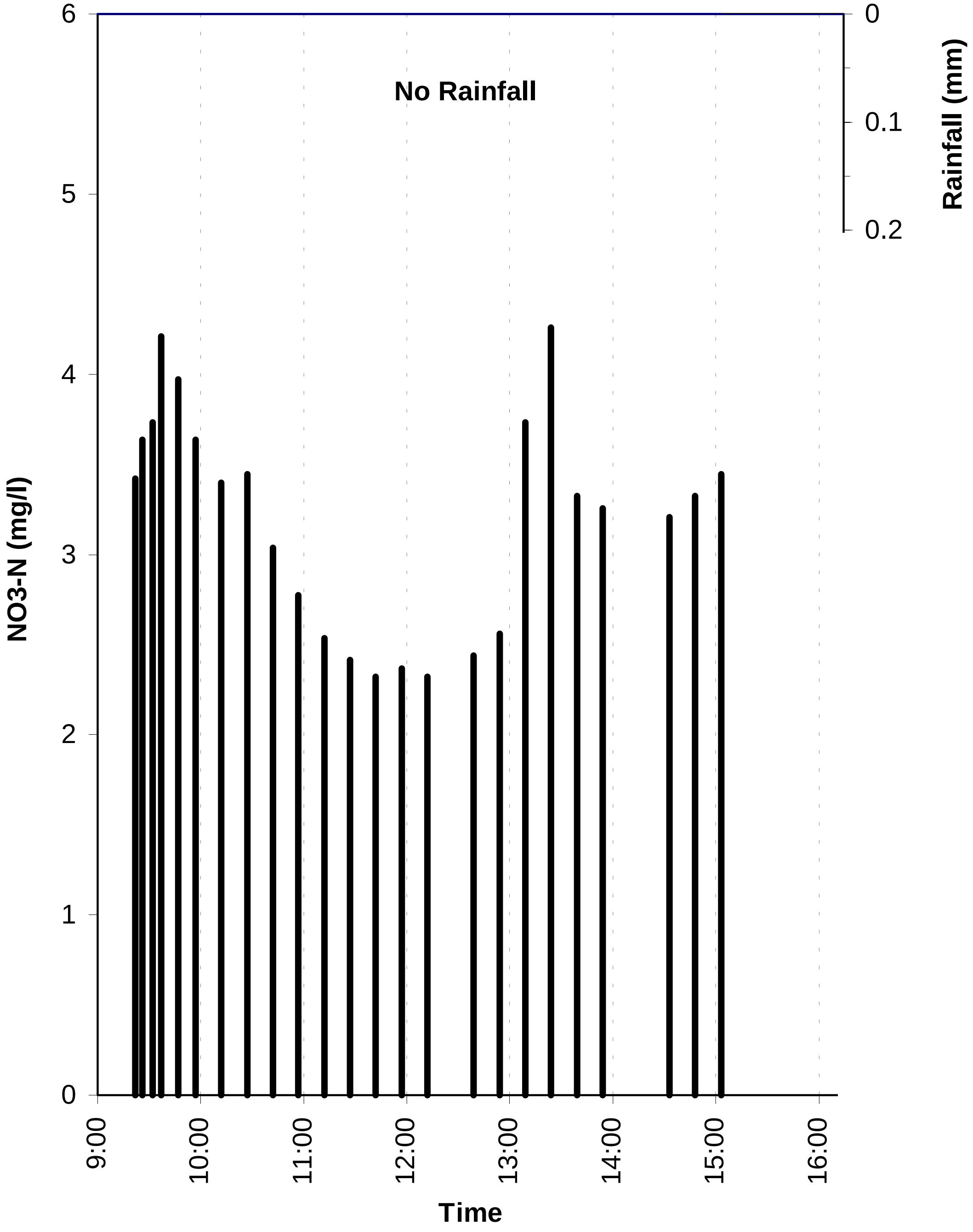

Sodium in Urban Runoff
24-26 July 1995
Na (mg/l)
400
350
300
250
200
150
100
50
0
Rainfall (mm)
0
0.5
1
1.5
18:00
22:00
2:00
6:00
10:00
14:00
18:00
22:00
2:00
6:00
10:00
14:00
18:00
Time


Copper in Urban Runoff
24-26 July 1995
Cu (µg/l)
150
125
100
75
50
25
0
Rainfall (mm)
0
0.5
1
1.5
18:00
22:00
2:00
6:00
10:00
14:00
18:00
22:00
2:00
6:00
10:00
14:00
18:00
Time

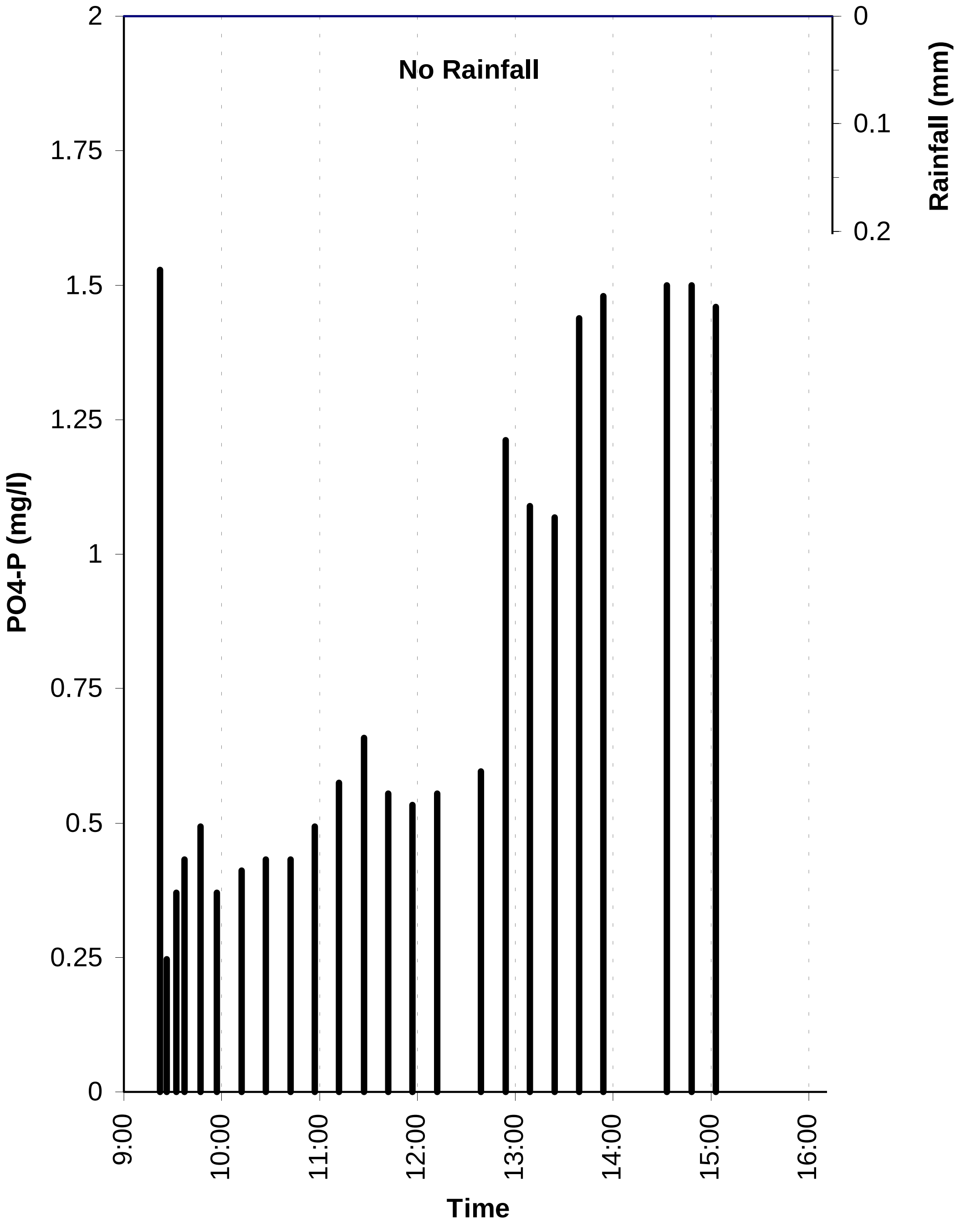


Zinc in Urban Runoff
24-26 July 1995

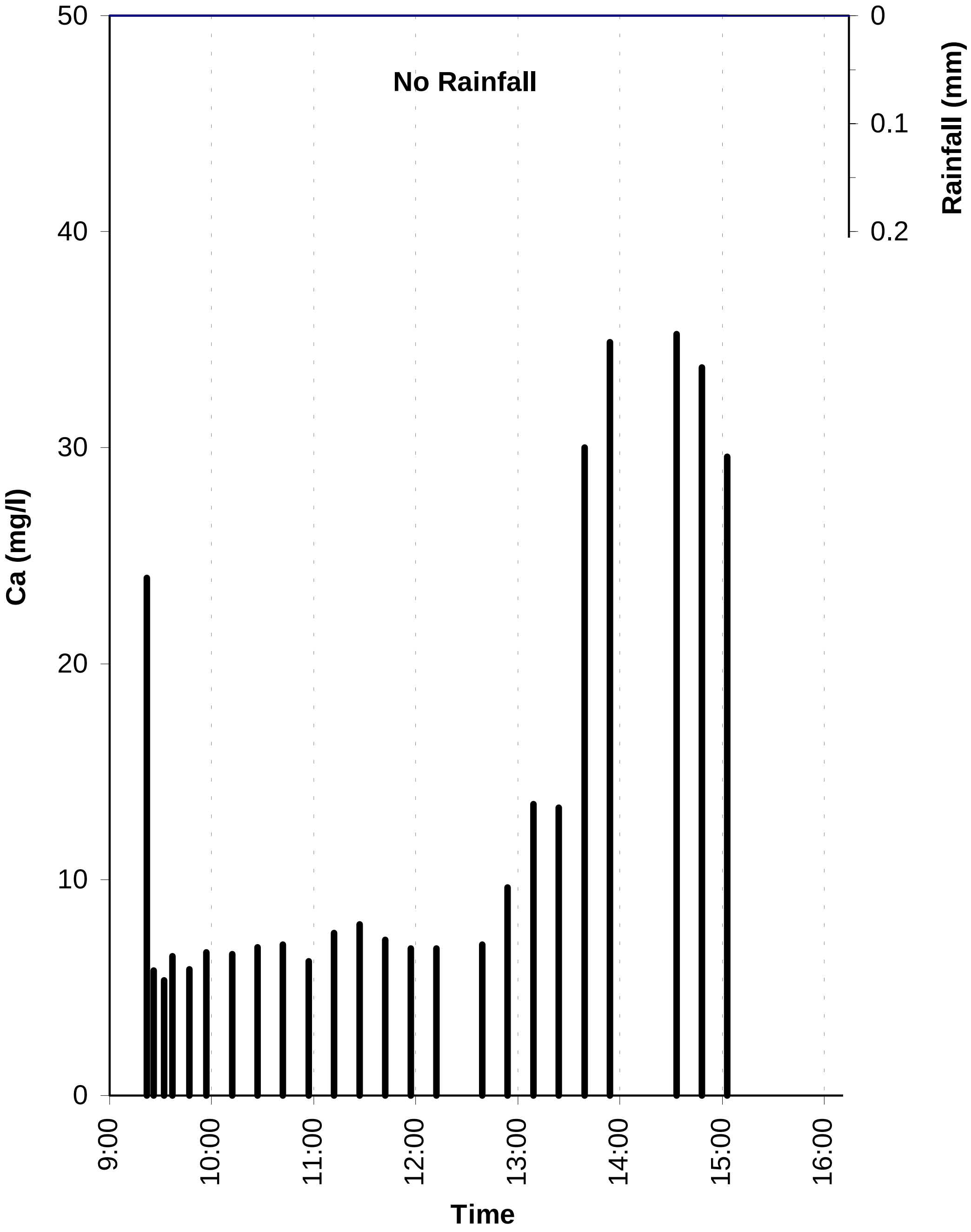
Nitrate-N in Urban Runoff
27 July 1995



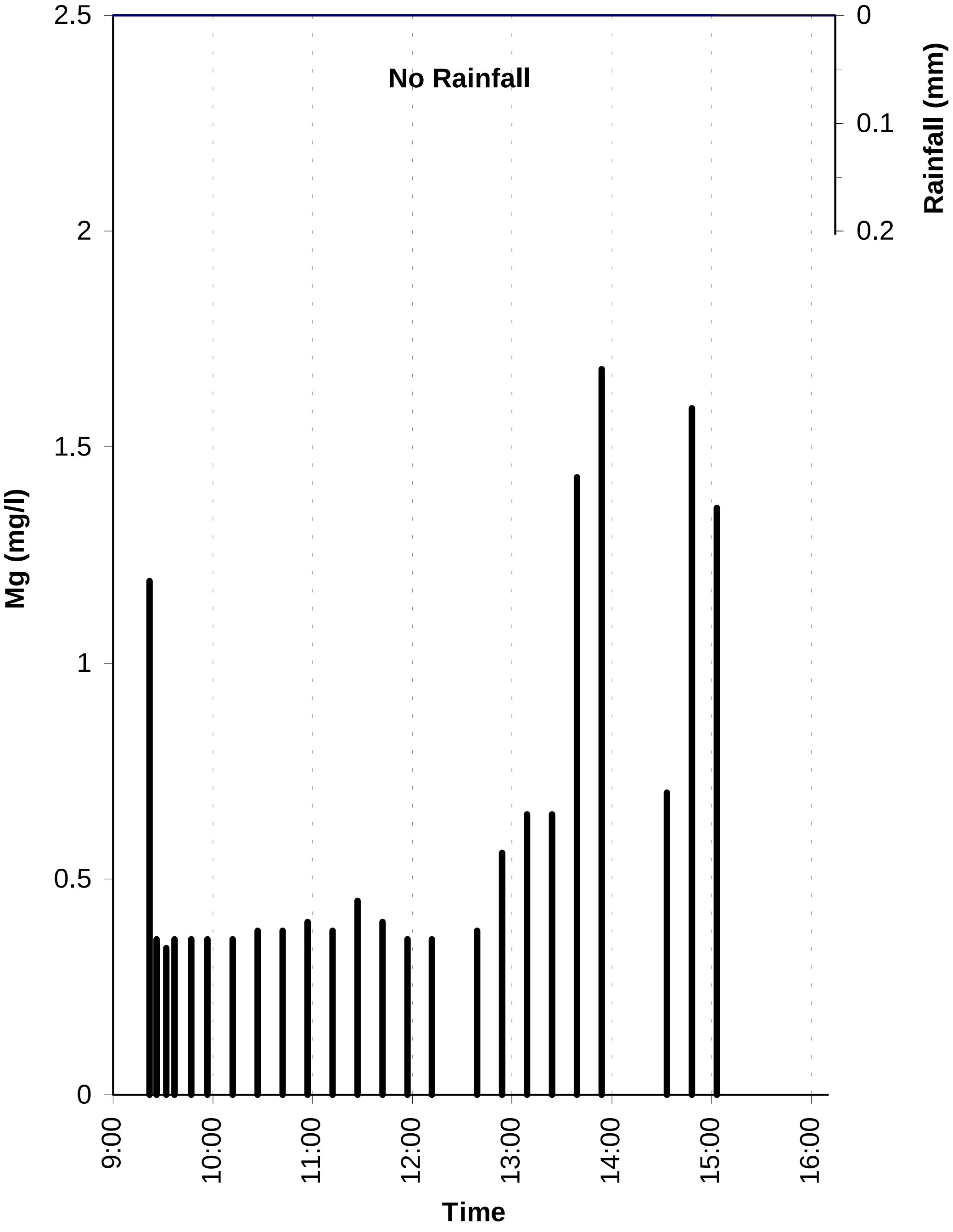
o-Phosphate-P in Urban Runoff
27 July 1995



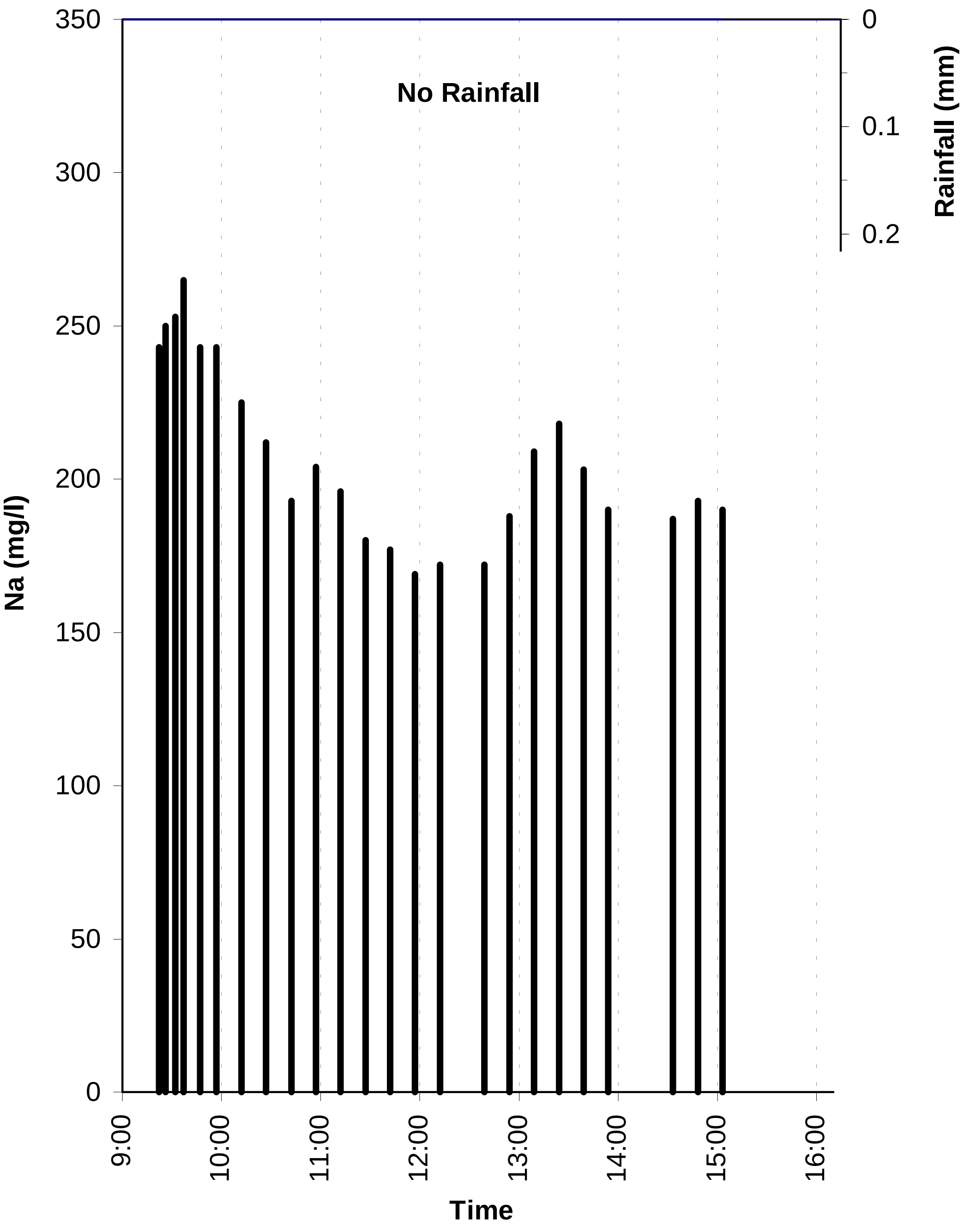
Calcium in Urban Runoff
27 July 1995



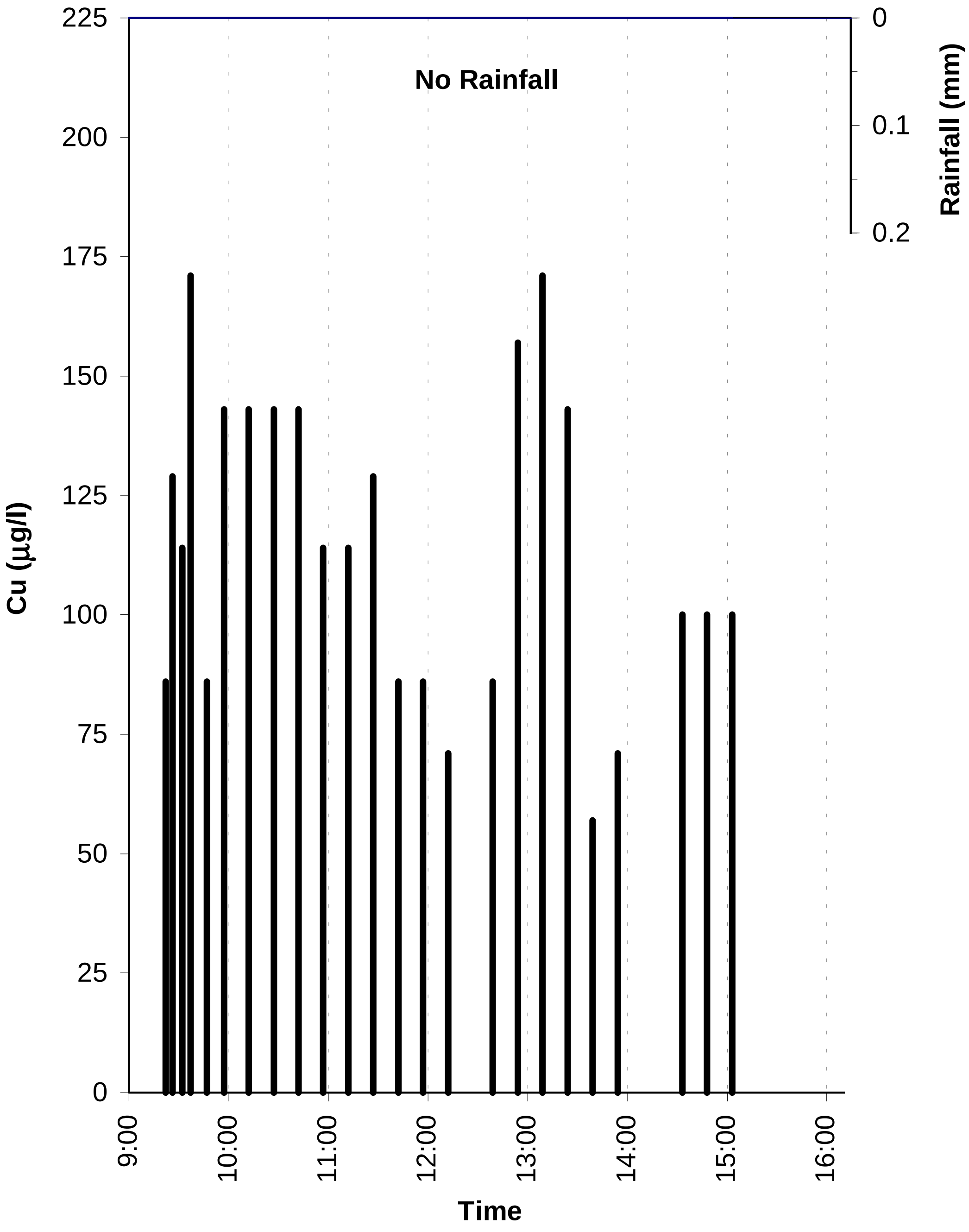
Magnesium in Urban Runoff
27 July 1995



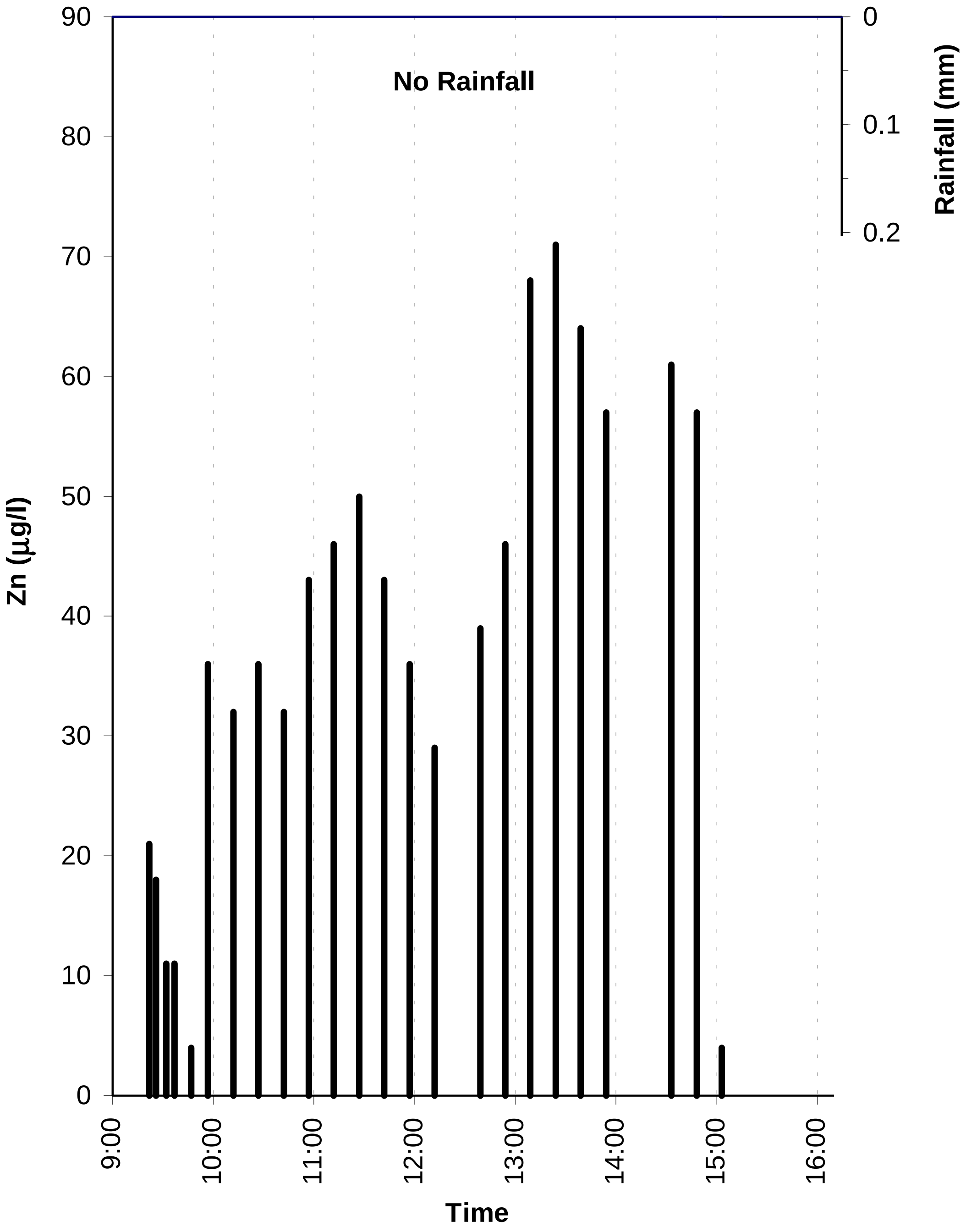
Sodium in Urban Runoff
27 July 1995



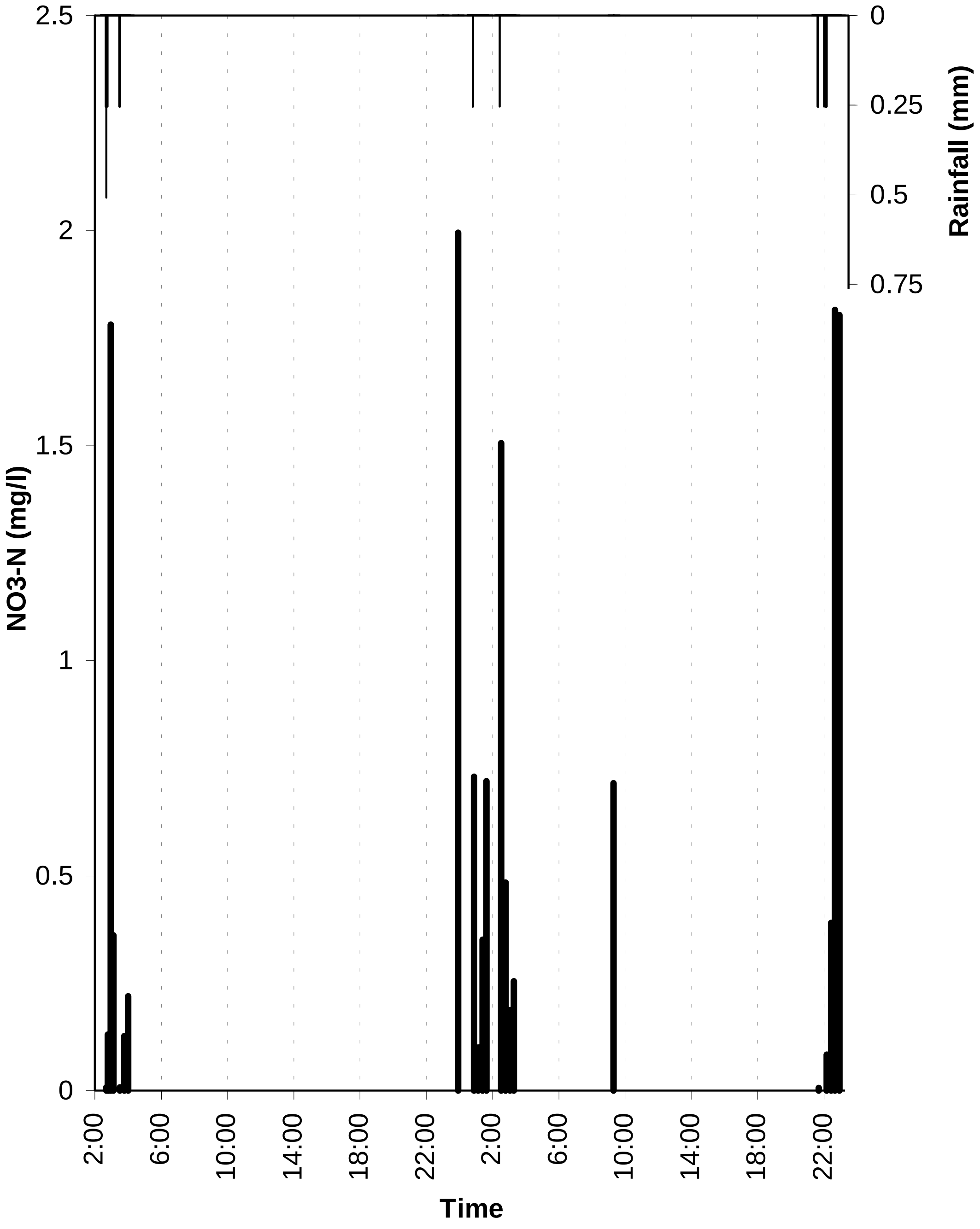
Copper in Urban Runoff
27 July 1995



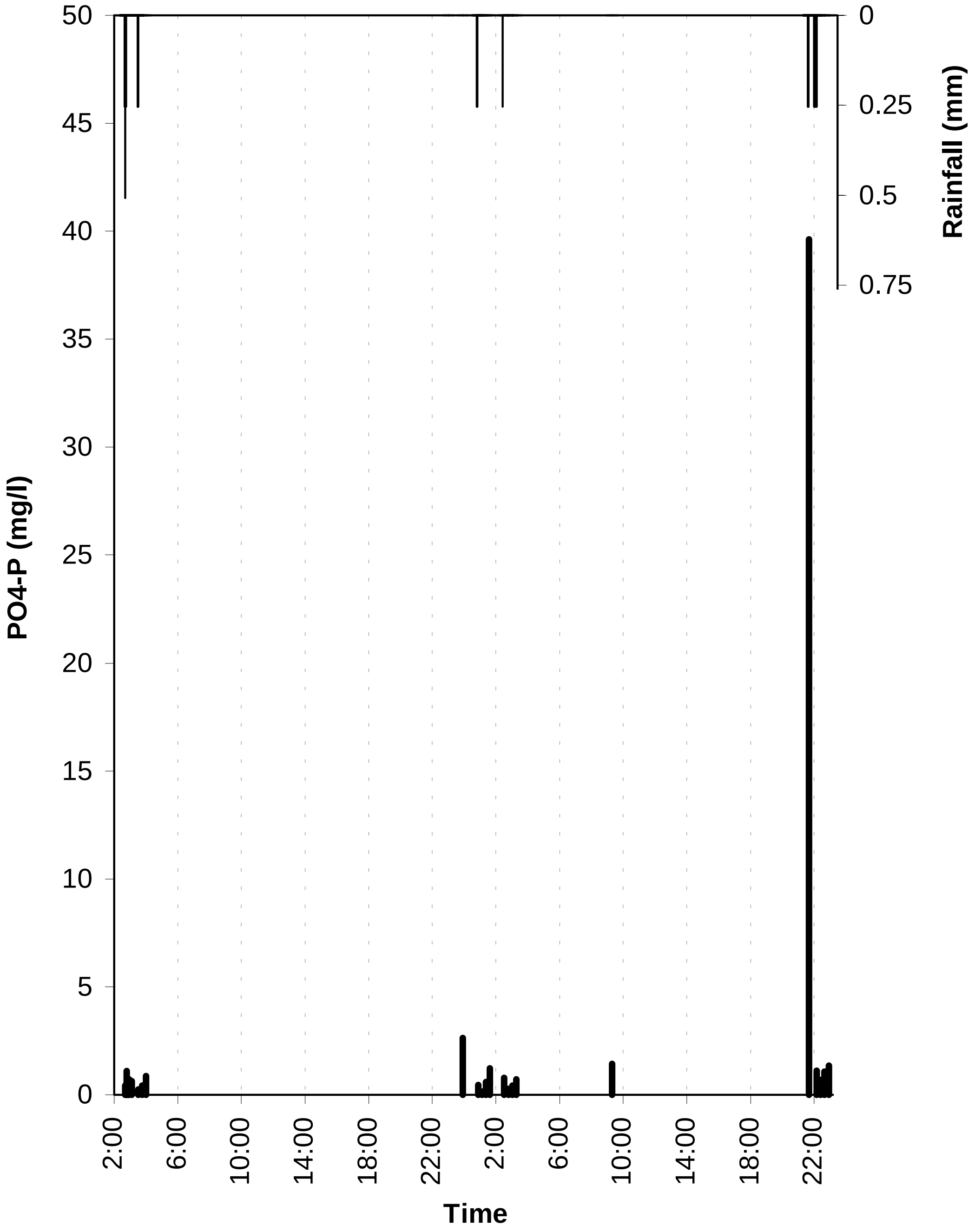
Zinc in Urban Runoff
27 July 1995



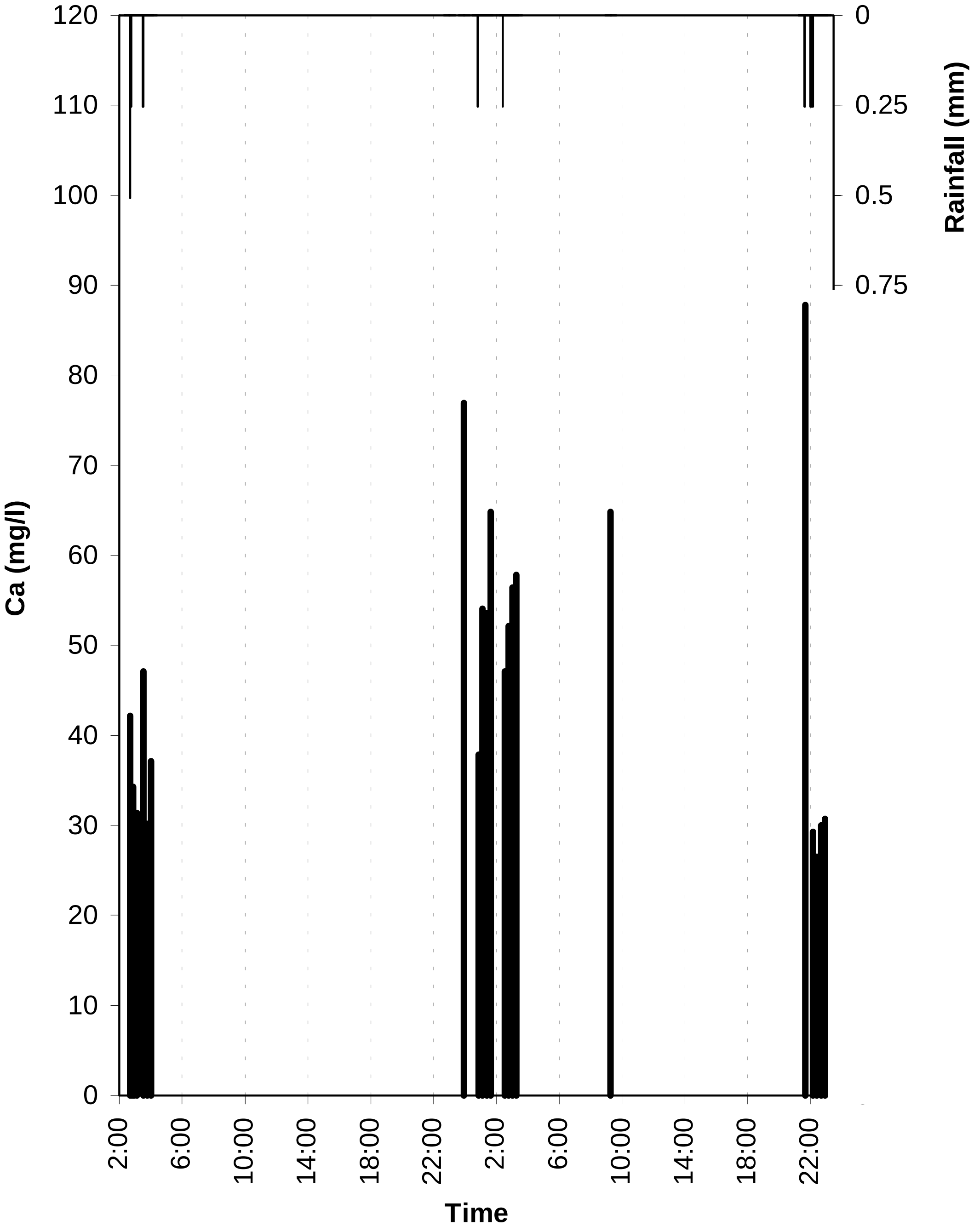
Nitrate-N in Urban Runoff
29-30 July 1995



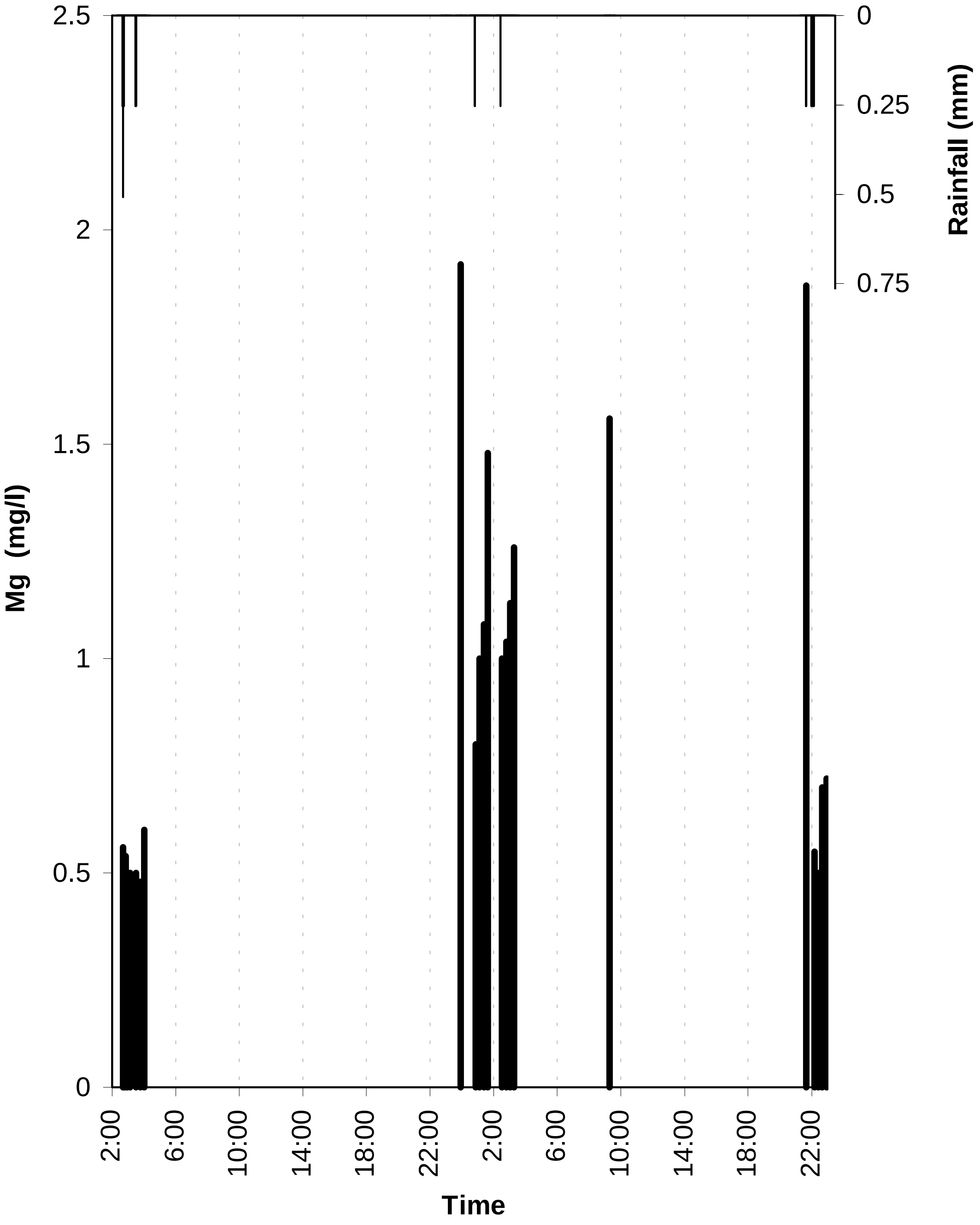
o-Phosphate-P in Urban Runoff
29-30 July 1995



