INTERNATIONAL JOINT COMMISSION

MENOMONEE RIVER
PILOT WATERSHED STUDY

SEMI-ANNUAL REPORT

COOPERATING AGENCIES

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POLLUTION FROM LAND USE
ACTIVITIES REFERENCE GROUP

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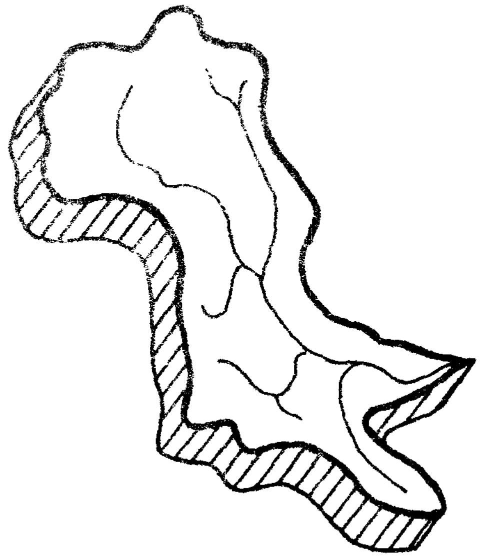

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SUMMARY - SEMI-ANNUAL REPORT

Introduction

The International Joint Commission, through the Great Lakes Water Quality Board, established the International Reference Group on Great Lakes Pollution from Land Use Activities (PLUARG) to study and report the effects of land use on water quality. The "Task C" assignment requires the detailed investigation of six major watersheds in Canada and the United States, which are representative of the full range of urban and rural land uses found in the Great Lakes basin. The Menomonee River watershed is serving as the focus of investigation on the impact of urban land uses on water quality and as the site for studying the effects of rapidly changing land use patterns in an urban setting. The data will be used to extrapolate the effects of urban land use on the water quality of the Great Lakes.

The specific objectives of the Menomonee River Pilot Watershed Study are:

1. To determine the levels and quantities of major and trace constituents including, but not limited to, nutrients, pesticides and sediments reaching or moving in flow systems likely to reach Lake Michigan.
2. To define the sources and evaluate the behavior of pollutants for a metropolitan complex with particular emphasis on the impact of residential and industrial, including utility facilities, transportational, recreational, agricultural and constructional activities associated with rapid urbanization.
3. To develop the predictive capability necessary to facilitate extension of the findings from the Menomonee River Watershed Study to other urban settings, leading to an eventual goal of integrating pollution inputs from urban sources to the entire Great Lakes basin.

This report will review the progress toward achieving the specific objectives of the study since the October 1975 semi-annual report.

Progress

The river monitoring activities continued to accomplish the goals of the first objective. The field activities included baseline river surveys and monitoring of runoff events. Regular baseline river surveys for nutrients, total alkalinity, hardness, chloride, color, total dissolved solids, suspended solids, suspended volatile solids and total organic carbon were conducted once a week at the 12 automatic stations and 2 grab stations. Regular baseline river survey sampling frequency increased to twice a week during spring melt and will decrease to twice a month beginning in April. Preliminary plots of baseline, total P and (nitrate + nitrite)-N concentrations from the 1975 field year indicated increasing concentrations during periods of high flow and many of the remaining values were within a relatively narrow range. Further interpretation awaits statistical and graphical analysis of all the baseline data. Simultaneous grab samples and comparison samples were obtained during the regular baseline river surveys for quality control purposes. In general, the quality control data indicated that the sampling program was providing accurate data. Data from the September 3, 1975 baseline quarterly metal survey and September 9, 1975 baseline quarterly organic compound survey were compiled. The metal concentrations tend to increase below the Underwood Creek station (413007) which was the same trend observed for the June 25, 1975 metal survey. As in the June 9, 1975 organic survey, most of the organic concentrations for the June 11, 1975 organic survey were below detection limits. Biweekly baseline water sampling continued at three bridge sites located in the estuary area of the river. Continuous *in situ* electronic monitoring of temperature, dissolved oxygen, conductivity and pH continued at five of the automatic stations. The United States Geological Survey (USGS) continued monitoring discharge at 11 automatic stations, precipitation at 7 automatic stations and sediment concentration at all the automatic stations. The 1975 water-year discharge records were completed, and the sediment records from 1975 are almost completed. Water quality surveys were conducted at the Germantown waste treatment facility and at the City of Menomonee Falls--Parkside and Parkview waste treatment facilities. Biological monitoring was begun at 5 automatic stations, and samples will be analyzed for macroinvertebrates and periphyton community composition. Biological samples are collected on six suspended, modified Hester-Dendy samplers made of Masonite and Conservation Webbing. Besides the water quality river surveys, the yearly macrobenthic survey was undertaken on November 3, 4 and 5, 1975.

Collection of water quality samples during runoff events continued as an important part of the river monitoring activities. Since October 1975, six runoff events were sampled for regular baseline river survey parameters (nutrient, etc.) at four stations (413005, 413010, 413011 and 463001). Event data that have already been summarized indicated that the concentration of total P, total Kjeldahl N, total and suspended solids usually increased during a runoff event. The change in nutrients and solids concentrations coincided, most often, with changes in the hydrograph and the concentrations were substantially higher than baseline values. Metal concentrations also increased during runoff events and reached concentrations substantially higher than those of the baseline quarterly survey samples. The events on August 20, 1975 and November 29 through December 1, 1975 have been monitored for metals. In contrast to concentration trends for metals and nutrients during events, the concentration of organic components measured during the November 20 - 21, 1975 event did not increase and were below the limits of detection for the methods used. Quarterly monitoring for organic components and metals will continue during runoff events. The stations chosen for event sampling will be rotated to obtain seasonal runoff data of all the parameters at each automatic station as an essential part of the river monitoring objectives. The baseline and event concentrations are being combined with the appropriate discharge data to provide loading values. Preliminary loading data indicated that the loading of many of the parameters during an event was a significant fraction of the total baseline loading for the entire month. Data from all the sampling activities have been edited and stored on computer mass storage to allow for reporting and statistical analysis. The stored data have been programmed for mechanical plotting in terms of concentration and loading.

The two principal approaches used to achieve the goals of objective 2 are providing an inventory of land use characteristics and investigating the impact of various land uses on water quality. A Land Data Management System (Land DMS) was designed to store, retrieve, analyze and display land data--in tabular or graphic form. Nine data types have been coded for the entire watershed, and the coding of two additional data types is in progress. Land DMS work elements completed or in progress since October 1975 include: 1) a computer program was obtained from the National Geodetic Survey to convert cell corner coordinates from the Wisconsin State Plane Coordinate System to the Universal Transverse Mercator System and incorporating the program into the data management phase of the Land DMS; 2) coding of soils data for the watershed was completed and the coding of ground elevation data and land use data by individual cells was initiated; 3) work was started on the software additions needed to determine the characteristics of the total area tributary to each of the monitoring stations established in the watershed; and 4) the Land DMS was used to prepare a tabular summary of soil types for each of the 244 sub-basins in the watershed.

The remote sensing project is also providing land data in support of the second objective. The remote sensing project is developing techniques for mapping land cover and hydrologically active source areas in the watershed from small scale color-IR imagery. The techniques developed will be used to determine the applicability of remote sensing data in hydrological modeling efforts. Photographic missions utilizing color and color infrared imagery have been flown approximately once per month during the summer and fall months of 1975. Thus far, two scenes near Menomonee Falls in Waukesha County, dated July 16 and October 6, 1975, have been digitized in the wavelength intervals, 4456 to 4550 Å (red), 5450 to 5550 Å (blue), and 6450 to 6550 Å (green), using a 100 micron spot size representing a pixel size of 7.5 meters on a side. To date, 29 signatures have been developed for the July 16 data representing 5 categories of land cover, and 39 signatures representing 6 categories of land cover have been developed for the October 6 data. Land cover maps were developed, and the output displayed on conventional paper printouts as well as on a color cathode ray tube system.

The specific land use studies are being used to determine the impact of various homogeneous and/or predominant land use areas on water quality in support of objective 2. Sampling stations at eight of the study sites, representing major land uses in the watershed, have been completed. Preliminary grab sampling of snowmelt runoff was started March 18, 1976 at selected specific land use study sites to scan for the predominant Group C parameters.