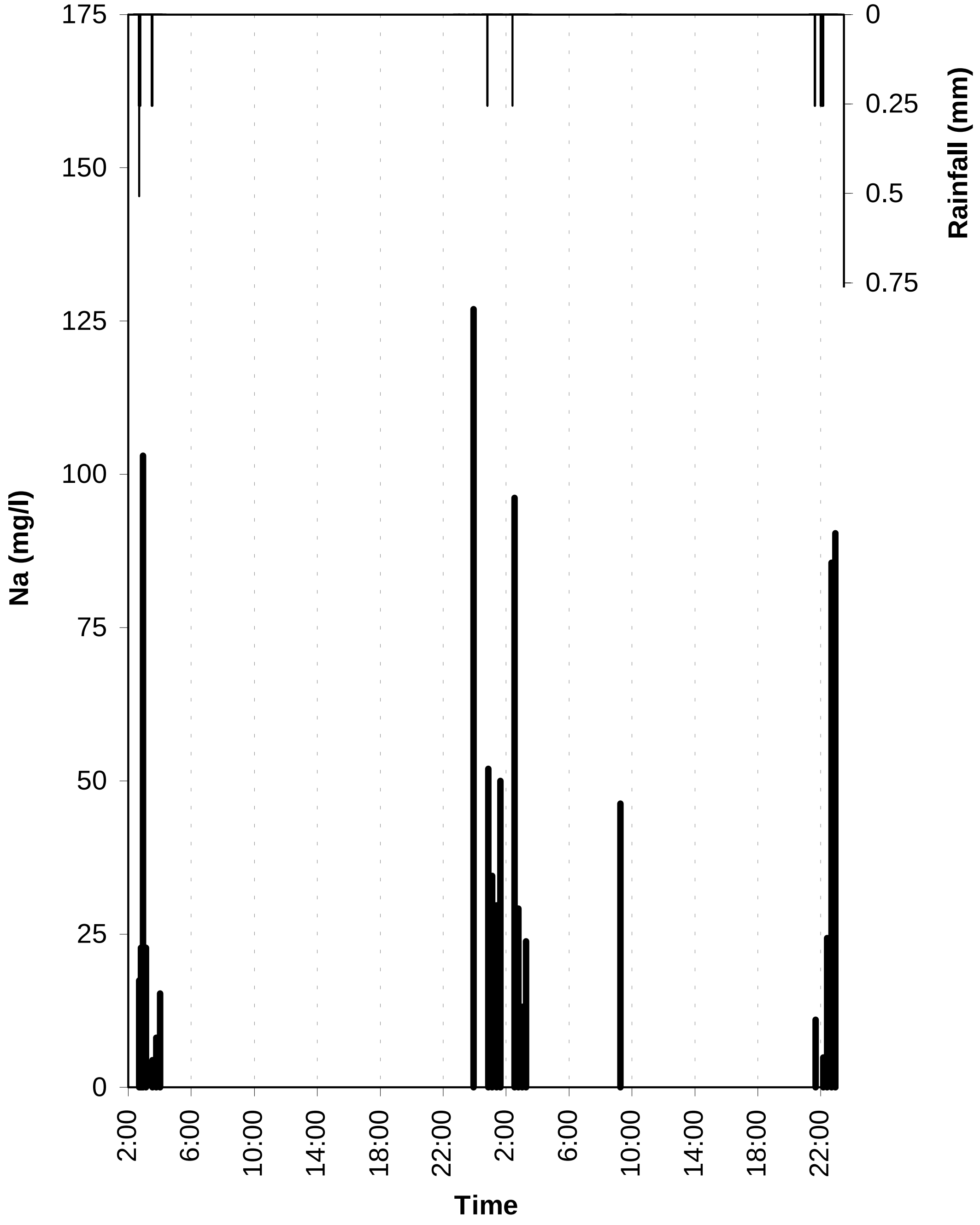
Calcium in Urban Runoff
29-30 July 1995



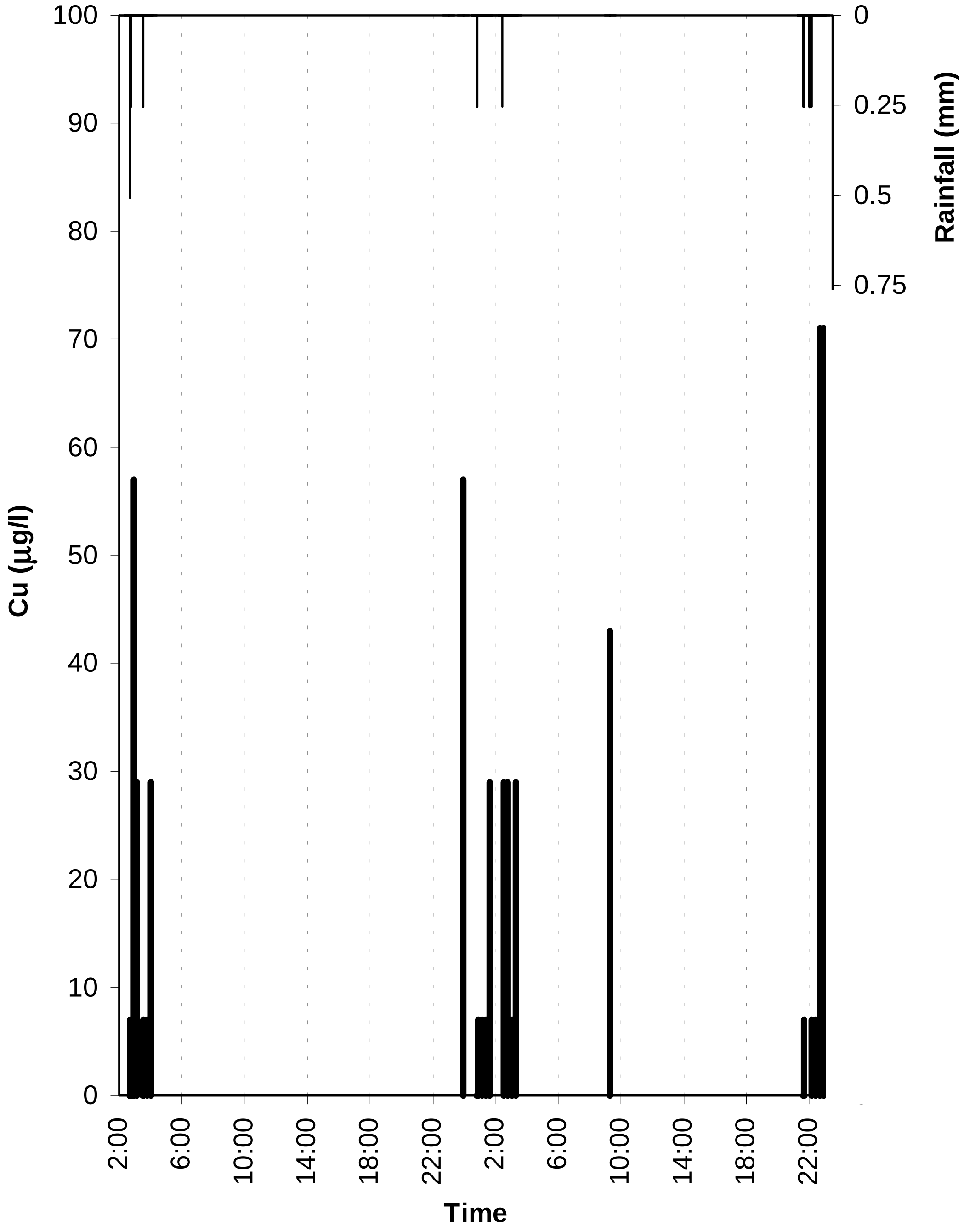
Magnesium in Urban Runoff
29-30 July 1995



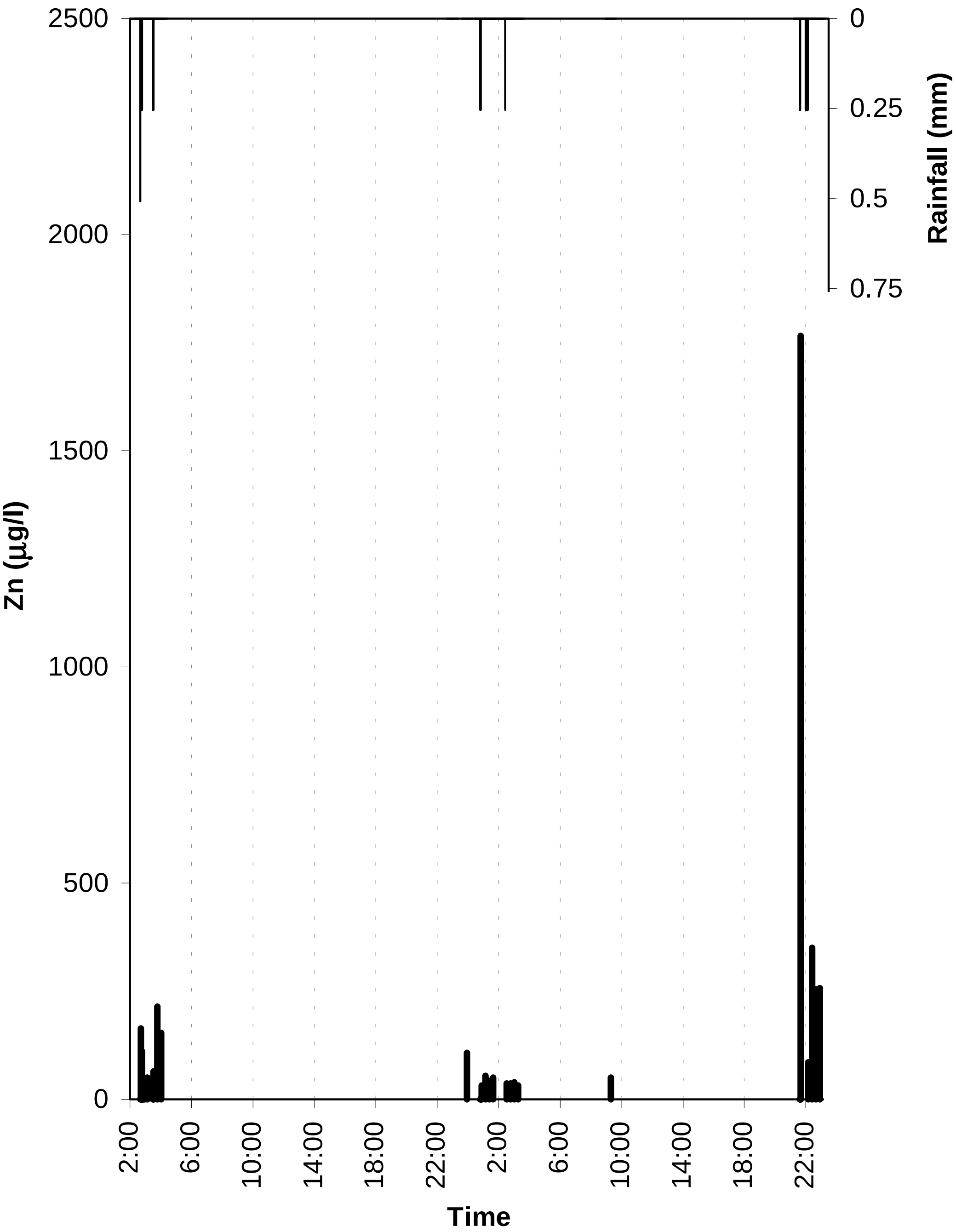
Sodium in Urban Runoff
29-30 July 1995



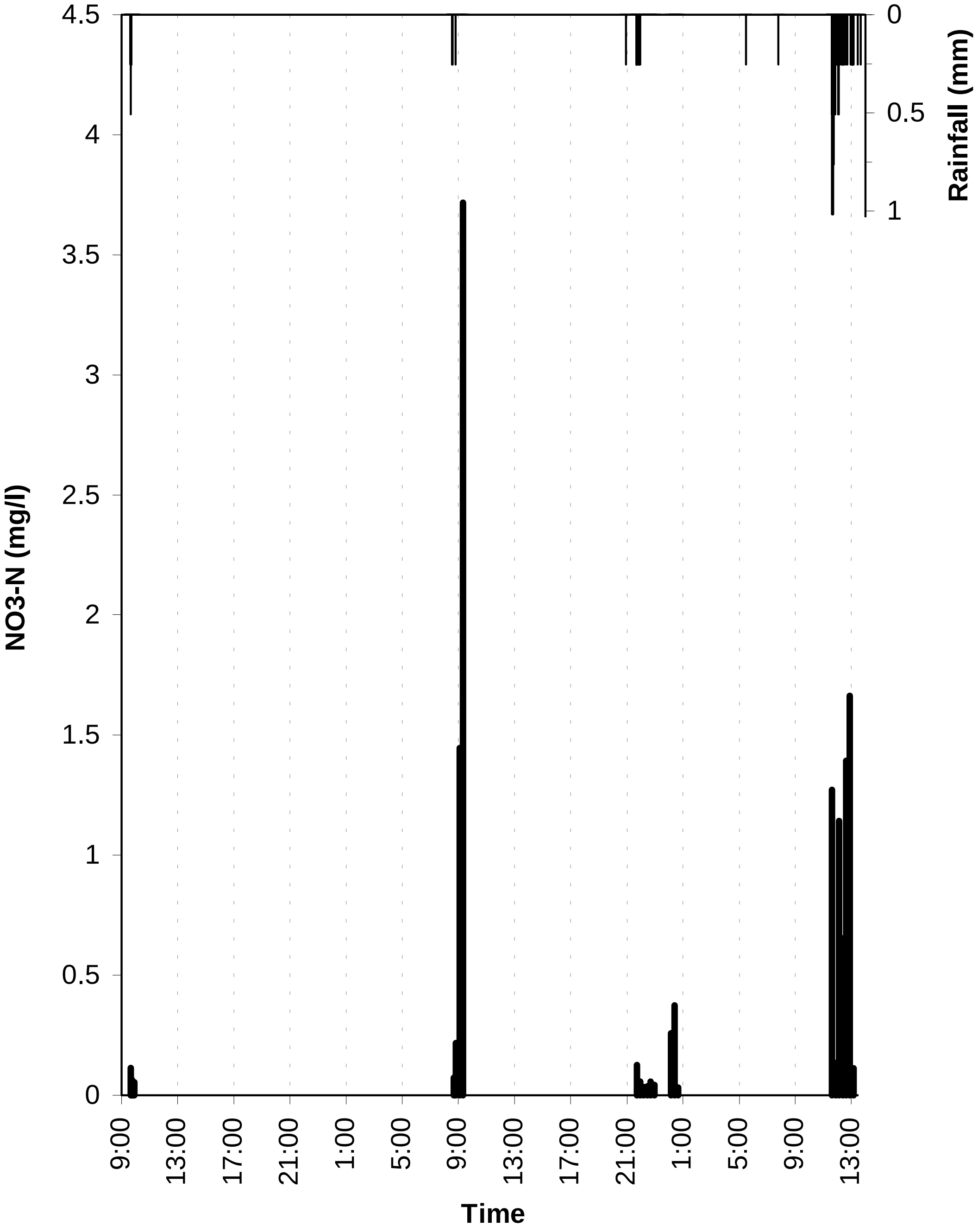
Copper in Urban Runoff
29-30 July 1995



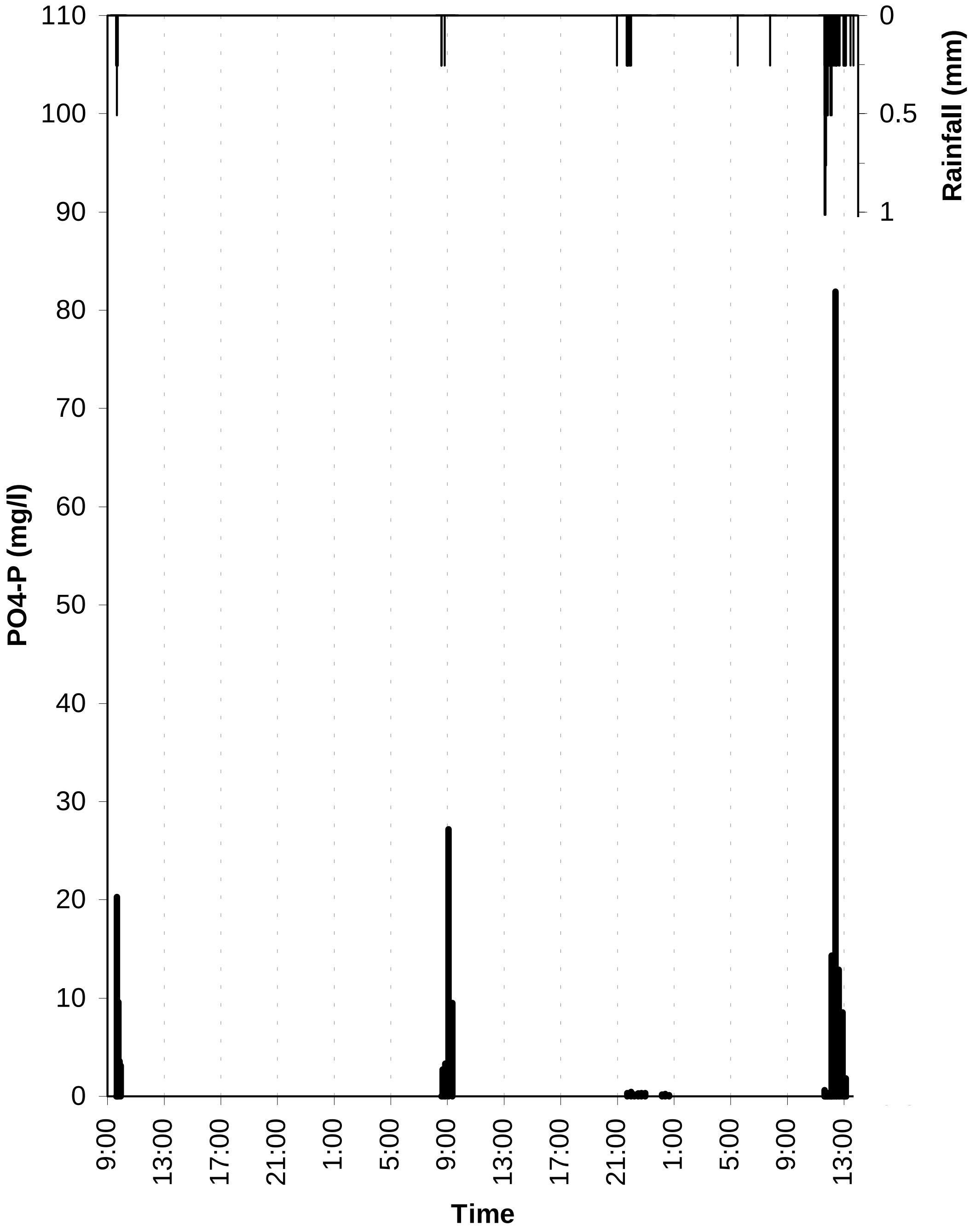
Zinc in Urban Runoff
29-30 July 1995



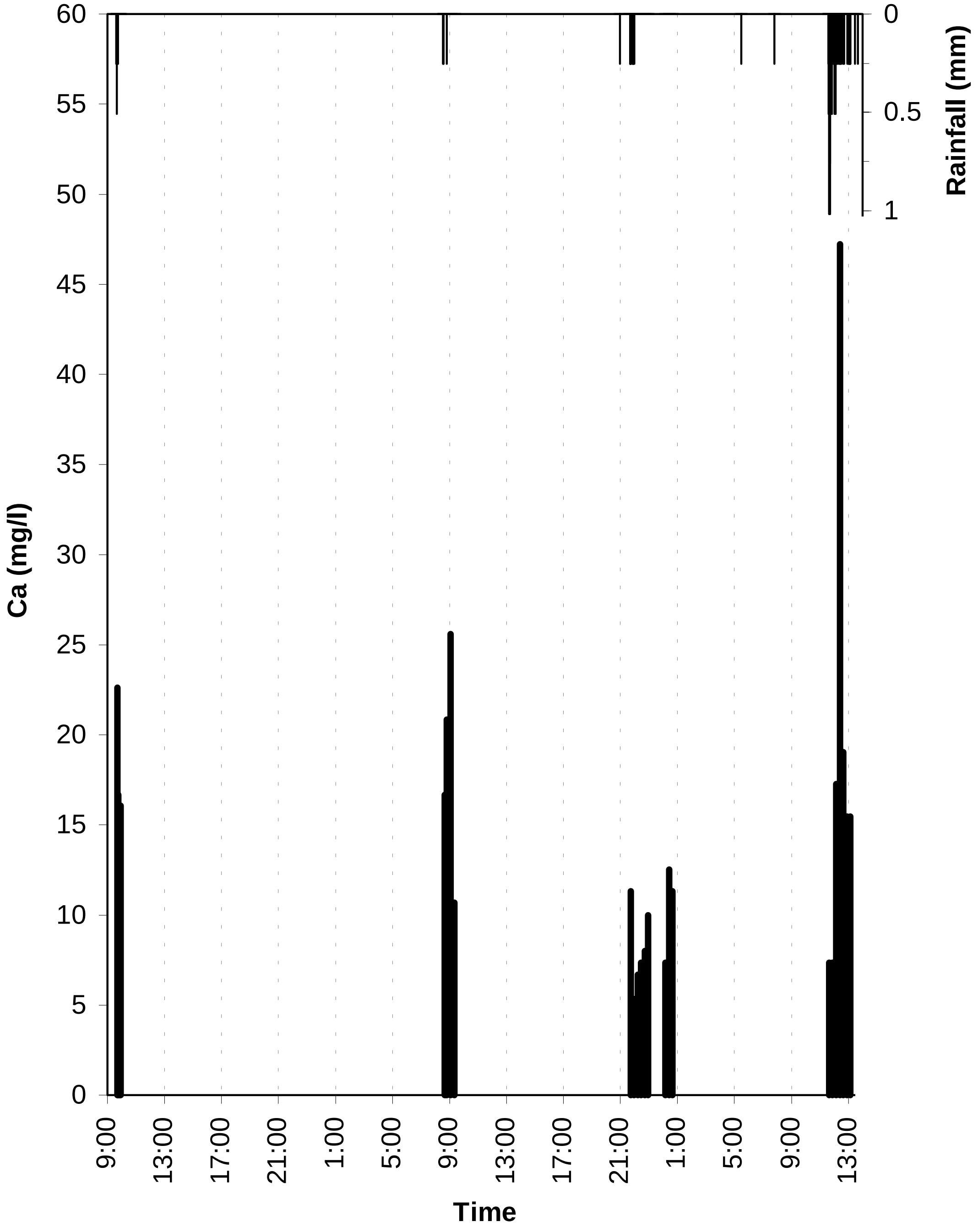
Nitrate-N in Urban Runoff
1-3 August 1995



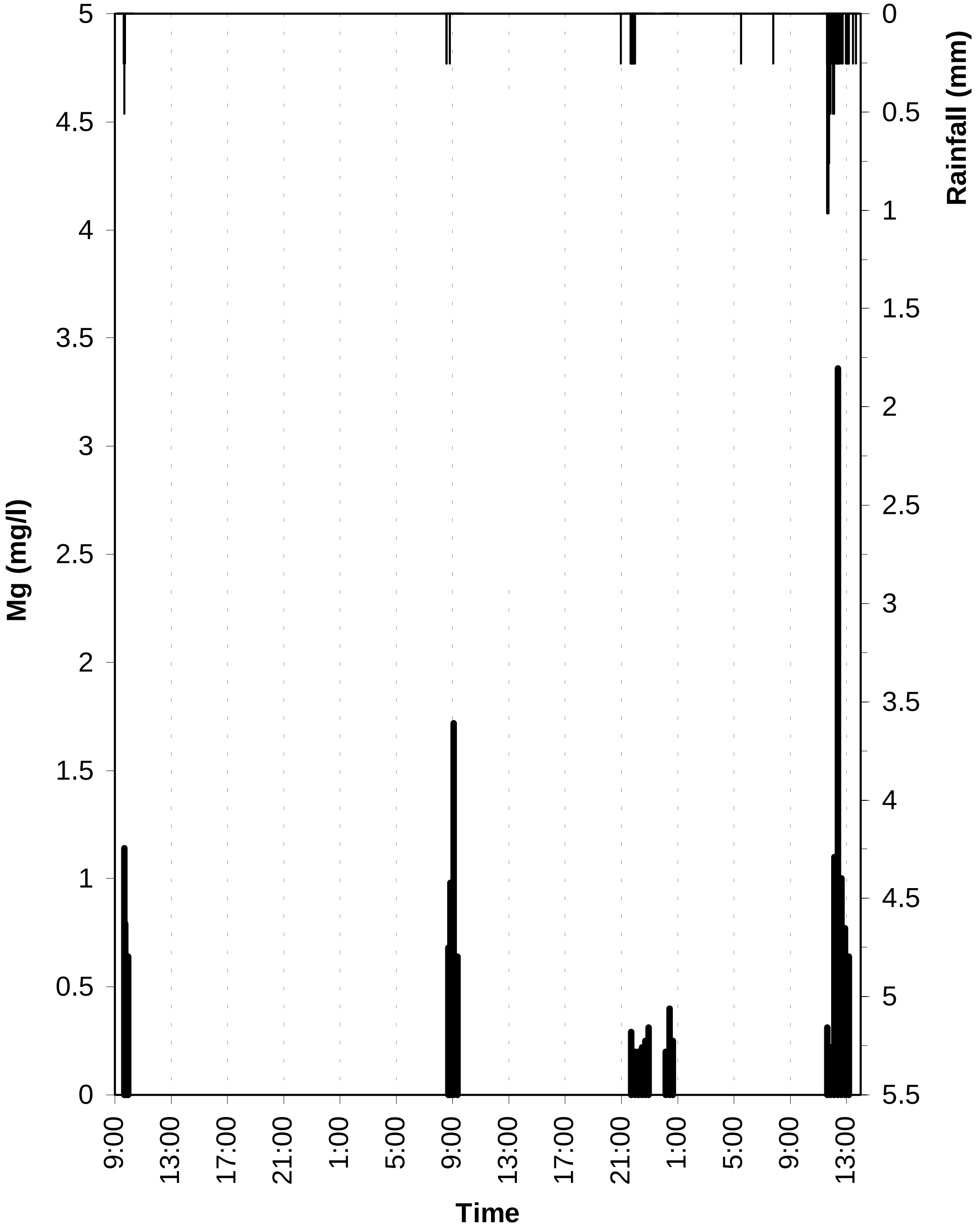
o-Phosphate-P in Urban Runoff
1-3 August 1995



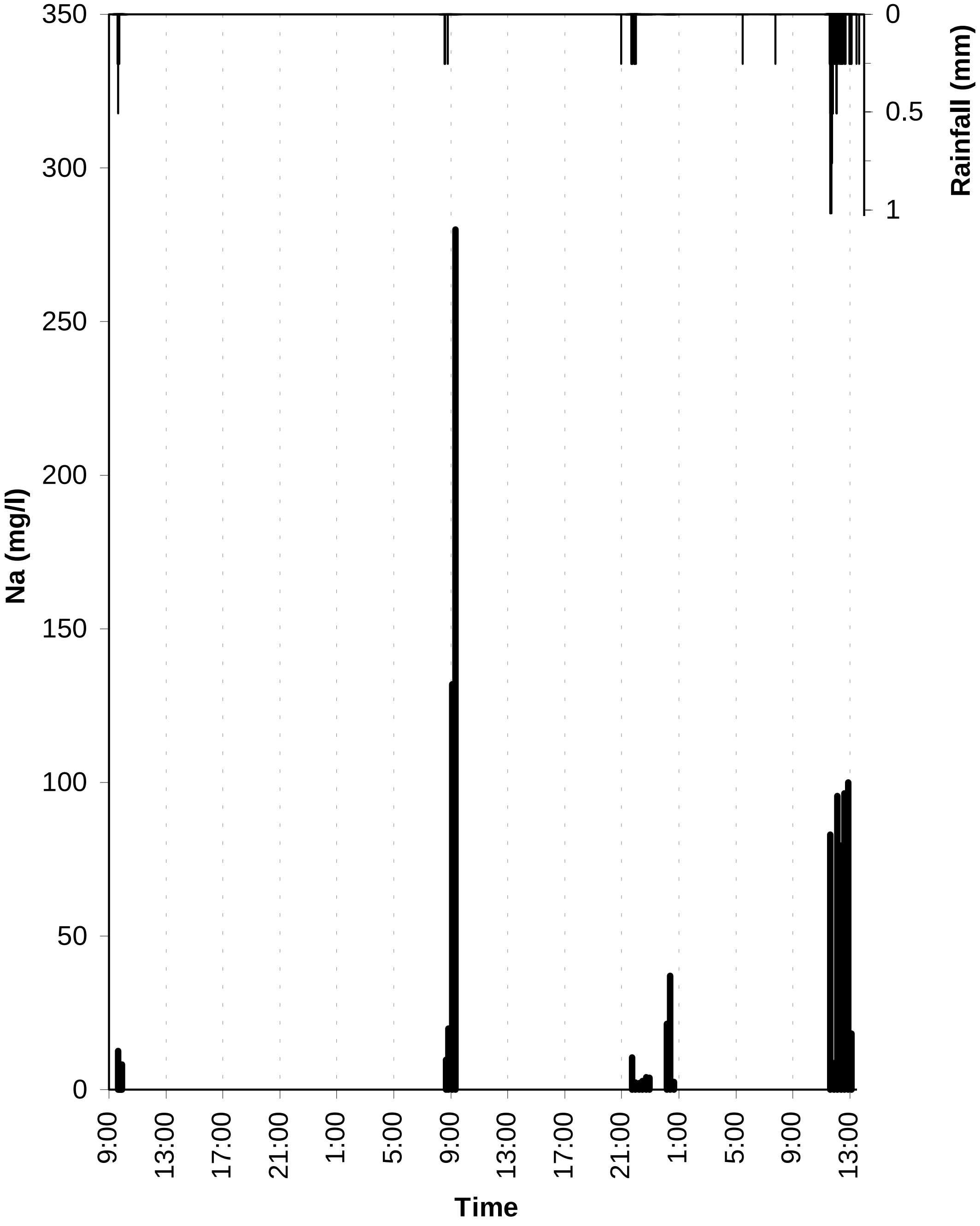
Calcium in Urban Runoff
1-3 August 1995



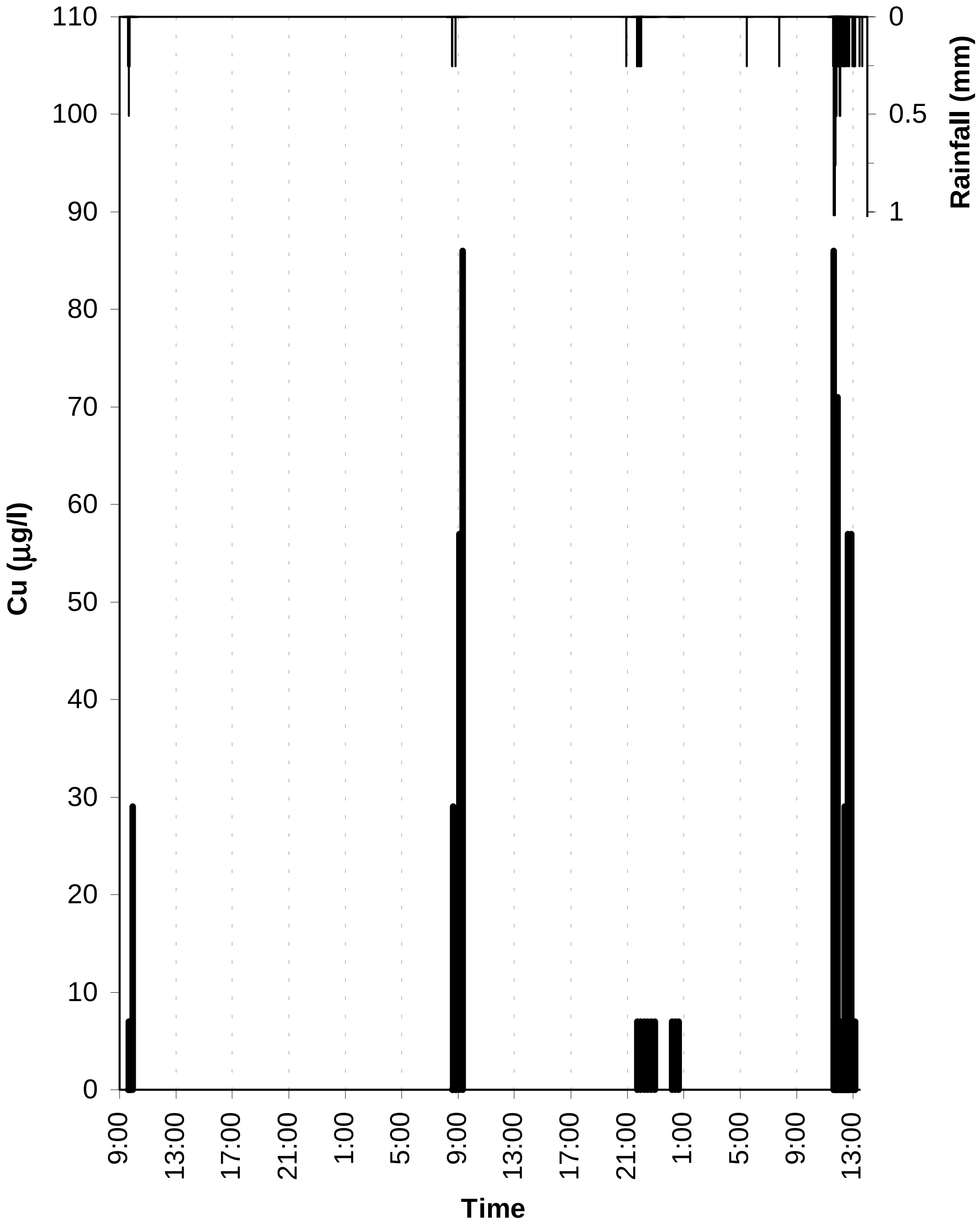
Magnesium in Urban Runoff
1-3 August 1995

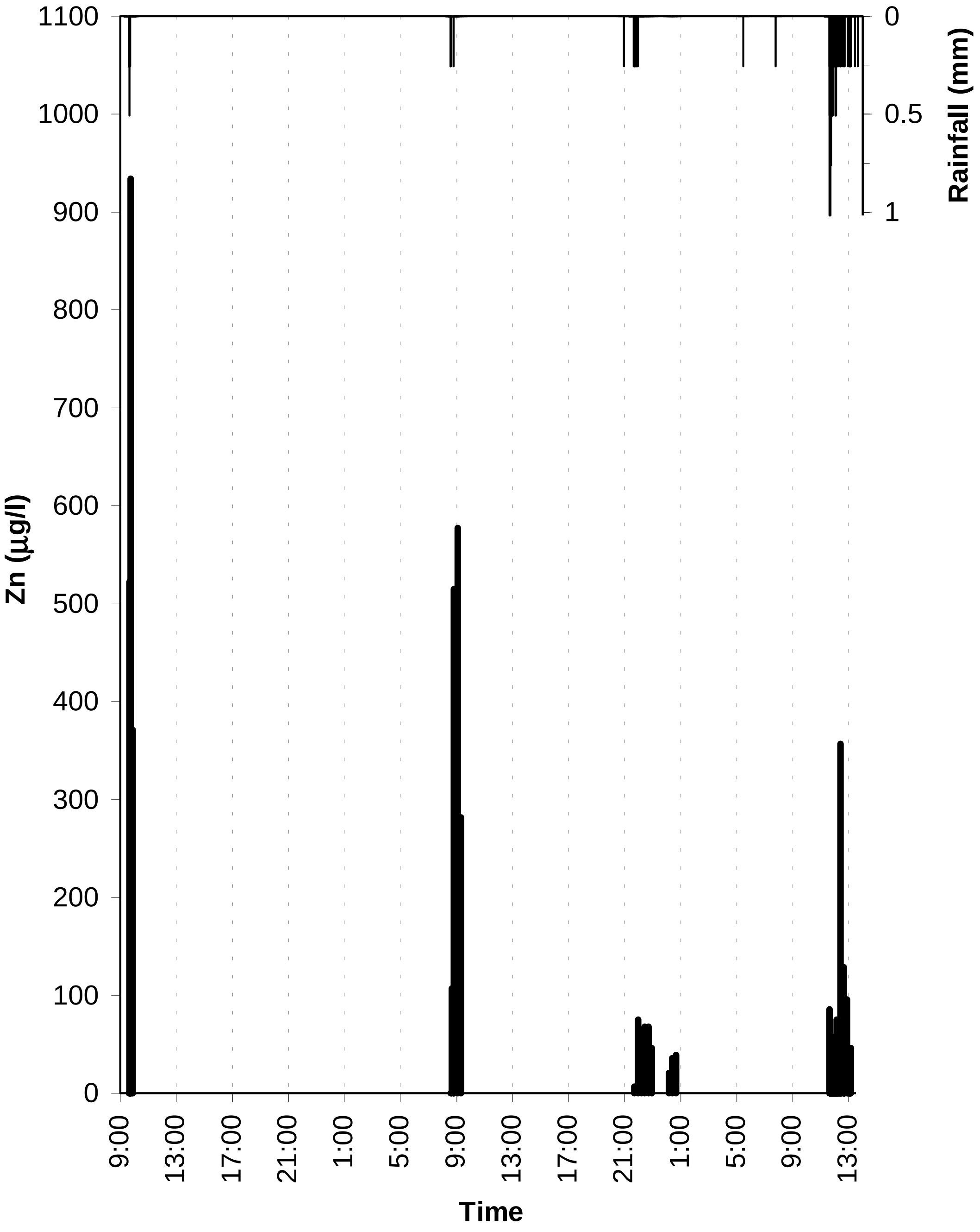


Sodium in Urban Runoff
1-3 August 1995



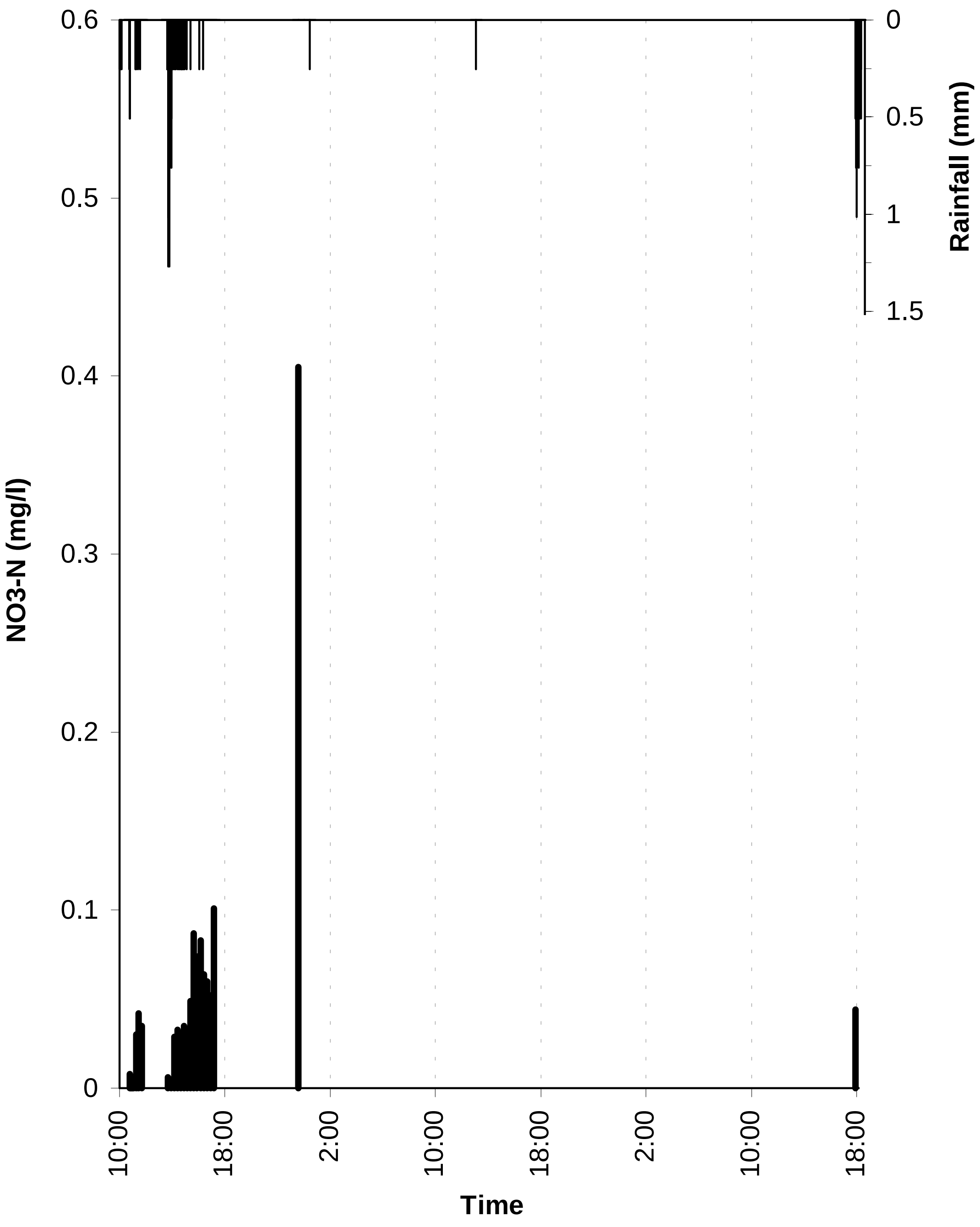
Copper in Urban Runoff
1-3 August 1995



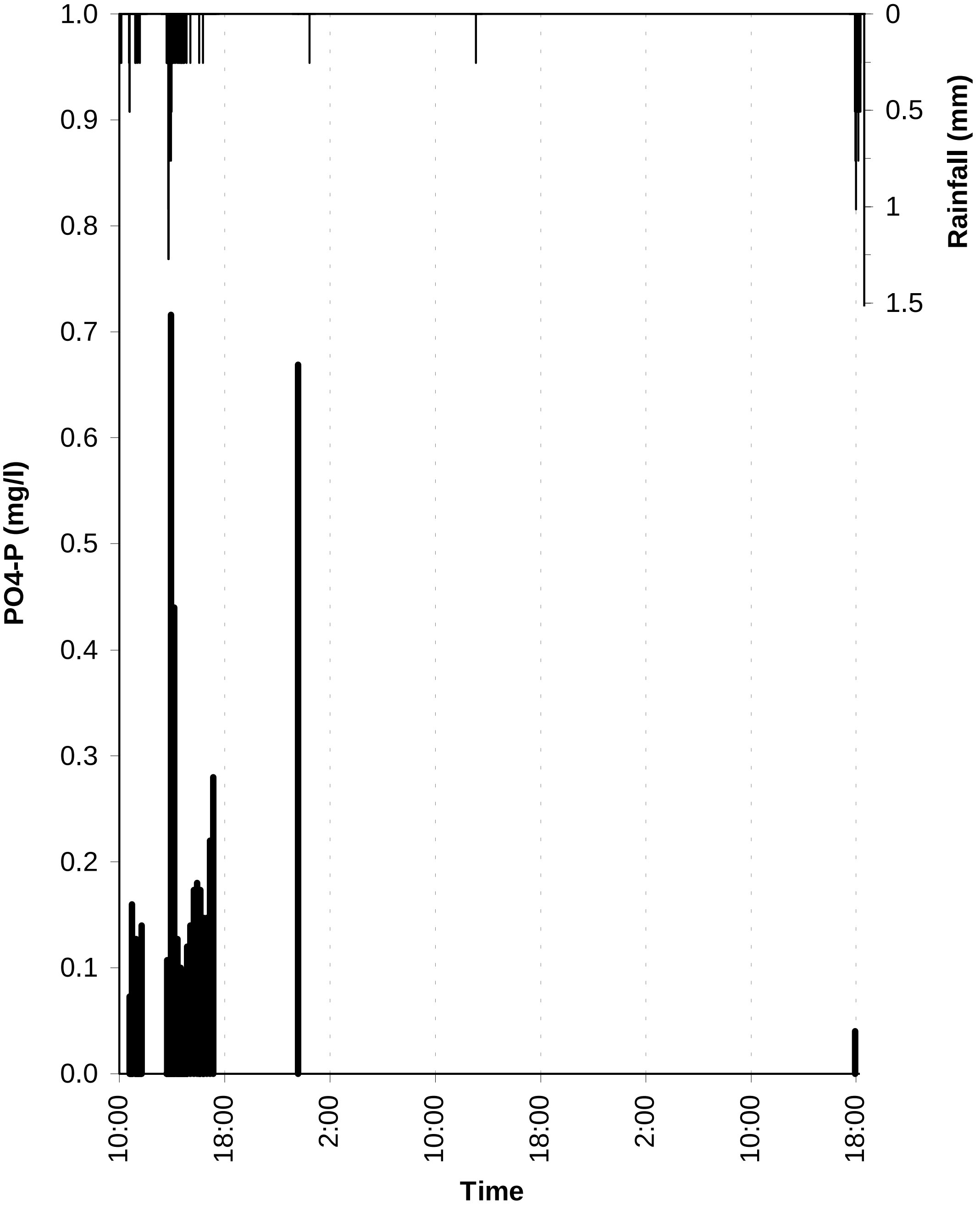


Zinc in Urban Runoff
1-3 August 1995

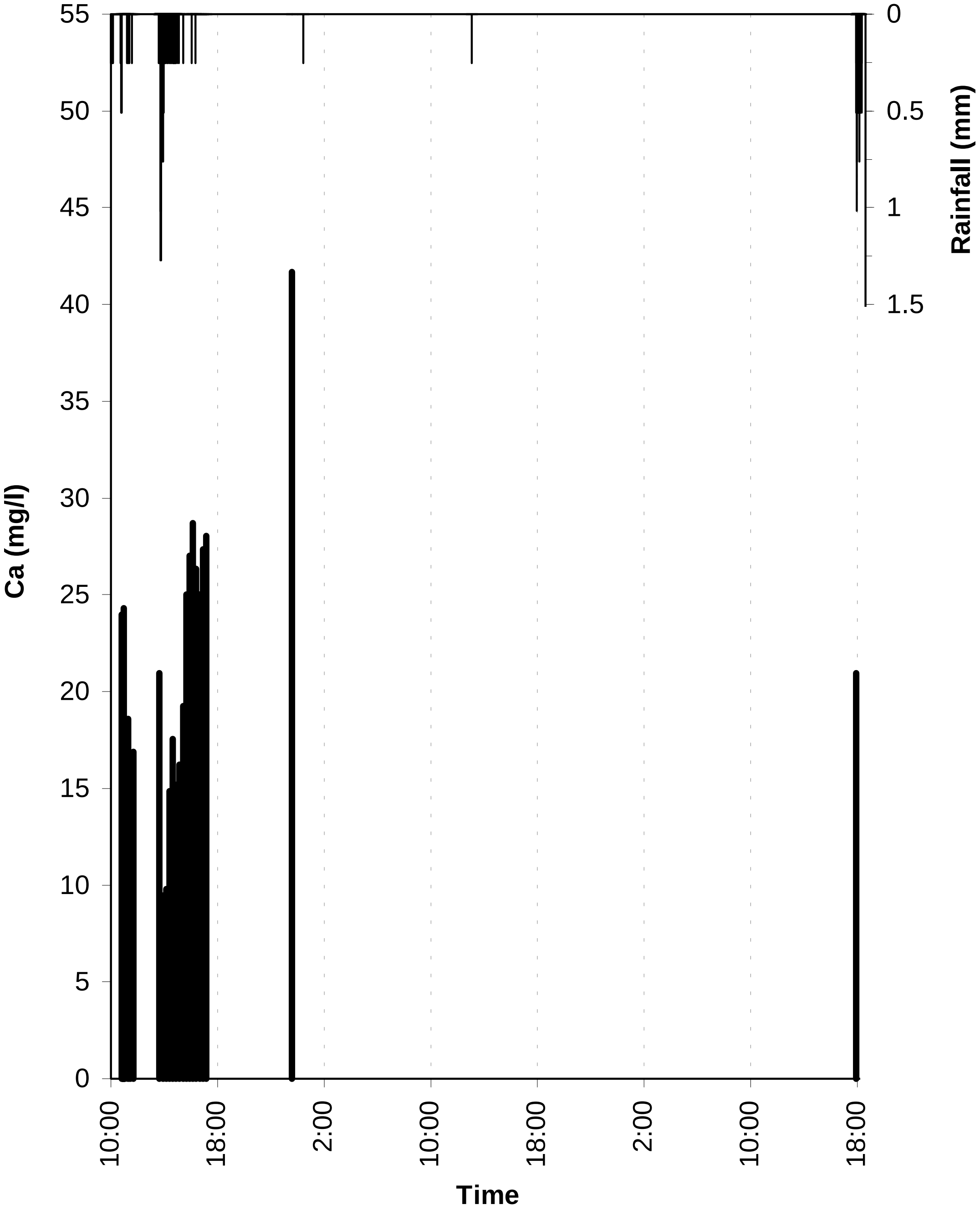
Nitrate-N in Urban Runoff
4-6 August 1995

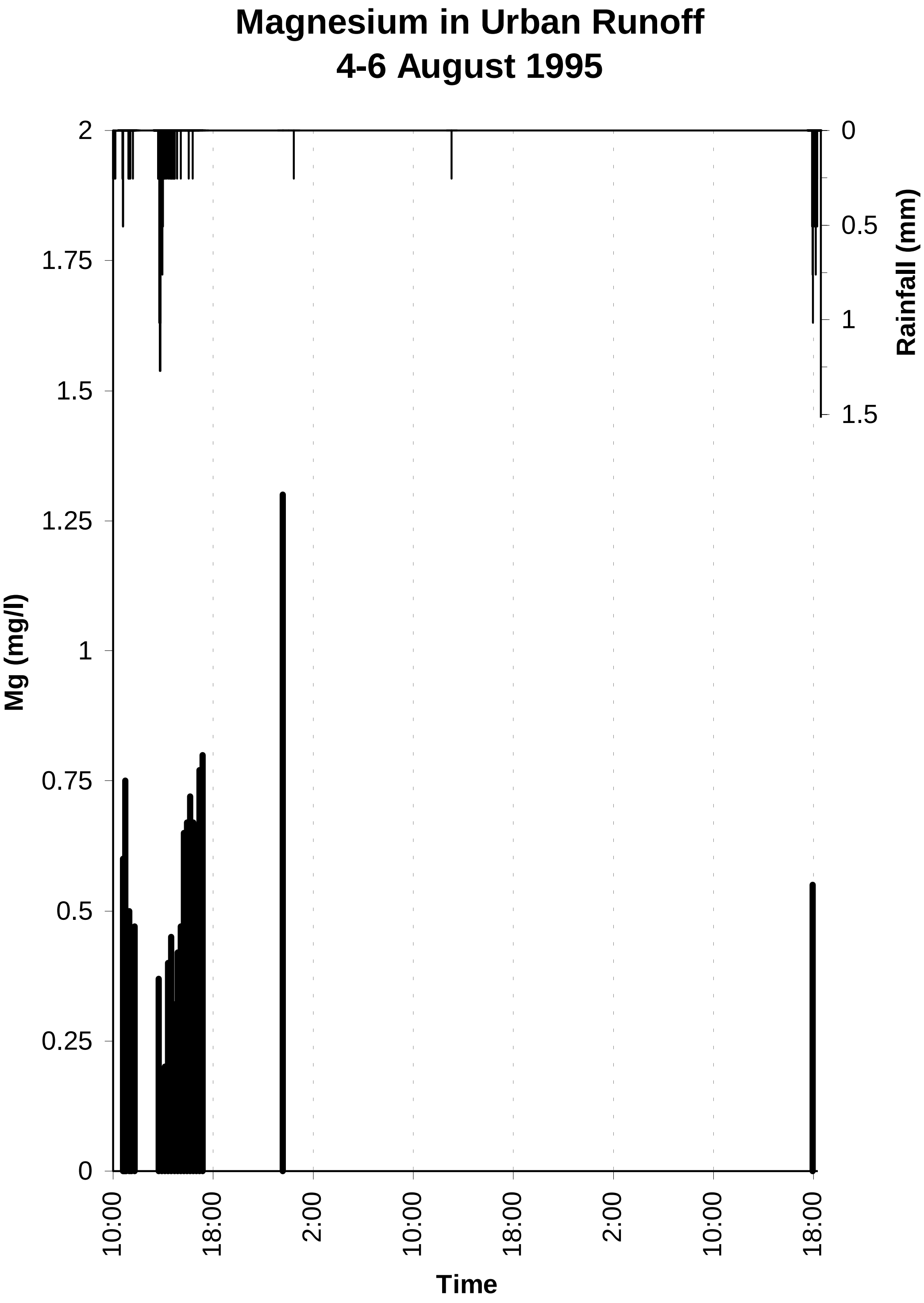


o-Phosphate-P in Urban Runoff
4-6 August 1995

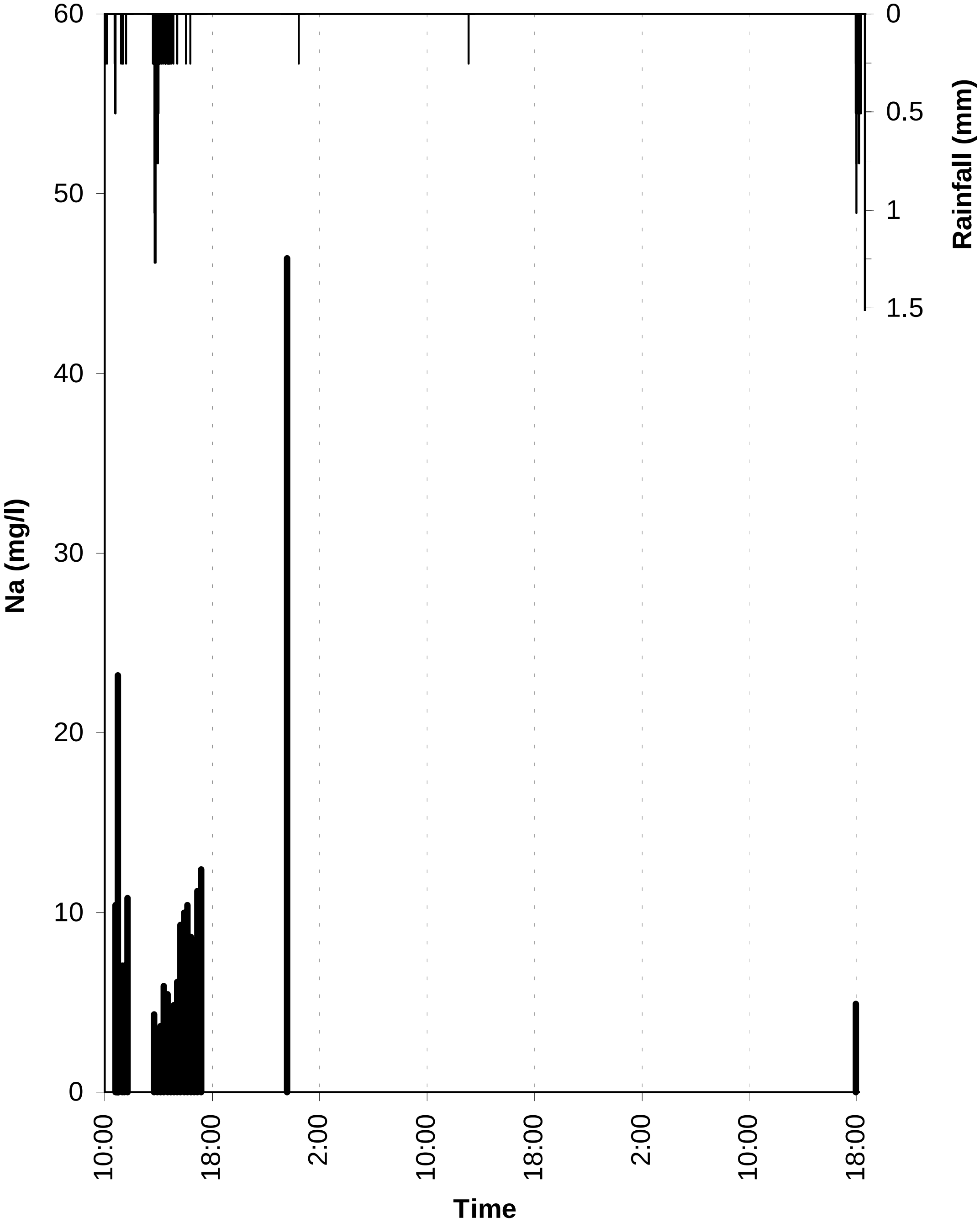


Calcium in Urban Runoff
4-6 August 1995

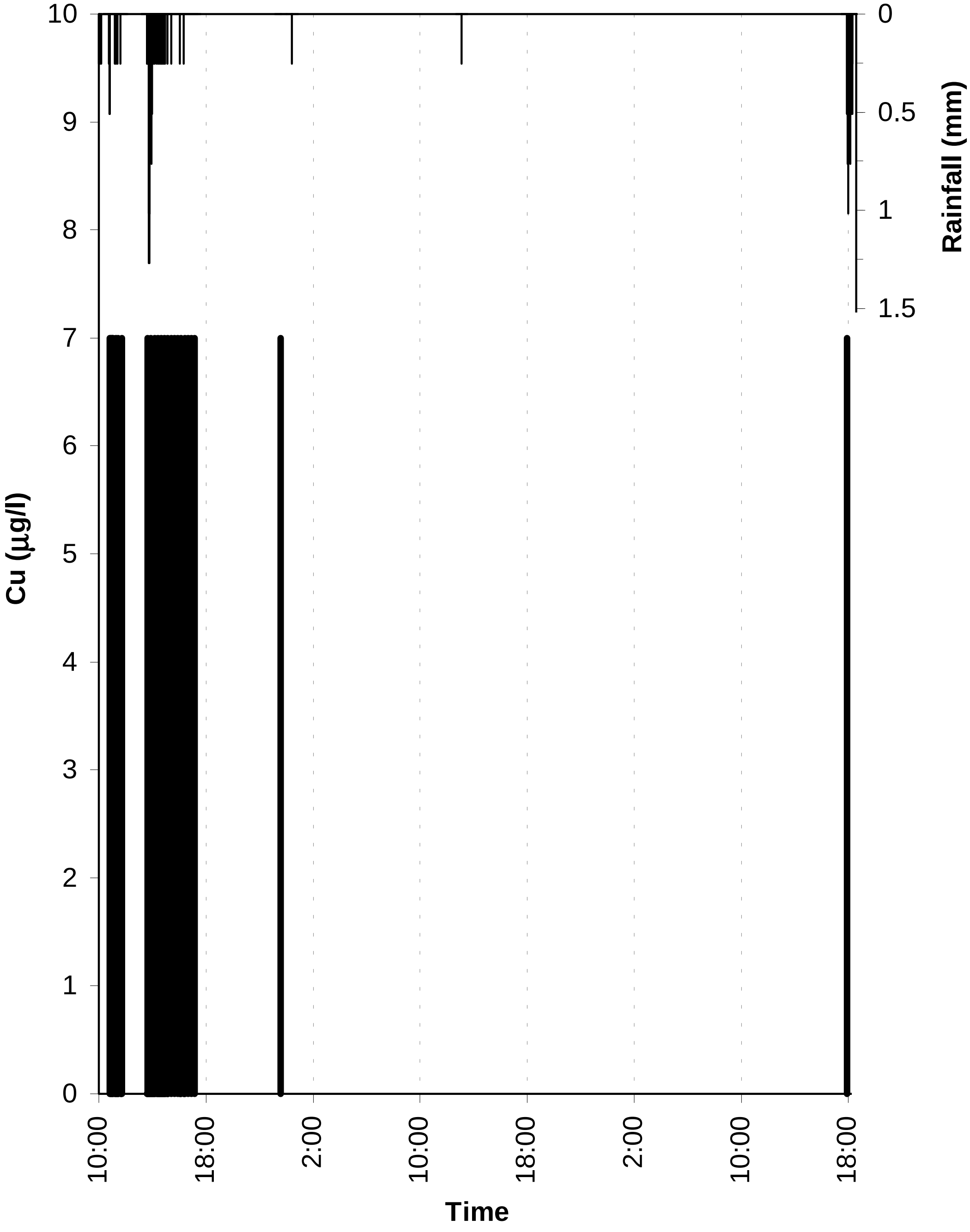



Magnesium in Urban Runoff
4-6 August 1995
Mg (mg/l)
2
1.75
1.5
1.25
1
0.75
0.5
0.25
0
Rainfall (mm)
0
0.5
1
1.5
10:00
18:00
2:00
10:00
18:00
2:00
10:00
18:00
Time

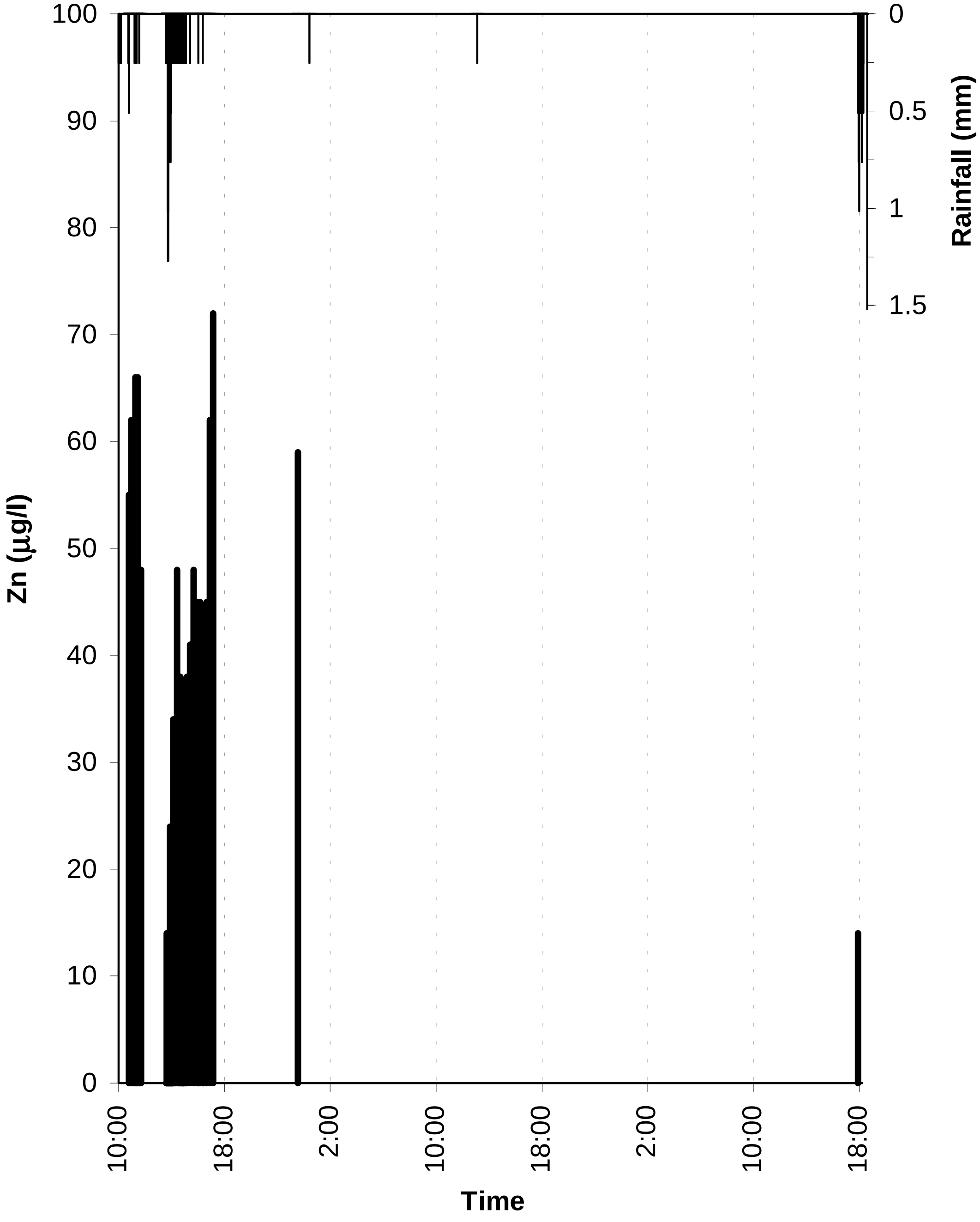
Sodium in Urban Runoff
4-6 August 1995



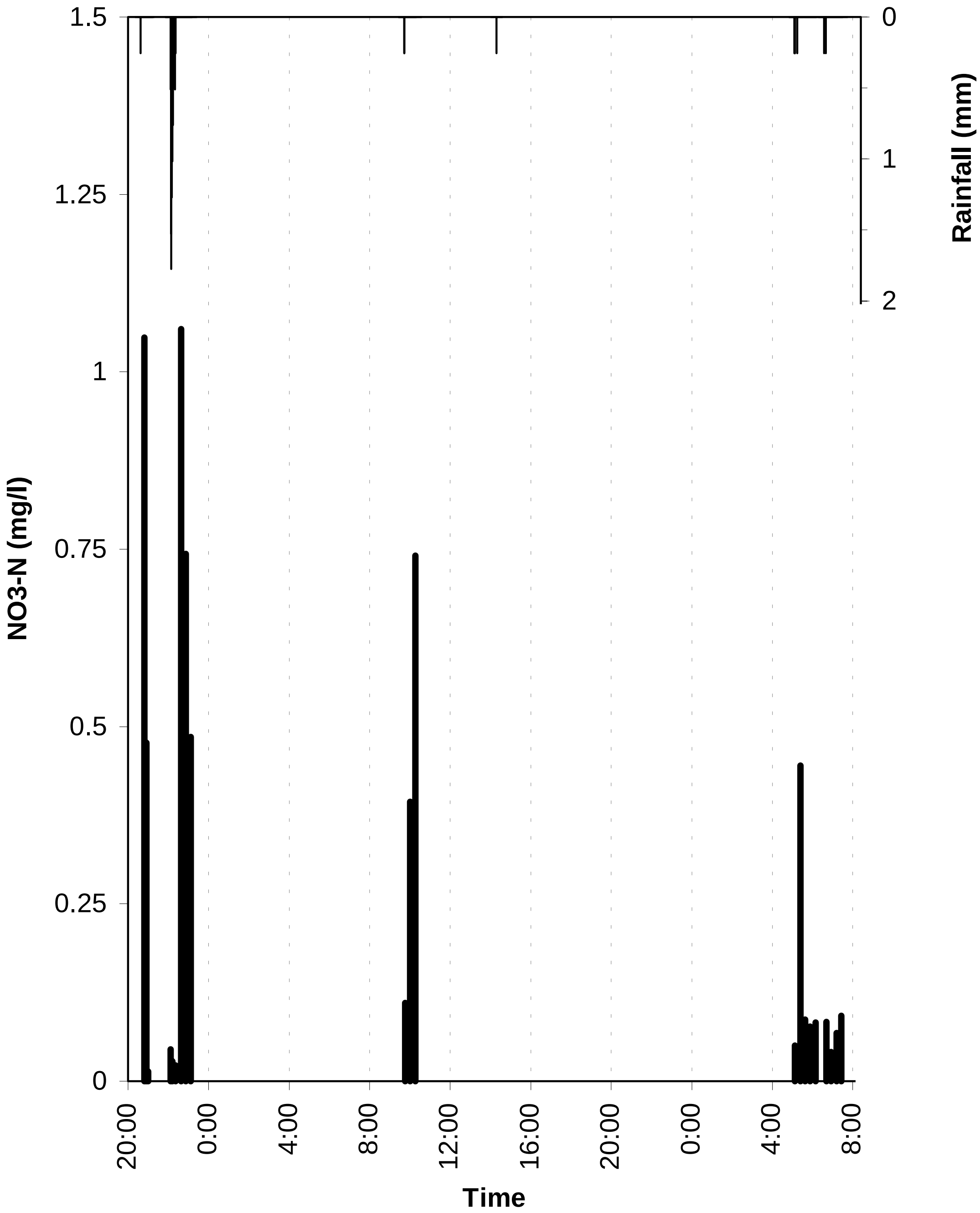
Copper in Urban Runoff
4-6 August 1995



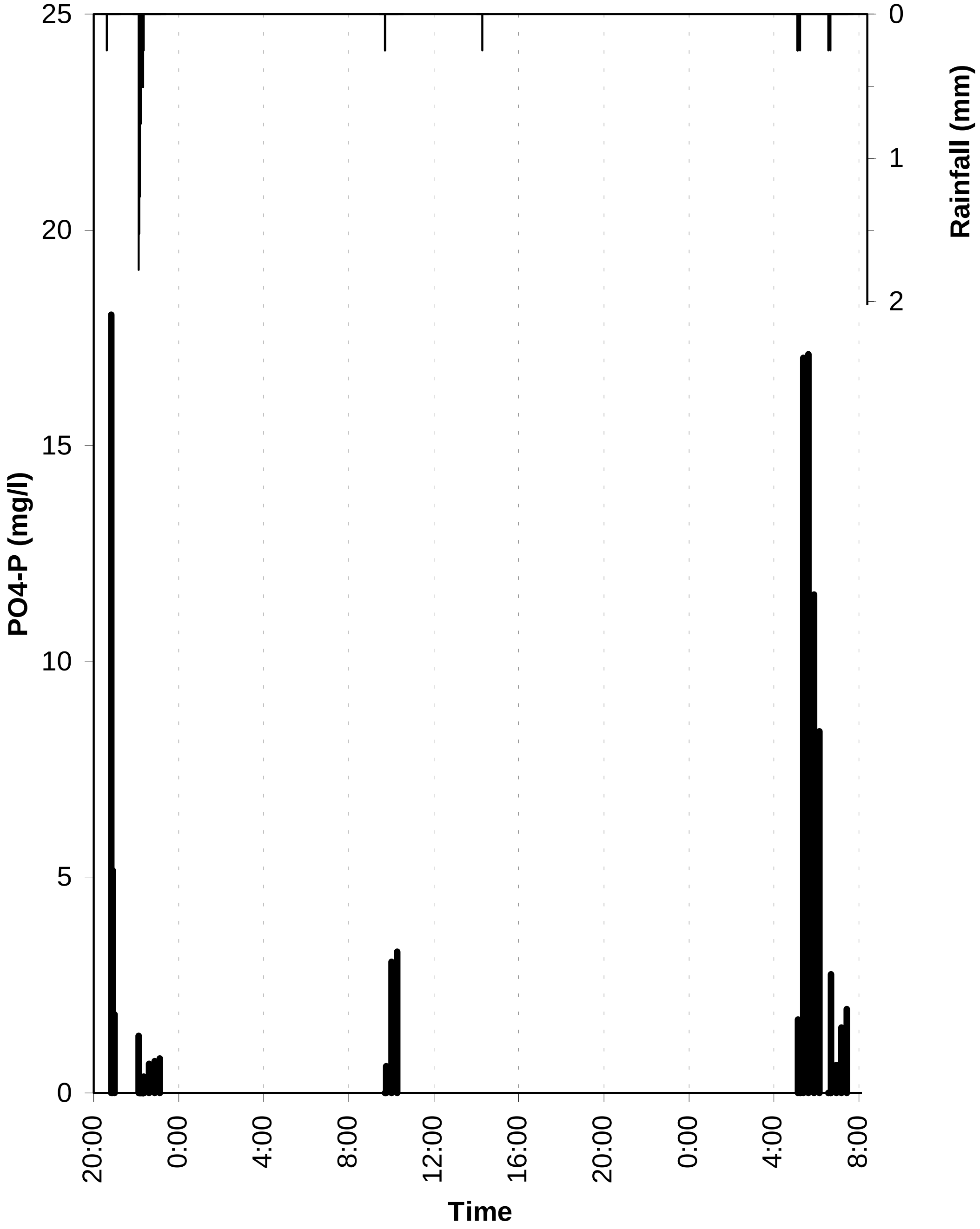
Zinc in Urban Runoff
4-6 August 1995



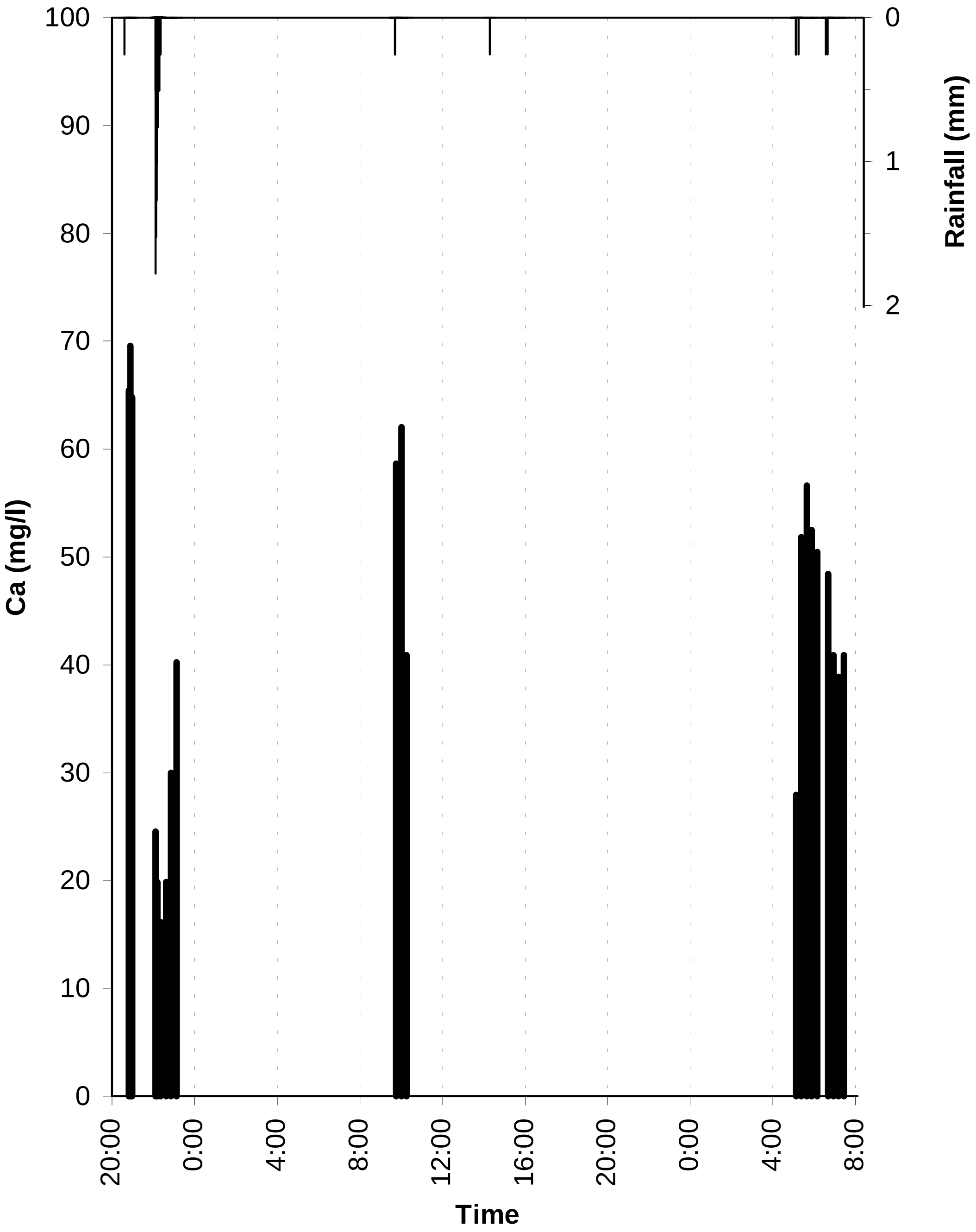
Nitrate-N in Urban Runoff
7-9 August 1995



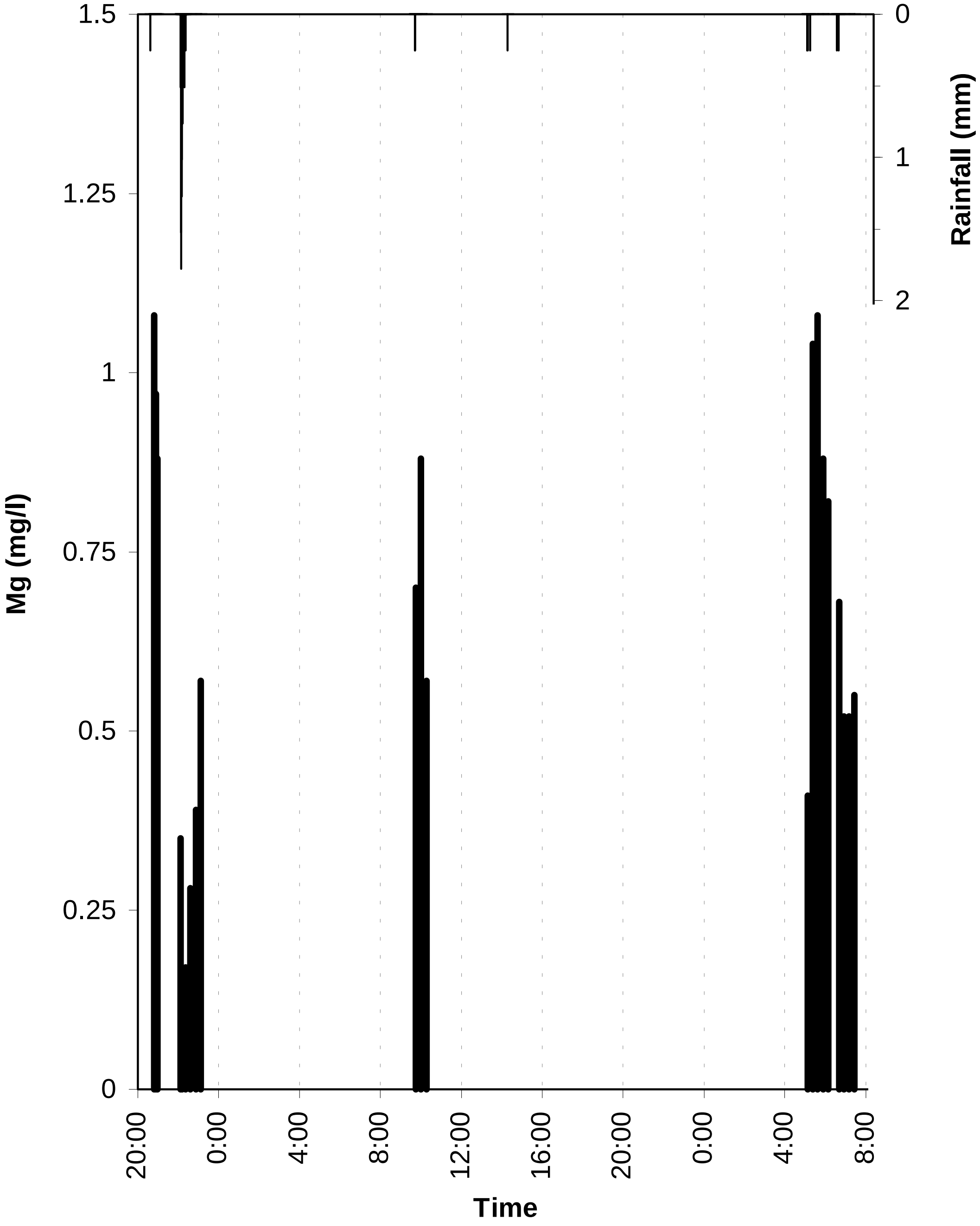
o-Phosphate-P in Urban Runoff
7-9 August 1995



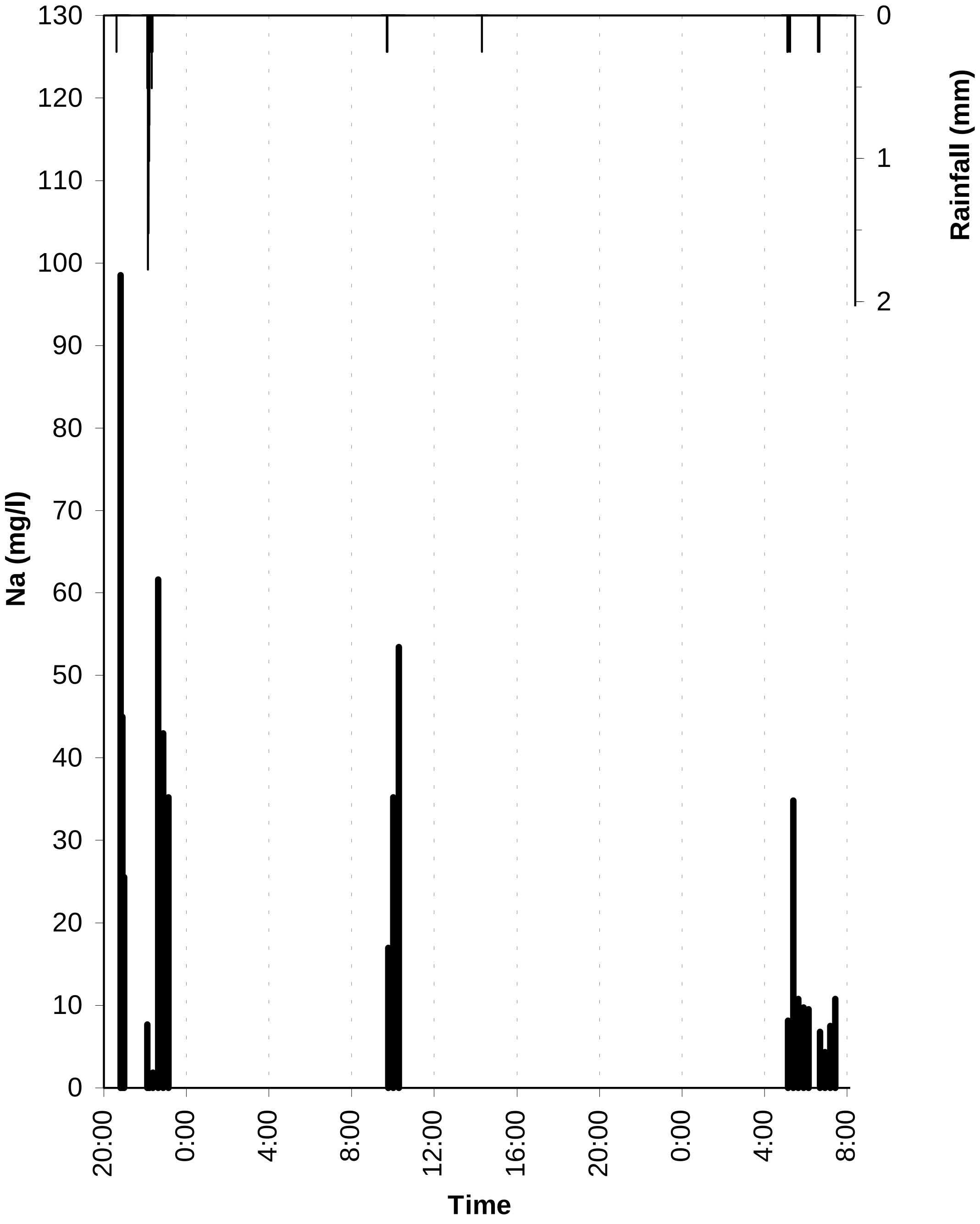
Calcium in Urban Runoff
7-9 August 1995



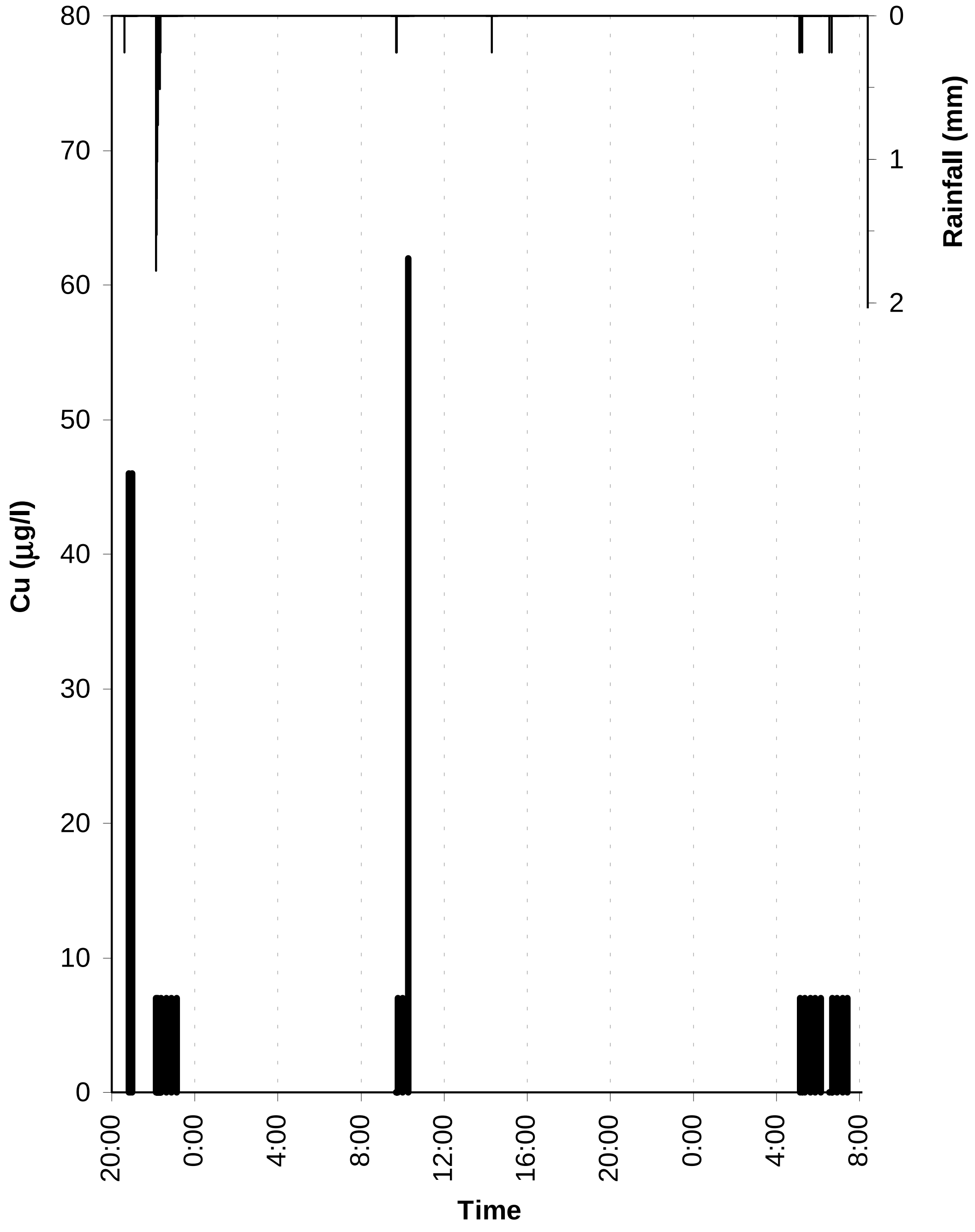
Magnesium in Urban Runoff
7-9 August 1995