An air and precipitation monitoring program is being established presently in the watershed in support of objective 2. The monitoring system was designed to study the influence of atmospheric processes in the cycling of elements in the watershed. A primary objective of the program is to determine the relative contribution of different land use practices to the total weight and chemical composition of the aerosols measured over the watershed. The atmospheric study will quantify the mass of aerosols entering the watershed from rain and dry fallout deposition. To date, the aerosol collection methodology has been evaluated. The rain and aerosol collectors are presently being installed at seven of the automatic river stations.

Objective 3 is being achieved by an effort to develop land use-water quality models. Modeling techniques and mathematical models applicable to the land use-water quality models have been reviewed and evaluated for possible use. The digital computer model selected as the basic simulation tool for the Menomonee River Pilot Watershed Study is based on a hydrologic-hydraulic model that originated at Stanford University and is now available with a water quality feature from the consulting firm of Hydrocomp, Inc. This selection was based on considerations--amongst others--of the Hydrocomp Model, the Wisconsin Hydrologic Transport Model (WHTM), the EPA Storm Water Management Model (SWMM), the Corps of Engineers Storage, Treatment and Overflow Model (STORM) and working experience with the Hydrocomp Model, SWMM, STORM and a new model called LANDRUN. The Southeastern Wisconsin Regional Planning Commission (SEWRPC), in their cooperative effort with the Menomonee River Project, and including coordination with their programs supported by Section 208 funds under Public Law 92-500, is evaluating the Hydrocomp Model. Data base efforts for the model have concentrated recently on completing channel data and developing diffuse source data and point source data. Since the October 1975 semi-annual report, a successful calibration of the hydrologic submodel and hydraulic submodel was accomplished, and continued calibration efforts have concentrated primarily on achieving a preliminary calibration of the water quality submodel.

The model, LANDRUN, is being developed to supplement the Hydrocomp Model in areas where it does not meet project objectives and as a model that will achieve independently most of the goals of objective 3. The LANDRUN model represents a dynamic hydrologic transport model which transforms precipitation into surface runoff, interflow, and groundwater aquifer recharge quantity and quality. Most of the model parameters and some inputs are related to land use within the modeled watersheds. A soil adsorption model applicable to phosphorous, pesticide and heavy metals transport was developed, tested and is being incorporated as a subroutine into "LANDRUN."

Development is proceeding on a less complex model that would relate empirically runoff quality to land use, climate, and hydrologic and other factors which contribute to runoff quality. This model assumes that the concentration of a chemical in surface runoff varies temporally about a mean runoff concentration in a predictable manner. Runoff water quality has been observed at three small watersheds in Milwaukee during the course of 20 events. Interpretation of mean concentrations of the various parameters during runoff events began in December 1975. Plots of relative concentrations as a function of a time ratio are presently being generated by computer for each event.

In summary, the Menomonee River Pilot Watershed Study was designed to investigate the impact of urban and urbanizing land use on water quality and to extrapolate these effects to the entire Great Lakes basin. The overall goals of the study were divided into the three aforementioned specific objectives. Since October 1975, the river monitoring activities in support of the first objective have been continued with an emphasis on runoff event monitoring. The projects designed to accomplish the second objective have progressed on schedule. The progress included:

1) continued coding of land types into the Land Data Management System, 2) development of land cover maps using remote sensing, 3) completion of construction at eight specific land use sites and initiation of sampling, and 4) testing of air samplers presently being installed for the atmospheric monitoring project. The modeling activities in support of objective 3 have been defined more clearly with the choice of the Hydrocomp Model as the basic simulation tool for the study, and the continued development of "LANDRUN" as an independent model supplemental to the Hydrocomp Model.

APPENDIX A

RIVER MONITORING ACTIVITIES

Introduction

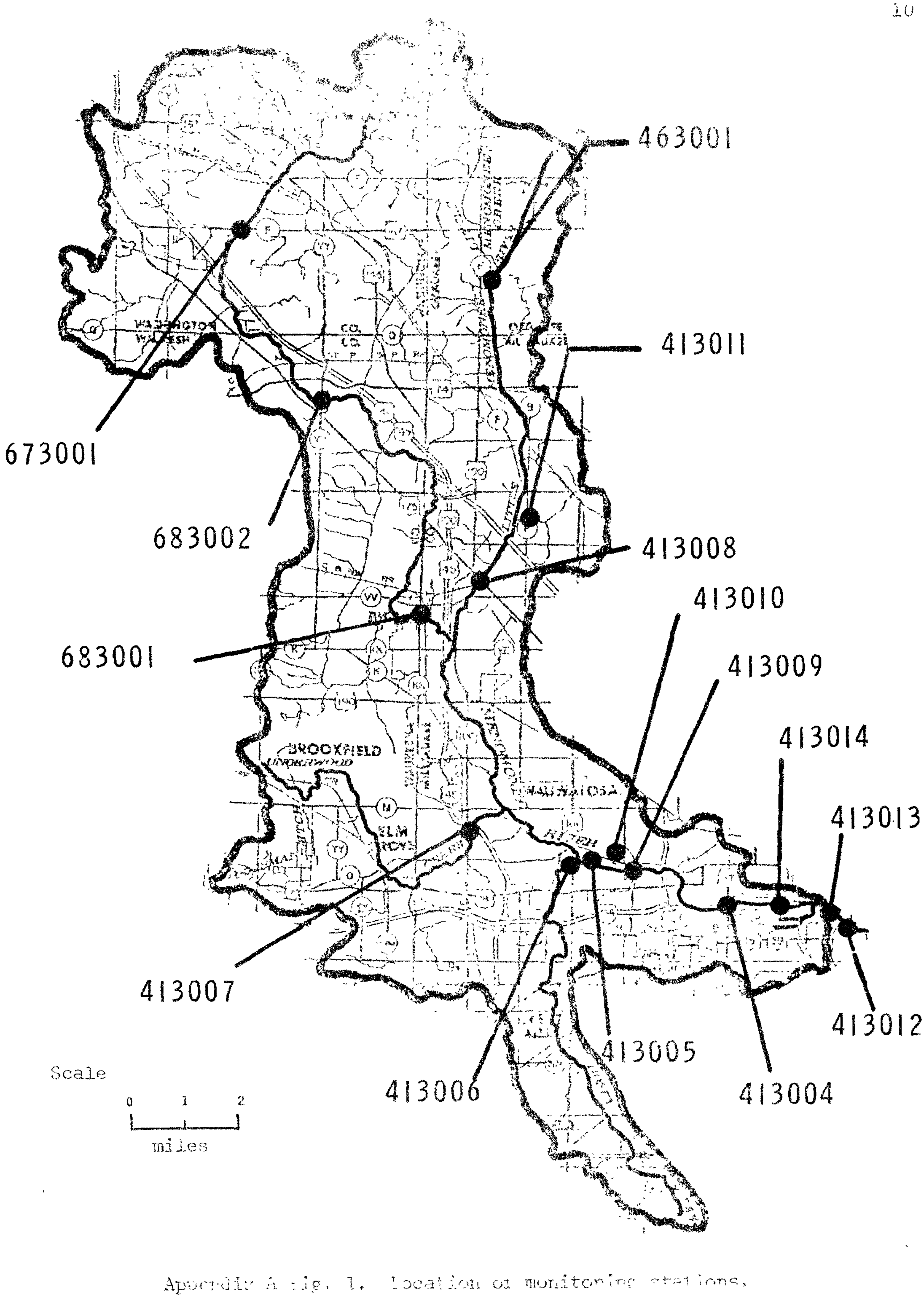
The objective of the river monitoring activities is to determine the types and quantities of various water quality parameters in the waters of the Menomonee River and its principal tributaries. Parameters of concern include the "core" list established by the Task C Technical Committee of the Pollution from Land Use Activities Reference Group (PLUARG) and other parameters likely to affect Lake Michigan water quality. The river monitoring activities will provide basic information about the hydrology, hydraulics and water quality of the watershed. Interpretation and assessment of monitoring data will be undertaken by the development of land use-water quality models.

Preliminary monitoring of the river began in February, 1973 with the establishment of three stations by the Wisconsin Department of Natural Resources (WDNR). Intensive sampling of the river and its tributaries began in January, 1975 after site selection and construction of 12 automatic monitoring stations.