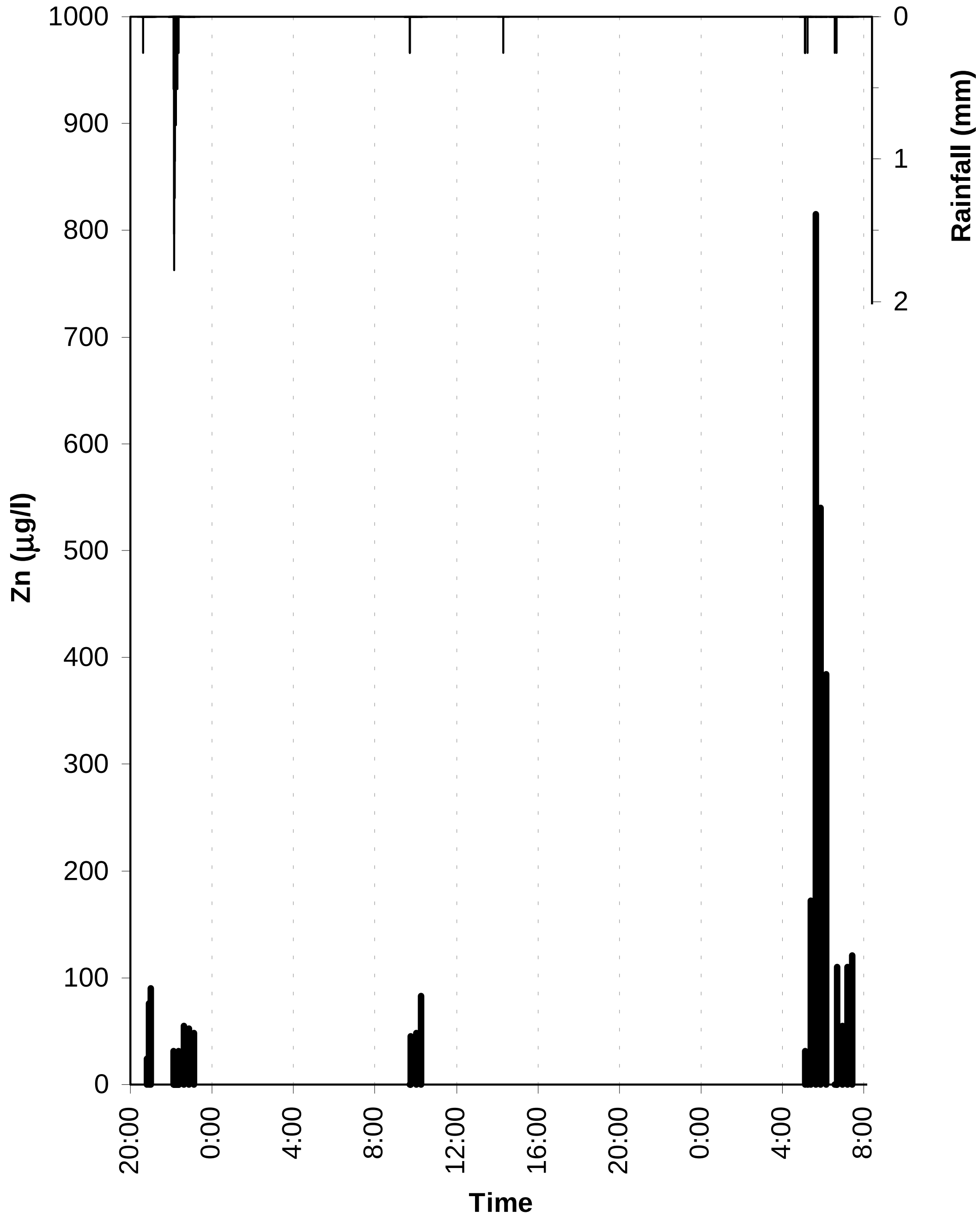
Sodium in Urban Runoff
7-9 August 1995

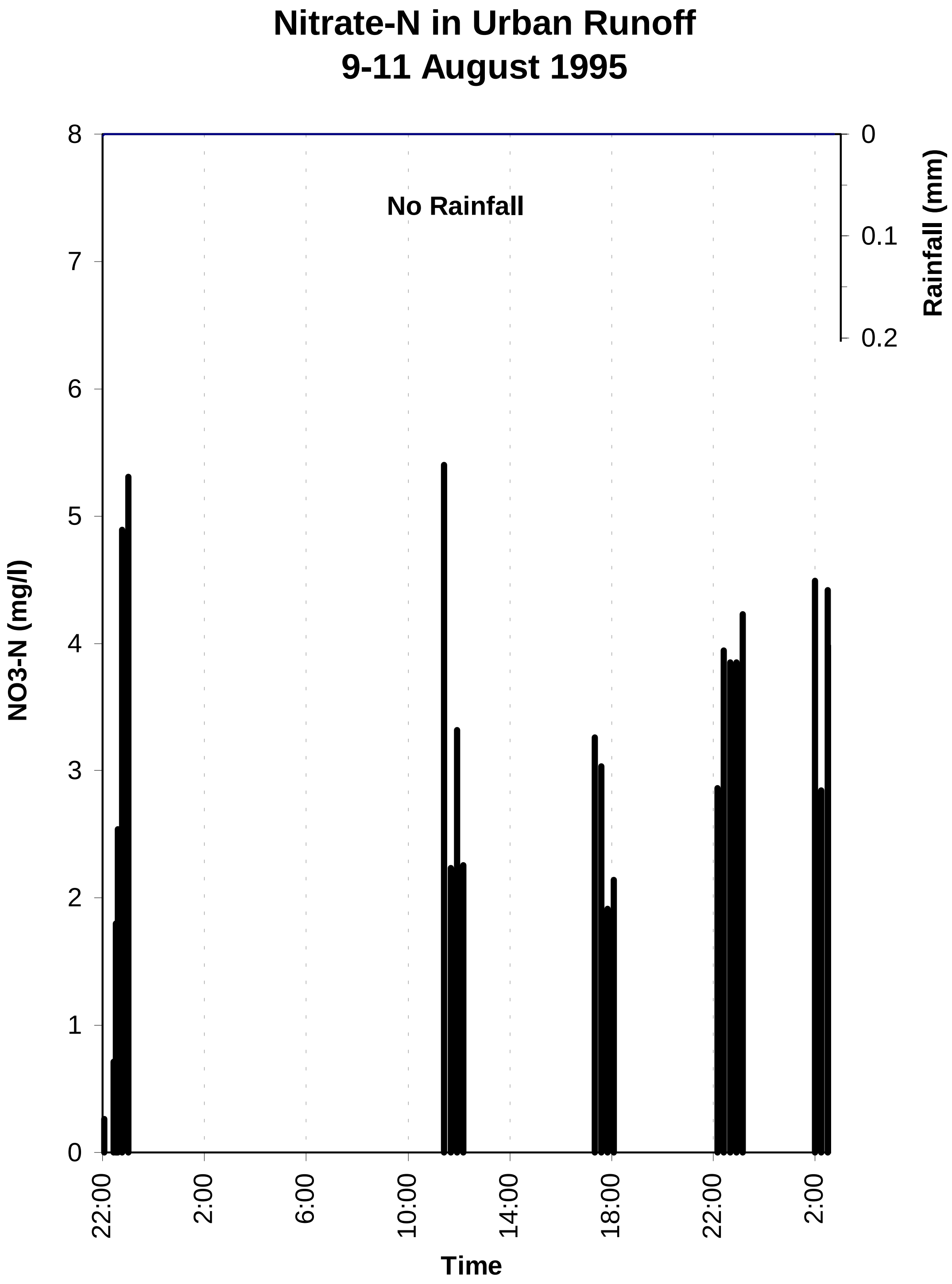


Copper in Urban Runoff
7-9 August 1995

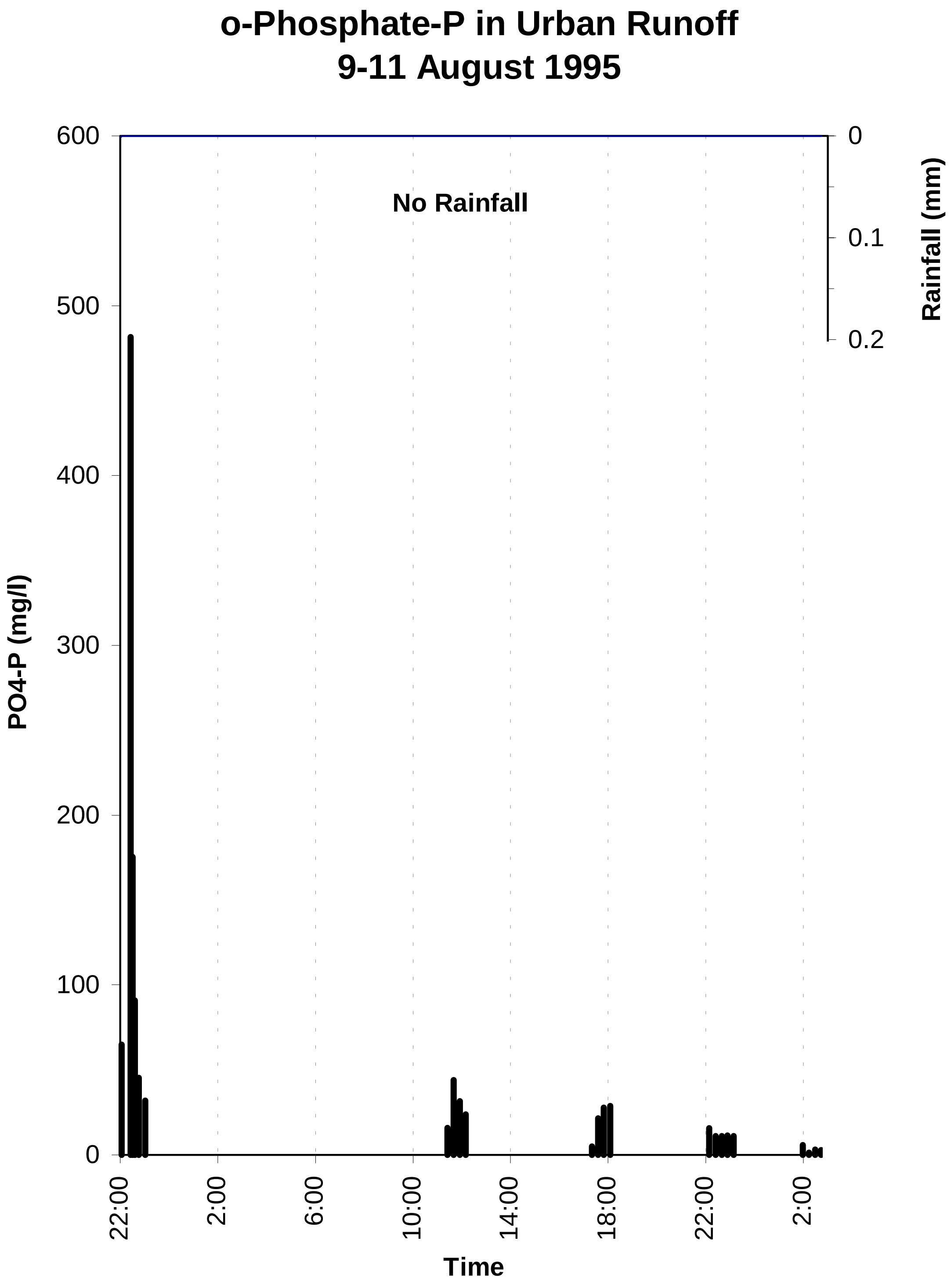


Zinc in Urban Runoff
7-9 August 1995

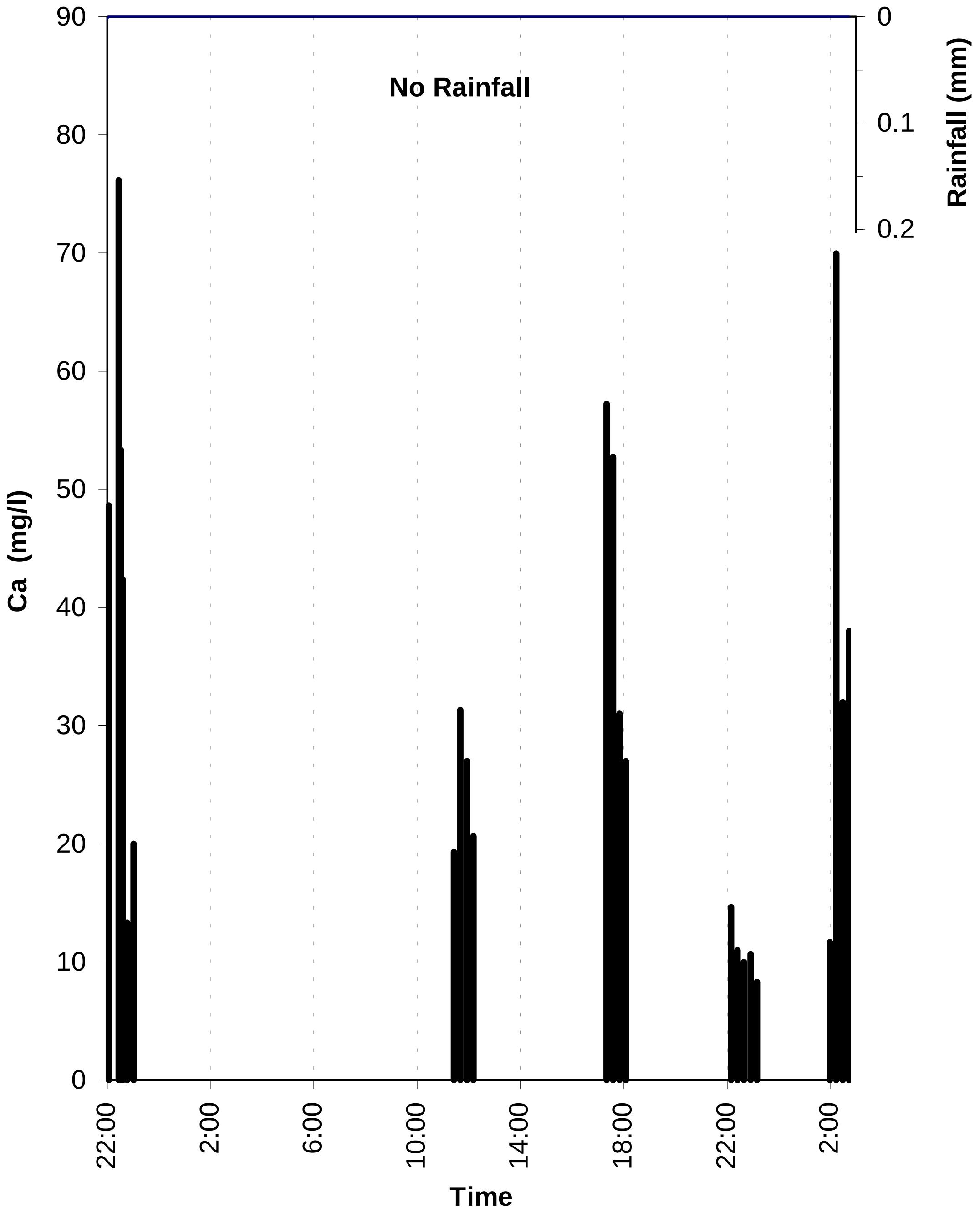


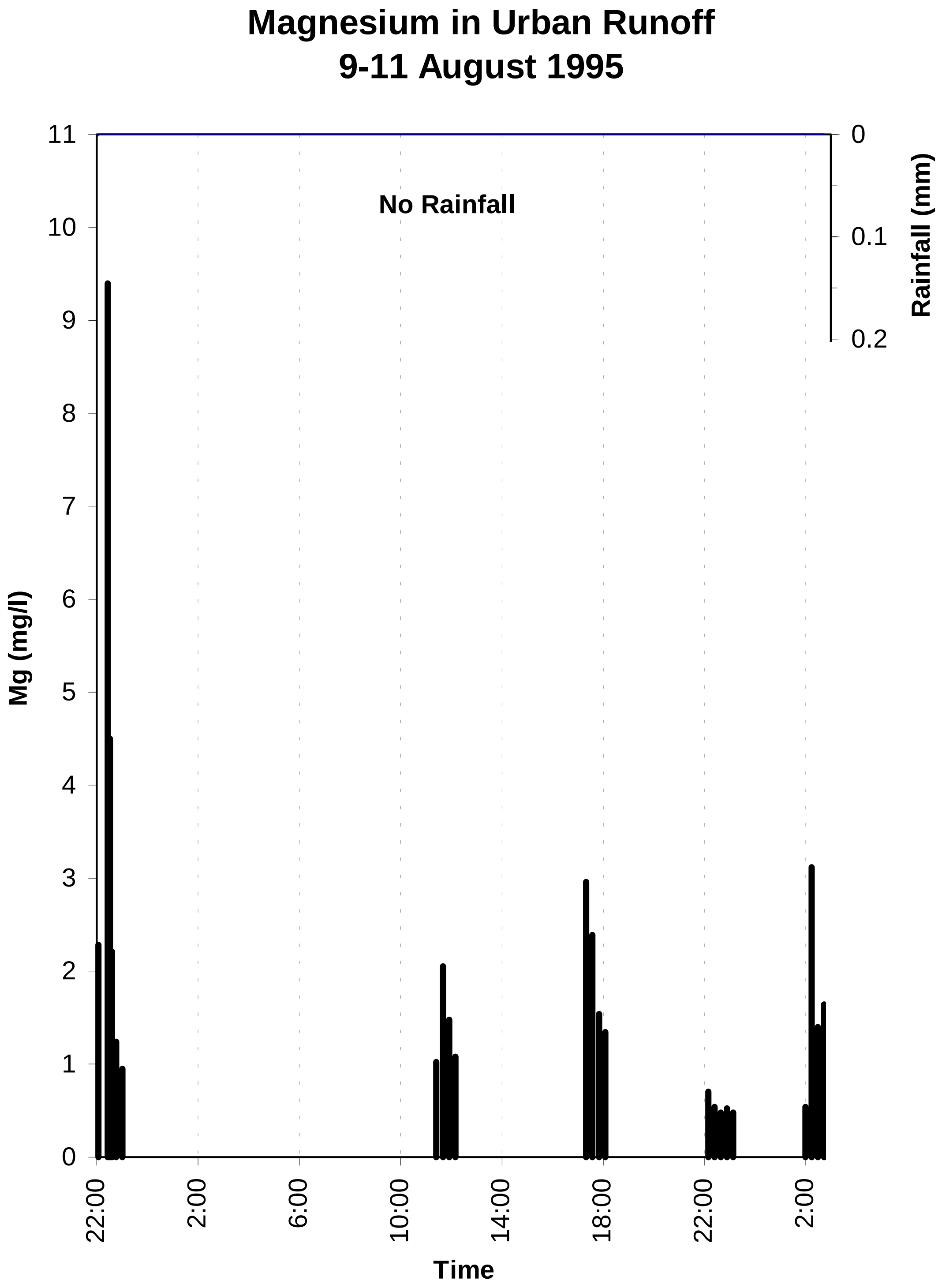


Nitrate-N in Urban Runoff
9-11 August 1995
No Rainfall
NO3-N (mg/l)
Rainfall (mm)
Time
0
1
2
3
4
5
6
7
8
0
0.1
0.2
22:00
2:00
6:00
10:00
14:00
18:00
22:00
2:00

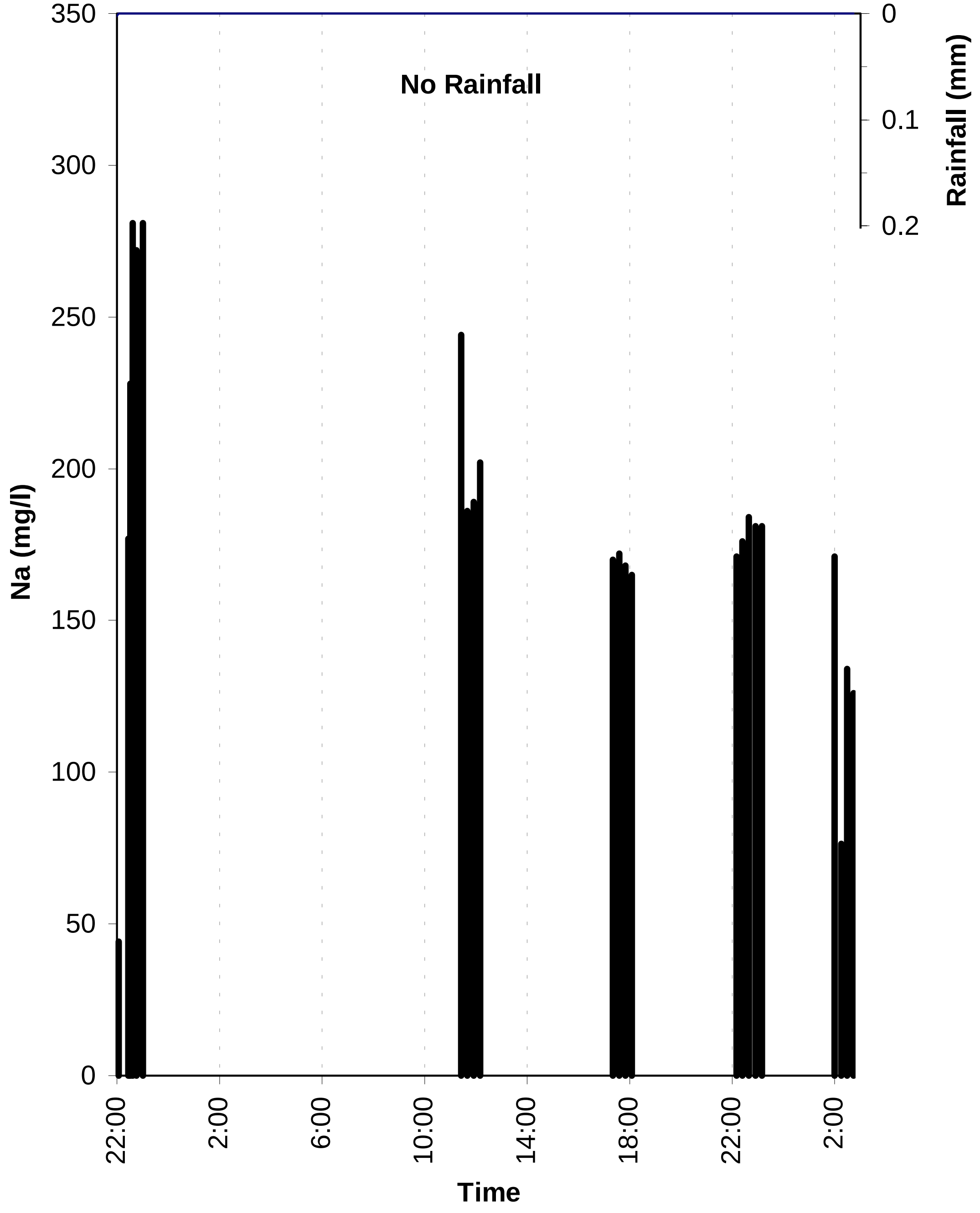

o-Phosphate-P in Urban Runoff
9-11 August 1995
No Rainfall
PO4-P (mg/l)
600
500
400
300
200
100
0
Rainfall (mm)
0
0.1
0.2
22:00
2:00
6:00
10:00
14:00
18:00
22:00
2:00
Time

Calcium in Urban Runoff
9-11 August 1995

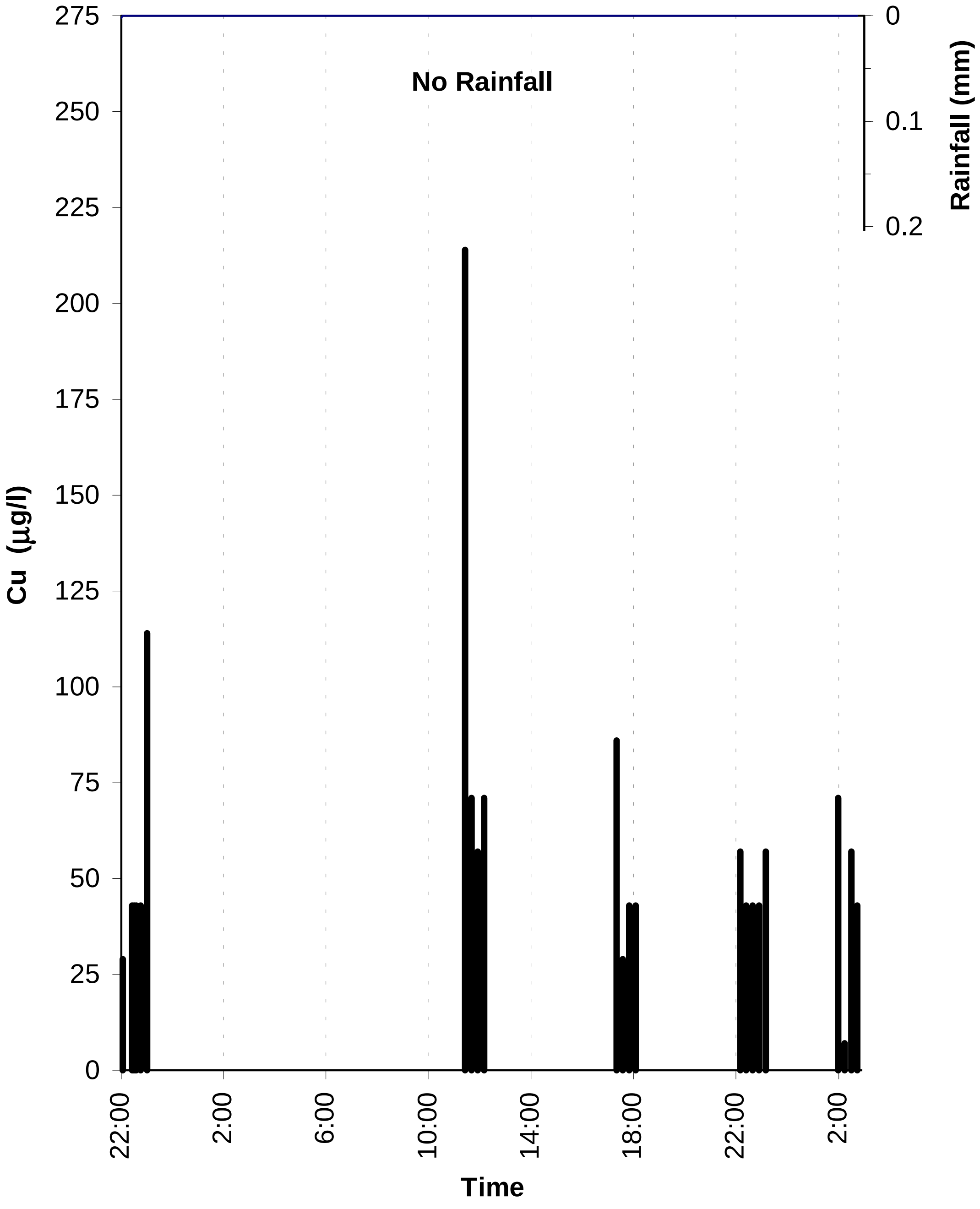



Magnesium in Urban Runoff
9-11 August 1995
No Rainfall
Mg (mg/l)
Rainfall (mm)
Time
11
10
9
8
7
6
5
4
3
2
1
0
0
0.1
0.2
22:00
2:00
6:00
10:00
14:00
18:00
22:00
2:00

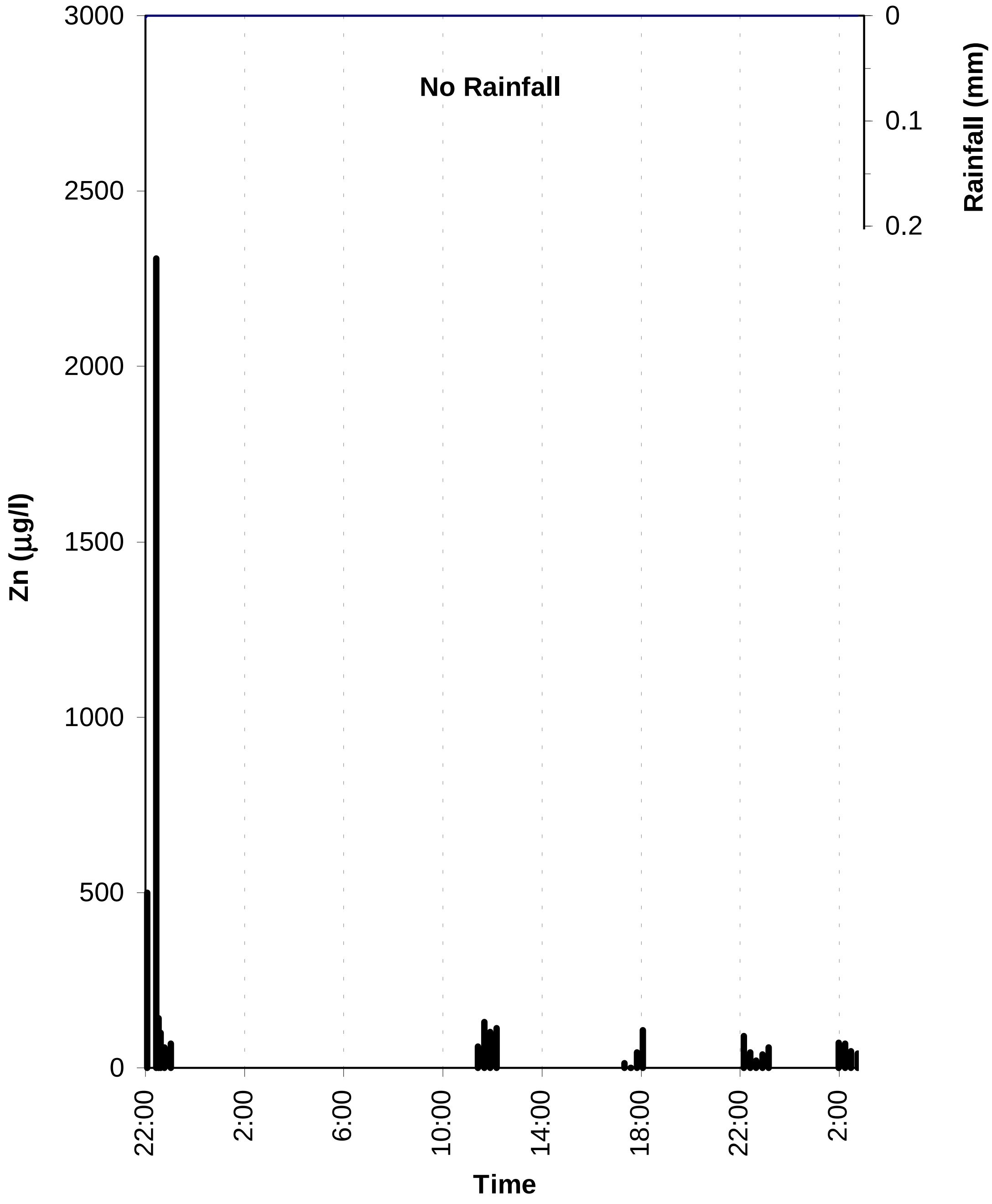
Sodium in Urban Runoff
9-11 August 1995

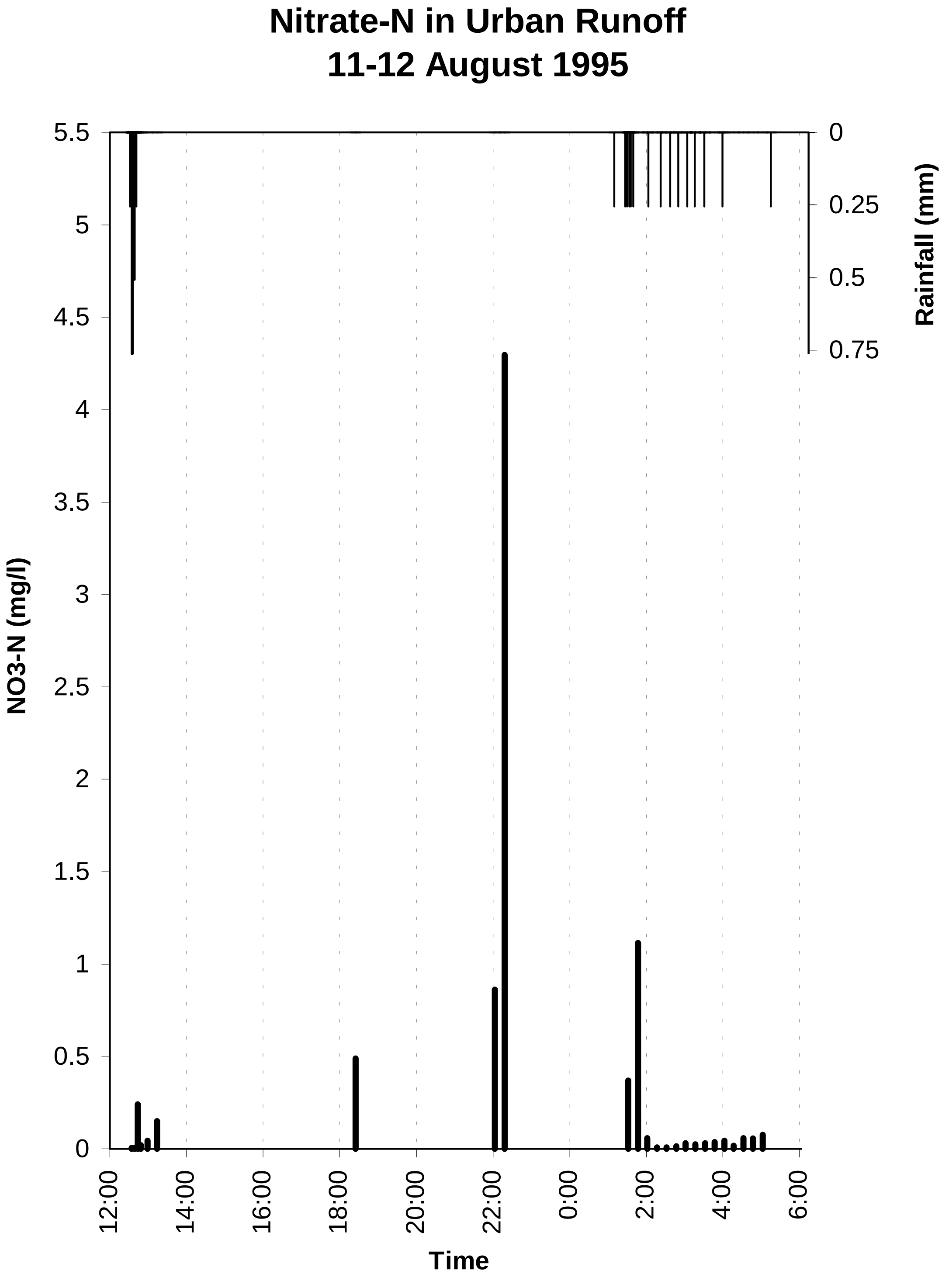


Copper in Urban Runoff
9-11 August 1995

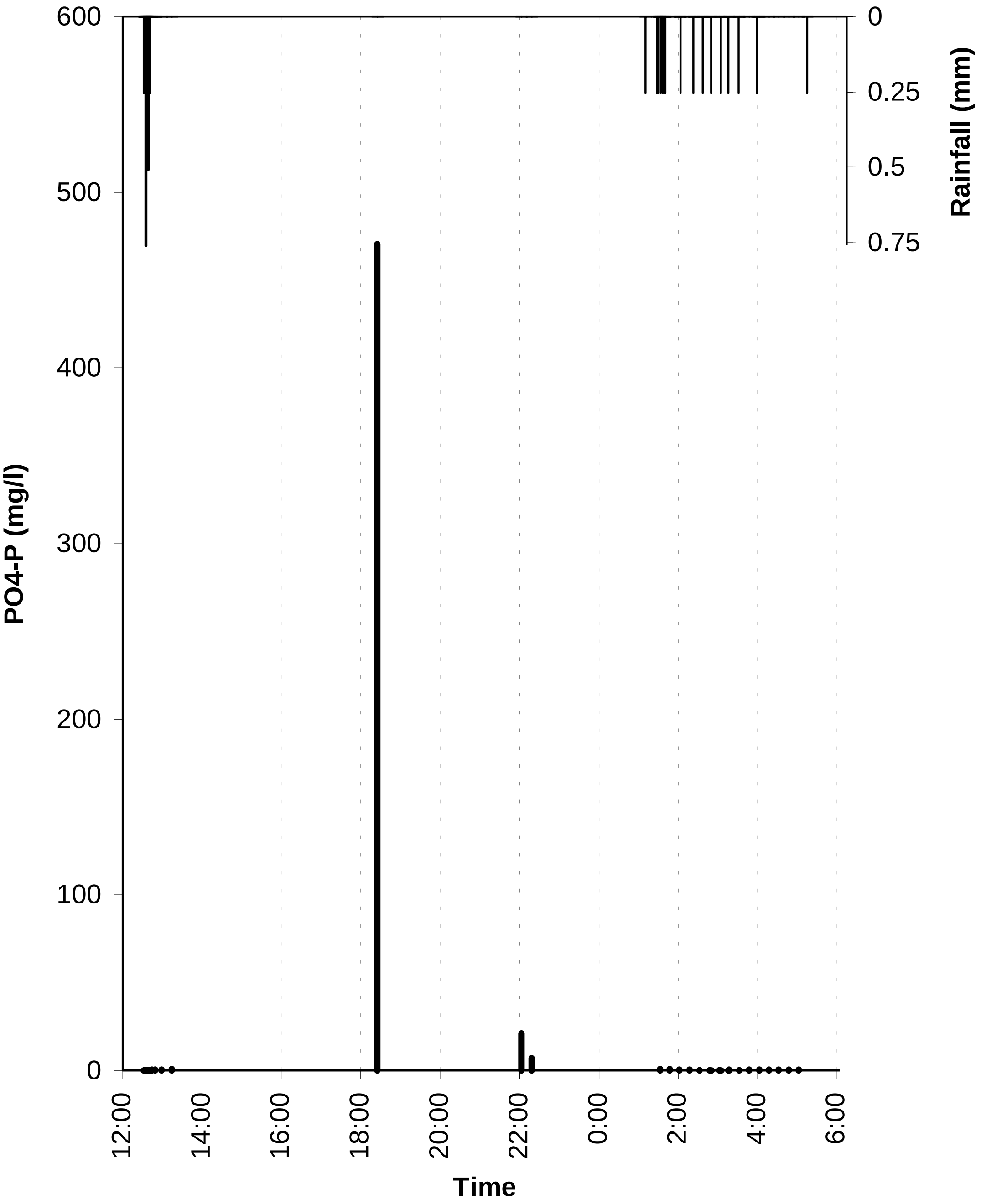


Zinc in Urban Runoff
9-11 August 1995

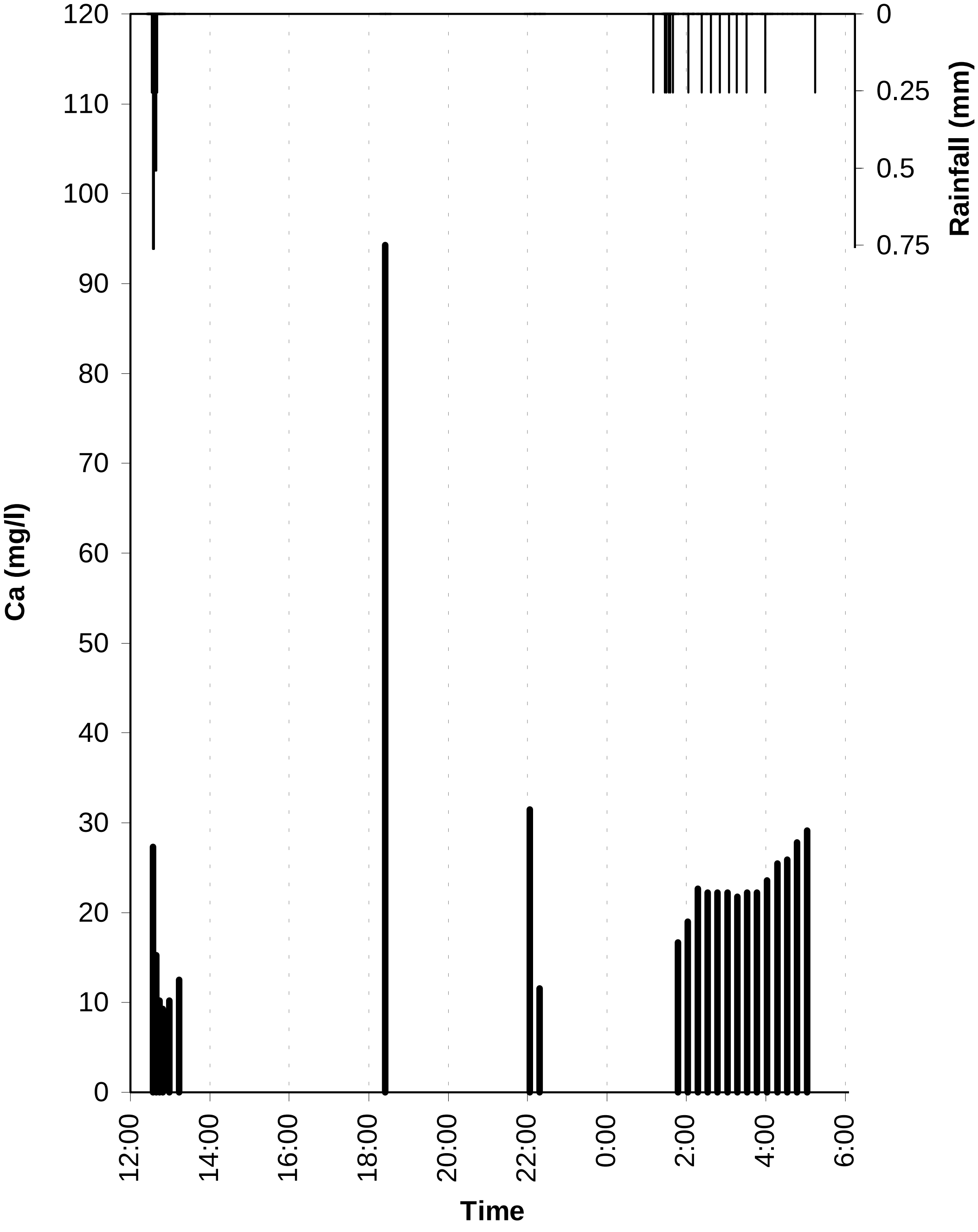



Nitrate-N in Urban Runoff
11-12 August 1995
NO3-N (mg/l)
5.5
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
Rainfall (mm)
0
0.25
0.5
0.75
12:00
14:00
16:00
18:00
20:00
22:00
0:00
2:00
4:00
6:00
Time

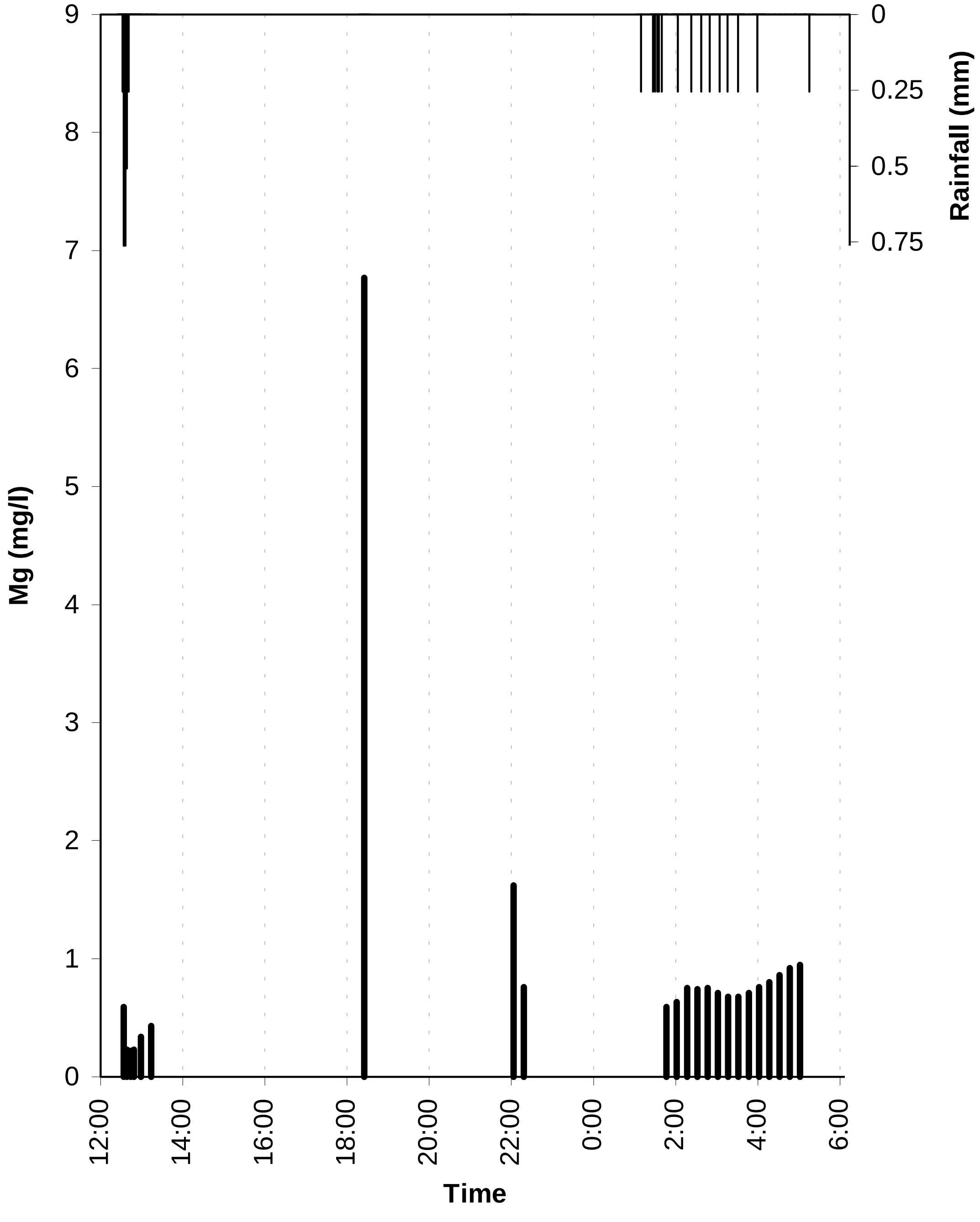
o-Phosphate-P in Urban Runoff
11-12 August 1995



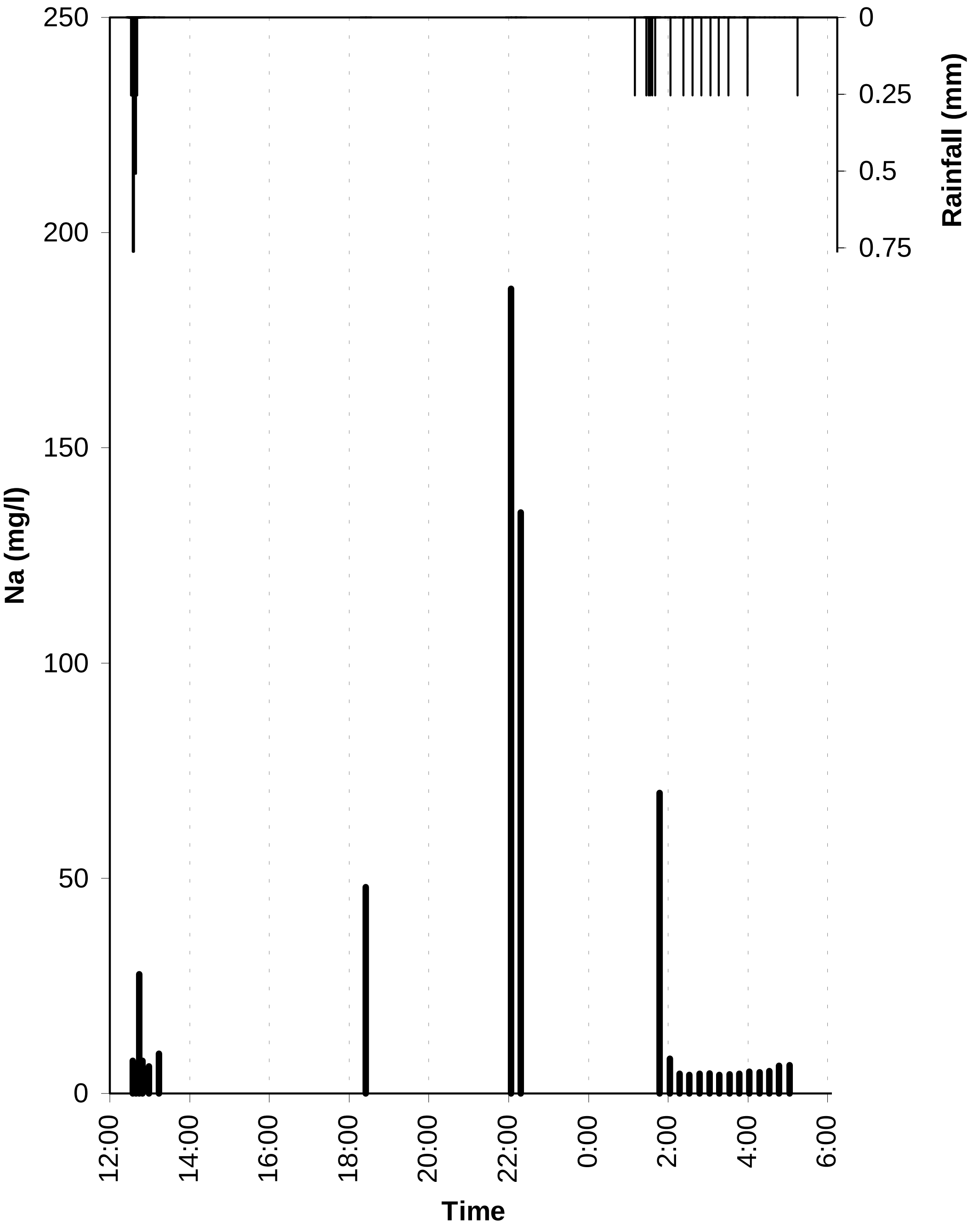
Calcium in Urban Runoff
11-12 August 1995



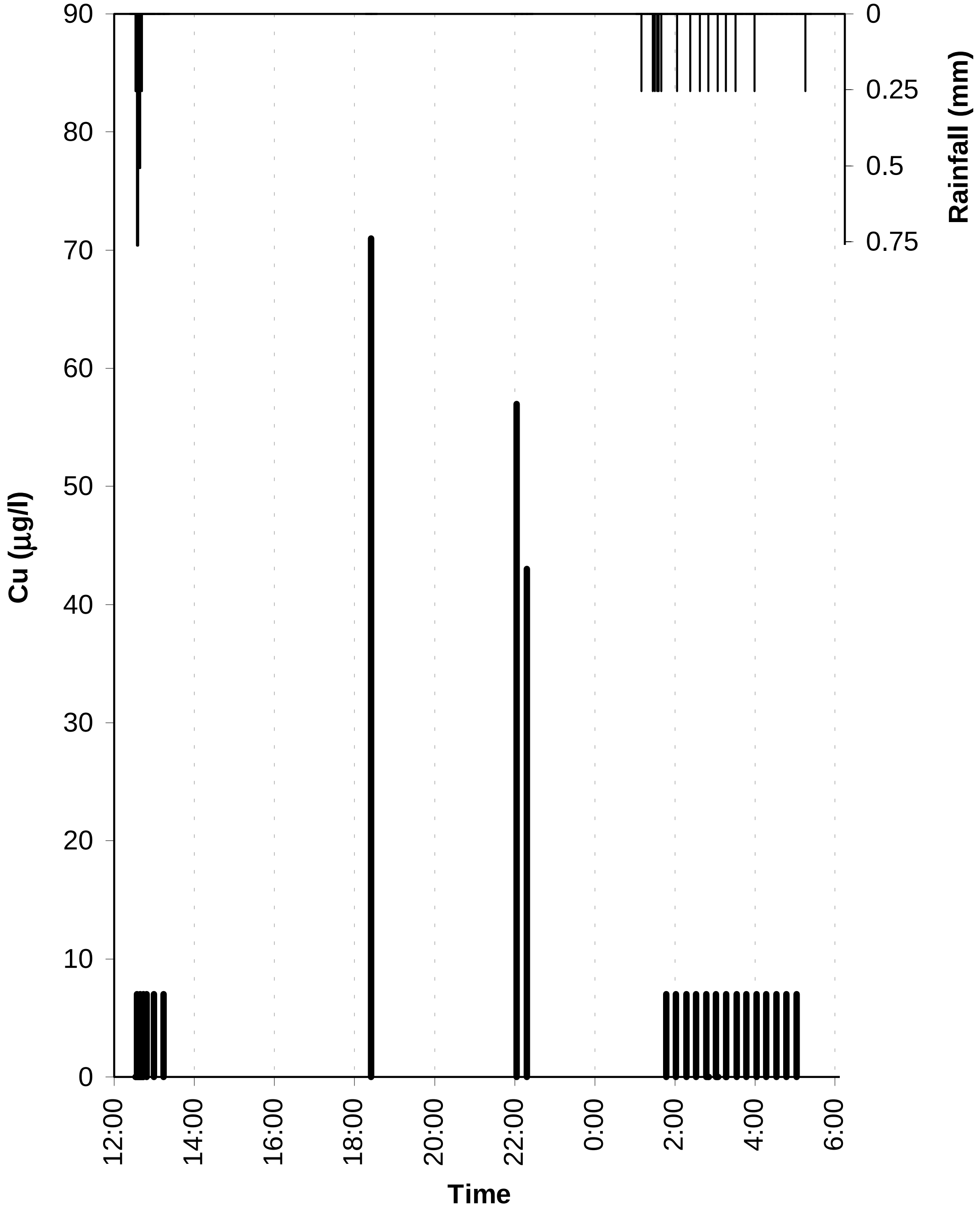
Magnesium in Urban Runoff
11-12 August 1995



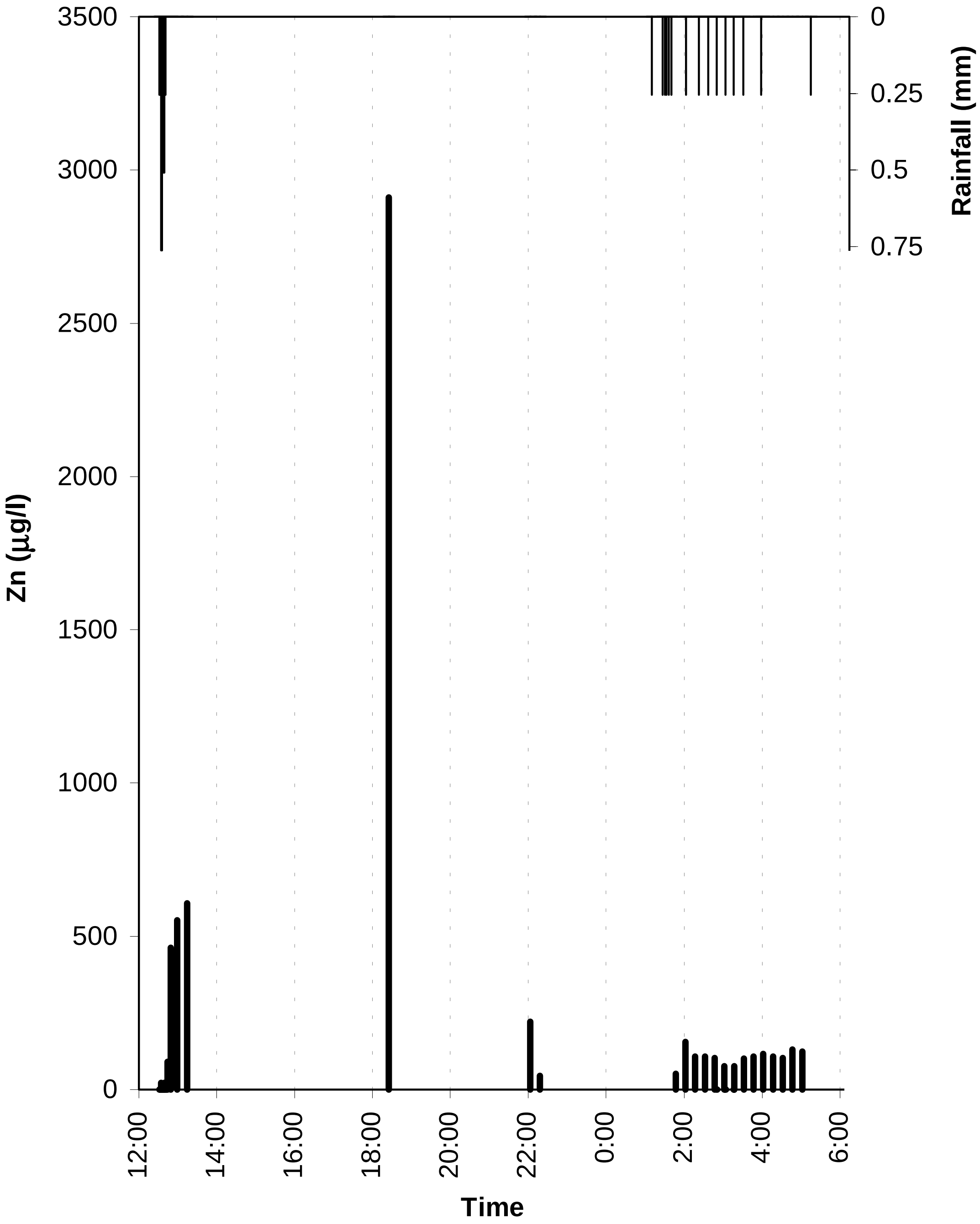
Sodium in Urban Runoff
11-12 August 1995



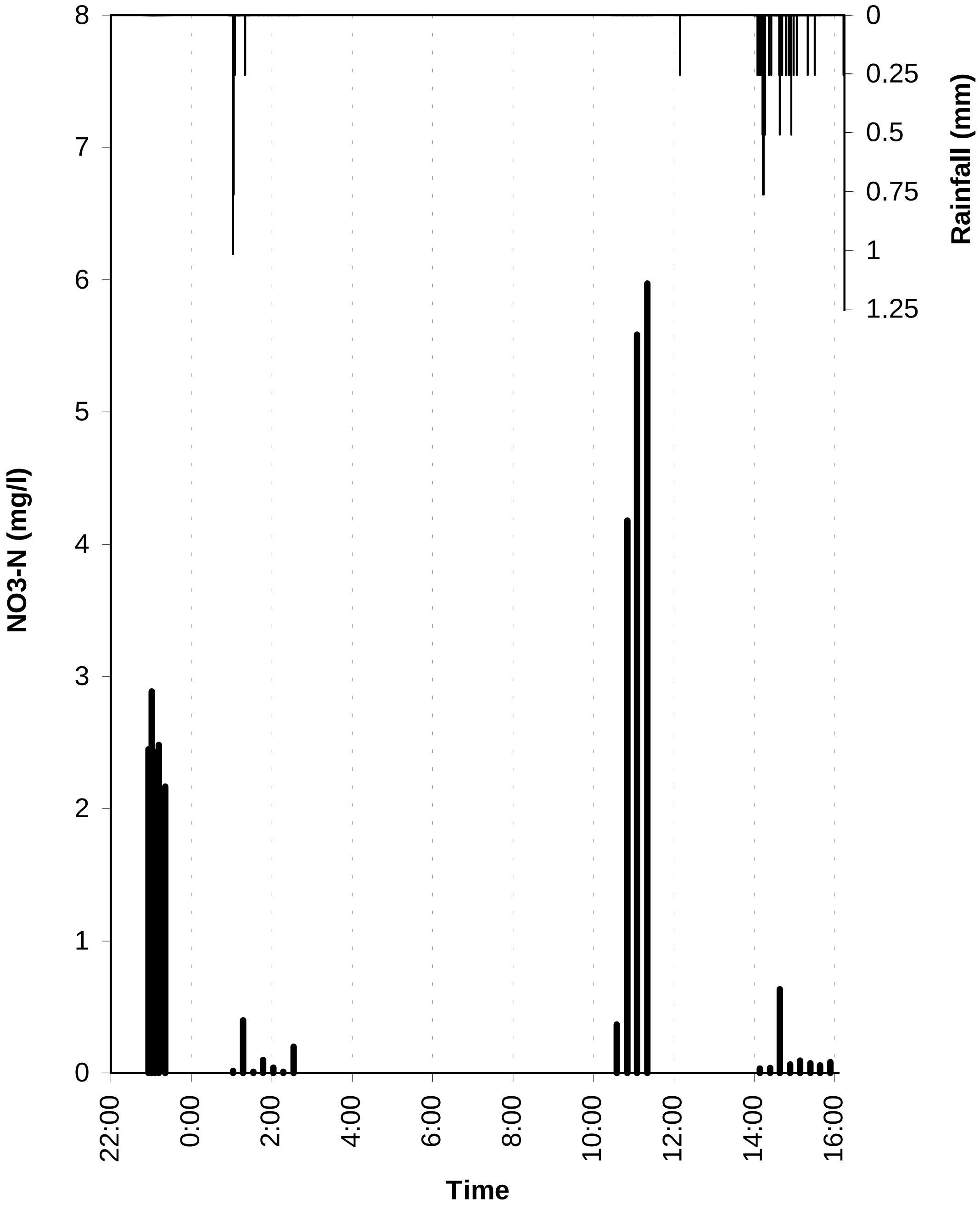
Copper in Urban Runoff
11-12 August 1995



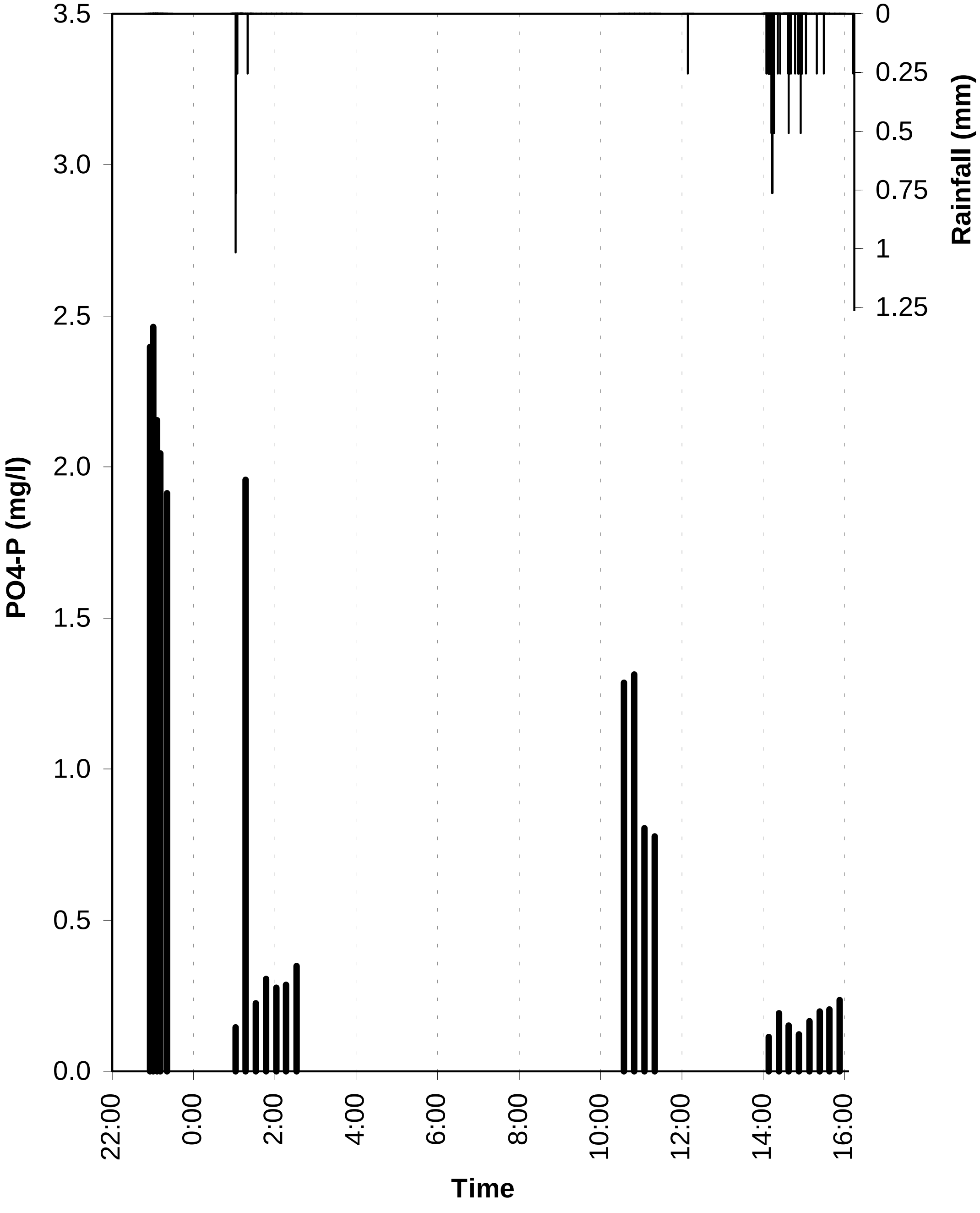
Zinc in Urban Runoff
11-12 August 1995



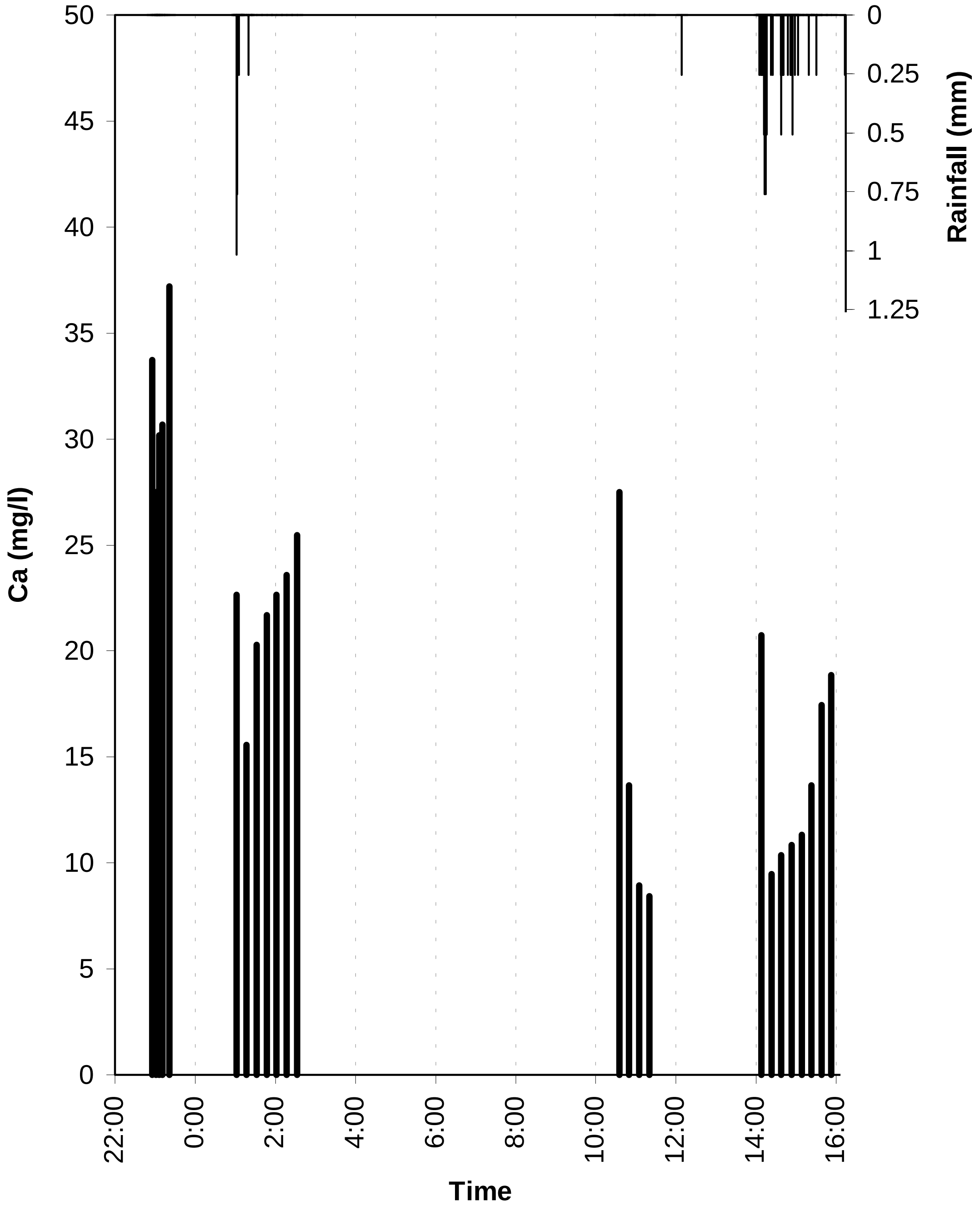
Nitrate-N in Urban Runoff
14-15 August 1995



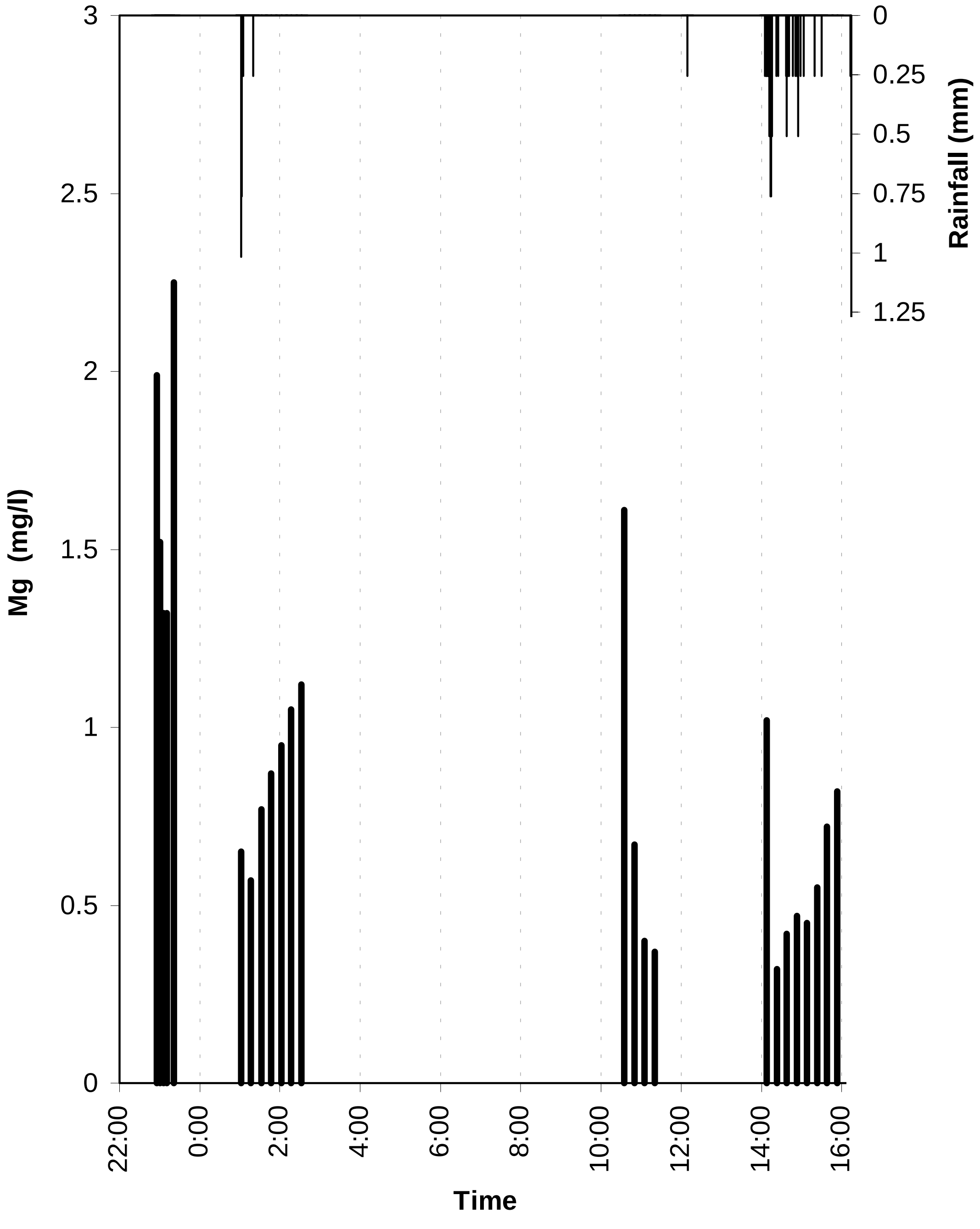
o-Phosphate-P in Urban Runoff
14-15 August 1995



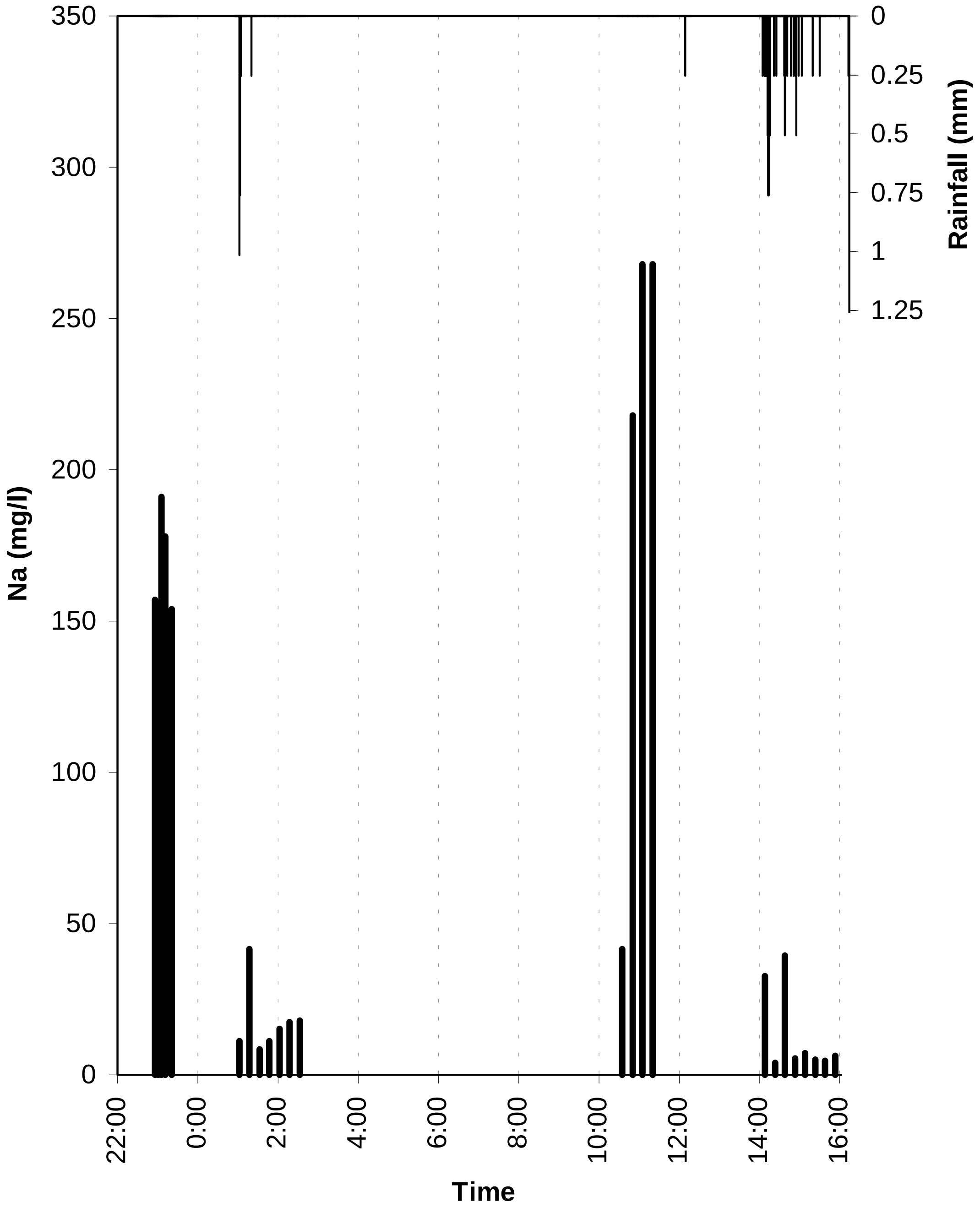
Calcium in Urban Runoff
14-15 August 1995

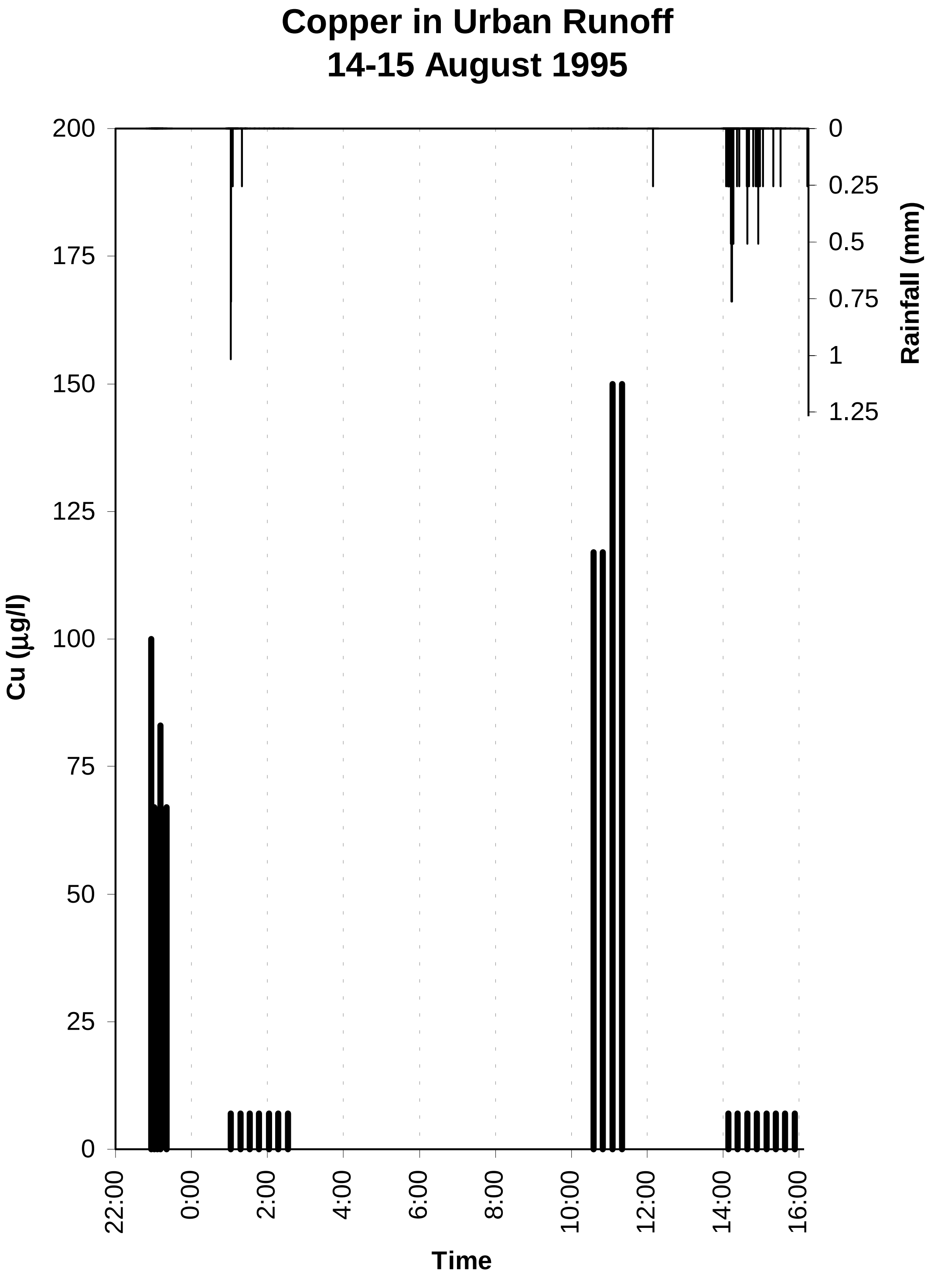


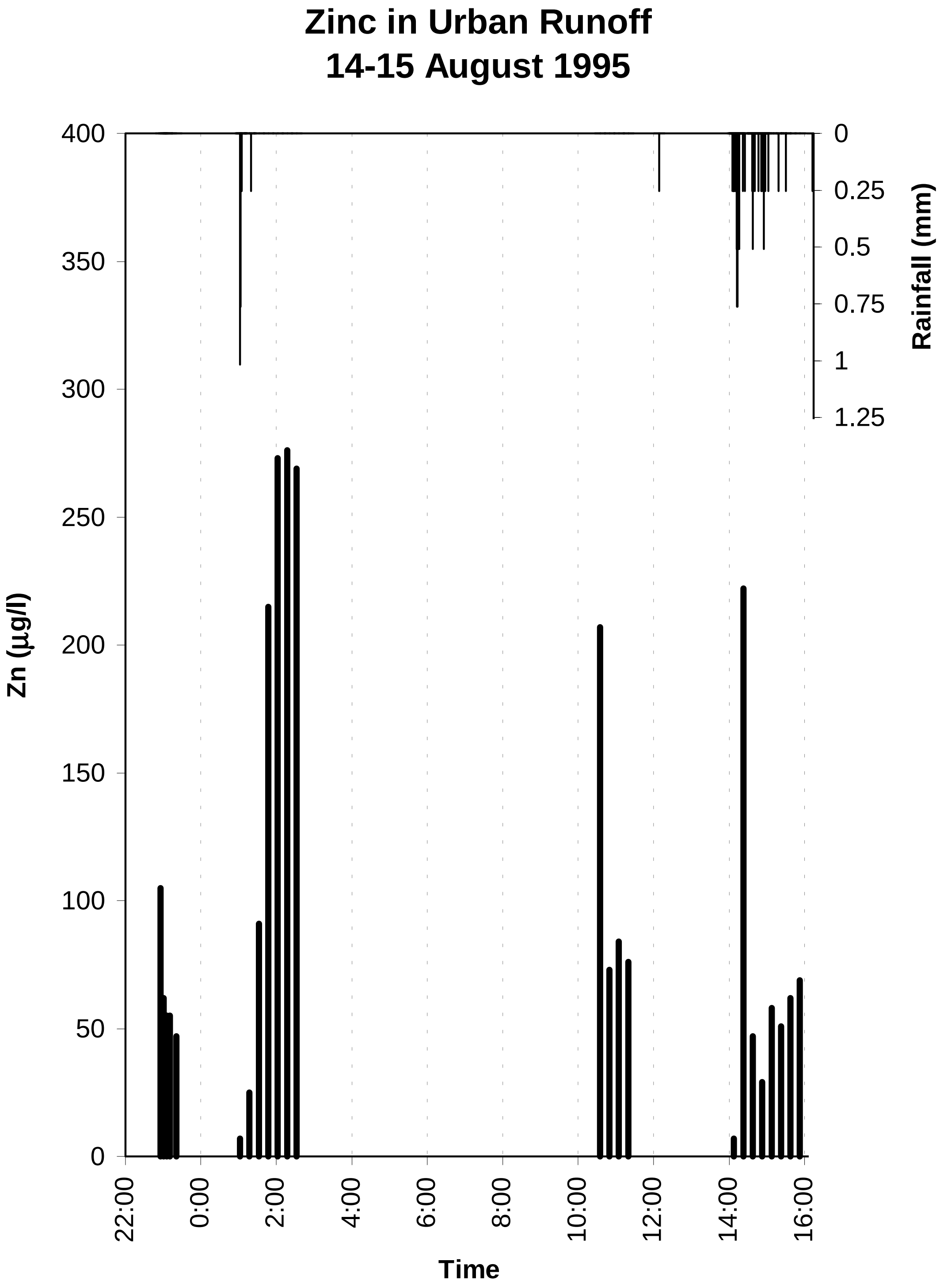
Magnesium in Urban Runoff
14-15 August 1995



Sodium in Urban Runoff
14-15 August 1995

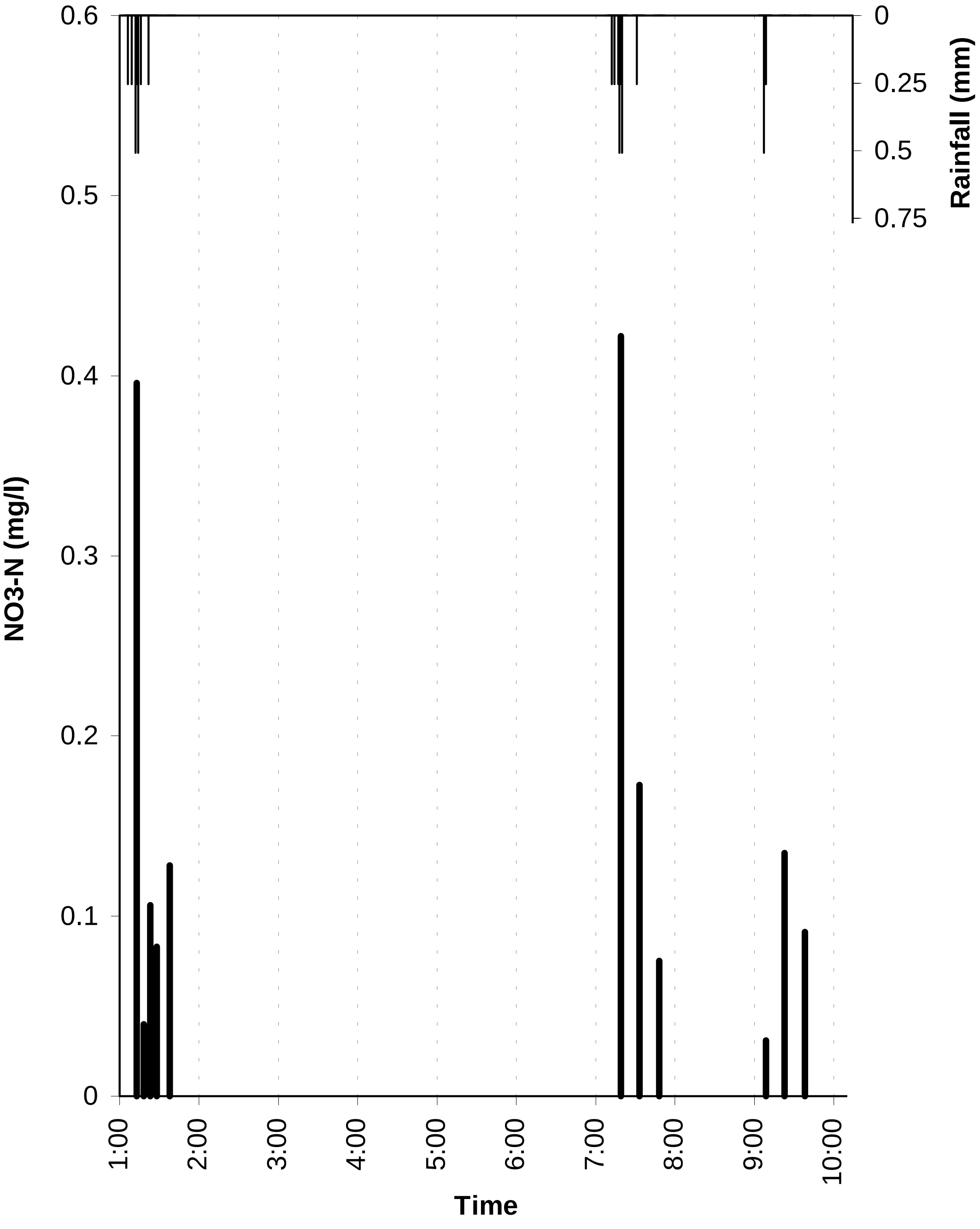



Copper in Urban Runoff
14-15 August 1995
Cu (µg/l)
200
175
150
125
100
75
50
25
0
Rainfall (mm)
0
0.25
0.5
0.75
1
1.25
22:00
0:00
2:00
4:00
6:00
8:00
10:00
12:00
14:00
16:00
Time

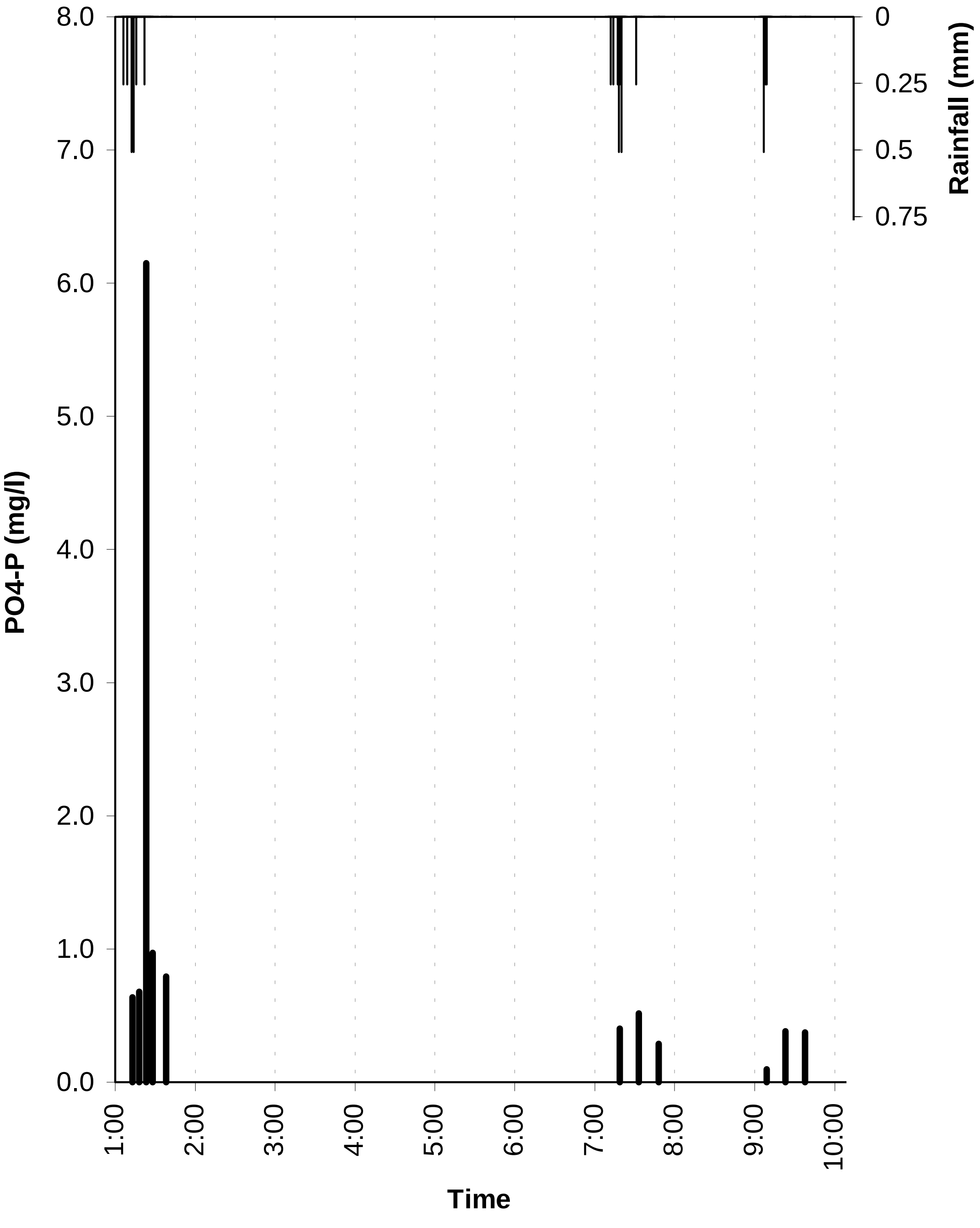


Zinc in Urban Runoff
14-15 August 1995
Zn (µg/l)
400
350
300
250
200
150
100
50
0
Rainfall (mm)
0
0.25
0.5
0.75
1
1.25
22:00
0:00
2:00
4:00
6:00
8:00
10:00
12:00
14:00
16:00
Time

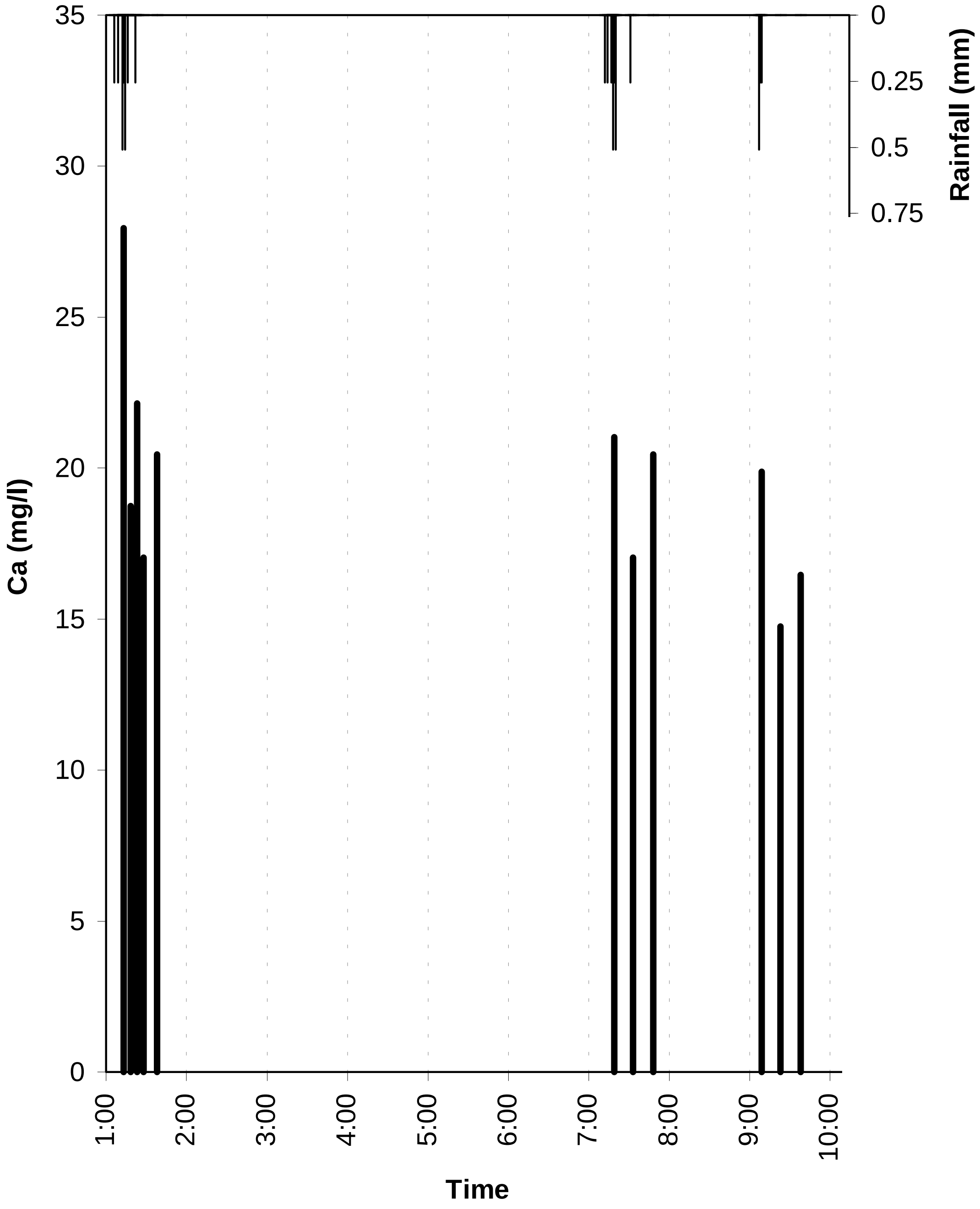
Nitrate-N in Urban Runoff
8 September 1995



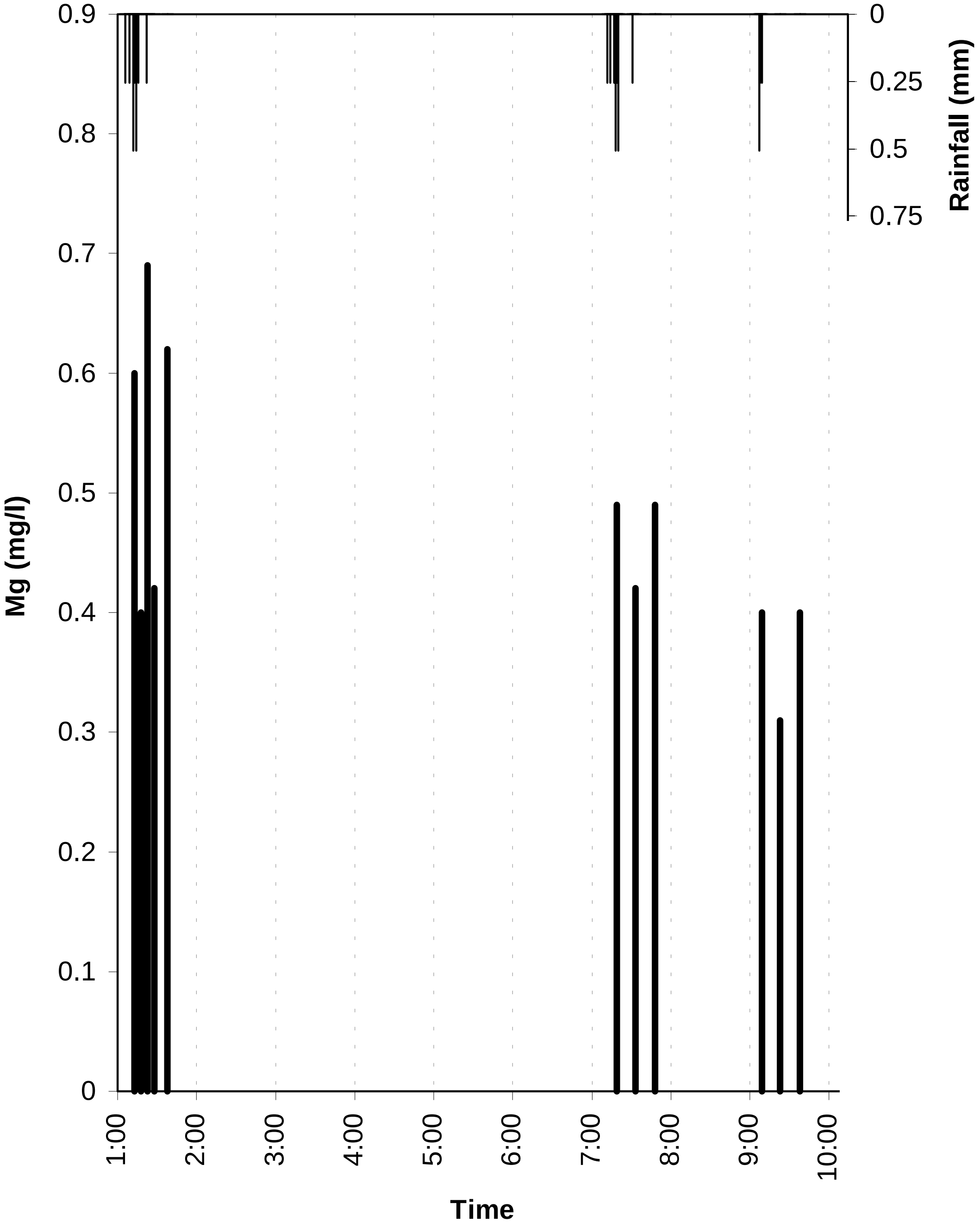
o-Phosphate-P in Urban Runoff
8 September 1995