Progress

Field activities

The field activities included both baseline surveys and event sampling. The baseline survey parameters included nutrients, total alkalinity, hardness, chloride, color, total dissolved solids, suspended solids, total volatile solids, and total organic carbon. Conductivity, pH, temperature and dissolved oxygen were also measured for each sample immediately after collection. Regular baseline river samples were obtained from each of the 14 river sampling sites (12 automatic monitoring stations and 2 grab sample sites (Appendix A Fig. 1)) once a week from October, 1975 to April 1, 1976. A lack of flow from December 15, 1975 to March 22, 1976 excluded the Schoonmaker Creek station (site 403010) from the regular baseline river surveys. Baseline river sampling frequency increased to twice a week during the spring melts occurring between February 15 and March 6, 1976. Beginning in April, 1976, the regular baseline river surveys will



Appendix A Fig. 1. Location of monitoring stations.

be conducted biweekly except during periods of high flow. In addition to the routine baseline survey samples, quality control samples were obtained at one of the stations during each baseline survey. Quality control samples consisted of two simultaneous grab samples and a comparison sample obtained with the automatic sampler. The sampling program provided information on sample storage effects and river homogeneity and compared sample collection methods.

Two baseline surveys for metals and organics were completed in 1975 (October, 1975 Semi-Annual Report). Four baseline surveys for metals, organics and bacteria will be done in 1976.

Biweekly sampling was continued for surface, mid-depth, and bottom waters at three bridge sites located in the estuary areas of the river. The list of parameters for the estuary samples was the same as that for the regular baseline river survey and also included temperature and dissolved oxygen profiles.

Monitoring of temperature, dissolved oxygen, conductivity and pH was continued at the same 5 river stations. Equipment repairs and conversion resulted in temporary shutdown of two stations. The 124th Street station (683001) was out of order between November 19, 1975 to January 6, 1976, and the River Lane Road station (673001) has been out of order since October 13, 1975. A weekly calibration schedule for each site has been in effect except for periods of high water which prevent the removal of *in situ* equipment. Calibration was curtailed from February 12, 1976 to March 11, 1976 due to spring ice breakup and high water levels. However, all operating units continued to function properly during this period and only a small portion of the data is questionable. The data are presently being digitized.

Water quality surveys were also conducted at the Germantown waste treatment facility on September 18 and 19, 1975 and at the Parkside and Parkview waste treatment facilities of the City of Menomonee Falls on June 19-20 and 23-24, 1975. The measured parameters for the 24-hour composite surveys included nutrients, metals, bacteria and organics.

The yearly macrobenthic survey was done on November 3 through 5, 1975 and consisted of 4 quantitative and 12 qualitative sampling surveys at 13 representative sites. Sorting and identification of species present are still in progress at this time.

The United States Geological Survey (U.S.G.S.) monitored discharge on a continuing basis at 11 river stations. Work on the 1975 water-year discharge records was completed and the corrected flow data put on a magnetic tape. The flow data are being programmed by the WDNR to be compatible with the stored water quality data. Rain data were collected by the U.S.G.S. at 8 rain gauging sites in the watershed. The U.S.G.S. continues to monitor suspended sediment concentrations using the automatic samplers at the 12 river monitoring stations. The sediment records are about completed for the 1975 water year.

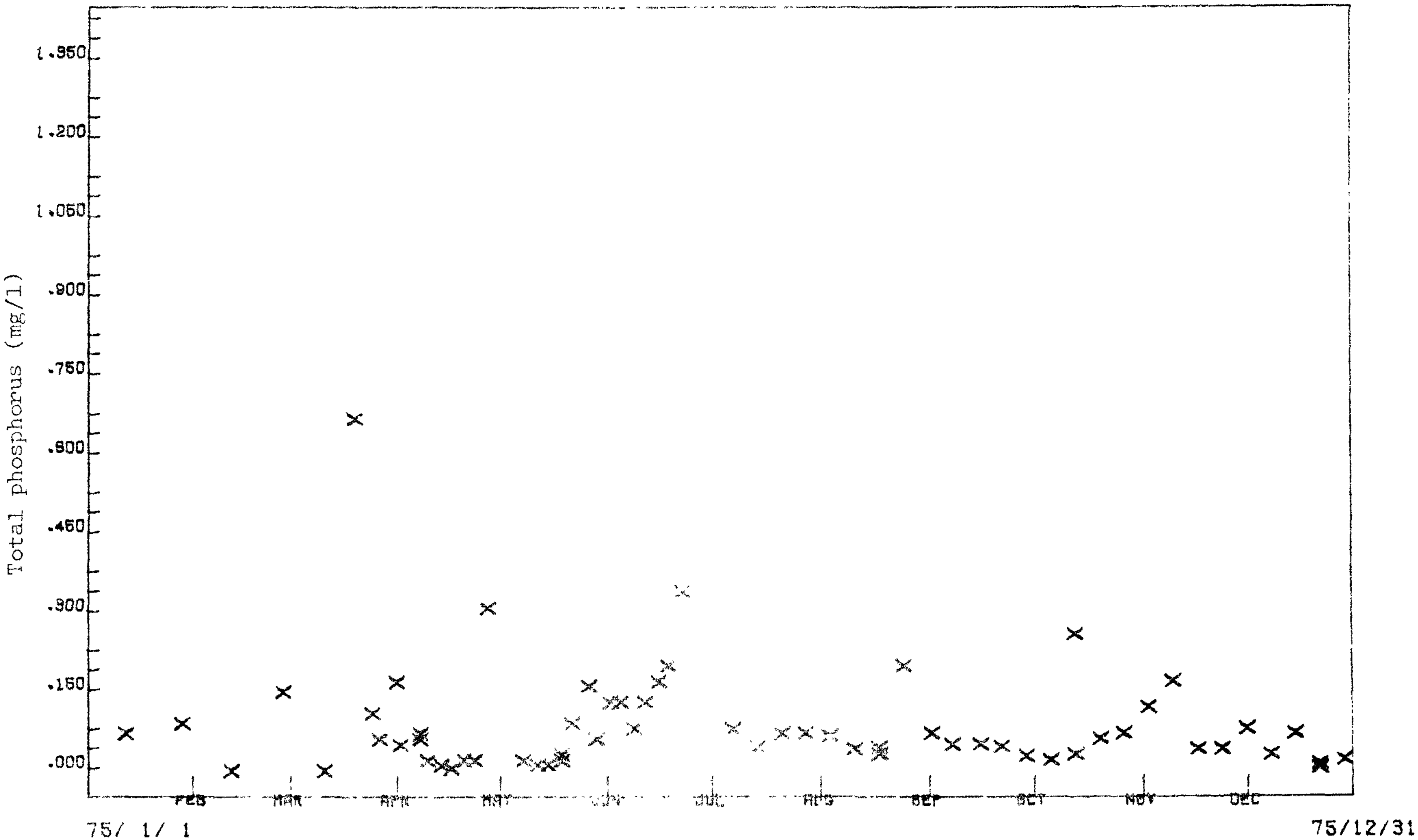
Collection of water quality samples during runoff events has continued as an important part of the river monitoring activities. Event samples were collected from 4 automatic river stations (stations 413005, 413010, 413011 and 463001) and were analyzed for most of the water quality parameters. For event sampling, the automatic samplers were set to collect water on a timed basis after the stage recorder reached a predetermined level. Insufficient runoff or automatic sampler malfunction prevented collection of samples from some or all of the 4 stations during some events. If possible, manual grab samples were obtained when an automatic sampler was not operational. Event samples were collected for analyses of: metals on August 20, 1975 at stations 413005 and 413010; pesticides on November 20-21, 1975 at station 413005; and metals and organics on November 29 through December 1, 1975 at station 413005 and on February 12-16, 1976 (snowmelt) at stations 413005 and 413010.

Runoff event samples, analyzed for the same parameters as a regular baseline river survey, were collected during seven events since August, 1975. These events occurred on: September 5, 1975 at station 413005; February 12-16 (snowmelt) and 16-17, 1976 at station 413005 and station 413010; February 18, 1976 at station 413005; February 24-27, 1976 at all four sites (snowmelt); and March 1-5 and 12, 1976 at all four sites. Before September 5, 1975, event samples had been collected for four events (October, 1975 Semi-Annual Report). Two additional event-sampling stations will be added by the end of April, 1976. Event sampling will be rotated among the 12 automatic sampling stations so that all stations will be monitored during each season by the end of the 1977 field year.