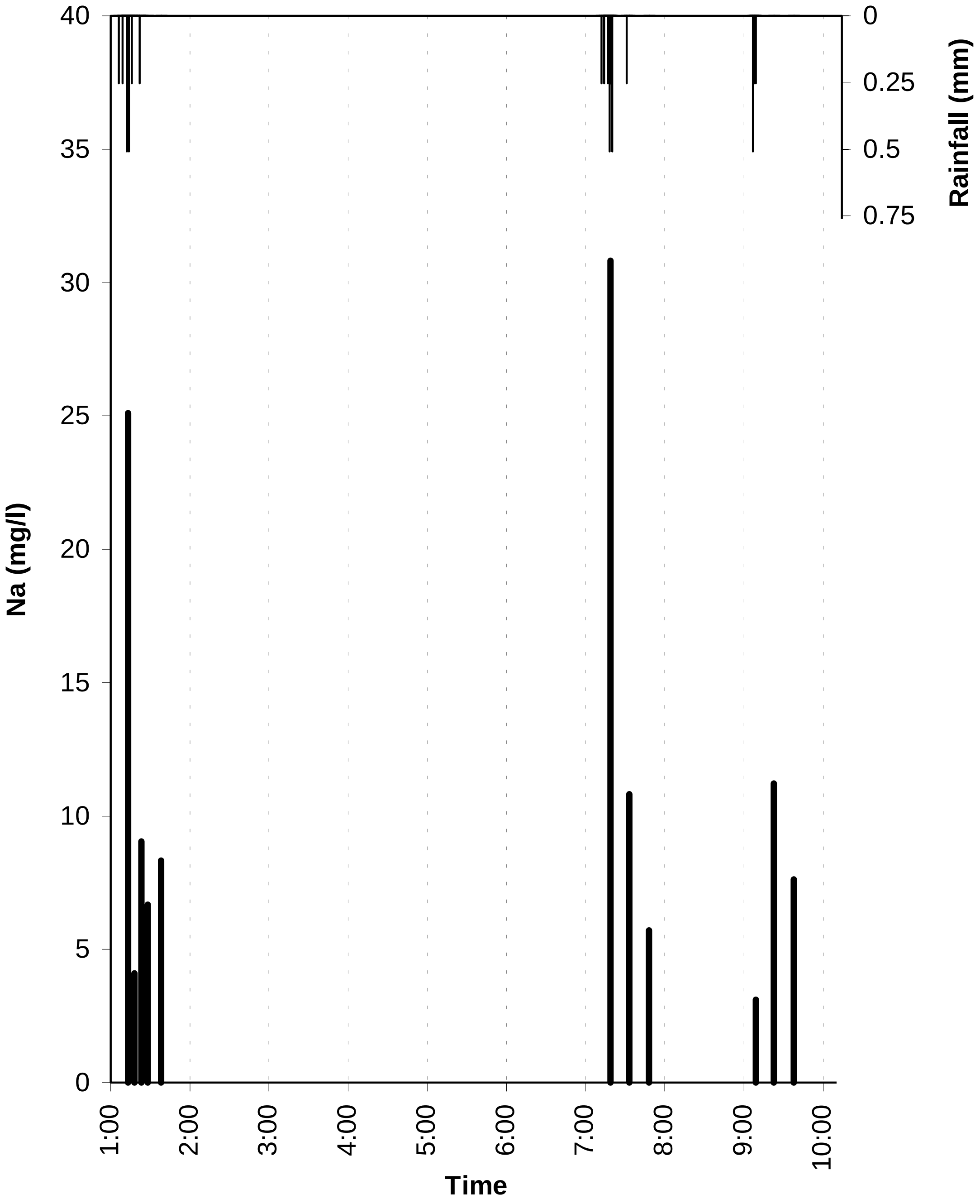
Calcium in Urban Runoff
8 September 1995



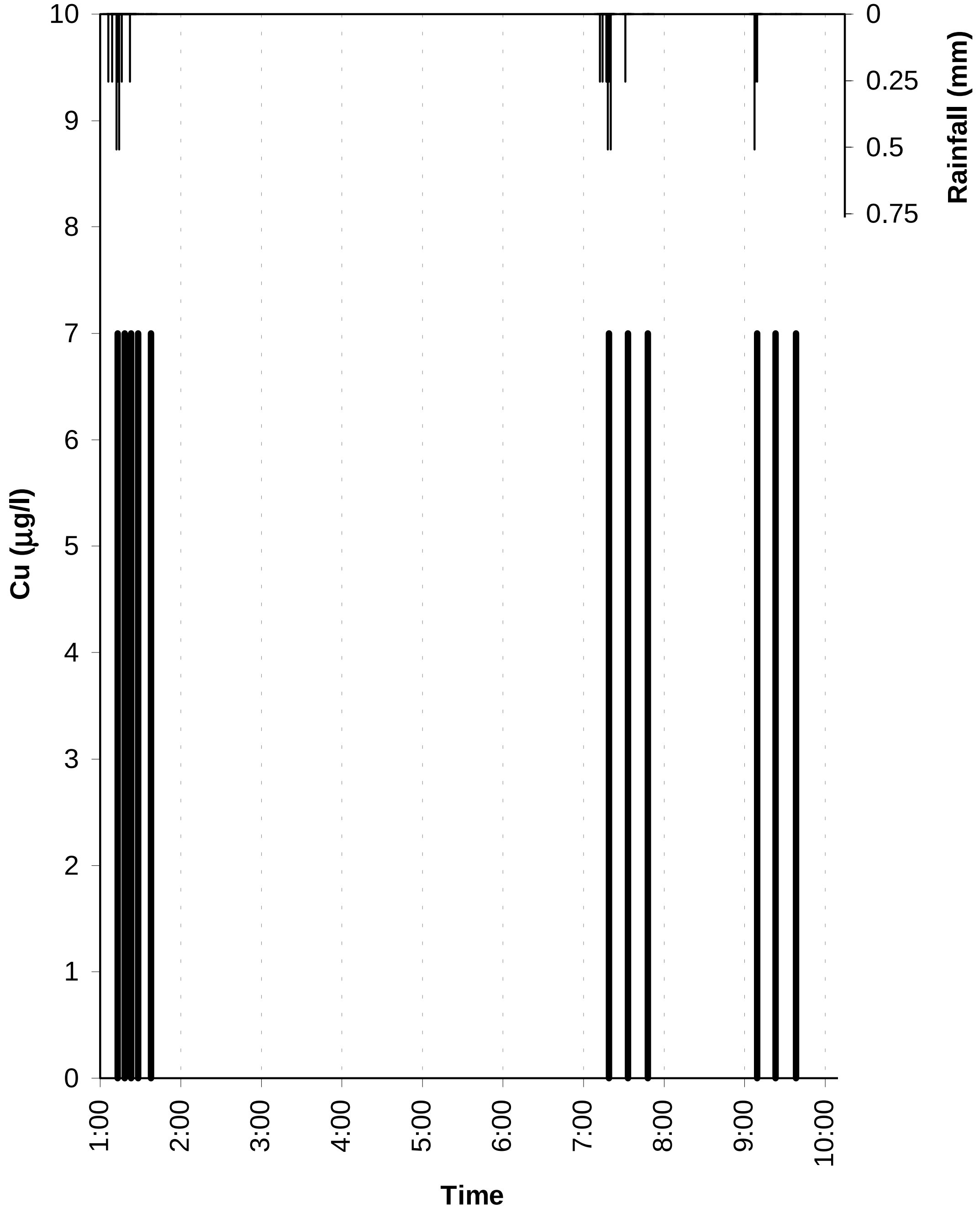
Magnesium in Urban Runoff
8 September 1995

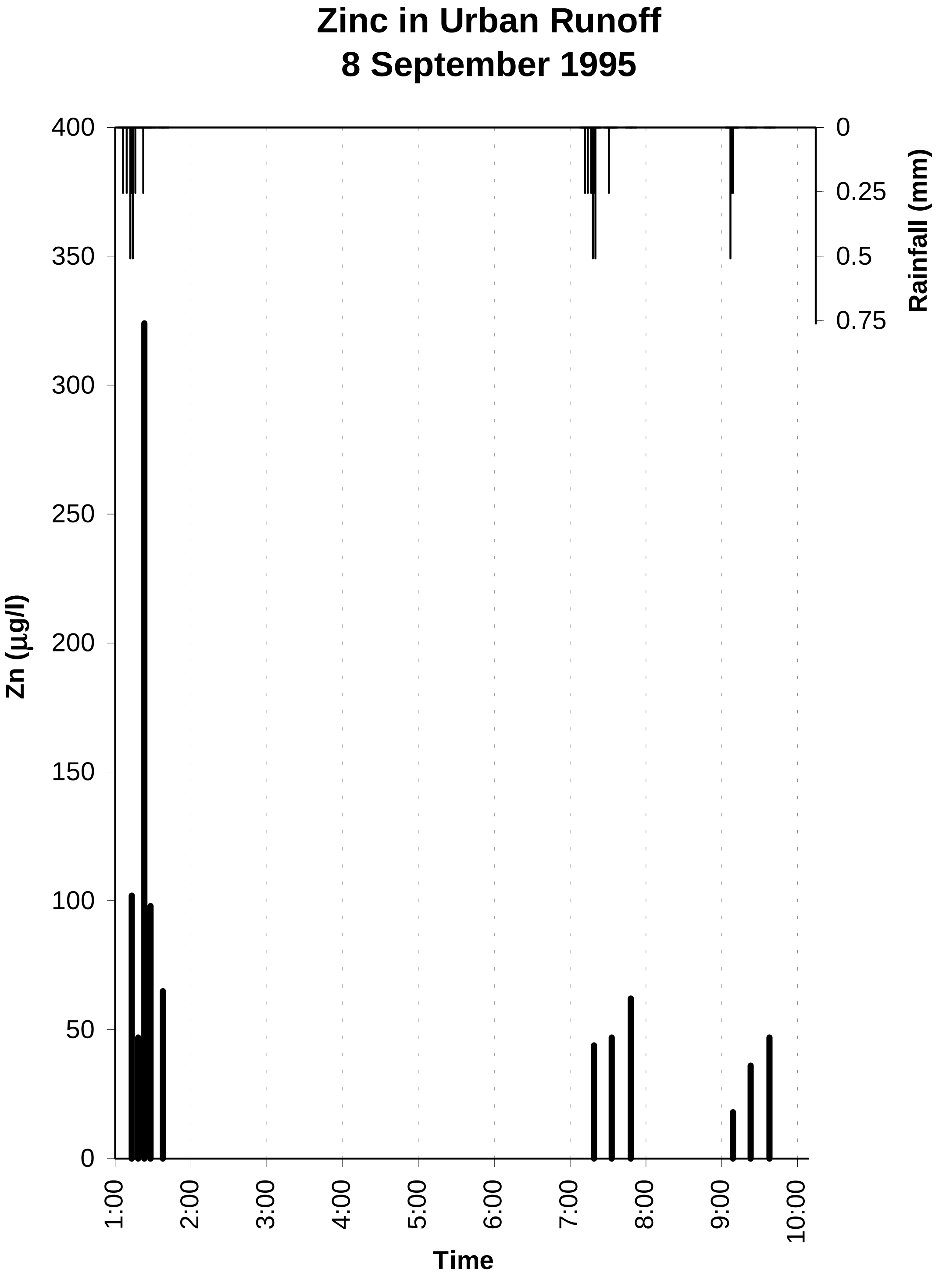


Sodium in Urban Runoff
8 September 1995



Copper in Urban Runoff
8 September 1995




Zinc in Urban Runoff
8 September 1995
Zn (µg/l)
400
350
300
250
200
150
100
50
0
Rainfall (mm)
0
0.25
0.5
0.75
1:00
2:00
3:00
4:00
5:00
6:00
7:00
8:00
9:00
10:00
Time

APPENDIX B

Raw Data Sets Obtained for Unfiltered Runoff Samples Collected During Phase III

Phase III Water Quality Data Sheets for Unfiltered Runoff from the Palace Hotel

Date	Time	Rainfall (mm)	Sample No.	NO_3-N (mg/l)	PO_4-P (mg/l)	Ca (mg/l)	Mg (mg/l)	Na (mg/l)	Ag (ug/l)	Cd (ug/l)	Cr (ug/l)	Cu (ug/l)	Fe (ug/l)	Mn (ug/l)	Ni (ug/l)	Pb (ug/l)	Zn (ug/l)
30-Jun-95	nd	nd	1	2.01	2.14	164	5.79	51.7	<0.2	<0.5	<4	33.0	250	<10	<5	<3	120
30-Jun-95	nd	nd	2	2.10	1.95	158	5.83	82.0	<0.2	<0.5	<4	33.0	<30	<10	<5	<3	62.0
30-Jun-95	nd	nd	3	2.12	1.43	161	6.16	46.4	<0.2	<0.5	<4	33.0	<30	<10	<5	<3	65.0
30-Jun-95	nd	nd	4	2.06	1.91	175	6.22	48.2	<0.2	<0.5	<4	33.0	208	44	<5	6.6	127
30-Jun-95	nd	nd	5	2.31	3.18	162	6.04	62.8	<0.2	<0.5	<4	33.0	<30	<10	<5	3.4	109
30-Jun-95	nd	nd	6	2.31	3.59	158	5.96	55.8	<0.2	<0.5	<4	33.0	125	<10	<5	<3	105
30-Jun-95	nd	nd	7	2.42	3.80	151	5.59	59.9	<0.2	<0.5	<4	33.0	<30	<10	<5	<3	65.0
30-Jun-95	nd	nd	8	2.49	3.92	151	5.59	48.2	<0.2	<0.5	<4	33.0	<30	<10	<5	<3	72.0
30-Jun-95	nd	nd	9	2.68	5.37	146	5.49	72.1	<0.2	<0.5	<4	33.0	<30	<10	<5	<3	76.0
30-Jun-95	nd	nd	10	2.65	5.29	142	5.38	74.4	<0.2	<0.5	<4	33.0	<30	<10	<5	<3	44.0
30-Jun-95	nd	nd	11	2.61	5.58	144	5.48	83.1	<0.2	<0.5	<4	33.0	<30	<10	<5	<3	62.0
30-Jun-95	nd	nd	12	2.61	5.44	142	5.46	76.7	<0.2	<0.5	<4	33.0	<30	<10	<5	<3	62.0
New Data Set																	
6-Jul-95	nd	*	1	0.02	0.89	48.1	1.15	15.7	<0.2	<0.5	<4	28.0	87	<10	<5	<3	57.0
6-Jul-95	nd	*	2	0.07	0.89	46.8	1.17	15.3	<0.2	<0.5	<4	28.0	<30	<10	<5	<3	44.0
6-Jul-95	nd	*	3	0.07	1.13	46.1	1.22	15.7	<0.2	<0.5	<4	28.0	<30	<10	<5	<3	37.0
6-Jul-95	nd	*	4	0.02	1.10	46.8	1.24	19.3	<0.2	<0.5	<4	28.0	65	<10	<5	<3	34.0
6-Jul-95	nd	*	5	0.01	1.14	43.5	1.17	17.7	<0.2	<0.5	<4	28.0	65	<10	<5	<3	34.0
6-Jul-95	nd	*	6	0.01	1.13	44.2	1.17	15.3	<0.2	<0.5	<4	28.0	65	<10	<5	<3	34.0
6-Jul-95	nd	*	7	0.01	1.44	46.1	1.22	23.3	<0.2	<0.5	<4	28.0	65	<10	<5	<3	34.0
6-Jul-95	nd	*	8	0.01	1.46	45.5	1.24	21.8	<0.2	<0.5	<4	28.0	44	<10	<5	<3	34.0
New Data Set																	24.0
7-Jul-95	nd	*	1	0.003	0.03	55.6	0.88	6.25	<0.2	<0.5	<4	28.0	<30	<10	<5	<3	
7-Jul-95	nd	*	2	0.004	0.01	52.8	0.85	5.83	<0.2	<0.5	<4	28.0	<30	<10	<5	<3	20.0
7-Jul-95	nd	*	3	0.004	0.19	56.5	1.37	26.5	<0.2	<0.5	<4	42.0	<30	<10	<5	<3	34.0
7-Jul-95	nd	*	4	0.004	0.13	59.3	1.25	19.4	<0.2	<0.5	<4	42.0	<30	<10	<5	<3	34.0
7-Jul-95	nd	*	5	0.01	0.03	58.3	0.99	8.54	<0.2	<0.5	<4	28.0	65	<10	<5	<3	41.0
7-Jul-95	nd	*	6	0.004	0.04	61.1	0.99	11.2	<0.2	<0.5	<4	28.0	65	<10	<5	<3	44.0
7-Jul-95	nd	*	7	0.004	0.29	54.6	1.19	17.1	<0.2	<0.5	<4	28.0	<30	<10	<5	<3	34.0
7-Jul-95	nd	*	8	0.004	0.27	55.6	1.16	19.0	<0.2	<0.5	<4	28.0	<30	<10	<5	<3	34.0
7-Jul-95	nd	*	9	0.002	0.27	26.9	0.43	3.95	<0.2	<0.5	<4	28.0	<30	<10	<5	<3	34.0
7-Jul-95	nd	*	10	0.00	0.26	24.0	0.40	3.12	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	30.0
7-Jul-95	nd	*	11	0.01	0.29	26.0	0.54	6.04	<0.2	<0.5	<4	28.0	<30	<10	<5	<3	348
7-Jul-95	nd	*	12	0.03	0.29	25.0	0.52	6.67	<0.2	<0.5	<4	28.0	<30	<10	<5	<3	378
7-Jul-95	nd	*	13	0.06	0.37	30.8	0.67	9.79	<0.2	<0.5	<4	28.0	<30	<10	<5	<3	348
7-Jul-95	nd	*	14	0.07	0.38	30.8	0.69	10.8	<0.2	<0.5	<4	28.0	<30	<10	<5	<3	348
7-Jul-95	nd	*	15	0.07	0.43	36.5	0.78	15.1	<0.2	<0.5	<4	28.0	<30	<10	<5	<3	314
7-Jul-95	nd	*	16	0.08	0.44	37.0	0.78	16.3	<0.2	<0.5	<4	28.0	<30	<10	<5	<3	331
7-Jul-95	nd	*	17	0.10	0.54	38.9	0.85	15.5	<0.2	<0.5	<4	28.0	<30	<10	<5	<3	355
7-Jul-95	nd	*	18	0.10	0.54	38.9	0.85	18.6	<0.2	<0.5	<4	28.0	<30	<10	<5	<3	361
7-Jul-95	nd	*	21	0.004	0.48	41.7	0.89	17.1	<0.2	<0.5	<4	28.0	<30	<10	<5	<3	162
7-Jul-95	nd	*	22	0.003	0.49	41.7	0.89	17.5	<0.2	<0.5	<4	28.0	<30	<10	<5	<3	152
7-Jul-95	nd	*	23	0.004	0.51	40.7	0.90	16.3	<0.2	<0.5	<4	125	<30	<10	<5	12.2	152
7-Jul-95	nd	*	24	0.003	0.51	42.6	0.89	20.6	<0.2	<0.5	<4	42.0	<30	<10	<5	<3	152

nd = not determined. * Total rainfall recorded for July 6 and 7 was 4.83 mm and 7.34 mm respectively

Phase III Water Quality Data Sheets for Unfiltered Runoff from the Palace Hotel

Date	Time	Rainfall (mm)	Sample No.	NO_3-N (mg/l)	PO_4-P (mg/l)	Ca (mg/l)	Mg (mg/l)	Na (mg/l)	Ag (ug/l)	Cd (ug/l)	Cr (ug/l)	Cu (ug/l)	Fe (ug/l)	Mn (ug/l)	Ni (ug/l)	Pb (ug/l)	Zn (ug/l)
10-Jul-95	9:51	0.51	1	0.00	0.04	25.7	0.53	2.66	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	10.0
10-Jul-95	9:52	0.00	2	0.03	0.05	22.8	0.57	3.30	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	10.0
10-Jul-95	9:53	0.25															
10-Jul-95	9:55	0.00	3	0.02	0.08	26.5	0.53	5.50	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	14.0
10-Jul-95	9:56	0.00	4	0.04	0.08	25.0	0.53	4.75	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	20.0
10-Jul-95	10:00	0.00	5	0.02	0.12	22.1	0.50	3.46	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	20.0
10-Jul-95	10:01	0.00	6	0.03	0.14	21.3	0.50	3.95	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	17.0
10-Jul-95	10:05	0.00	7	0.48	0.85	47.1	1.47	42.6	<0.2	<0.5	<4	42.0	<30	<10	<5	<3	37.0
10-Jul-95	10:06	0.00	8	0.47	0.84	47.1	1.47	39.6	<0.2	<0.5	<4	42.0	<30	<10	<5	<3	41.0
10-Jul-95	10:14	0.00	9	0.06	0.33	21.3	0.60	10.0	<0.2	<0.5	<4	28.0	<30	<10	<5	<3	47.0
10-Jul-95	10:15	0.00	10	0.06	0.33	22.1	0.57	7.25	<0.2	<0.5	<4	28.0	<30	<10	<5	<3	51.0
10-Jul-95	16:31	0.25															
10-Jul-95	16:33	0.00	11	0.06	0.09	36.0	0.70	7.02	<0.2	<0.5	<4	28.0	<30	<10	<5	<3	24.0
10-Jul-95	16:34	0.00	12	0.05	0.06	34.6	0.67	5.19	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	24.0
10-Jul-95	16:35	0.00	13	0.02	0.04	33.8	0.67	2.85	<0.2	<0.5	<4	28.0	<30	<10	<5	<3	24.0
10-Jul-95	16:36	0.00	14	0.01	0.03	32.4	0.63	2.58	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	24.0
	New Data Set																
11-Jul-95	nd	*	1	0.64	30.4	39.5	2.59	117	<0.2	<0.5	<4	42.0	<30	<10	<5	<3	108
11-Jul-95	nd	*	2	0.56	32.8	41.3	2.83	128	<0.2	<0.5	<4	42.0	<30	<10	<5	<3	101
11-Jul-95	nd	*	3	0.66	38.3	51.4	2.89	125	<0.2	<0.5	<4	42.0	<30	<10	<5	<3	231
11-Jul-95	nd	*	4	0.53	40.1	47.4	3.09	118	<0.2	<0.5	<4	56.0	<30	<10	<5	<3	255
11-Jul-95	nd	*	5	0.34	153	83.9	7.08	123	<0.2	<0.5	<4	83.0	<30	73	9.50	<3	1271
11-Jul-95	nd	*	6	0.32	149	82.9	7.41	128	<0.2	<0.5	<4	83.0	<30	63	10.0	<3	1295
11-Jul-95	nd	*	7	0.29	180	82.6	7.69	125	<0.2	<0.5	<4	92.0	<30	94	10.0	<3	1771
11-Jul-95	nd	*	8	0.26	178	80.4	7.50	114	<0.2	<0.5	<4	92.0	<30	94	10.0	<3	1762
11-Jul-95	nd	*	9	0.57	114	44.9	5.63	61.7	<0.2	<0.5	<4	28.0	<30	<10	7.50	<3	112
11-Jul-95	nd	*	10	0.57	112	40.6	6.02	129	<0.2	<0.5	<4	28.0	<30	<10	10.0	<3	73.0
11-Jul-95	nd	*	11	2.16	13.5	27.5	1.94	315	<0.2	<0.5	<4	42.0	<30	<10	<5	<3	133
11-Jul-95	nd	*	12	2.37	10.7	26.1	1.89	420	<0.2	<0.5	<4	56.0	<30	<10	<5	<3	115
11-Jul-95	nd	*	13	2.80	10.5	25.0	1.78	475	<0.2	<0.5	<4	56.0	<30	<10	<5	<3	126
11-Jul-95	nd	*	14	3.24	10.2	24.6	1.76	438	<0.2	<0.5	<4	56.0	<30	<10	<5	<3	126
	New Data Set																
13-Jul-95	12:21	0.00	1	1.25	23.0	15.6	1.23	314	<0.2	<0.5	<4	42.0	<30	<10	<5	<3	87.0
13-Jul-95	12:26	0.00	2	0.79	15.8	15.0	1.27	310	<0.2	<0.5	<4	42.0	<30	<10	<5	<3	25.0
13-Jul-95	12:31	0.00	3	1.80	17.4	14.4	1.23	307	<0.2	<0.5	<4	56.0	<30	<10	<5	<3	28.0
13-Jul-95	12:36	0.00	4	1.93	14.6	14.4	1.17	278	<0.2	<0.5	<4	56.0	<30	<10	<5	<3	25.0
13-Jul-95	12:46	0.00	5	2.66	7.81	11.1	0.91	317	<0.2	<0.5	<4	69.0	<30	<10	<5	<3	18.0
13-Jul-95	13:01	0.00	6	2.98	4.22	6.66	0.54	327	<0.2	<0.5	<4	56.0	<30	<10	<5	<3	28.0
13-Jul-95	13:16	0.00	7	3.20	3.42	6.11	0.45	330	<0.2	<0.5	<4	56.0	<30	<10	<5	<3	21.0
13-Jul-95	18:12	0.00	8	3.04	5.05	8.33	0.54	301	<0.2	<0.5	<4	56.0	<30	<10	<5	<3	28.0
13-Jul-95	18:27	0.00	9	2.58	4.96	12.2	0.98	304	<0.2	<0.5	<4	153	<30	<10	<5	<3	39.0
13-Jul-95	18:42	0.00	10	2.58	3.82	10.0	0.68	278	<0.2	<0.5	<4	69.0	<30	<10	<5	<3	42.0
13-Jul-95	22:51	0.00	11	2.42	4.06	11.7	0.77	261	<0.2	<0.5	<4	42.0	<30	<10	<5	3	21.0
13-Jul-95	23:06	0.00	12	2.76	5.48	8.33	0.61	333	<0.2	<0.5	<4	56.0	<30	<10	<5	<3	21.0
13-Jul-95	23:21	0.00	13	2.63	9.83	8.88	0.81	336	<0.2	<0.5	<4	56.0	<30	<10	<5	<3	25.0
13-Jul-95	23:36	0.00	14	3.49	7.49	8.33	0.75	359	<0.2	<0.5	<4	56.0	<30	<10	<5	<3	25.0
13-Jul-95	23:51	0.00	15	4.15	5.54	7.22	0.61	366	<0.2	<0.5	<4	56.0	<30	<10	<5	<3	25.0

nd = not determined. * Total rainfall recorded for July 11 was 0.25 mm

Phase III Water Quality Data Sheets for Unfiltered Runoff from the Palace Hotel

Date	Time	Rainfall (mm)	Sample No.	NO_3-N (mg/l)	PO_4-P (mg/l)	Ca (mg/l)	Mg (mg/l)	Na (mg/l)	Ag (ug/l)	Cd (ug/l)	Cr (ug/l)	Cu (ug/l)	Fe (ug/l)	Mn (ug/l)	Ni (ug/l)	Pb (ug/l)	Zn (ug/l)
14-Jul-95	23:15	0.25															
14-Jul-95	23:16	0.00	1	1.01	1.78	38.5	1.39	135	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	54.0
14-Jul-95	23:20	0.00	2	0.01	0.98	49.6	1.41	66.4	<0.2	<0.5	<4	56.0	<30	<10	<5	<3	99.0
14-Jul-95	23:25	0.00	3	0.01	0.95	52.5	1.37	44.2	<0.2	<0.5	<4	56.0	<30	<10	<5	9.1	71.0
14-Jul-95	23:30	0.25	4	0.29	1.09	53.7	1.54	48.9	<0.2	<0.5	<4	42.0	<30	<10	<5	<3	54.0
14-Jul-95	23:40	0.00	5	0.72	0.25	46.7	1.21	57.8	<0.2	<0.5	<4	42.0	<30	<10	<5	<3	37.0
14-Jul-95	23:54	0.25															
14-Jul-95	23:55	0.00	6	1.28	0.48	41.8	1.28	90.5	<0.2	<0.5	<4	42.0	<30	<10	<5	<3	24.0
15-Jul-95	0:03	0.25															
15-Jul-95	0:10	0.00	7	0.21	0.43	25.0	0.66	18.4	<0.2	<0.5	<4	42.0	<30	<10	<5	<3	31.0
15-Jul-95	0:23	0.25															
15-Jul-95	0:25	0.00	8	0.12	0.52	25.0	0.64	9.37	<0.2	<0.5	<4	28.0	<30	<10	<5	<3	157
15-Jul-95	0:36	0.25															
15-Jul-95	0:40	0.00	9	0.04	0.19	25.0	0.57	3.61	<0.2	<0.5	<4	28.0	<30	<10	<5	<3	48.0
15-Jul-95	0:41	0.25															
15-Jul-95	0:55	0.00	10	0.08	0.39	23.8	0.57	5.31	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	122
15-Jul-95	1:10	0.00	11	0.08	0.43	27.9	0.64	6.87	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	316
15-Jul-95	1:21	0.25															
15-Jul-95	1:25	0.00	12	0.12	0.51	31.1	0.77	9.37	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	425
15-Jul-95	1:40	0.00	13	0.12	0.56	33.6	0.83	11.1	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	435
15-Jul-95	1:55	0.00	14	0.08	0.41	38.5	0.99	8.43	<0.2	<0.5	<4	28.0	<30	<10	<5	<3	276
15-Jul-95	2:09	0.25															
15-Jul-95	2:10	0.00	15	0.08	0.39	41.0	0.99	6.87	<0.2	<0.5	<4	28.0	<30	<10	<5	<3	174
15-Jul-95	2:25	0.00	16	0.13	0.61	37.3	0.97	10.5	<0.2	<0.5	<4	28.0	<30	<10	<5	<3	238
15-Jul-95	2:40	0.00	17	0.20	0.73	31.5	0.95	18.4	<0.2	<0.5	<4	28.0	<30	<10	<5	<3	289
15-Jul-95	2:54	0.00	18	0.25	0.82	31.2	0.97	22.6	<0.2	<0.5	<4	28.0	<30	<10	<5	<3	279
15-Jul-95	3:10	0.00	19	0.30	0.87	30.4	0.95	25.8	<0.2	<0.5	<4	28.0	<30	<10	<5	<3	272
15-Jul-95	3:25	0.00	20	0.37	1.01	30.4	0.97	30.5	<0.2	<0.5	<4	42.0	<30	<10	<5	<3	262
15-Jul-95	3:46	0.00	21	0.49	1.05	33.3	1.06	36.8	<0.2	<0.5	<4	42.0	<30	<10	<5	<3	221
15-Jul-95	4:00	0.00	22	0.57	1.12	32.6	0.99	39.5	<0.2	<0.5	<4	42.0	<30	<10	<5	<3	211
15-Jul-95	4:15	0.00	23	0.43	0.96	36.6	1.17	35.8	<0.2	<0.5	<4	42.0	<30	<10	<5	<3	157
15-Jul-95	4:29	0.25															
15-Jul-95	4:30	0.00	24	0.35	0.92	39.1	1.19	33.2	<0.2	<0.5	<4	42.0	<30	<10	<5	<3	136

Phase III Water Quality Data Sheets for Unfiltered Runoff from the Palace Hotel

Date	Time	Rainfall (mm)	Sample No.	NO_3-N (mg/l)	PO_4-P (mg/l)	Ca (mg/l)	Mg (mg/l)	Na (mg/l)	Ag (ug/l)	Cd (ug/l)	Cr (ug/l)	Cu (ug/l)	Fe (ug/l)	Mn (ug/l)	Ni (ug/l)	Pb (ug/l)	Zn (ug/l)
17-Jul-95	11:18	0.00	1	3.01	7.07	29.6	3.33	226	<0.2	<0.5	<4	314	125	<10	<5	<3	429
17-Jul-95	11:23	0.00	2	2.34	27.6	42.1	3.77	234	<0.2	<0.5	<4	300	<30	<10	<5	<3	216
17-Jul-95	11:28	0.00	3	1.17	71.8	51.8	4.78	212	<0.2	<0.5	<4	257	<30	<10	6	50	416
17-Jul-95	11:33	0.00	4	2.61	42.7	47.9	5.08	228	<0.2	<0.5	<4	129	<30	<10	<5	<3	230
17-Jul-95	13:17	0.51	5	0.05	0.98	14.4	0.68	11.6	<0.2	<0.5	<4	43.0	<30	<10	<5	4	78.0
17-Jul-95	13:27	0.51	6	0.05	0.53	7.00	0.27	3.3	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	51.0
17-Jul-95	13:41	0.25															
17-Jul-95	13:42	0.00	7	0.01	0.48	5.33	0.20	3.13	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	85.0
17-Jul-95	13:44	0.25															
17-Jul-95	13:57	0.00	8	0.45	0.73	9.3	0.77	35.6	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	68.0
17-Jul-95	17:15	0.00	9	0.13	1.02	16.8	1.26	34.0	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	3.00
18-Jul-95	3:47	0.25															
18-Jul-95	3:48	0.00	10	0.18	0.51	17.1	0.68	12.7	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	24.0
18-Jul-95	4:00	0.25															
18-Jul-95	4:03	0.00	11	0.11	0.21	9.33	0.39	4.90	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	10.0
18-Jul-95	4:17	0.25															
18-Jul-95	4:18	0.00	12	0.04	0.21	5.33	0.20	2.64	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	34.0
18-Jul-95	4:33	0.00	13	0.05	0.24	7.67	0.32	4.21	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	61.0
18-Jul-95	10:03	0.00	14	0.59	1.03	35.1	1.64	56.9	<0.2	<0.5	<4	86.0	<30	<10	<5	<3	74.0
18-Jul-95	10:18	0.00	15	4.54	0.34	12.0	2.18	202	<0.2	<0.5	<4	100	<30	<10	<5	<3	68.0
18-Jul-95	10:20	0.00	16	4.14	0.27	9.00	2.01	212	<0.2	<0.5	<4	100	<30	<10	<5	<3	47.0
New Data Set																	
18-Jul-95	11:06	0.00	1	2.62	0.26	13.7	0.95	158	<0.2	<0.5	<4	71	<30	<10	<5	<3	47.0
18-Jul-95	11:11	0.00	2	2.49	0.25	15.5	0.94	167	<0.2	<0.5	<4	100	<30	<10	<5	<3	68.0
18-Jul-95	11:16	0.00	3	2.56	0.24	8.23	0.49	151	<0.2	<0.5	<4	57.0	<30	<10	<5	<3	27.0
18-Jul-95	12:19	0.00	4	2.34	0.50	19.0	0.82	144	<0.2	<0.5	<4	71.0	<30	<10	<5	<3	41.0
18-Jul-95	12:24	0.00	5	2.64	0.65	43.4	1.64	201	<0.2	<0.5	<4	229	<30	<10	<5	<3	155
18-Jul-95	14:55	0.00	6	0.31	0.07	31.1	0.74	27.0	<0.2	<0.5	<4	43.0	<30	<10	<5	<3	24.0
18-Jul-95	15:05	0.00	7	0.60	0.33	27.0	1.07	44.4	<0.2	<0.5	<4	43.0	<30	<10	<5	<3	24.0
18-Jul-95	15:20	0.00	8	0.00	0.21	20.2	0.49	7.11	<0.2	<0.5	<4	29.0	<30	<10	<5	<3	24.0
18-Jul-95	23:16	0.00	9	1.37	0.38	30.5	1.28	67.4	<0.2	<0.5	<4	43.0	<30	<10	<5	<3	27.0
18-Jul-95	23:31	0.00	10	0.00	0.18	32.2	0.84	21.8	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	17.0
19-Jul-95	1:31	0.00	11	0.00	0.04	26.4	0.60	3.84	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	17.0
19-Jul-95	1:46	0.00	12	0.02	0.08	22.0	0.54	3.26	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	10.0
19-Jul-95	6:24	0.00	13	0.04	0.28	43.4	1.17	10.3	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	37.0
19-Jul-95	6:36	0.00	14	0.02	0.21	31.6	0.84	4.80	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	20.0

Phase III Water Quality Data Sheets for Unfiltered Runoff from the Palace Hotel

Date	Time	Rainfall (mm)	Sample No.	NO_3-N (mg/l)	PO_4-P (mg/l)	Ca (mg/l)	Mg (mg/l)	Na (mg/l)	Ag (ug/l)	Cd (ug/l)	Cr (ug/l)	Cu (ug/l)	Fe (ug/l)	Mn (ug/l)	Ni (ug/l)	Pb (ug/l)	Zn (ug/l)
19-Jul-95	11:56	0.25	1	0.07	0.06	18.5	0.17	4.82	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	30.0
19-Jul-95	11:59	0.25															
19-Jul-95	12:01	0.00	2	0.12	0.79	20.7	0.29	26.2	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	41.0
19-Jul-95	12:06	0.00	3	1.35	72.9	46.4	4.06	175	<0.2	<0.5	<4	71.0	<30	<10	<5	<3	20.0
19-Jul-95	12:11	0.00	4	0.75	330	66.1	13.79	167	<0.2	<0.5	<4	29.0	<30	40	19	<3	182
19-Jul-95	12:34	0.00	5	1.53	107	14.1	6.23	286	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	1.0
19-Jul-95	18:05	0.25															
19-Jul-95	22:43	0.00	6	0.00	7.03	14.7	0.90	25.1	<0.2	<0.5	<4	29.0	<30	<10	<5	<3	155
19-Jul-95	22:53	0.00	7	0.13	35.6	29.9	1.59	16.5	<0.2	<0.5	<4	29.0	<30	40	<5	<3	247
19-Jul-95	23:08	0.00	8	0.08	4.53	13.0	0.23	8.92	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	48.0
20-Jul-95	1:29	0.25	9	0.00	0.24	16.8	0.17	3.36	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	14.0
20-Jul-95	1:30	0.25															
20-Jul-95	1:44	0.00	10	0.04	0.52	7.60	0.09	3.70	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	125
20-Jul-95	1:59	0.00	11	0.06	0.43	8.15	0.12	4.39	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	213
20-Jul-95	17:13	0.51	12	0.13	0.79	10.9	0.18	10.0	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	182
20-Jul-95	17:23	0.25															
20-Jul-95	17:28	0.00	13	1.36	0.68	58.2	3.98	58.5	<0.2	<0.5	<4	29.0	<30	<10	<5	<3	47.0
20-Jul-95	17:43	0.00	14	1.02	0.11	30.1	1.44	15.9	<0.2	<0.5	<4	29.0	<30	<10	<5	<3	30.0
20-Jul-95	18:25	0.00	15	0.17	0.17	12.5	0.17	4.65	<0.2	<0.5	<4	29.0	<30	<10	<5	<3	20.0
21-Jul-95	5:54	0.25															
21-Jul-95	7:47	0.00	16	0.21	0.93	11.4	0.21	19.18	<0.2	<0.5	<4	29.0	<30	<10	<5	<3	44.0
21-Jul-95	8:03	0.25															
21-Jul-95	8:04	0.00	17	0.00	0.08	15.8	0.12	4.48	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	17.0
21-Jul-95	8:06	0.25															
21-Jul-95	8:19	0.00	18	0.03	0.22	9.23	0.11	4.22	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	24.0
21-Jul-95	8:53	0.00	19	0.00	0.13	16.8	0.18	5.35	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	37.0
21-Jul-95	11:33	0.25	20	0.07	0.67	13.0	0.19	12.7	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	37.0
21-Jul-95	11:35	0.25															
21-Jul-95	11:48	0.00	21	0.05	0.46	10.3	0.16	8.92	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	57.0
21-Jul-95	14:51	0.25															
21-Jul-95	14:54	0.00	22	0.01	0.03	16.3	0.12	2.50	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	10.0
21-Jul-95	15:01	0.25															
21-Jul-95	15:09	0.00	23	0.00	0.08	17.9	0.19	4.05	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	30.0
21-Jul-95	15:24	0.00	24	0.00	0.05	17.4	0.15	3.87	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	30.0

Phase III Water Quality Data Sheets for Unfiltered Runoff from the Palace Hotel

Date	Time	Rainfall (mm)	Sample No.	NO_3-N (mg/l)	PO_4-P (mg/l)	Ca (mg/l)	Mg (mg/l)	Na (mg/l)	Ag (ug/l)	Cd (ug/l)	Cr (ug/l)	Cu (ug/l)	Fe (ug/l)	Mn (ug/l)	Ni (ug/l)	Pb (ug/l)	Zn (ug/l)
24-Jul-95	18:17	0.25	1	0.01	0.06	17.9	0.58	3.97	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	18.0
24-Jul-95	18:21	0.25															
24-Jul-95	18:22	0.00	2	0.01	0.09	13.8	0.38	3.77	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	18.0
24-Jul-95	18:27	0.00	3	0.51	2.16	12.1	0.78	55.1	<0.2	<0.5	<4	29.0	<30	<10	<5	<3	50.0
24-Jul-95	18:32	0.00	4	0.01	0.43	9.01	0.40	7.30	<0.2	<0.5	<4	29.0	<30	<10	<5	<3	43.0
24-Jul-95	18:42	0.00	5	0.06	0.28	9.73	0.45	6.53	<0.2	<0.5	<4	29.0	<30	<10	<5	<3	189
24-Jul-95	20:04	0.00	6	0.13	0.66	15.8	0.80	17.3	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	407
24-Jul-95	21:15	0.76	7	0.01	0.23	15.3	0.42	6.53	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	14.0
24-Jul-95	21:23	0.25															
24-Jul-95	21:30	0.00	8	0.03	0.19	7.55	0.28	4.48	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	54.0
24-Jul-95	21:44	0.25															
24-Jul-95	21:45	0.00	9	0.01	0.34	11.8	0.48	4.08	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	307
24-Jul-95	22:00	0.00	10	0.03	0.32	13.7	0.58	5.38	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	39.0
24-Jul-95	22:12	0.00	11	0.06	0.31	14.2	0.65	9.61	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	311
25-Jul-95	15:35	0.25	12	0.25	0.23	21.0	1.08	30.0	<0.2	<0.5	<4	29.0	<30	<10	<5	<3	29.0
25-Jul-95	15:40	0.25															
25-Jul-95	15:50	0.00	13	0.08	0.16	8.02	0.28	4.69	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	100
25-Jul-95	16:05	0.00	14	0.07	0.18	9.89	0.38	4.79	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	218
26-Jul-95	10:53	0.00	15	2.43	0.08	79.3	4.20	35.5	<0.2	<0.5	<4	7.00	100	<10	<5	<3	46.0
26-Jul-95	11:11	0.00	16	2.21	0.07	79.3	4.33	33.6	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	36.0
26-Jul-95	14:09	0.00	17	1.82	1.38	37.9	1.57	127	<0.2	<0.5	<4	43.0	<30	<10	<5	<3	43.0
26-Jul-95	14:24	0.00	18	2.33	1.79	24.7	1.15	160	<0.2	<0.5	<4	43.0	<30	<10	<5	<3	54.0
26-Jul-95	15:22	0.00	19	2.77	1.92	18.2	0.90	268	<0.2	<0.5	<4	114	<30	<10	<5	<3	171
26-Jul-95	15:37	0.00	20	3.79	1.71	12.2	0.62	292	<0.2	<0.5	<4	86.0	<30	<10	<5	<3	104
26-Jul-95	15:52	0.00	21	3.95	1.49	9.84	0.48	286	<0.2	<0.5	<4	71.0	<30	<10	<5	<3	71.0
26-Jul-95	18:01	0.00	22	4.38	1.68	17.1	0.97	268	<0.2	<0.5	<4	114	<30	<10	<5	<3	61.0
26-Jul-95	19:34	0.00	23	4.31	1.40	9.16	0.70	295	<0.2	<0.5	<4	71.0	<30	<10	<5	<3	68.0
26-Jul-95	19:49	0.00	24	4.18	1.50	10.3	0.60	305	<0.2	<0.5	<4	71.0	<30	<10	<5	<3	64.0

Phase III Water Quality Data Sheets for Unfiltered Runoff from the Palace Hotel

Date	Time	Rainfall (mm)	Sample No.	NO_3-N (mg/l)	PO_4-P (mg/l)	Ca (mg/l)	Mg (mg/l)	Na (mg/l)	Ag (ug/l)	Cd (ug/l)	Cr (ug/l)	Cu (ug/l)	Fe (ug/l)	Mn (ug/l)	Ni (ug/l)	Pb (ug/l)	Zn (ug/l)
27-Jul-95	9:22	0.00	1	3.42	1.53	24.0	1.19	243	<0.2	<0.5	<4	86.0	<30	<10	<5	<3	21.0
27-Jul-95	9:26	0.00	2	3.64	0.25	5.79	0.36	250	<0.2	<0.5	<4	129	<30	<10	<5	<3	18.0
27-Jul-95	9:32	0.00	3	3.73	0.37	5.33	0.34	253	<0.2	<0.5	<4	114	<30	<10	<5	<3	11.0
27-Jul-95	9:37	0.00	4	4.21	0.43	6.44	0.36	265	<0.2	<0.5	<4	171	40	<10	<5	<3	11.0
27-Jul-95	9:47	0.00	5	3.97	0.49	5.85	0.36	243	<0.2	<0.5	<4	86.0	40	<10	<5	<3	4.00
27-Jul-95	9:57	0.00	6	3.64	0.37	6.62	0.36	243	<0.2	<0.5	<4	143	40	<10	<5	<3	36.0
27-Jul-95	10:12	0.00	7	3.40	0.41	6.56	0.36	225	<0.2	<0.5	<4	143	<30	<10	<5	<3	32.0
27-Jul-95	10:27	0.00	8	3.45	0.43	6.86	0.38	212	<0.2	<0.5	<4	143	40	<10	<5	<3	36.0
27-Jul-95	10:42	0.00	9	3.04	0.43	6.98	0.38	193	<0.2	<0.5	<4	143	40	<10	<5	<3	32.0
27-Jul-95	10:57	0.00	10	2.78	0.49	6.21	0.40	204	<0.2	<0.5	<4	114	40	<10	<5	<3	43.0
27-Jul-95	11:12	0.00	11	2.54	0.58	7.51	0.38	196	<0.2	<0.5	<4	114	40	<10	<5	<3	46.0
27-Jul-95	11:27	0.00	12	2.42	0.66	7.92	0.45	180	<0.2	<0.5	<4	129	40	<10	<5	<3	50.0
27-Jul-95	11:42	0.00	13	2.32	0.56	7.21	0.40	177	<0.2	<0.5	<4	86.0	<30	<10	<5	<3	43.0
27-Jul-95	11:57	0.00	14	2.37	0.53	6.80	0.36	169	<0.2	<0.5	<4	86.0	<30	<10	<5	<3	36.0
27-Jul-95	12:12	0.00	15	2.32	0.56	6.80	0.36	172	<0.2	<0.5	<4	71.0	<30	<10	<5	<3	29.0
27-Jul-95	12:39	0.00	16	2.44	0.60	6.98	0.38	172	<0.2	<0.5	<4	86.0	<30	<10	<5	<3	39.0
27-Jul-95	12:54	0.00	17	2.56	1.21	9.64	0.56	188	<0.2	<0.5	<4	157	<30	<10	<5	<3	46.0
27-Jul-95	13:09	0.00	18	3.73	1.09	13.5	0.65	209	<0.2	<0.5	<4	171	<30	<10	<5	<3	68.0
27-Jul-95	13:24	0.00	19	4.26	1.07	13.3	0.65	218	<0.2	<0.5	<4	143	<30	<10	<5	<3	71.0
27-Jul-95	13:39	0.00	20	3.33	1.44	30.0	1.43	203	<0.2	<0.5	<4	57.0	<30	<10	<5	<3	64.0
27-Jul-95	13:54	0.00	21	3.25	1.48	34.9	1.68	190	<0.2	<0.5	<4	71.0	<30	<10	<5	<3	57.0
27-Jul-95	14:33	0.00	22	3.21	1.50	35.3	0.70	187	<0.2	<0.5	<4	100	<30	<10	<5	<3	61.0
27-Jul-95	14:48	0.00	23	3.33	1.50	33.7	1.59	193	<0.2	<0.5	<4	100	<30	<10	<5	<3	57.0
27-Jul-95	15:03	0.00	24	3.45	1.46	29.6	1.36	190	<0.2	<0.5	<4	100	<30	<10	<5	<3	2.0

Phase III Water Quality Data Sheets for Unfiltered Runoff from the Palace Hotel

Date	Time	Rainfall (mm)	Sample No.	NO_3-N (mg/l)	PO_4-P (mg/l)	Ca (mg/l)	Mg (mg/l)	Na (mg/l)	Ag (ug/l)	Cd (ug/l)	Cr (ug/l)	Cu (ug/l)	Fe (ug/l)	Mn (ug/l)	Ni (ug/l)	Pb (ug/l)	Zn (ug/l)
29-Jul-95	2:42	0.25	1	0.01	0.43	42.1	0.56	17.5	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	164
29-Jul-95	2:46	0.25															
29-Jul-95	2:47	0.00	2	0.13	1.09	34.3	0.46	22.8	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	111
29-Jul-95	2:52	0.00	3	0.05	0.62	34.3	0.54	4.82	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	51.0
29-Jul-95	2:57	0.00	4	1.78	0.72	19.7	0.41	103	<0.2	<0.5	<4	57.0	<30	<10	<5	<3	14.0
29-Jul-95	3:07	0.00	5	0.36	0.64	31.4	0.50	22.8	<0.2	<0.5	<4	29.0	<30	<10	<5	<3	50.0
29-Jul-95	3:31	0.25	6	0.01	0.27	47.1	0.50	4.48	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	64.0
29-Jul-95	3:46	0.00	7	0.13	0.43	30.2	0.48	8.12	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	214
29-Jul-95	4:01	0.00	8	0.22	0.86	37.1	0.60	15.3	<0.2	<0.5	<4	29.0	<30	<10	<5	<3	154
29-Jul-95	23:56	0.00	9	2.00	2.62	76.9	1.92	127	<0.2	<0.5	<4	57.0	<30	<10	<5	<3	107
30-Jul-95	0:49	0.25															
30-Jul-95	0:53	0.00	10	0.73	0.45	37.9	0.80	51.9	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	32.0
30-Jul-95	1:08	0.00	11	0.10	0.14	54.1	1.00	34.5	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	54.0
30-Jul-95	1:23	0.00	12	0.35	0.58	53.6	1.08	29.7	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	43.0
30-Jul-95	1:38	0.00	13	0.72	1.23	64.9	1.48	50.0	<0.2	<0.5	<4	29.0	<30	<10	<5	<3	50.0
30-Jul-95	2:25	0.25															
30-Jul-95	2:32	0.00	14	1.51	0.78	47.1	1.00	96.2	<0.2	<0.5	<4	29.0	<30	<10	<5	<3	36.0
30-Jul-95	2:47	0.00	15	0.48	0.29	52.1	1.04	29.2	<0.2	<0.5	<4	29.0	<30	<10	<5	<3	36.0
30-Jul-95	3:02	0.00	16	0.19	0.43	56.4	1.13	13.2	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	39.0
30-Jul-95	3:17	0.00	17	0.26	0.72	57.9	1.26	23.9	<0.2	<0.5	<4	29.0	<30	<10	<5	<3	32.0
30-Jul-95	9:17	0.00	18	0.72	1.42	64.9	1.56	46.3	<0.2	<0.5	<4	43.0	<30	<10	<5	<3	50.0
30-Jul-95	21:39	0.25															
30-Jul-95	21:40	0.00	19	0.01	39.6	87.8	1.87	11.1	<0.2	<0.5	<4	7.00	<30	40	<5	<3	1766
30-Jul-95	22:09	0.25															
30-Jul-95	22:10	0.00	21	0.08	1.11	29.3	0.55	4.91	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	86.0
30-Jul-95	22:25	0.00	22	0.39	0.68	26.5	0.50	24.4	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	350
30-Jul-95	22:40	0.00	23	1.82	1.07	30.0	0.70	85.6	<0.2	<0.5	<4	71.0	<30	<10	<5	<3	254
30-Jul-95	22:55	0.00	24	1.80	1.36	30.7	0.72	90.4	<0.2	<0.5	<4	71.0	<30	<10	<5	<3	257

Phase III Water Quality Data Sheets for Unfiltered Runoff from the Palace Hotel

Date	Time	Rainfall (mm)	Sample No.	NO_3-N (mg/l)	PO_4-P (mg/l)	Ca (mg/l)	Mg (mg/l)	Na (mg/l)	Ag (ug/l)	Cd (ug/l)	Cr (ug/l)	Cu (ug/l)	Fe (ug/l)	Mn (ug/l)	Ni (ug/l)	Pb (ug/l)	Zn (ug/l)
1-Aug-95	9:40	0.25	1	0.11	20.3	22.6	1.14	12.6	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	522
1-Aug-95	9:43	0.25															
1-Aug-95	9:45	0.00	2	0.06	9.60	16.7	0.79	6.25	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	934
1-Aug-95	9:50	0.00	3	0.05	3.53	14.3	0.60	6.25	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	279
1-Aug-95	9:55	0.00	4	0.06	3.10	16.1	0.64	8.12	<0.2	<0.5	<4	29.0	<30	<10	<5	<3	371
2-Aug-95	8:35	0.25															
2-Aug-95	8:40	0.00	5	0.07	2.74	16.7	0.68	9.68	<0.2	<0.5	<4	29.0	<30	<10	<5	<3	107
2-Aug-95	8:48	0.25															
2-Aug-95	8:50	0.00	6	0.22	3.35	20.8	0.98	19.9	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	515
2-Aug-95	9:05	0.00	7	1.45	27.2	25.6	1.72	132	<0.2	<0.5	<4	57.0	<30	30	<5	<3	577
2-Aug-95	9:20	0.00	8	3.72	9.47	10.7	0.64	280	<0.2	<0.5	<4	86.0	<30	<10	<5	<3	282
2-Aug-95	21:42	0.25	9	0.13	0.31	11.3	0.29	10.5	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	7.00
2-Aug-95	21:54	0.25															
2-Aug-95	21:57	0.00	10	0.06	0.42	5.33	0.20	2.24	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	75.0
2-Aug-95	21:58	0.25															
2-Aug-95	22:12	0.00	11	0.04	0.18	6.67	0.20	2.07	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	39.0
2-Aug-95	22:27	0.00	12	0.04	0.28	7.33	0.22	2.75	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	68.0
2-Aug-95	22:42	0.00	13	0.06	0.32	8.00	0.25	4.05	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	68.0
2-Aug-95	22:57	0.00	14	0.04	0.35	10.0	0.31	3.87	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	46.0
3-Aug-95	0:09	0.00	15	0.26	0.17	7.33	0.20	21.4	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	21.0
3-Aug-95	0:24	0.00	16	0.38	0.20	12.5	0.40	37.0	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	36.0
3-Aug-95	0:39	0.00	17	0.03	0.12	11.3	0.25	2.50	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	39.0
3-Aug-95	11:38	1.02	18	1.27	0.62	7.33	0.31	83.0	<0.2	<0.5	<4	86.0	<30	<10	<5	<3	86.0
3-Aug-95	11:53	0.25	19	0.14	0.33	7.33	0.22	8.75	<0.2	<0.5	<4	71.0	<30	<10	<5	<3	57.0
3-Aug-95	12:08	0.25	20	1.14	14.3	17.3	1.10	95.5	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	75.0
3-Aug-95	12:23	0.25	21	0.65	81.9	47.2	3.36	79.5	<0.2	<0.5	<4	29.0	<30	90	<5	<3	357
3-Aug-95	12:37	0.25															
3-Aug-95	12:38	0.00	22	1.39	12.8	19.0	1.0	96.4	<0.2	<0.5	<4	57.0	<30	<10	<5	<3	129
3-Aug-95	12:42	0.25															
3-Aug-95	12:53	0.00	23	1.66	8.53	15.5	0.77	100	<0.2	<0.5	<4	57.0	<30	<10	<5	<3	96.0
3-Aug-95	13:08	0.25	24	0.11	1.82	15.5	0.64	18.3	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	46.0

Phase III Water Quality Data Sheets for Unfiltered Runoff from the Palace Hotel

Date	Time	Rainfall (mm)	Sample No.	NO_3-N (mg/l)	PO_4-P (mg/l)	Ca (mg/l)	Mg (mg/l)	Na (mg/l)	Ag (ug/l)	Cd (ug/l)	Cr (ug/l)	Cu (ug/l)	Fe (ug/l)	Mn (ug/l)	Ni (ug/l)	Pb (ug/l)	Zn (ug/l)
4-Aug-95	10:48	0.51	1	0.01	0.07	24.0	0.60	10.4	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	55.0
4-Aug-95	10:53	0.00	2	0.01	0.05	15.9	0.35	4.25	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	21.0
4-Aug-95	10:58	0.00	3	0.01	0.16	24.3	0.75	23.2	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	62.0
4-Aug-95	11:03	0.00	4	0.01	0.13	14.2	0.37	5.58	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	52.0
4-Aug-95	11:17	0.25	5	0.03	0.13	18.6	0.50	7.04	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	66.0
4-Aug-95	11:23	0.25															
4-Aug-95	11:27	0.00	6	0.04	0.11	16.2	0.40	7.04	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	66.0
4-Aug-95	11:35	0.25															
4-Aug-95	11:42	0.00	7	0.04	0.14	16.9	0.47	10.8	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	48.0
4-Aug-95	13:39	0.25	8	0.01	0.11	20.9	0.37	4.33	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	14.0
4-Aug-95	13:54	0.51	9	0.01	0.72	9.45	0.15	1.66	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	24.0
4-Aug-95	14:06	0.25															
4-Aug-95	14:09	0.00	10	0.03	0.44	9.79	0.20	3.67	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	34.0
4-Aug-95	14:24	0.25	11	0.03	0.13	14.9	0.40	5.90	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	48.0
4-Aug-95	14:34	0.25															
4-Aug-95	14:39	0.00	12	0.03	0.10	17.6	0.45	5.45	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	38.0
4-Aug-95	14:52	0.25															
4-Aug-95	14:54	0.00	13	0.04	0.09	15.2	0.32	4.50	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	28.0
4-Aug-95	15:06	0.25															
4-Aug-95	15:09	0.00	14	0.03	0.12	16.2	0.42	4.83	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	38.0
4-Aug-95	15:24	0.25	15	0.05	0.14	19.3	0.47	6.13	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	41.0
4-Aug-95	15:39	0.00	16	0.09	0.17	25.0	0.65	9.31	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	48.0
4-Aug-95	15:54	0.00	17	0.07	0.18	27.0	0.67	10.0	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	45.0
4-Aug-95	16:03	0.25															
4-Aug-95	16:09	0.00	18	0.08	0.17	28.7	0.72	10.4	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	45.0
4-Aug-95	16:21	0.25															
4-Aug-95	16:24	0.00	19	0.06	0.15	26.4	0.67	8.63	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	41.0
4-Aug-95	16:39	0.00	20	0.06	0.15	25.0	0.65	7.95	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	45.0
4-Aug-95	16:54	0.00	21	0.05	0.22	27.4	0.77	11.2	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	62.0
4-Aug-95	17:09	0.00	22	0.10	0.28	28.0	0.80	12.4	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	72.0
4-Aug-95	23:34	0.00	23	0.41	0.67	41.7	1.30	46.4	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	59.0
6-Aug-95	17:55	0.51	24	0.04	0.04	20.9	0.55	4.91	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	14.0

Phase III Water Quality Data Sheets for Unfiltered Runoff from the Palace Hotel

Date	Time	Rainfall (mm)	Sample No.	NO_3-N (mg/l)	PO_4-P (mg/l)	Ca (mg/l)	Mg (mg/l)	Na (mg/l)	Ag (ug/l)	Cd (ug/l)	Cr (ug/l)	Cu (ug/l)	Fe (ug/l)	Mn (ug/l)	Ni (ug/l)	Pb (ug/l)	Zn (ug/l)
7-Aug-95	20:37	0.25															
7-Aug-95	20:49	0.00	1	1.05	18.0	65.5	1.08	98.5	<0.2	<0.5	<4	46.0	<30	<10	<5	<3	24.0
7-Aug-95	20:54	0.00	2	0.48	5.16	69.5	0.97	45.0	<0.2	<0.5	<4	7.00	91	<10	<5	<3	76.0
7-Aug-95	20:59	0.00	3	0.01	1.82	64.8	0.88	25.5	<0.2	<0.5	<4	46.0	<30	<10	<5	<3	90.0
7-Aug-95	22:07	0.51	4	0.05	1.32	24.5	0.35	7.72	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	31.0
7-Aug-95	22:12	0.76	5	0.03	0.11	19.9	0.17	1.50	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	2.00
7-Aug-95	22:21	0.25															
7-Aug-95	22:22	0.00	6	0.02	0.38	16.2	0.17	1.82	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	31.0
7-Aug-95	22:37	0.00	7	1.06	0.67	19.9	0.28	61.6	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	55.0
7-Aug-95	22:52	0.00	8	0.74	0.74	30.0	0.39	43.0	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	52.0
7-Aug-95	23:07	0.00	9	0.49	0.81	40.2	0.57	35.2	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	48.0
8-Aug-95	9:43	0.25															
8-Aug-95	9:46	0.00	10	0.11	0.63	58.6	0.70	17.0	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	45.0
8-Aug-95	10:01	0.00	11	0.39	3.04	62.0	0.88	35.2	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	48.0
8-Aug-95	10:16	0.00	12	0.74	3.28	40.9	0.57	53.4	<0.2	<0.5	<4	62.0	<30	<10	<5	<3	83.0
9-Aug-95	5:08	0.25	13	0.05	1.71	28.0	0.41	8.18	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	31.0
9-Aug-95	5:14	0.25															
9-Aug-95	5:23	0.00	14	0.45	17.0	51.8	1.04	34.9	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	172
9-Aug-95	5:38	0.00	15	0.09	17.1	56.6	1.08	10.8	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	815
9-Aug-95	5:53	0.00	16	0.08	11.5	52.5	0.88	9.77	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	540
9-Aug-95	6:08	0.00	17	0.08	8.38	50.5	0.82	9.54	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	384
9-Aug-95	6:39	0.25															
9-Aug-95	6:41	0.00	18	0.08	2.75	48.4	0.68	6.81	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	110
9-Aug-95	6:56	0.00	19	0.04	0.65	40.9	0.52	4.36	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	55.0
9-Aug-95	7:11	0.00	20	0.07	1.52	38.9	0.52	7.50	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	110
9-Aug-95	7:26	0.00	21	0.09	1.94	40.9	0.55	10.8	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	121

Phase III Water Quality Data Sheets for Unfiltered Runoff from the Palace Hotel

Date	Time	Rainfall (mm)	Sample No.	NO_3-N (mg/l)	PO_4-P (mg/l)	Ca (mg/l)	Mg (mg/l)	Na (mg/l)	Ag (ug/l)	Cd (ug/l)	Cr (ug/l)	Cu (ug/l)	Fe (ug/l)	Mn (ug/l)	Ni (ug/l)	Pb (ug/l)	Zn (ug/l)
9-Aug-95	22:21	0.00	1	0.27	64.8	48.6	2.28	44.2	<0.2	<0.5	<4	29.0	<30	40	<5	<3	500
9-Aug-95	22:26	0.00	2	0.71	482	76.2	9.40	177	<0.2	<0.5	<4	43.0	<30	250	37.8	<3	2308
9-Aug-95	22:31	0.00	3	1.80	175	53.4	4.50	228	<0.2	<0.5	<4	43.0	<30	40	18.9	<3	141
9-Aug-95	22:36	0.00	4	2.54	91.0	42.4	2.21	281	<0.2	<0.5	<4	43.0	<30	<10	9.10	<3	100
9-Aug-95	22:46	0.00	5	4.89	45.3	13.3	1.24	272	<0.2	<0.5	<4	43.0	<30	<10	<5	<3	59.0
9-Aug-95	23:01	0.00	6	5.31	32.0	20.0	0.95	281	<0.2	<0.5	<4	114	<30	<10	<5	<3	69.0
10-Aug-95	11:25	0.00	7	5.40	16.0	19.3	1.02	244	<0.2	<0.5	<4	214	<30	<10	<5	<3	62.0
10-Aug-95	11:40	0.00	8	2.24	44.2	31.3	2.05	186	<0.2	<0.5	<4	71.0	<30	<10	<5	<3	131
10-Aug-95	11:55	0.00	9	3.32	31.5	27.0	1.48	189	<0.2	<0.5	<4	57.0	<30	<10	<5	<3	103
10-Aug-95	12:10	0.00	10	2.26	23.7	20.7	1.08	202	<0.2	<0.5	<4	71.0	<30	<10	<5	<3	114
10-Aug-95	17:20	0.00	11	3.26	5.02	57.2	2.96	170	<0.2	<0.5	<4	86.0	<30	<10	<5	<3	14.0
10-Aug-95	17:35	0.00	12	3.03	21.3	52.8	2.39	172	<0.2	<0.5	<4	29.0	<30	<10	<5	<3	2.0
10-Aug-95	17:50	0.00	13	1.92	27.7	31.0	1.54	168	<0.2	<0.5	<4	43.0	<30	<10	<5	<3	45.0
10-Aug-95	18:05	0.00	14	2.14	28.6	27.0	1.34	165	<0.2	<0.5	<4	43.0	<30	<10	<5	<3	107
10-Aug-95	22:09	0.00	15	2.86	15.8	14.7	0.70	171	<0.2	<0.5	<4	57.0	<30	<10	<5	<3	90.0
10-Aug-95	22:24	0.00	16	3.94	11.1	11.0	0.54	176	<0.2	<0.5	<4	43.0	<30	<10	<5	<3	45.0
10-Aug-95	22:39	0.00	17	3.85	10.9	10.0	0.48	184	<0.2	<0.5	<4	43.0	<30	<10	<5	<3	21.0
10-Aug-95	22:54	0.00	18	3.85	11.4	10.7	0.52	181	<0.2	<0.5	<4	43.0	<30	<10	<5	<3	38.0
10-Aug-95	23:09	0.00	19	4.23	10.9	8.33	0.48	181	<0.2	<0.5	<4	57.0	<30	<10	<5	<3	59.0
11-Aug-95	1:59	0.00	20	4.49	5.79	11.7	0.54	171	<0.2	<0.5	<4	71.0	<30	<10	<5	<3	72.0
11-Aug-95	2:14	0.00	21	2.84	1.16	70.0	3.12	76.36	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	69.0
11-Aug-95	2:29	0.00	22	4.42	2.93	32.0	1.40	134	<0.2	<0.5	<4	57.0	<30	<10	<5	3	48.0
11-Aug-95	2:44	0.00	23	3.98	2.64	38.0	1.64	126	<0.2	<0.5	<4	43.0	<30	<10	<5	<3	41.0

Phase III Water Quality Data Sheets for Unfiltered Runoff from the Palace Hotel

Date	Time	Rainfall (mm)	Sample No.	NO_3-N (mg/l)	PO_4-P (mg/l)	Ca (mg/l)	Mg (mg/l)	Na (mg/l)	Ag (ug/l)	Cd (ug/l)	Cr (ug/l)	Cu (ug/l)	Fe (ug/l)	Mn (ug/l)	Ni (ug/l)	Pb (ug/l)	Zn (ug/l)
11-Aug-95	12:34	0.76	1	0.01	0.11	27.3	0.59	7.58	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	21.0
11-Aug-95	12:39	0.51	2	0.01	0.08	15.3	0.23	1.96	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	21.0
11-Aug-95	12:41	0.25															
11-Aug-95	12:44	0.00	3	0.24	0.63	10.2	0.22	27.8	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	90.0
11-Aug-95	12:49	0.00	4	0.02	0.52	9.26	0.23	7.58	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	462
11-Aug-95	12:59	0.00	5	0.04	0.53	10.2	0.34	6.29	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	553
11-Aug-95	13:14	0.00	6	0.15	0.80	12.5	0.43	9.19	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	607
11-Aug-95	18:25	0.00	7	0.49	470	94.3	6.77	47.9	<0.2	<0.5	<4	71.0	<30	150	11	<3	2910
11-Aug-95	22:03	0.00	8	0.86	21.1	31.5	1.62	187	<0.2	<0.5	<4	57.0	<30	30	<5	<3	221
11-Aug-95	22:18	0.00	9	4.30	6.92	11.6	0.76	135	<0.2	<0.5	<4	43.0	<30	<10	<5	<3	45.0
12-Aug-95	1:30	0.25															
12-Aug-95	1:32	0.00	10	0.37	0.86	nd	nd	nd	<0.2	<0.5	<4	nd	nd	nd	nd	nd	nd
12-Aug-95	1:40	0.25															
12-Aug-95	1:47	0.00	11	1.11	0.91	16.7	0.59	69.8	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	52.0
12-Aug-95	2:02	0.00	12	0.06	0.61	19.0	0.63	8.06	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	155
12-Aug-95	2:03	0.25															
12-Aug-95	2:17	0.00	13	0.01	0.48	22.7	0.75	4.60	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	107
12-Aug-95	2:23	0.25															
12-Aug-95	2:32	0.00	14	0.01	0.40	22.2	0.74	4.26	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	107
12-Aug-95	2:37	0.25															
12-Aug-95	2:47	0.00	15	0.02	0.37	22.2	0.75	4.55	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	103
12-Aug-95	2:50	0.25															
12-Aug-95	3:02	0.00	16	0.03	0.45	22.2	0.71	4.71	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	76.0
12-Aug-95	3:16	0.25															
12-Aug-95	3:17	0.00	17	0.03	0.47	21.8	0.68	4.32	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	76.0
12-Aug-95	3:31	0.25															
12-Aug-95	3:32	0.00	18	0.03	0.44	22.2	0.68	4.38	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	100
12-Aug-95	3:47	0.00	19	0.04	0.48	22.2	0.71	4.55	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	107
12-Aug-95	3:59	0.25															
12-Aug-95	4:02	0.00	20	0.05	0.60	23.6	0.76	5.00	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	117
12-Aug-95	4:17	0.00	21	0.02	0.55	25.5	0.80	4.88	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	107
12-Aug-95	4:32	0.00	22	0.06	0.60	25.9	0.86	5.16	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	103
12-Aug-95	4:47	0.00	23	0.06	0.66	27.8	0.92	6.45	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	131
12-Aug-95	5:02	0.00	24	0.08	0.64	29.2	0.95	6.61	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	124

nd = not determined

Phase III Water Quality Data Sheets for Unfiltered Runoff from the Palace Hotel

Date	Time	Rainfall (mm)	Sample No.	NO$_3$-N (mg/l)	PO$_4$-P (mg/l)	Ca (mg/l)	Mg (mg/l)	Na (mg/l)	Ag (ug/l)	Cd (ug/l)	Cr (ug/l)	Cu (ug/l)	Fe (ug/l)	Mn (ug/l)	Ni (ug/l)	Pb (ug/l)	Zn (ug/l)
14-Aug-95	22:56	0.00	1	2.45	2.40	33.7	1.99	157	<0.2	<0.5	<4	100	<30	<10	<5	<3	105
14-Aug-95	23:01	0.00	2	2.88	2.46	27.5	1.52	152	<0.2	<0.5	<4	67	<30	<10	<5	<3	62.0
14-Aug-95	23:06	0.00	3	2.43	2.16	30.2	1.32	191	<0.2	<0.5	<4	50	<30	<10	<5	<3	55.0
14-Aug-95	23:11	0.00	4	2.48	2.05	30.7	1.32	178	<0.2	<0.5	<4	83	<30	<10	<5	<3	55.0
14-Aug-95	23:21	0.00	5	2.17	1.91	37.2	2.25	154	<0.2	<0.5	<4	67	<30	<10	<5	<3	47.0
15-Aug-95	1:02	1.02	6	0.02	0.15	22.6	0.65	11.1	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	7.00
15-Aug-95	1:05	0.25															
15-Aug-95	1:17	0.00	7	0.40	1.96	15.6	0.57	41.6	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	25.0
15-Aug-95	1:20	0.25															
15-Aug-95	1:32	0.00	8	0.01	0.23	20.3	0.77	8.43	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	91.0
15-Aug-95	1:47	0.00	9	0.10	0.31	21.7	0.87	11.1	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	215
15-Aug-95	2:02	0.00	10	0.04	0.28	22.6	0.95	15.3	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	273
15-Aug-95	2:17	0.00	11	0.01	0.29	23.6	1.05	17.4	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	276
15-Aug-95	2:32	0.00	12	0.20	0.35	25.5	1.12	17.9	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	269
15-Aug-95	10:35	0.00	13	0.36	1.29	27.5	1.61	41.6	<0.2	<0.5	<4	117	<30	<10	<5	<3	207
15-Aug-95	10:50	0.00	14	4.18	1.31	13.7	0.67	218	<0.2	<0.5	<4	117	<30	<10	<5	<3	73.0
15-Aug-95	11:05	0.00	15	5.58	0.80	8.94	0.40	268	<0.2	<0.5	<4	150	<30	<10	<5	<3	84.0
15-Aug-95	11:20	0.00	16	5.97	0.78	8.42	0.37	268	<0.2	<0.5	<4	150	<30	<10	<5	<3	76.0
15-Aug-95	14:08	0.25	17	0.03	0.11	20.8	1.02	32.6	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	7.00
15-Aug-95	14:22	0.25															
15-Aug-95	14:23	0.00	18	0.04	0.19	9.47	0.32	3.97	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	222
15-Aug-95	14:38	0.51	19	0.63	0.15	10.4	0.42	39.5	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	47.0
15-Aug-95	14:53	0.25	20	0.07	0.12	10.8	0.47	5.31	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	29.0
15-Aug-95	15:03	0.25															
15-Aug-95	15:08	0.00	21	0.09	0.17	11.3	0.45	7.18	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	58.0
15-Aug-95	15:19	0.25															
15-Aug-95	15:23	0.00	22	0.07	0.20	13.7	0.55	5.00	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	51.0
15-Aug-95	15:30	0.25															
15-Aug-95	15:38	0.00	23	0.06	0.20	17.5	0.72	4.65	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	62.0
15-Aug-95	15:53	0.00	24	0.08	0.24	18.9	0.82	6.25	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	69.0
	New Data Set																
8-Sep-95	1:13	0.25	1	0.40	0.64	28.0	0.60	25.1	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	102.0
8-Sep-95	1:16	0.25															
8-Sep-95	1:18	0.00	2	0.04	0.68	18.8	0.40	4.10	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	47.0
8-Sep-95	1:22	0.25															
8-Sep-95	1:23	0.00	3	0.11	6.15	22.2	0.69	9.04	<0.2	<0.5	<4	7.00	100	<10	<5	<3	324.0
8-Sep-95	0:00	0.00	4	0.08	0.97	17.0	0.42	6.67	<0.2	<0.5	<4	7.00	60	<10	<5	<3	98.0
8-Sep-95	1:38	0.00	5	0.13	0.79	20.5	0.62	8.33	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	65.0
8-Sep-95	7:19	0.25	6	0.42	0.40	21.0	0.49	30.8	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	44.0
8-Sep-95	7:31	0.25															
8-Sep-95	7:33	0.00	7	0.17	0.52	17.0	0.42	10.8	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	47.0
8-Sep-95	7:48	0.00	8	0.08	0.29	20.5	0.49	5.71	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	62.0
8-Sep-95	9:09	0.25	9	0.03	0.10	19.9	0.40	3.12	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	18.0
8-Sep-95	9:23	0.00	10	0.14	0.38	14.8	0.31	11.2	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	36.0
8-Sep-95	9:38	0.00	11	0.09	0.38	16.5	0.40	7.61	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	47.0

APPENDIX C

Raw Data Sets Obtained for Filtered Runoff Samples Collected During Phase III

Phase III Water Quality Data Sheets for Filtered Runoff from the Palace Hotel

Date	Time	Rainfall (mm)	Sample No.	NO_3-N (mg/l)	PO_4-P (mg/l)	Ca (mg/l)	Mg (mg/l)	Na (mg/l)	Ag (ug/l)	Cd (ug/l)	Cr (ug/l)	Cu (ug/l)	Fe (ug/l)	Mn (ug/l)	Ni (ug/l)	Pb (ug/l)	Zn (ug/l)
30-Jun-95	nd	nd	1	nd	2.12	152	5.85	52.9	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	29.0
30-Jun-95	nd	nd	2	nd	1.99	157	10.2	64.5	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	22.0
30-Jun-95	nd	nd	3	nd	1.43	159	6.19	55.8	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	25.0
30-Jun-95	nd	nd	4	nd	1.79	154	6.01	60.5	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	22.0
30-Jun-95	nd	nd	5	nd	3.18	158	6.12	65.1	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	36.0
30-Jun-95	nd	nd	6	nd	3.55	154	5.93	66.9	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	29.0
30-Jun-95	nd	nd	7	nd	3.86	151	5.56	68.0	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	36.0
30-Jun-95	nd	nd	8	nd	3.90	150	5.53	55.8	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	36.0
30-Jun-95	nd	nd	9	nd	5.13	145	5.48	61.6	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	29.0
30-Jun-95	nd	nd	10	nd	5.25	143	5.55	73.8	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	29.0
30-Jun-95	nd	nd	11	nd	5.54	141	5.48	82.6	<0.2	<0.5	<4	33.0	<30	<10	<5	<3	36.0
30-Jun-95	nd	nd	12	nd	5.27	140	5.42	29.1	<0.2	<0.5	<4	33.0	<30	<10	<5	<3	36.0
New Data Set																	
6-Jul-95	nd	*	1	nd	0.91	45.5	1.15	14.3	<0.2	<0.5	<4	28.0	<30	<10	<5	<3	27.0
6-Jul-95	nd	*	2	nd	0.89	45.5	1.15	14.3	<0.2	<0.5	<4	28.0	<30	<10	<5	<3	24.0
6-Jul-95	nd	*	3	nd	1.15	46.1	1.19	14.7	<0.2	<0.5	<4	28.0	<30	<10	<5	<3	24.0
6-Jul-95	nd	*	4	nd	1.11	46.1	1.19	17.0	<0.2	<0.5	<4	28.0	<30	<10	<5	<3	20.0
6-Jul-95	nd	*	5	nd	1.14	42.9	1.19	17.0	<0.2	<0.5	<4	28.0	<30	<10	<5	<3	20.0
6-Jul-95	nd	*	6	nd	1.15	42.2	1.19	15.3	<0.2	<0.5	<4	28.0	<30	<10	<5	<3	20.0
6-Jul-95	nd	*	7	nd	1.45	44.8	1.24	23.0	<0.2	<0.5	<4	28.0	<30	<10	<5	<3	20.0
6-Jul-95	nd	*	8	nd	1.46	45.5	1.28	21.8	<0.2	<0.5	<4	28.0	<30	<10	<5	<3	20.0
New Data Set																	
7-Jul-95	nd	*	1	nd	0.02	56.5	0.85	6.25	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	17.0
7-Jul-95	nd	*	2	nd	0.01	54.6	0.81	5.00	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	17.0
7-Jul-95	nd	*	3	nd	0.19	60.2	1.36	20.2	<0.2	<0.5	<4	28.0	<30	<10	<5	<3	27.0
7-Jul-95	nd	*	4	nd	0.13	61.1	1.23	17.8	<0.2	<0.5	<4	28.0	<30	<10	<5	<3	27.0
7-Jul-95	nd	*	5	nd	0.03	60.2	0.96	8.33	<0.2	<0.5	<4	28.0	<30	<10	<5	<3	30.0
7-Jul-95	nd	*	6	nd	0.03	62.0	0.98	9.16	<0.2	<0.5	<4	28.0	<30	<10	<5	<3	34.0
7-Jul-95	nd	*	7	nd	0.27	54.6	1.21	15.5	<0.2	<0.5	<4	28.0	<30	<10	<5	<3	24.0
7-Jul-95	nd	*	8	nd	0.26	56.5	1.17	16.7	<0.2	<0.5	<4	28.0	<30	<10	<5	<3	24.0
7-Jul-95	nd	*	9	nd	0.26	28.7	0.43	3.12	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	24.0
7-Jul-95	nd	*	10	nd	0.25	25.0	0.40	2.91	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	24.0
7-Jul-95	nd	*	11	nd	0.28	26.0	0.52	6.25	<0.2	<0.5	<4	28.0	<30	<10	<5	<3	294
7-Jul-95	nd	*	12	nd	0.28	26.0	0.51	5.62	<0.2	<0.5	<4	28.0	<30	<10	<5	<3	314
7-Jul-95	nd	*	13	nd	0.36	30.8	0.63	9.79	<0.2	<0.5	<4	28.0	<30	<10	<5	<3	280
7-Jul-95	nd	*	14	nd	0.37	31.7	0.63	11.6	<0.2	<0.5	<4	28.0	<30	<10	<5	<3	274
7-Jul-95	nd	*	15	nd	0.42	31.7	0.76	13.5	<0.2	<0.5	<4	28.0	<30	<10	<5	<3	230
7-Jul-95	nd	*	16	nd	0.43	37.5	0.78	14.7	<0.2	<0.5	<4	28.0	<30	<10	<5	<3	226
7-Jul-95	nd	*	17	nd	0.53	40.7	0.87	15.9	<0.2	<0.5	<4	28.0	<30	<10	<5	<3	280
7-Jul-95	nd	*	18	nd	0.53	40.7	0.83	16.3	<0.2	<0.5	<4	28.0	<30	<10	<5	<3	277
7-Jul-95	nd	*	21	nd	0.46	40.7	0.83	14.3	<0.2	<0.5	<4	28.0	<30	<10	<5	<3	101
7-Jul-95	nd	*	22	nd	0.46	38.9	0.83	15.9	<0.2	<0.5	<4	28.0	<30	<10	<5	<3	98.0
7-Jul-95	nd	*	23	nd	0.47	38.9	0.81	15.1	<0.2	<0.5	<4	28.0	<30	<10	<5	<3	98.0
7-Jul-95	nd	*	24	nd	0.47	39.8	0.83	15.5	<0.2	<0.5	<4	28.0	<30	<10	<5	<3	84.0

nd = not determined. * Total rainfall recorded for July 6 and 7 was 4.83 mm and 7.34 mm respectively

Phase III Water Quality Data Sheets for Filtered Runoff from the Palace Hotel

Date	Time	Rainfall (mm)	Sample #	NO_3-N (mg/l)	PO_4-P (mg/l)	Ca (mg/l)	Mg (mg/l)	Na (mg/l)	Ag (ug/l)	Cd (ug/l)	Cr (ug/l)	Cu (ug/l)	Fe (ug/l)	Mn (ug/l)	Ni (ug/l)	Pb (ug/l)	Zn (ug/l)
10-Jul-95	9:51	0.51	1	nd	0.04	25.7	0.53	2.58	<0.2	<0.5	<4	28.0	<30	<10	<5	<3	2.00
10-Jul-95	9:52	0.00	2	nd	0.05	23.5	0.53	3.79	<0.2	<0.5	<4	28.0	<30	<10	<5	<3	2.00
10-Jul-95	9:53	0.25															
10-Jul-95	9:55	0.00	3	nd	0.07	27.2	0.57	5.48	<0.2	<0.5	<4	28.0	109	<10	<5	<3	2.00
10-Jul-95	9:56	0.00	4	nd	0.07	25.0	0.57	4.91	<0.2	<0.5	<4	28.0	<30	<10	<5	<3	14.0
10-Jul-95	10:00	0.00	5	nd	0.12	22.1	0.50	3.54	<0.2	<0.5	<4	28.0	<30	<10	<5	<3	14.0
10-Jul-95	10:01	0.00	6	nd	0.13	20.6	0.50	3.46	<0.2	<0.5	<4	28.0	109	<10	<5	<3	10.0
10-Jul-95	10:05	0.00	7	nd	0.86	44.2	1.40	39.1	<0.2	<0.5	<4	28.0	<30	<10	<5	<3	24.0
10-Jul-95	10:06	0.00	8	nd	0.84	44.9	1.47	38.7	<0.2	<0.5	<4	28.0	65	<10	<5	<3	30.0
10-Jul-95	10:14	0.00	9	nd	0.33	21.3	0.60	10.0	<0.2	<0.5	<4	125	<30	<10	<5	<3	230
10-Jul-95	10:15	0.00	10	nd	0.33	20.6	0.57	8.50	<0.2	<0.5	<4	28.0	<30	<10	<5	<3	37.0
10-Jul-95	16:31	0.25															
10-Jul-95	16:33	0.00	11	nd	0.09	36.2	0.67	4.43	<0.2	<0.5	<4	28.0	<30	<10	<5	<3	10.0
10-Jul-95	16:34	0.00	12	nd	0.06	33.8	0.67	3.46	<0.2	<0.5	<4	28.0	<30	<10	<5	<3	10.0
10-Jul-95	16:35	0.00	13	nd	0.03	33.8	0.63	2.82	<0.2	<0.5	<4	28.0	<30	<10	<5	<3	7.00
10-Jul-95	16:36	0.00	14	nd	0.03	33.1	0.60	2.74	<0.2	<0.5	<4	28.0	<30	<10	<5	<3	7.00
	New Data Set																
11-Jul-95	nd	*	1	nd	29.7	34.4	2.70	131	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	11.0
11-Jul-95	nd	*	2	nd	32.1	34.1	2.47	128	<0.2	<0.5	<4	42.0	<30	<10	<5	<3	4.00
11-Jul-95	nd	*	3	nd	38.3	48.2	2.68	128	<0.2	<0.5	<4	42.0	<30	<10	<5	<3	31.0
11-Jul-95	nd	*	4	nd	41.0	48.6	2.96	126	<0.2	<0.5	<4	42.0	<30	<10	<5	<3	35.0
11-Jul-95	nd	*	5	nd	129	73.4	6.30	125	<0.2	<0.5	<4	42.0	<30	52	7.50	<3	77.0
11-Jul-95	nd	*	6	nd	154	77.2	6.77	131	<0.2	<0.5	<4	42.0	<30	63	9.50	<3	98.0
11-Jul-95	nd	*	7	nd	152	78.5	6.23	109	<0.2	<0.5	<4	56.0	<30	63	10.0	<3	129.0
11-Jul-95	nd	*	8	nd	173	76.3	5.73	110	<0.2	<0.5	<4	42.0	<30	73	10.0	<3	126.0
11-Jul-95	nd	*	9	nd	113	37.7	5.64	200	<0.2	<0.5	<4	7.00	<30	<10	6.50	<3	7.00
11-Jul-95	nd	*	10	nd	113	36.2	5.89	209	<0.2	<0.5	<4	7.0	<30	<10	7.50	<3	7.00
11-Jul-95	nd	*	11	nd	13.5	25.7	1.86	200	<0.2	<0.5	<4	42.0	<30	<10	<5	<3	18.0
11-Jul-95	nd	*	12	nd	11.0	25.7	1.76	207	<0.2	<0.5	<4	42.0	<30	<10	<5	<3	14.0
11-Jul-95	nd	*	13	nd	10.3	23.6	1.67	235	<0.2	<0.5	<4	42.0	<30	<10	<5	<3	14.0
11-Jul-95	nd	*	14	nd	10.2	23.9	1.72	262	<0.2	<0.5	<4	42.0	<30	<10	<5	<3	14.0
	New Data Set																
13-Jul-95	12:21	0.00	1	nd	23.0	15.0	1.19	291	<0.2	<0.5	<4	56.0	<30	<10	<5	<3	42.0
13-Jul-95	12:26	0.00	2	nd	16.0	15.0	1.21	317	<0.2	<0.5	<4	69.0	<30	<10	<5	<3	32.0
13-Jul-95	12:31	0.00	3	nd	17.6	14.4	1.27	288	<0.2	<0.5	<4	69.0	<30	<10	<5	<3	21.0
13-Jul-95	12:36	0.00	4	nd	14.6	15.6	1.25	268	<0.2	<0.5	<4	56.0	<30	<10	<5	<3	25.0
13-Jul-95	12:46	0.00	5	nd	7.73	11.7	0.93	297	<0.2	<0.5	<4	56.0	<30	<10	<5	<3	21.0
13-Jul-95	13:01	0.00	6	nd	4.14	7.77	0.57	310	<0.2	<0.5	<4	56.0	<30	<10	<5	<3	25.0
13-Jul-95	13:16	0.00	7	nd	3.42	7.22	0.50	291	<0.2	<0.5	<4	42.0	<30	<10	<5	<3	21.0
13-Jul-95	18:12	0.00	8	nd	5.09	9.44	0.61	294	<0.2	<0.5	<4	42.0	<30	<10	<5	<3	28.0
13-Jul-95	18:27	0.00	9	nd	4.92	12.2	0.95	271	<0.2	<0.5	<4	139	<30	<10	<5	<3	39.0
13-Jul-95	18:42	0.00	10	nd	3.75	11.1	0.73	278	<0.2	<0.5	<4	56.0	<30	<10	<5	<3	32.0
13-Jul-95	22:51	0.00	11	nd	4.47	12.8	0.89	245	<0.2	<0.5	<4	42.0	<30	<10	<5	<3	25.0
13-Jul-95	23:06	0.00	12	nd	5.66	8.33	0.64	278	<0.2	<0.5	<4	42.0	<30	<10	<5	<3	21.0
13-Jul-95	23:21	0.00	13	nd	9.80	10.0	0.86	304	<0.2	<0.5	<4	42.0	<30	<10	<5	<3	21.0
13-Jul-95	23:36	0.00	14	nd	7.53	8.88	0.81	343	<0.2	<0.5	<4	42.0	<30	<10	<5	<3	28.0
13-Jul-95	23:51	0.00	15	nd	5.50	8.33	0.70	346	<0.2	<0.5	<4	42.0	<30	<10	<5	<3	21.0