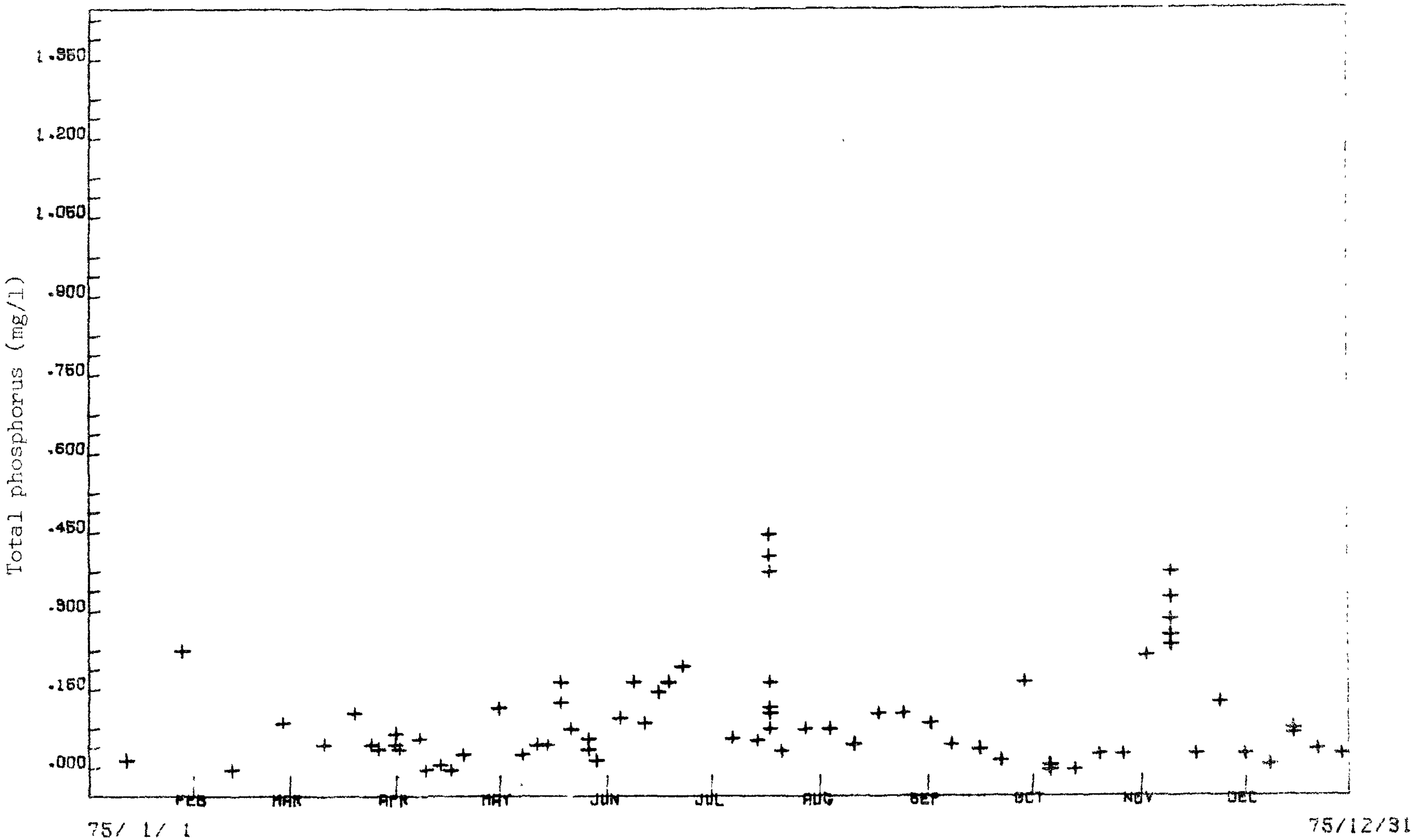
Data from the sampling activities have been edited and stored on computer mass storage to allow for reporting and statistical analyses. The data may be accessed through batch processing or terminal input and output. Interpretation of the water quality data is facilitated by programming the stored information for mechanical plotting in terms of concentrations and loadings. Appendix B contains more detailed information concerning the structure of the data files and how the program functions for storing and retrieving data.

Water quality data

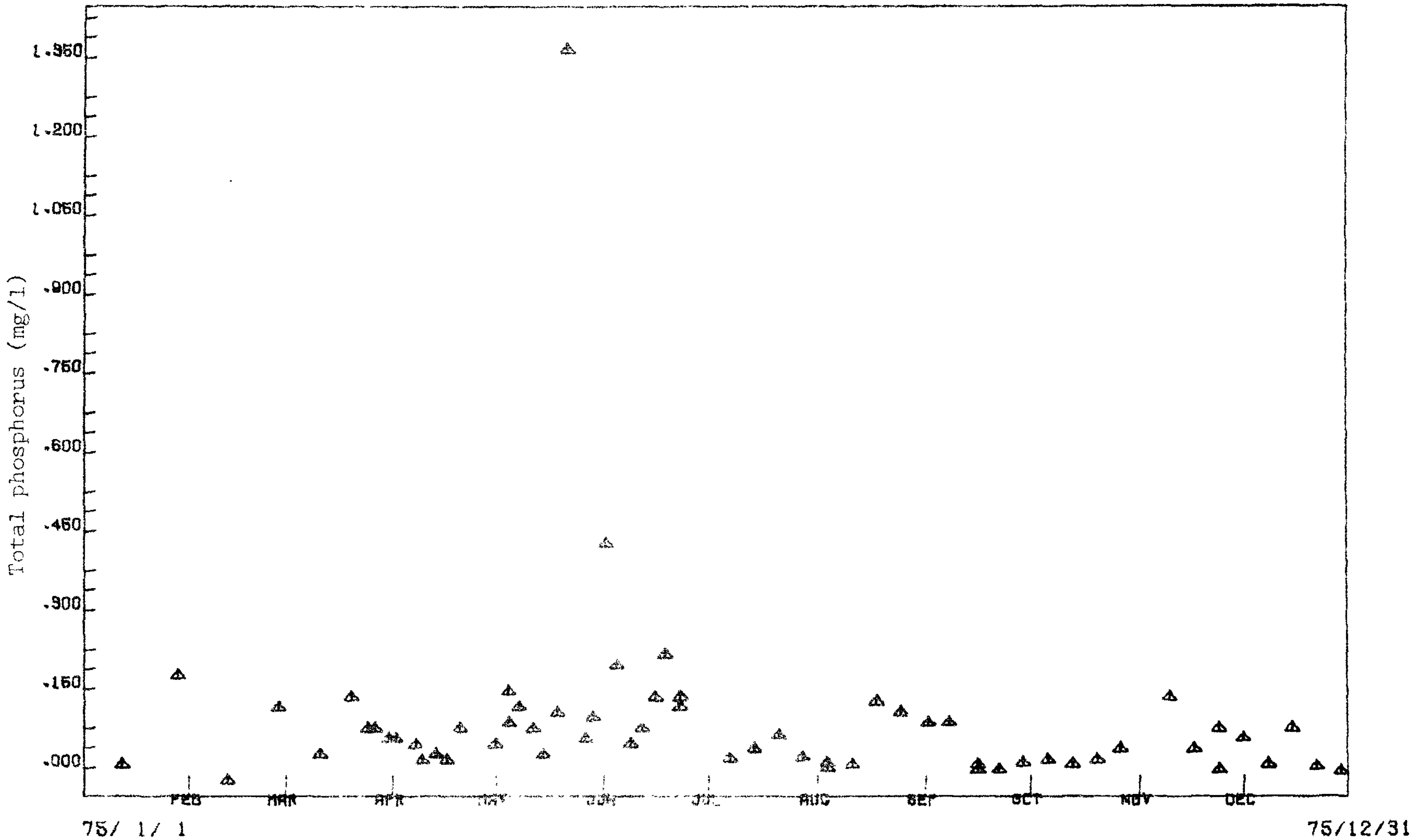
The regular baseline river surveys (nutrients, etc.) and baseline surveys for metals, organics and bacteria provided information on the values of the various parameters between runoff events. Preliminary graphs of concentration versus time for total P and (nitrate + nitrite)-N at 70th Street, Underwood Creek, Noyes Creek, and Donges Bay Road (stations 413005, 413007, 413011, 463001, respectively) were plotted for the entire 1975 field year. The plots include event data along with the baseline survey data. Many of the values of total P fall within a relatively narrow range for the entire year of baseline survey data; this is illustrated for stations 413007, 413001 and 463001 by Appendix A Figs. 2, 3, 4, and 5. Total P concentrations were generally higher at station 413005 than at the other 3 stations, and the range of values was larger. Concentrations during regular baseline river surveys for station 413005 ranged from about 0.2 to 0.4 mg/l, while the concentrations at the other 3 stations ranged from about 0.025 to 0.1 mg/l. The location of station 413005 toward the lower end of the Menomonee River probably accounts for the higher total P concentrations. Comparison of total P concentrations outside the above ranges with available flow data indicated the higher concentrations of total P were observed on days of relatively high flow. An example was the relatively high values for total P on June 24 and June 30, which were days of high flow related to runoff events. These results corroborate the increase in the concentrations



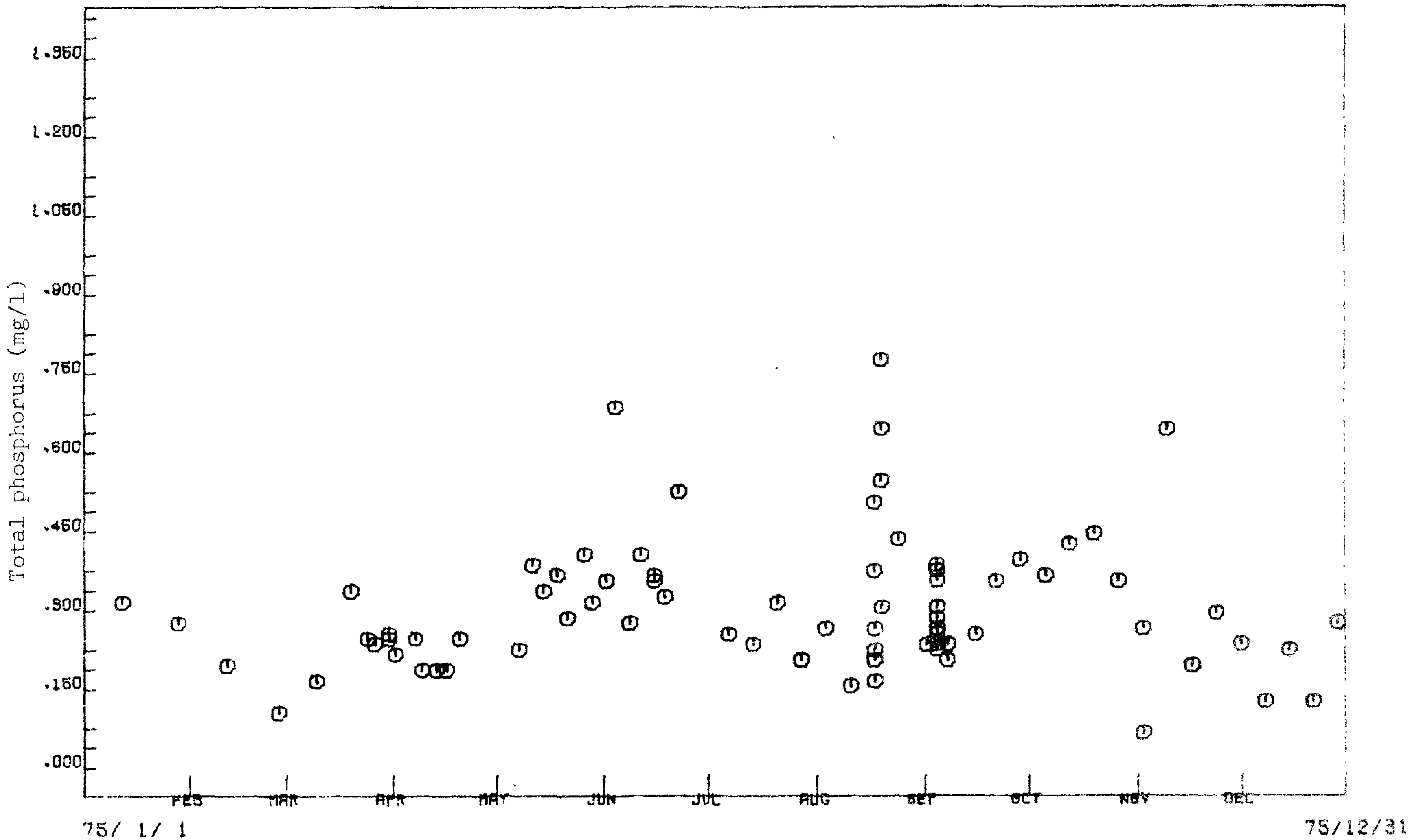
Appendix A Fig. 2. Total phosphorus concentrations at Bones Bay Road station during 1975.



Appendix A Fig. 3. Total phosphorus concentrations at Noyes Creek station during 1975.



Appendix A Fig. 4. Total phosphorus concentrations at Underwood Creek station during 1975.



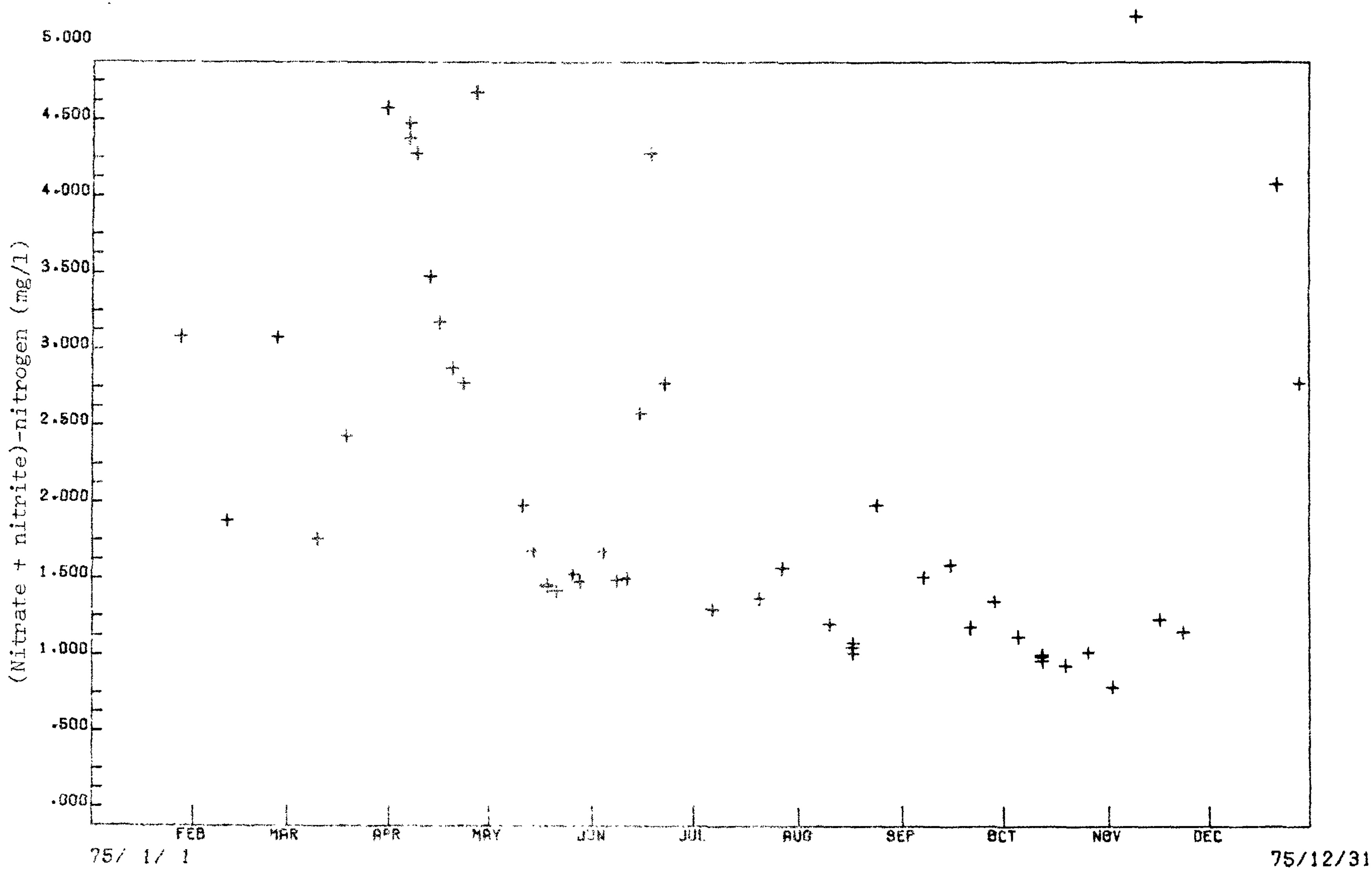
Appendix A Fig. 5. Total phosphorus concentrations at 70th Street station during 1975.