nd = not determined. * Total rainfall recorded for July 11 was 0.25 mm

Phase III Water Quality Data Sheets for Filtered Runoff from the Palace Hotel

Date	Time	Rainfall (mm)	Sample #	NO_3-N (mg/l)	PO_4-P (mg/l)	Ca (mg/l)	Mg (mg/l)	Na (mg/l)	Ag (ug/l)	Cd (ug/l)	Cr (ug/l)	Cu (ug/l)	Fe (ug/l)	Mn (ug/l)	Ni (ug/l)	Pb (ug/l)	Zn (ug/l)
14-Jul-95	23:15	0.25															
14-Jul-95	23:16	0.00	1	nd	1.77	33.0	1.28	121	<0.2	<0.5	<4	42.0	<30	<10	<5	<3	94.0
14-Jul-95	23:20	0.00	2	nd	0.99	43.1	1.30	57.8	<0.2	<0.5	<4	42.0	<30	<10	<5	<3	80.0
14-Jul-95	23:25	0.00	3	nd	0.95	46.4	1.32	42.1	<0.2	<0.5	<4	42.0	<30	<10	<5	<3	56.0
14-Jul-95	23:30	0.25	4	nd	1.13	47.1	1.48	48.4	<0.2	<0.5	<4	42.0	<30	<10	<5	<3	46.0
14-Jul-95	23:40	0.00	5	nd	0.25	40.2	1.19	51.7	<0.2	<0.5	<4	42.0	<30	<10	<5	<3	42.0
14-Jul-95	23:54	0.25															
14-Jul-95	23:55	0.00	6	nd	0.48	38.4	1.28	87.9	<0.2	<0.5	<4	42.0	<30	<10	<5	<3	25.0
15-Jul-95	0:03	0.25															
15-Jul-95	0:10	0.00	7	nd	0.43	22.5	0.66	17.4	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	18.0
15-Jul-95	0:23	0.25															
15-Jul-95	0:25	0.00	8	nd	0.53	22.1	0.61	8.43	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	133
15-Jul-95	0:36	0.25															
15-Jul-95	0:40	0.00	9	nd	0.19	22.5	0.52	3.51	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	42.0
15-Jul-95	0:41	0.25															
15-Jul-95	0:55	0.00	10	nd	0.35	20.7	0.55	4.89	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	119
15-Jul-95	1:10	0.00	11	nd	0.43	25.4	0.64	6.56	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	283
15-Jul-95	1:21	0.25															
15-Jul-95	1:25	0.00	12	nd	0.52	27.9	0.75	8.12	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	388
15-Jul-95	1:40	0.00	13	nd	0.56	30.8	0.82	9.37	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	353
15-Jul-95	1:55	0.00	14	nd	0.41	34.4	0.90	7.50	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	227
15-Jul-95	2:09	0.25															
15-Jul-95	2:10	0.00	15	nd	0.39	30.8	0.90	6.25	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	140
15-Jul-95	2:25	0.00	16	nd	0.61	32.6	0.95	9.68	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	206
15-Jul-95	2:40	0.00	17	nd	0.73	31.9	0.93	16.3	<0.2	<0.5	<4	28.0	<30	<10	<5	<3	259
15-Jul-95	2:54	0.00	18	nd	0.82	31.2	0.97	22.1	<0.2	<0.5	<4	28.0	<30	<10	<5	<3	241
15-Jul-95	3:10	0.00	19	nd	0.89	30.8	0.95	24.7	<0.2	<0.5	<4	28.0	<30	<10	<5	<3	238
15-Jul-95	3:25	0.00	20	nd	0.99	30.8	0.95	28.9	<0.2	<0.5	<4	28.0	<30	<10	<5	<3	224
15-Jul-95	3:46	0.00	21	nd	1.05	33.3	1.04	34.7	<0.2	<0.5	<4	28.0	<30	<10	<5	<3	185
15-Jul-95	4:00	0.00	22	nd	1.14	33.3	1.01	38.9	<0.2	<0.5	<4	28.0	<30	<10	<5	<3	178
15-Jul-95	4:15	0.00	23	nd	0.96	36.6	1.10	34.2	<0.2	<0.5	<4	42.0	<30	<10	<5	<3	119
15-Jul-95	4:29	0.25															
15-Jul-95	4:30	0.00	24	nd	0.95	38.8	1.19	31.6	<0.2	<0.5	<4	28.0	<30	<10	<5	<3	112

nd = not determined

Phase III Water Quality Data Sheets for Filtered Runoff from the Palace Hotel

Date	Time	Rainfall (mm)	Sample #	NO_3-N (mg/l)	PO_4-P (mg/l)	Ca (mg/l)	Mg (mg/l)	Na (mg/l)	Ag (ug/l)	Cd (ug/l)	Cr (ug/l)	Cu (ug/l)	Fe (ug/l)	Mn (ug/l)	Ni (ug/l)	Pb (ug/l)	Zn (ug/l)
17-Jul-95	11:18	0.00	1	nd	nd	30.2	3.08	226	<0.2	<0.5	<4	308	<30	<10	<5	<3	159
17-Jul-95	11:23	0.00	2	nd	nd	38.4	3.61	223	<0.2	<0.5	<4	308	<30	<10	<5	<3	112
17-Jul-95	11:28	0.00	3	nd	nd	52.4	5.04	212	<0.2	<0.5	<4	246	<30	<10	5.5	<3	64.0
17-Jul-95	11:33	0.00	4	nd	nd	46.0	4.94	207	<0.2	<0.5	<4	92.0	<30	<10	<5	<3	7.00
17-Jul-95	13:17	0.51	5	nd	nd	13.0	0.68	12.7	<0.2	<0.5	<4	31.0	<30	<10	<5	<3	108
17-Jul-95	13:27	0.51	6	nd	nd	6.67	0.29	3.62	<0.2	<0.5	<4	31.0	<30	<10	<5	<3	47.0
17-Jul-95	13:41	0.25															
17-Jul-95	13:42	0.00	7	nd	nd	6.00	0.27	3.62	<0.2	<0.5	<4	31.0	<30	<10	<5	<3	135
17-Jul-95	13:44	0.25															
17-Jul-95	13:57	0.00	8	nd	nd	9.67	0.77	31.3	<0.2	<0.5	<4	31.0	<30	<10	<5	<3	68.0
17-Jul-95	17:15	0.00	9	nd	nd	26.0	1.29	30.8	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	7.00
18-Jul-95	3:47	0.25															
18-Jul-95	3:48	0.00	10	nd	nd	16.1	0.63	13.2	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	7.00
18-Jul-95	4:00	0.25															
18-Jul-95	4:03	0.00	11	nd	nd	9.67	0.39	4.90	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	14.0
18-Jul-95	4:17	0.25															
18-Jul-95	4:18	0.00	12	nd	nd	6.00	0.23	2.64	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	24.0
18-Jul-95	4:33	0.00	13	nd	nd	8.67	0.32	4.11	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	37.0
18-Jul-95	10:03	0.00	14	nd	nd	34.5	1.62	53.4	<0.2	<0.5	<4	92.0	<30	<10	<5	<3	44.0
18-Jul-95	10:18	0.00	15	nd	nd	10.3	2.09	183	<0.2	<0.5	<4	77.0	<30	<10	<5	<3	34.0
18-Jul-95	10:20	0.00	16	nd	nd	9.00	2.00	196	<0.2	<0.5	<4	62.0	<30	<10	<5	<3	24.0
New Data Set																	
18-Jul-95	11:06	0.00	1	nd	nd	14.3	0.97	118	<0.2	<0.5	<4	57.0	<30	<10	<5	<3	27.0
18-Jul-95	11:11	0.00	2	nd	nd	15.5	0.90	179	<0.2	<0.5	<4	71.0	<30	<10	<5	<3	37.0
18-Jul-95	11:16	0.00	3	nd	nd	8.82	0.45	170	<0.2	<0.5	<4	43.0	<30	<10	<5	<3	20.0
18-Jul-95	12:19	0.00	4	nd	nd	19.0	0.74	165	<0.2	<0.5	<4	57.0	<30	<10	<5	<3	30.0
18-Jul-95	12:24	0.00	5	nd	nd	43.9	1.63	210	<0.2	<0.5	<4	214	<30	<10	<5	<3	135
18-Jul-95	14:55	0.00	6	nd	nd	30.5	0.66	25.3	<0.2	<0.5	<4	29.0	<30	<10	<5	<3	24.0
18-Jul-95	15:05	0.00	7	nd	nd	25.0	1.03	48.3	<0.2	<0.5	<4	29.0	<30	<10	<5	<3	17.0
18-Jul-95	15:20	0.00	8	nd	nd	21.4	0.45	8.07	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	37.0
18-Jul-95	23:16	0.00	9	nd	nd	27.5	1.17	85.7	<0.2	<0.5	<4	29.0	<30	<10	<5	<3	14.0
18-Jul-95	23:31	0.00	10	nd	nd	32.2	0.76	22.5	<0.2	<0.5	<4	29.0	<30	<10	<5	<3	14.0
19-Jul-95	1:31	0.00	11	nd	nd	28.1	0.52	4.23	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	3.00
19-Jul-95	1:46	0.00	12	nd	nd	22.6	0.52	3.46	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	3.00
19-Jul-95	6:24	0.00	13	nd	nd	41.6	1.07	11.4	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	20.0
19-Jul-95	6:36	0.00	14	nd	nd	32.2	0.82	5.19	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	14.0

nd = not determined

Phase III Water Quality Data Sheets for Filtered Runoff from the Palace Hotel

Date	Time	Rainfall (mm)	Sample #	NO_3-N (mg/l)	PO_4-P (mg/l)	Ca (mg/l)	Mg (mg/l)	Na (mg/l)	Ag (ug/l)	Cd (ug/l)	Cr (ug/l)	Cu (ug/l)	Fe (ug/l)	Mn (ug/l)	Ni (ug/l)	Pb (ug/l)	Zn (ug/l)
19-Jul-95	11:56	0.25	1	nd	nd	13.0	0.19	4.65	<0.2	<0.5	<4	29.0	<30	<10	<5	<3	30.0
19-Jul-95	11:59	0.25															
19-Jul-95	12:01	0.00	2	nd	nd	17.4	0.85	21.9	<0.2	<0.5	<4	29.0	<30	<10	<5	<3	27.0
19-Jul-95	12:06	0.00	3	nd	nd	41.8	4.08	191	<0.2	<0.5	<4	71.0	<30	<10	<5	<3	3.00
19-Jul-95	12:11	0.00	4	nd	nd	59.3	13.5	157	<0.2	<0.5	<4	29.0	<30	50	19	<3	189
19-Jul-95	12:34	0.00	5	nd	nd	10.3	6.27	286	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	3.00
19-Jul-95	18:05	0.25															
19-Jul-95	22:43	0.00	6	nd	nd	13.6	0.86	25.1	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	115
19-Jul-95	22:53	0.00	7	nd	nd	27.7	1.63	15.4	<0.2	<0.5	<4	7.00	<30	20	<5	<3	179
19-Jul-95	23:08	0.00	8	nd	nd	12.0	0.23	8.92	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	41.0
20-Jul-95	1:29	0.25	9	nd	nd	16.3	0.18	3.27	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	3.00
20-Jul-95	1:30	0.25															
20-Jul-95	1:44	0.00	10	nd	nd	6.52	0.09	3.62	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	91.0
20-Jul-95	1:59	0.00	11	nd	nd	7.60	0.12	4.22	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	166
20-Jul-95	17:13	0.51	12	nd	nd	10.3	0.19	8.21	<0.2	<0.5	<4	29.0	<30	<10	<5	<3	149
20-Jul-95	17:23	0.25															
20-Jul-95	17:28	0.00	13	nd	nd	55.1	3.90	49.5	<0.2	<0.5	<4	29.0	<30	<10	<5	<3	47.0
20-Jul-95	17:43	0.00	14	nd	nd	29.9	1.42	12.7	<0.2	<0.5	<4	29.0	<30	<10	<5	<3	30.0
20-Jul-95	18:25	0.00	15	nd	nd	12.0	0.17	4.56	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	17.0
21-Jul-95	5:54	0.25															
21-Jul-95	7:47	0.00	16	nd	nd	11.4	0.22	14.9	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	44.0
21-Jul-95	8:03	0.25															
21-Jul-95	8:04	0.00	17	nd	nd	15.2	0.14	4.31	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	14.0
21-Jul-95	8:06	0.25															
21-Jul-95	8:19	0.00	18	nd	nd	8.69	0.11	3.87	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	24.0
21-Jul-95	8:53	0.00	19	nd	nd	16.3	0.19	4.91	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	27.0
21-Jul-95	11:33	0.25	20	nd	nd	12.0	0.20	9.28	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	27.0
21-Jul-95	11:35	0.25															
21-Jul-95	11:48	0.00	21	nd	nd	9.78	0.17	8.21	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	44.0
21-Jul-95	14:51	0.25															
21-Jul-95	14:54	0.00	22	nd	nd	15.2	0.13	2.32	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	3.00
21-Jul-95	15:01	0.25															
21-Jul-95	15:09	0.00	23	nd	nd	16.8	0.21	3.87	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	27.0
21-Jul-95	15:24	0.00	24	nd	nd	16.8	0.16	3.62	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	34.0

nd = not determined

Phase III Water Quality Data Sheets for Filtered Runoff from the Palace Hotel

Date	Time	Rainfall (mm)	Sample #	NO_3-N (mg/l)	PO_4-P (mg/l)	Ca (mg/l)	Mg (mg/l)	Na (mg/l)	Ag (ug/l)	Cd (ug/l)	Cr (ug/l)	Cu (ug/l)	Fe (ug/l)	Mn (ug/l)	Ni (ug/l)	Pb (ug/l)	Zn (ug/l)
24-Jul-95	18:17	0.25	1	nd	nd	17.2	0.52	3.79	<0.2	<0.5	<4	7.00	<30	30	<5	<3	11.0
24-Jul-95	18:21	0.25															
24-Jul-95	18:22	0.00	2	nd	nd	13.3	0.35	0.41	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	36.0
24-Jul-95	18:27	0.00	3	nd	nd	11.2	0.72	39.1	<0.2	<0.5	<4	29.0	<30	<10	<5	<3	39.0
24-Jul-95	18:32	0.00	4	nd	nd	8.90	0.35	4.08	<0.2	<0.5	<4	29.0	<30	<10	<5	<3	164
24-Jul-95	18:42	0.00	5	nd	nd	9.79	0.42	3.77	<0.2	<0.5	<4	29.0	<30	<10	<5	<3	289
24-Jul-95	20:04	0.00	6	nd	nd	15.7	0.75	9.23	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	4.00
24-Jul-95	21:15	0.76	7	nd	nd	15.5	0.40	3.77	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	7.00
24-Jul-95	21:23	0.25															
24-Jul-95	21:30	0.00	8	nd	nd	7.60	0.28	2.85	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	366
24-Jul-95	21:44	0.25															
24-Jul-95	21:45	0.00	9	nd	nd	12.1	0.45	2.65	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	11.0
24-Jul-95	22:00	0.00	10	nd	nd	13.8	0.60	3.46	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	46.0
24-Jul-95	22:12	0.00	11	nd	nd	14.5	0.65	4.69	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	236
25-Jul-95	15:35	0.25	12	nd	nd	21.4	1.11	22.7	<0.2	<0.5	<4	29.0	<30	<10	<5	<3	14.0
25-Jul-95	15:40	0.25															
25-Jul-95	15:50	0.00	13	nd	nd	7.96	0.30	3.06	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	64.0
25-Jul-95	16:05	0.00	14	nd	nd	9.27	0.38	3.16	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	146
26-Jul-95	10:53	0.00	15	nd	nd	78.5	4.22	23.9	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	7.00
26-Jul-95	11:11	0.00	16	nd	nd	79.0	4.39	23.9	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	14.0
26-Jul-95	14:09	0.00	17	nd	nd	37.9	1.42	88.8	<0.2	<0.5	<4	29.0	<30	<10	<5	<3	29.0
26-Jul-95	14:24	0.00	18	nd	nd	24.6	1.13	129	<0.2	<0.5	<4	29.0	<30	<10	<5	<3	36.0
26-Jul-95	15:22	0.00	19	nd	nd	18.9	1.00	234	<0.2	<0.5	<4	100	<30	<10	<5	<3	139
26-Jul-95	15:37	0.00	20	nd	nd	13.3	0.68	271	<0.2	<0.5	<4	86.0	<30	<10	<5	<3	79.0
26-Jul-95	15:52	0.00	21	nd	nd	9.68	0.52	286	<0.2	<0.5	<4	71.0	<30	<10	<5	<3	57.0
26-Jul-95	18:01	0.00	22	nd	nd	17.8	1.04	258	<0.2	<0.5	<4	100	<30	<10	<5	<3	46.0
26-Jul-95	19:34	0.00	23	nd	nd	11.6	0.72	274	<0.2	<0.5	<4	71.0	<30	<10	<5	<3	39.0
26-Jul-95	19:49	0.00	24	nd	nd	10.1	0.65	283	<0.2	<0.5	<4	71.0	<30	<10	<5	<3	39.0

nd = not determined

Phase III Water Quality Data Sheets for Filtered Runoff from the Palace Hotel

Date	Time	Rainfall (mm)	Sample #	NO_3-N (mg/l)	PO_4-P (mg/l)	Ca (mg/l)	Mg (mg/l)	Na (mg/l)	Ag (ug/l)	Cd (ug/l)	Cr (ug/l)	Cu (ug/l)	Fe (ug/l)	Mn (ug/l)	Ni (ug/l)	Pb (ug/l)	Zn (ug/l)
27-Jul-95	9:22	0.00	1	nd	nd	34.4	1.14	212	<0.2	<0.5	<4	71.0	<30	<10	<5	<3	29.0
27-Jul-95	9:26	0.00	2	nd	nd	9.02	0.29	217	<0.2	<0.5	<4	100	<30	<10	<5	<3	7.00
27-Jul-95	9:32	0.00	3	nd	nd	7.84	0.29	209	<0.2	<0.5	<4	86.0	<30	<10	<5	<3	7.00
27-Jul-95	9:37	0.00	4	nd	nd	9.51	0.27	225	<0.2	<0.5	<4	100	<30	<10	<5	<3	11.0
27-Jul-95	9:47	0.00	5	nd	nd	8.72	0.29	212	<0.2	<0.5	<4	29.0	<30	<10	<5	<3	2.00
27-Jul-95	9:57	0.00	6	nd	nd	9.51	0.29	203	<0.2	<0.5	<4	100	<30	<10	<5	<3	18.0
27-Jul-95	10:12	0.00	7	nd	nd	9.90	0.31	187	<0.2	<0.5	<4	86.0	<30	<10	<5	<3	29.0
27-Jul-95	10:27	0.00	8	nd	nd	11.0	0.31	181	<0.2	<0.5	<4	86.0	<30	<10	<5	<3	4.00
27-Jul-95	10:42	0.00	9	nd	nd	11.0	0.31	162	<0.2	<0.5	<4	71.0	<30	<10	<5	<3	4.00
27-Jul-95	10:57	0.00	10	nd	nd	11.3	0.31	182	<0.2	<0.5	<4	71.0	<30	<10	<5	<3	7.00
27-Jul-95	11:12	0.00	11	nd	nd	12.2	0.31	177	<0.2	<0.5	<4	71.0	<30	<10	<5	<3	11.0
27-Jul-95	11:27	0.00	12	nd	nd	13.3	0.38	166	<0.2	<0.5	<4	71.0	<30	<10	<5	<3	14.0
27-Jul-95	11:42	0.00	13	nd	nd	12.1	0.34	159	<0.2	<0.5	<4	71.0	<30	<10	<5	<3	7.00
27-Jul-95	11:57	0.00	14	nd	nd	11.4	0.31	161	<0.2	<0.5	<4	29.0	<30	<10	<5	<3	7.00
27-Jul-95	12:12	0.00	15	nd	nd	11.4	0.31	154	<0.2	<0.5	<4	29.0	<30	<10	<5	<3	7.00
27-Jul-95	12:39	0.00	16	nd	nd	11.8	0.31	154	<0.2	<0.5	<4	29.0	<30	<10	<5	<3	14.0
27-Jul-95	12:54	0.00	17	nd	nd	16.5	0.49	166	<0.2	<0.5	<4	114	<30	<10	<5	<3	21.0
27-Jul-95	13:09	0.00	18	nd	nd	18.8	0.60	190	<0.2	<0.5	<4	143	<30	<10	<5	<3	36.0
27-Jul-95	13:24	0.00	19	nd	nd	18.1	0.58	196	<0.2	<0.5	<4	114	<30	<10	<5	<3	36.0
27-Jul-95	13:39	0.00	20	nd	nd	39.4	1.34	171	<0.2	<0.5	<4	57.0	<30	<10	<5	<3	25.0
27-Jul-95	13:54	0.00	21	nd	nd	45.2	1.66	159	<0.2	<0.5	<4	71.0	<30	<10	<5	<3	14.0
27-Jul-95	14:33	0.00	22	nd	nd	47.2	1.63	162	<0.2	<0.5	<4	86.0	<30	<10	<5	<3	32.0
27-Jul-95	14:48	0.00	23	nd	nd	43.4	1.50	171	<0.2	<0.5	<4	86.0	<30	<10	<5	<3	18.0
27-Jul-95	15:03	0.00	24	nd	nd	39.6	1.28	168	<0.2	<0.5	<4	71.0	<30	<10	<5	<3	18.0

nd = not determined

Phase III Water Quality Data Sheets for Filtered Runoff from the Palace Hotel

Date	Time	Rainfall (mm)	Sample #	NO_3-N (mg/l)	PO_4-P (mg/l)	Ca (mg/l)	Mg (mg/l)	Na (mg/l)	Ag (ug/l)	Cd (ug/l)	Cr (ug/l)	Cu (ug/l)	Fe (ug/l)	Mn (ug/l)	Ni (ug/l)	Pb (ug/l)	Zn (ug/l)
29-Jul-95	2:42	0.25	1	nd	nd	40.0	0.62	12.1	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	146
29-Jul-95	2:46	0.25															
29-Jul-95	2:47	0.00	2	nd	nd	34.3	0.53	18.5	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	82.0
29-Jul-95	2:52	0.00	3	nd	nd	34.3	0.55	4.48	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	39.0
29-Jul-95	2:57	0.00	4	nd	nd	25.8	0.50	80.8	<0.2	<0.5	<4	29.0	<30	<10	<5	<3	21.0
29-Jul-95	3:07	0.00	5	nd	nd	32.9	0.60	18.0	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	68.0
29-Jul-95	3:31	0.25	6	nd	nd	47.9	0.53	4.05	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	43.0
29-Jul-95	3:46	0.00	7	nd	nd	31.4	0.53	6.56	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	154
29-Jul-95	4:01	0.00	8	nd	nd	37.1	0.63	11.6	<0.2	<0.5	<4	29.0	<30	<10	<5	<3	111
29-Jul-95	23:56	0.00	9	nd	nd	77.7	1.89	102	<0.2	<0.5	<4	57.0	<30	<10	<5	<3	64.0
30-Jul-95	0:49	0.25															
30-Jul-95	0:53	0.00	10	nd	nd	37.1	0.68	47.9	<0.2	<0.5	<4	29.0	<30	<10	<5	<3	18.0
30-Jul-95	1:08	0.00	11	nd	nd	54.7	0.93	29.2	<0.2	<0.5	<4	29.0	<30	<10	<5	<3	39.0
30-Jul-95	1:23	0.00	12	nd	nd	50.7	1.02	26.0	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	18.0
30-Jul-95	1:38	0.00	13	nd	nd	64.2	1.42	47.9	<0.2	<0.5	<4	29.0	<30	<10	<5	<3	18.0
30-Jul-95	2:25	0.25															
30-Jul-95	2:32	0.00	14	nd	nd	47.1	0.93	89.4	<0.2	<0.5	<4	29.0	<30	<10	<5	<3	14.0
30-Jul-95	2:47	0.00	15	nd	nd	50.7	0.84	24.4	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	14.0
30-Jul-95	3:02	0.00	16	nd	nd	53.4	1.00	10.0	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	21.0
30-Jul-95	3:17	0.00	17	nd	nd	54.7	1.08	22.3	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	21.0
30-Jul-95	9:17	0.00	18	nd	nd	69.6	1.69	46.3	<0.2	<0.5	<4	29.0	<30	<10	<5	<3	29.0
30-Jul-95	21:39	0.25															
30-Jul-95	21:40	0.00	19	nd	nd	89.1	1.85	10.0	<0.2	<0.5	<4	7.00	<30	40	<5	<3	1644
30-Jul-95	22:09	0.25															
30-Jul-95	22:10	0.00	21	nd	nd	29.3	0.53	4.65	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	57.0
30-Jul-95	22:25	0.00	22	nd	nd	27.3	0.48	19.1	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	236
30-Jul-95	22:40	0.00	23	nd	nd	28.6	0.63	76.9	<0.2	<0.5	<4	57.0	<30	<10	<5	<3	104
30-Jul-95	22:55	0.00	24	nd	nd	32.1	0.68	77.9	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	107

nd = not determined

Phase III Water Quality Data Sheets for Filtered Runoff from the Palace Hotel

Date	Time	Rainfall (mm)	Sample #	NO$_3$-N (mg/l)	PO$_4$-P (mg/l)	Ca (mg/l)	Mg (mg/l)	Na (mg/l)	Ag (ug/l)	Cd (ug/l)	Cr (ug/l)	Cu (ug/l)	Fe (ug/l)	Mn (ug/l)	Ni (ug/l)	Pb (ug/l)	Zn (ug/l)
1-Aug-95	9:40	0.25	1	nd	nd	21.4	1.20	9.68	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	407
1-Aug-95	9:43	0.25															
1-Aug-95	9:45	0.00	2	nd	nd	16.1	0.79	5.00	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	737
1-Aug-95	9:50	0.00	3	nd	nd	13.7	0.60	4.83	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	218
1-Aug-95	9:55	0.00	4	nd	nd	14.9	0.64	5.93	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	293
2-Aug-95	8:35	0.25															
2-Aug-95	8:40	0.00	5	nd	nd	16.1	0.68	7.50	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	104
2-Aug-95	8:48	0.25															
2-Aug-95	8:50	0.00	6	nd	nd	19.6	0.94	16.2	<0.2	<0.5	<4	29.0	<30	<10	<5	<3	318
2-Aug-95	9:05	0.00	7	nd	nd	23.8	1.55	112	<0.2	<0.5	<4	57.0	<30	<10	<5	<3	100
2-Aug-95	9:20	0.00	8	nd	nd	10.0	0.62	274	<0.2	<0.5	<4	86.0	<30	<10	<5	<3	43.0
2-Aug-95	21:42	0.25	9	nd	nd	10.1	0.31	8.12	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	11.0
2-Aug-95	21:54	0.25															
2-Aug-95	21:57	0.00	10	nd	nd	6.00	0.20	1.89	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	104
2-Aug-95	21:58	0.25															
2-Aug-95	22:12	0.00	11	nd	nd	6.67	0.18	2.67	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	57.0
2-Aug-95	22:27	0.00	12	nd	nd	7.33	0.25	2.67	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	93.0
2-Aug-95	22:42	0.00	13	nd	nd	8.00	0.25	3.79	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	43.0
2-Aug-95	22:57	0.00	14	nd	nd	9.33	0.34	3.44	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	50.0
3-Aug-95	0:09	0.00	15	nd	nd	6.67	0.20	17.8	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	50.0
3-Aug-95	0:24	0.00	16	nd	nd	12.5	0.38	34.9	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	68.0
3-Aug-95	0:39	0.00	17	nd	nd	10.7	0.27	2.24	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	2.00
3-Aug-95	11:38	1.02	18	nd	nd	7.33	0.31	72.3	<0.2	<0.5	<4	71.0	<30	<10	<5	<3	75.0
3-Aug-95	11:53	0.25	19	nd	nd	6.67	0.22	5.93	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	39.0
3-Aug-95	12:08	0.25	20	nd	nd	16.7	1.06	75.9	<0.2	<0.5	<4	71.0	<30	<10	<5	<3	50.0
3-Aug-95	12:23	0.25	21	nd	nd	46.1	3.33	79.5	<0.2	<0.5	<4	43.0	<30	50	<5	<3	282
3-Aug-95	12:37	0.25															
3-Aug-95	12:38	0.00	22	nd	nd	17.9	1.00	84.8	<0.2	<0.5	<4	43.0	<30	<10	<5	<3	29.0
3-Aug-95	12:42	0.25															
3-Aug-95	12:53	0.00	23	nd	nd	14.9	0.79	94.6	<0.2	<0.5	<4	29.0	<30	<10	<5	<3	21.0
3-Aug-95	13:08	0.25	24	nd	nd	15.5	0.64	14.2	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	25.0

nd = not determined

Phase III Water Quality Data Sheets for Filtered Runoff from the Palace Hotel

Date	Time	Rainfall (mm)	Sample #	NO_3-N (mg/l)	PO_4-P (mg/l)	Ca (mg/l)	Mg (mg/l)	Na (mg/l)	Ag (ug/l)	Cd (ug/l)	Cr (ug/l)	Cu (ug/l)	Fe (ug/l)	Mn (ug/l)	Ni (ug/l)	Pb (ug/l)	Zn (ug/l)
4-Aug-95	10:48	0.51	1	nd	nd	21.3	0.57	10.0	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	52.0
4-Aug-95	10:53	0.00	2	nd	nd	14.2	0.32	3.79	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	17.0
4-Aug-95	10:58	0.00	3	nd	nd	22.0	0.72	21.3	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	59.0
4-Aug-95	11:03	0.00	4	nd	nd	12.8	0.37	5.37	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	34.0
4-Aug-95	11:17	0.25	5	nd	nd	17.6	0.47	5.74	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	66.0
4-Aug-95	11:23	0.25															
4-Aug-95	11:27	0.00	6	nd	nd	14.5	0.42	5.74	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	52.0
4-Aug-95	11:35	0.25															
4-Aug-95	11:42	0.00	7	nd	nd	16.6	0.45	9.44	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	38.0
4-Aug-95	13:39	0.25	8	nd	nd	19.3	0.40	3.92	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	10.0
4-Aug-95	13:54	0.51	9	nd	nd	10.0	0.15	1.32	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	14.0
4-Aug-95	14:06	0.25															
4-Aug-95	14:09	0.00	10	nd	nd	10.4	0.22	3.22	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	21.0
4-Aug-95	14:24	0.25	11	nd	nd	14.5	0.45	4.87	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	38.0
4-Aug-95	14:34	0.25															
4-Aug-95	14:39	0.00	12	nd	nd	15.9	0.42	4.68	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	28.0
4-Aug-95	14:52	0.25															
4-Aug-95	14:54	0.00	13	nd	nd	14.2	0.35	4.17	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	24.0
4-Aug-95	15:06	0.25															
4-Aug-95	15:09	0.00	14	nd	nd	14.5	0.40	4.49	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	41.0
4-Aug-95	15:24	0.25	15	nd	nd	17.9	0.52	4.93	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	38.0
4-Aug-95	15:39	0.00	16	nd	nd	23.3	0.67	8.51	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	48.0
4-Aug-95	15:54	0.00	17	nd	nd	26.0	0.70	9.25	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	38.0
4-Aug-95	16:03	0.25															
4-Aug-95	16:09	0.00	18	nd	nd	27.4	0.72	9.25	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	38.0
4-Aug-95	16:21	0.25															
4-Aug-95	16:24	0.00	19	nd	nd	25.7	0.67	8.14	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	28.0
4-Aug-95	16:39	0.00	20	nd	nd	23.6	0.65	7.22	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	28.0
4-Aug-95	16:54	0.00	21	nd	nd	25.3	0.77	10.0	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	55.0
4-Aug-95	17:09	0.00	22	nd	nd	27.7	0.75	10.6	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	59.0
4-Aug-95	23:34	0.00	23	nd	nd	40.2	1.27	44.2	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	45.0
6-Aug-95	17:55	0.51	24	nd	nd	19.3	0.55	4.62	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	10.0

nd = not determined

Phase III Water Quality Data Sheets for Filtered Runoff from the Palace Hotel

Date	Time	Rainfall (mm)	Sample #	NO$_3$-N (mg/l)	PO$_4$-P (mg/l)	Ca (mg/l)	Mg (mg/l)	Na (mg/l)	Ag (ug/l)	Cd (ug/l)	Cr (ug/l)	Cu (ug/l)	Fe (ug/l)	Mn (ug/l)	Ni (ug/l)	Pb (ug/l)	Zn (ug/l)
7-Aug-95	20:37	0.25															
7-Aug-95	20:49	0.00	1	nd	nd	66.1	1.06	113	<0.2	<0.5	<4	46.0	<30	<10	<5	<3	4.00
7-Aug-95	20:54	0.00	2	nd	nd	64.1	1.02	45.2	<0.2	<0.5	<4	7.00	73	<10	<5	<3	55.0
7-Aug-95	20:59	0.00	3	nd	nd	62.0	0.82	27.0	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	69.0
7-Aug-95	22:07	0.51	4	nd	nd	25.0	0.30	8.25	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	21.0
7-Aug-95	22:12	0.76	5	nd	nd	19.9	0.20	1.69	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	7.00
7-Aug-95	22:21	0.25															
7-Aug-95	22:22	0.00	6	nd	nd	16.2	0.17	1.96	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	21.0
7-Aug-95	22:37	0.00	7	nd	nd	20.6	0.28	61.6	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	14.0
7-Aug-95	22:52	0.00	8	nd	nd	30.7	0.41	42.1	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	24.0
7-Aug-95	23:07	0.00	9	nd	nd	40.9	0.57	35.0	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	31.0
8-Aug-95	9:43	0.25															
8-Aug-95	9:46	0.00	10	nd	nd	58.6	0.68	17.5	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	17.0
8-Aug-95	10:01	0.00	11	nd	nd	62.0	0.84	35.7	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	21.0
8-Aug-95	10:16	0.00	12	nd	nd	51.1	0.80	72.6	<0.2	<0.5	<4	62.0	<30	<10	<5	<3	55.0
9-Aug-95	5:08	0.25	13	nd	nd	27.9	0.39	8.50	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	7.00
9-Aug-95	5:14	0.25															
9-Aug-95	5:23	0.00	14	nd	nd	51.1	1.04	35.3	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	55.0
9-Aug-95	5:38	0.00	15	nd	nd	58.0	1.08	11.6	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	608
9-Aug-95	5:53	0.00	16	nd	nd	53.2	0.91	10.4	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	365
9-Aug-95	6:08	0.00	17	nd	nd	51.1	0.70	10.4	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	234
9-Aug-95	6:39	0.25															
9-Aug-95	6:41	0.00	18	nd	nd	49.1	0.70	7.25	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	69.0
9-Aug-95	6:56	0.00	19	nd	nd	41.6	0.52	4.55	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	38.0
9-Aug-95	7:11	0.00	20	nd	nd	40.2	0.55	8.50	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	107
9-Aug-95	7:26	0.00	21	nd	nd	43.6	0.59	12.4	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	93.0

nd = not determined

Phase III Water Quality Data Sheets for Filtered Runoff from the Palace Hotel

Date	Time	Rainfall (mm)	Sample #	NO_3-N (mg/l)	PO_4-P (mg/l)	Ca (mg/l)	Mg (mg/l)	Na (mg/l)	Ag (ug/l)	Cd (ug/l)	Cr (ug/l)	Cu (ug/l)	Fe (ug/l)	Mn (ug/l)	Ni (ug/l)	Pb (ug/l)	Zn (ug/l)
9-Aug-95	22:21	0.00	1	nd	nd	45.9	2.23	37.9	<0.2	<0.5	<4	29.0	<30	40	<5	<3	276
9-Aug-95	22:26	0.00	2	nd	nd	60.5	9.62	150	<0.2	<0.5	<4	43.0	<30	260	29.2	<3	2308
9-Aug-95	22:31	0.00	3	nd	nd	49.2	4.18	213	<0.2	<0.5	<4	43.0	<30	40	12.4	<3	110
9-Aug-95	22:36	0.00	4	nd	nd	38.2	2.14	250	<0.2	<0.5	<4	43.0	<30	<10	<5	<3	55.0
9-Aug-95	22:46	0.00	5	nd	nd	12.7	1.22	254	<0.2	<0.5	<4	43.0	<30	<10	<5	<3	28.0
9-Aug-95	23:01	0.00	6	nd	nd	18.7	0.95	263	<0.2	<0.5	<4	114	<30	<10	<5	<3	10.0
10-Aug-95	11:25	0.00	7	nd	nd	17.7	1.04	239	<0.2	<0.5	<4	214	<30	<10	<5	<3	38.0
10-Aug-95	11:40	0.00	8	nd	nd	30.3	2.01	181	<0.2	<0.5	<4	71.0	<30	<10	<5	<3	62.0
10-Aug-95	11:55	0.00	9	nd	nd	25.0	1.42	189	<0.2	<0.5	<4	57.0	<30	<10	<5	<3	7.00
10-Aug-95	12:10	0.00	10	nd	nd	18.7	1.04	194	<0.2	<0.5	<4	71.0	<30	<10	<5	<3	10.0
10-Aug-95	17:20	0.00	11	nd	nd	53.4	2.96	146	<0.2	<0.5	<4	86.0	<30	<10	<5	<3	4.00
10-Aug-95	17:35	0.00	12	nd	nd	19.2	2.48	158	<0.2	<0.5	<4	29.0	<30	<10	<5	<3	2.00
10-Aug-95	17:50	0.00	13	nd	nd	29.3	1.54	171	<0.2	<0.5	<4	43.0	<30	<10	<5	<3	7.00
10-Aug-95	18:05	0.00	14	nd	nd	25.3	1.36	168	<0.2	<0.5	<4	43.0	<30	<10	<5	<3	10.0
10-Aug-95	22:09	0.00	15	nd	nd	14.0	0.75	181	<0.2	<0.5	<4	57.0	<30	<10	<5	<3	7.00
10-Aug-95	22:24	0.00	16	nd	nd	11.0	0.56	194	<0.2	<0.5	<4	43.0	<30	<10	<5	<3	14.0
10-Aug-95	22:39	0.00	17	nd	nd	9.00	0.48	189	<0.2	<0.5	<4	43.0	<30	<10	<5	<3	14.0
10-Aug-95	22:54	0.00	18	nd	nd	9.33	0.48	189	<0.2	<0.5	<4	43.0	<30	<10	<5	<3	24.0
10-Aug-95	23:09	0.00	19	nd	nd	8.00	0.50	194	<0.2	<0.5	<4	57.0	<30	<10	<5	<3	31.0
11-Aug-95	1:59	0.00	20	nd	nd	10.3	0.48	189	<0.2	<0.5	<4	71.0	<30	<10	<5	<3	69.0
11-Aug-95	2:14	0.00	21	nd	nd	38.2	3.08	74.54	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	66.0
11-Aug-95	2:29	0.00	22	nd	nd	31.7	1.38	157	<0.2	<0.5	<4	57.0	<30	<10	<5	<3	55.0
11-Aug-95	2:44	0.00	23	nd	nd	35.3	1.58	142	<0.2	<0.5	<4	43.0	<30	<10	<5	<3	41.0

nd = not determined

Phase III Water Quality Data Sheets for Filtered Runoff from the Palace Hotel

Date	Time	Rainfall (mm)	Sample #	NO$_3$-N (mg/l)	PO$_4$-P (mg/l)	Ca (mg/l)	Mg (mg/l)	Na (mg/l)	Ag (ug/l)	Cd (ug/l)	Cr (ug/l)	Cu (ug/l)	Fe (ug/l)	Mn (ug/l)	Ni (ug/l)	Pb (ug/l)	Zn (ug/l)
11-Aug-95	12:34	0.76	1	nd	nd	24.2	0.55	7.41	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	14.0
11-Aug-95	12:39	0.51	2	nd	nd	16.7	0.21	1.91	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	14.0
11-Aug-95	12:41	0.25															
11-Aug-95	12:44	0.00	3	nd	nd	11.1	0.19	28.7	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	69.0
11-Aug-95	12:49	0.00	4	nd	nd	10.2	0.20	7.58	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	397
11-Aug-95	12:59	0.00	5	nd	nd	11.1	0.23	6.12	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	473
11-Aug-95	13:14	0.00	6	nd	nd	13.9	0.30	9.67	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	454
11-Aug-95	18:25	0.00	7	nd	nd	95.4	6.63	49.1	<0.2	<0.5	<4	71.0	<30	160	9	<3	2858
11-Aug-95	22:03	0.00	8	nd	nd	31.5	1.53	183	<0.2	<0.5	<4	57.0	<30	20	<5	<3	159
11-Aug-95	22:18	0.00	9	nd	nd	12.0	0.68	135	<0.2	<0.5	<4	43.0	<30	<10	<5	<3	41.0
12-Aug-95	1:30	0.25															
12-Aug-95	1:32	0.00	10	nd	nd	25.0	0.82	22.7	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	86.0
12-Aug-95	1:40	0.25															
12-Aug-95	1:47	0.00	11	nd	nd	22.2	nd	84.0	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	62.0
12-Aug-95	2:02	0.00	12	nd	nd	20.4	0.61	8.54	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	166
12-Aug-95	2:03	0.25															
12-Aug-95	2:17	0.00	13	nd	nd	22.7	0.70	4.94	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	107
12-Aug-95	2:23	0.25															
12-Aug-95	2:32	0.00	14	nd	nd	23.6	0.71	4.38	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	103
12-Aug-95	2:37	0.25															
12-Aug-95	2:47	0.00	15	nd	nd	23.1	0.71	4.71	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	100
12-Aug-95	2:50	0.25															
12-Aug-95	3:02	0.00	16	nd	nd	22.2	0.66	4.71	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	79.0
12-Aug-95	3:16	0.25															
12-Aug-95	3:17	0.00	17	nd	nd	21.8	0.66	4.32	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	69.0
12-Aug-95	3:31	0.25															
12-Aug-95	3:32	0.00	18	nd	nd	22.7	0.66	4.38	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	83.0
12-Aug-95	3:47	0.00	19	nd	nd	22.7	0.69	4.60	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	90.0
12-Aug-95	3:59	0.25															
12-Aug-95	4:02	0.00	20	nd	nd	24.1	0.72	4.94	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	97.0
12-Aug-95	4:17	0.00	21	nd	nd	25.0	0.76	4.83	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	100
12-Aug-95	4:32	0.00	22	nd	nd	26.9	0.79	5.32	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	93.0
12-Aug-95	4:47	0.00	23	nd	nd	26.9	0.84	6.45	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	86.0
12-Aug-95	5:02	0.00	24	nd	nd	27.3	0.89	6.77	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	83.0

nd = not determined

Phase III Water Quality Data Sheets for Filtered Runoff from the Palace Hotel

Date	Time	Rainfall (mm)	Sample #	NO_3-N (mg/l)	PO_4-P (mg/l)	Ca (mg/l)	Mg (mg/l)	Na (mg/l)	Ag (ug/l)	Cd (ug/l)	Cr (ug/l)	Cu (ug/l)	Fe (ug/l)	Mn (ug/l)	Ni (ug/l)	Pb (ug/l)	Zn (ug/l)
14-Aug-95	22:56	0.00	1	nd	nd	30.2	1.90	188	<0.2	<0.5	<4	83.0	<30	<10	<5	<3	98.0
14-Aug-95	23:01	0.00	2	nd	nd	24.4	1.41	179	<0.2	<0.5	<4	67.0	<30	<10	<5	<3	62.0
14-Aug-95	23:06	0.00	3	nd	nd	22.9	1.30	180	<0.2	<0.5	<4	67.0	<30	<10	<5	<3	44.0
14-Aug-95	23:11	0.00	4	nd	nd	28.3	1.28	171	<0.2	<0.5	<4	67.0	<30	<10	<5	<3	55.0
14-Aug-95	23:21	0.00	5	nd	nd	43.4	2.25	148	<0.2	<0.5	<4	67.0	<30	<10	<5	<3	36.0
15-Aug-95	1:02	1.02	6	nd	nd	20.3	0.65	10.6	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	2.00
15-Aug-95	1:05	0.25															
15-Aug-95	1:17	0.00	7	nd	nd	13.7	0.57	37.6	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	22.0
15-Aug-95	1:20	0.25															
15-Aug-95	1:32	0.00	8	nd	nd	18.4	0.75	8.07	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	84.0
15-Aug-95	1:47	0.00	9	nd	nd	19.3	0.90	10.6	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	156
15-Aug-95	2:02	0.00	10	nd	nd	20.8	0.95	14.7	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	204
15-Aug-95	2:17	0.00	11	nd	nd	21.7	1.02	16.5	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	229
15-Aug-95	2:32	0.00	12	nd	nd	23.1	1.10	17.6	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	218
15-Aug-95	10:35	0.00	13	nd	nd	25.2	1.56	40.6	<0.2	<0.5	<4	117	<30	<10	<5	<3	189
15-Aug-95	10:50	0.00	14	nd	nd	11.8	0.67	256	<0.2	<0.5	<4	117	<30	<10	<5	<3	51.0
15-Aug-95	11:05	0.00	15	nd	nd	7.36	0.40	337	<0.2	<0.5	<4	150	<30	<10	<5	<3	65.0
15-Aug-95	11:20	0.00	16	nd	nd	6.84	0.32	354	<0.2	<0.5	<4	150	<30	<10	<5	<3	58.0
15-Aug-95	14:08	0.25	17	nd	nd	18.4	1.02	31.2	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	2.00
15-Aug-95	14:22	0.25															
15-Aug-95	14:23	0.00	18	nd	nd	7.36	0.32	4.30	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	200
15-Aug-95	14:38	0.51	19	nd	nd	9.47	0.45	40.6	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	29.0
15-Aug-95	14:53	0.25	20	nd	nd	10.5	0.50	6.53	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	11.0
15-Aug-95	15:03	0.25															
15-Aug-95	15:08	0.00	21	nd	nd	10.5	0.45	6.92	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	55.0
15-Aug-95	15:19	0.25															
15-Aug-95	15:23	0.00	22	nd	nd	11.3	0.55	5.00	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	47.0
15-Aug-95	15:30	0.25															
15-Aug-95	15:38	0.00	23	nd	nd	15.6	0.75	4.72	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	36.0
15-Aug-95	15:53	0.00	24	nd	nd	16.5	0.82	6.53	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	58.0
New Data Set																	
8-Sep-95	1:13	0.25	1	nd	nd	27.8	0.62	23.46	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	80.0
8-Sep-95	1:16	0.25															
8-Sep-95	1:18	0.00	2	nd	nd	18.8	0.40	3.92	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	36.0
8-Sep-95	1:22	0.25															
8-Sep-95	1:23	0.00	3	nd	nd	21.6	0.71	8.57	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	192
8-Sep-95	0:00	0.00	4	nd	nd	18.2	0.44	6.19	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	80.0
8-Sep-95	1:38	0.00	5	nd	nd	21.6	0.64	7.61	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	44.0
8-Sep-95	7:19	0.25	6	nd	nd	19.9	0.51	30.0	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	18.0
8-Sep-95	7:31	0.25															
8-Sep-95	7:33	0.00	7	nd	nd	16.5	0.42	9.76	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	25.0
8-Sep-95	7:48	0.00	8	nd	nd	20.5	0.51	5.47	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	47.0
8-Sep-95	9:09	0.25	9	nd	nd	16.5	0.38	3.03	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	15.0
8-Sep-95	9:23	0.00	10	nd	nd	14.2	0.33	10.4	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	25.0
8-Sep-95	9:38	0.00	11	nd	nd	16.5	0.40	7.14	<0.2	<0.5	<4	7.00	<30	<10	<5	<3	22.0

nd = not determined