of total P observed during runoff events. The runoff events are indicated on the plots by more than three points for a particular date (Appendix A Figs. 3 and 5). Although no significant yearly seasonal trends in total P values were observed within the usually small range of values, some differences in the trends of total P concentrations were noticed from one month to another. For example, the total P concentrations in the high flow period at the end of March tended to be lower than the concentrations during the high flow period at the end of June for all stations.

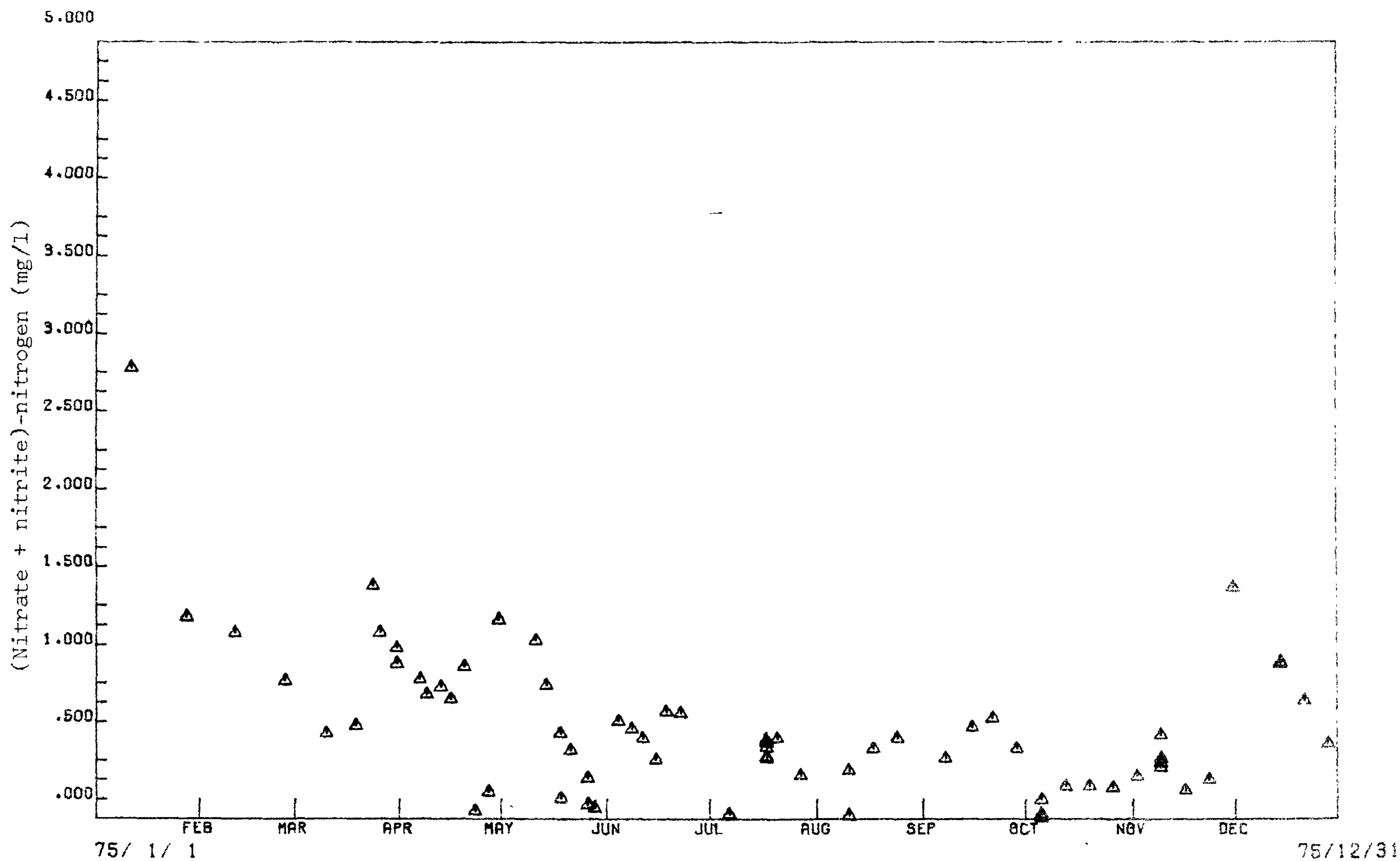
The opposite was observed for (nitrate + nitrite)-N concentrations (Appendix A Figs. 6, 7, 8, 9). The concentrations measured in March were higher than for June and other summer runoff events (Appendix A Figs. 7 and 9). The March concentrations were highest at station 463001 with values up to 6 mg/l, which were probably a result of the farming activities in that drainage area. The high (nitrate + nitrite)-N concentrations continued through April for stations 413005 and 463001. Contrary to the trends in total P values, the (nitrate + nitrite)-N concentrations increased to similar levels again at all stations in late November and for all of December. Except for several points, the remaining (nitrate + nitrite)-N values fell within a relatively narrow range. Station 463001 values were highest with a range of about 1 to 2 mg/l, while station 413005 had a range of about 0.5 to 1 mg/l and stations 413007 and 413011 had a range of about 0.1 to 0.5 mg/l. The above observations for total P and (nitrate + nitrite)-N are considered preliminary and only include a small portion of the available regular baseline river survey data.

A statistical analysis is presently underway for all the regular baseline river survey parameters at all the stations to better identify and characterize trends in the data. Available flow data will be programmed to identify more completely the various regular baseline river monitoring data biased by antecedent runoff events. Appropriate flow rates and baseline river survey data will be combined to provide estimates of monthly mean loadings of the various parameters at each of the stations.

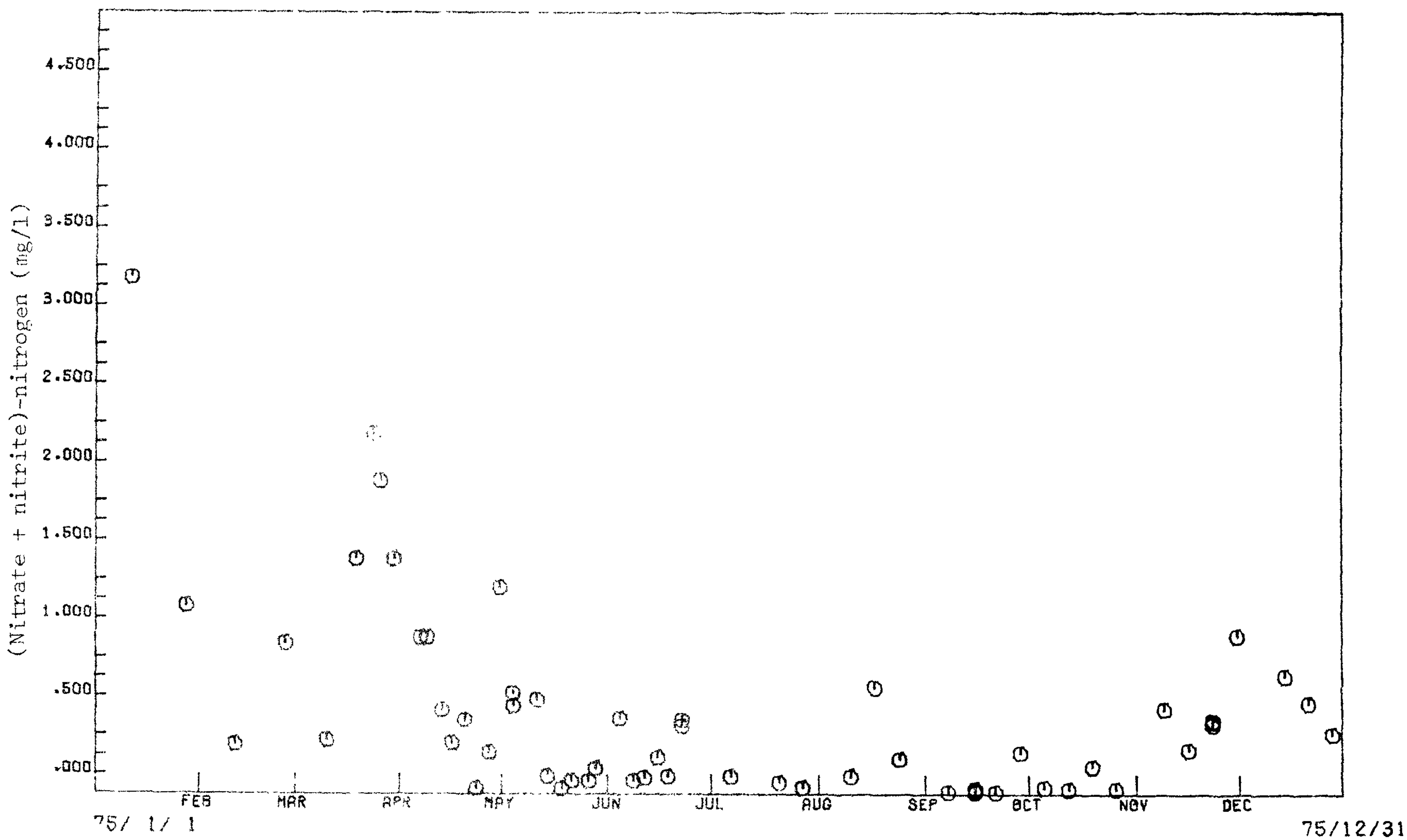
Quality control data obtained from replicate sampling during the regular baseline river surveys indicated the sampling procedure had



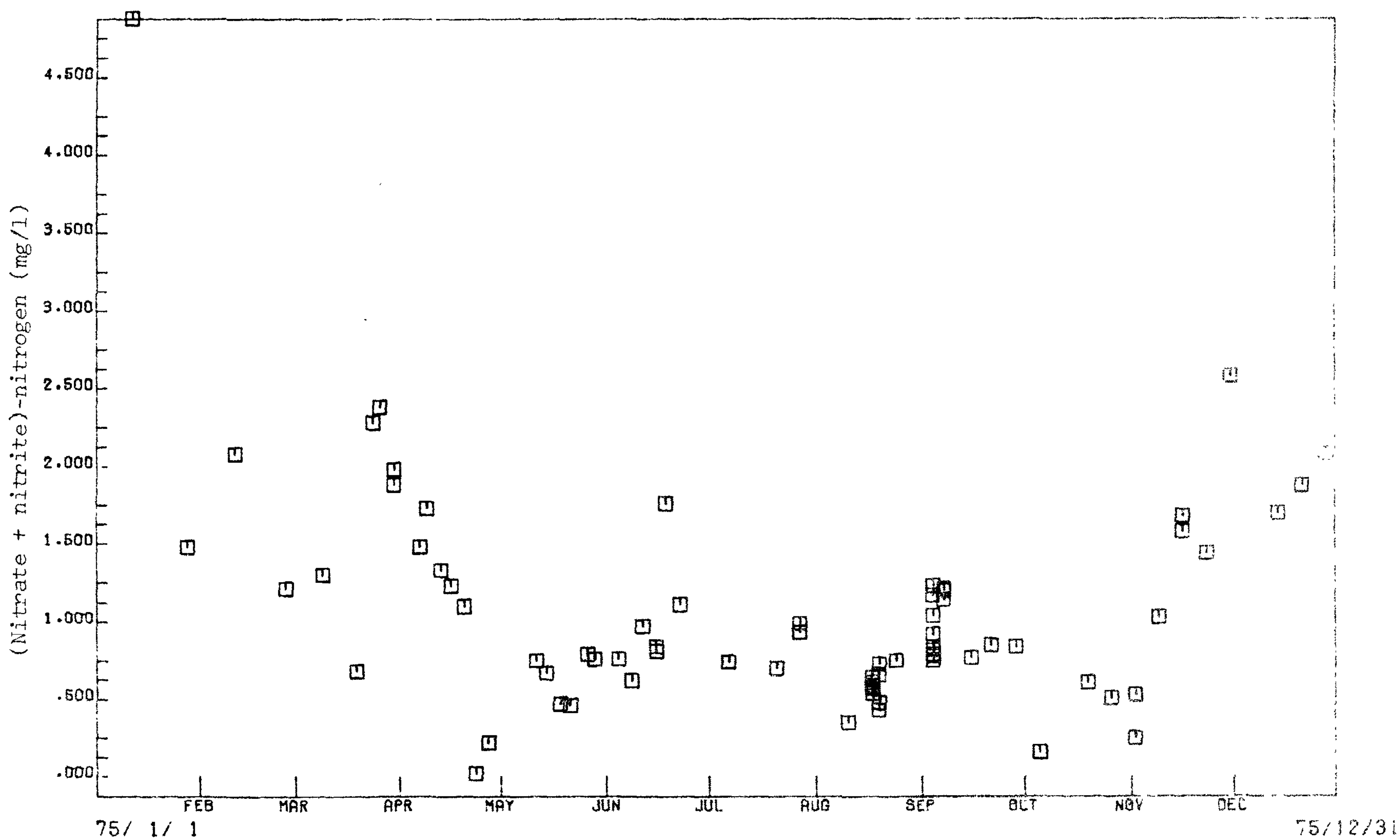
Appendix A Fig. 6. (Nitrate + nitrite)-nitrogen concentrations at Donges Bay Road station during 1975.



Appendix A Fig. 7. (Nitrate + nitrite)-nitrogen concentrations at Noyes Creek station during 1975.



Appendix A Fig. 8. (Nitrate + nitrite)-nitrogen concentrations at Underwood Creek station during 1975.



Appendix A Fig. 9. (Nitrate + nitrite)-nitrogen concentrations at 70th Street station during 1975.

little effect on the accuracy of the water quality data. The results of the simultaneous manual grab sampling program are presented in Appendix A Table 1. Questionable replication between simultaneous grabs are identified in the table. The criterion for inadequate replications was a deviation of greater than 20% from the mean of the two simultaneous grab samples. Only 14 of 192 analyses obtained for the simultaneous grab samples, or 7%, did not meet the above criterion. Ten of the 14 questionable values appeared on June 30, 1975 and the first three dates of August, 1975. Five of the 10 were on June 30, the first date simultaneous grab samples were obtained. Field personnel have indicated that the initial sampling technique probably accounts for the deviation in the June 30 data. The effect of storage was probably minimal in the deviations observed for other dates, since storage should have affected more samples. Most of the questionable ammonia values occurred at low ammonia levels (approaching limits of detection at 0.01 mg/l) where analytical error may be as high as 20%. Contamination by organic matter weighing 2 or 4 mg could have caused the observed differences in suspended solids values. Many of the results obtained on October 6 and 13, 1975 (Appendix A Table 1) with replicates from the automatic samplers demonstrated large deviations. Since the automatic samplers cannot obtain simultaneous replicate samples, the observed deviations were probably due to changes in river composition during the sampling interval.

Due to possible changes in river composition during sampling, a comparison sample from the automatic sampler and two manual grab samples were taken simultaneously. The results of the comparison sampling are given in Appendix A Table 2 and the questionable comparison analyses are identified. The criterion used for questionable values in the comparison sampling program was the same as used in the simultaneous grab sampling program. Only 10 of the 120 comparison analyses, or 8%, did not meet the criterion. In 7 of the 10 questionable analyses, the value for the automatic sampler was higher than for the manual grab samples. Seven of the 10 questionable analyses occurred on either November 11, 1975 at Falk Corporation (station 413004) or on November 24, 1975 at Underwood Creek (station 413007). Since most of the poor replicates occurred for

Appendix A Table 1. Comparison of simultaneous duplicate grab samples

Station	Date	Solids Total	Solids Susp.	Solids Voltile	Phosphorus Total	Phosphorus Sol.	Total Organic	NH₃-N	NO₃+NO₂ N	Total Alk.	Chl.	TOC	Cond.
		mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
413011	6-30-75	1020	28*	7	0.12*	0.078*	0.62	0.09	0.04	248	180	-	1500
		1050	13	6	0.07	0.027	0.61	0.10	0.04	242	180	-	1500
413008	6-30-75	684	34	13	0.19	0.074*	0.73	0.10	0.88	278	160*	-	990
		696	38	8	0.19	0.13	0.91	0.10	0.76	280	80	-	990
413010	6-30-75	765	3	3	0.08	0.079	0.34	0.04	0.21	210	180	-	1220
		755	4	4	0.07	0.070	0.29	0.06	0.21	210	185	-	1220
413007	8-4-75	700	3	2	0.043	0.022*	0.29*	0.09	0.04	148	125	-	1090
		705	5	2	0.055	0.013	0.43	0.07	0.05	152	120	-	1100
413011	8-11-75	530	18	3*	0.09	0.024	0.47*	0.04	0.02	164	85	10	770
		535	23	7	0.08	0.024	0.95	0.06	0.02	166	85	14.5	770
463001	8-18-75	740	7	4	0.074	0.045	0.38	0.07*	1.13	254	25	5.5	710
		775	7	2	0.082	0.045	0.38	0.13	1.20	258	24	5.5	710
413005	7-28-75	715	15	6	0.24	0.12	1.01	0.03	1.05	274	95	13	990
		705	15	8	0.24	0.12	1.13	0.03	1.05	274	95	13	990
683002	8-25-75	538	64	18	0.27	0.15	1.28	0.25	0.51	212	46	15.5	620
		565	62	21	0.30	0.15	1.02	0.21	0.49	212	38	13.0	620
413010	9-2-75	494	3	[illegible]	0.12	0.13	0.28	0.05*	0.15	184	105	6.5	810
		496	0	[illegible]	0.12	0.13	0.31	0.09	0.15	184	114	7.0	810
413005	9-8-75	702	15	2	0.27	0.19	0.71	0.04*	1.32	304	103	10.0	890
		704	13	2	0.27	0.19	0.74	0.07	1.33	304	100	8.5	890
413007	9-16-75	278	4	4	0.03	0.010	0.45	0.06*	0.02	220	125	3.5	1020
		946	3	2	0.0?	0.010	0.4?	0.0?	0.01	202	118	4.0	1020
683001	9-22-75	796	14	4	0.89	0.92	1.09	0.21	2.2	292	130	7.5	890
		7?0	15	5	0.93	0.9?	1.01	0.28	2.2	290	115	8.0	890
413008	9-29-75**	794	15	4	0.070	0.007	1.06	0.14	0.28	278	75	7.0	790
		778	16	4	0.070	0.009	[illegible]	0.16	0.29	[illegible]	78	9.0	790
413011	10-6-75**	746	6	4	[illegible]	[illegible]	0.79*	0.2?*	[illegible]	[illegible]	140	7.0	970
		810	5	4	[illegible]	[illegible]	1.51	0.07	0.?3	234	172	9.0	1050
463001	10-13-75**	[illegible]	22	[illegible]	0.25*	0.12*	1.38*	0.12*	1.08	[illegible]	86*	12.5	750
		642	4	[illegible]	[illegible]	0.05?	0.15	[illegible]	1.14	[illegible]	26	10.0	730
673001	10-20-75**	615	41	13	0.30	[illegible]	1.27	0.09	0.82	[illegible]	90	12.5	710
		610	38	16	0.30	0.19	[illegible]	[illegible]	0.82	[illegible]	90	9.0	720
683002	10-27-75	582	6	6	[illegible]	[illegible]	0.51	0.08	0.85	[illegible]	80	8.0	690
		556	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.05	0.82	[illegible]	80	8.0	690
412004	11-3-75	[illegible]	28*	14	0.27	[illegible]	[illegible]	0.48	[illegible]	[illegible]	88	9.0	590
		[illegible]	50	16	0.43	[illegible]	0.95	0.50	1.04	[illegible]	86	12.0	590
413006	11-10-75	[illegible]	24	1	0.1?	0.036	0.39	[illegible]	0.32	90	66	4.0	350
		239	25	2	0.13	0.075	0.49	0.12	0.32	92	[illegible]	3.5	350
41300?	11-17-75	754	3	1	[illegible]	[illegible]	0.69	0.12	[illegible]	[illegible]	105	6.0	850
		760	7	1	0.22	0.18	0.54	0.08	1.2	29?	125	5.5	850
413007	11-24-75	854	6	0	0.09	0.012	0.32	[illegible]	0.46	274	232	4.0	810
		[illegible]	2	5	0.0?	0.010	0.3?	0.13	0.44	274	105	5.5	810
683001	12-1-75	498	24	5	0.30	0.19	0.96	0.35	2.5	209	70	12.5	420
		506	26	5	0.30	0.15	0.87	0.30	2.5	210	65	13.5	420
413008	12-8-75	810	17	[illegible]	0.06	0.024	0.85	0.19	3.1	300	85	13.5	650
		734	15	5	0.06	0.026	0.90	0.20	3.1	301	85	11.5	650
413011	12-15-75	1112	22	6	0.11	0.016	0.54	0.32	1.0	286	330	10.5	1090
		1122	22	6	0.11	0.016	0.67	0.31	1.0	290	330	12.5	1090

*Duplicate samples deviating more than 20% from the mean.
**Duplicate samples from automatic sampler.

Appendix A Table 2. Comparison of automatic and manual grab sampling obtained during regular baseline river surveys

Station	Date	Sample Type	Solids Total	Solids Susp.	Phosphorus Total	Phosphorus Sol.	Total Organic N	NH_3-N	NO_3-N + NO_2-N	Total Alk.	Cl^-	TOC
			mg/l									
683002	10-27-75	Automatic	556	4	0.15	0.11	0.52	0.11*	0.35	307	86	[illegible]
		Grab	562	6	0.15	0.10	0.51	0.06*	0.85	309	80	8.0
413004	11-03-75	Automatic	680	154*	0.56*	0.13	2.0*	0.40	1.05	148	39	17*
		Grab	470	38*	0.27*	0.13	1.27*	0.48	1.05	146	28	9*
413006	11-10-75	Automatic	298	28	0.13	0.057	0.32	0.21*	0.30	89	66	[illegible]
		Grab	296	24	0.15	0.056	0.39	0.11*	0.32	50	66	[illegible]
413005	11-17-75	Automatic	742	7	0.23	0.16	0.65	0.40	1.7	296	115	[illegible]
		Grab	754	6	0.23	0.16	0.64	0.52	1.8	294	125	[illegible]
413007	11-24-75	Automatic	1,032	52*	0.11*	0.012	0.42	0.15	0.47	268	245	9.0*
		Grab	894	0*	0.03*	0.012	0.32	0.15	0.46	274	232	4.0*
683001	12-01-75	Automatic	506	28	0.29	0.18	0.73	0.33	2.5	205	98	12
		Grab	498	24	0.30	0.19	0.95	0.33	2.5	209	79	[illegible]
413008	12-08-75	Automatic	796	18	0.06	0.027	0.97	0.19	3.1	300	90	16
		Grab	810	17	0.06	0.028	0.85	0.19	3.1	300	85	13.[illegible]
413011	12-15-75	Automatic	1,132	26	0.10	0.024	0.57	0.28	1.0	290	350	7
		Grab	1,112	22	0.11	0.016	0.54	0.32	1.0	286	330	[illegible]
463001	12-22-75	Automatic	708	2	0.034	0.027	0.91	0.27	4.2	272	40	[illegible]
		Grab	734	2	0.042	0.027	1.05	0.25	4.2	276	47	12.[illegible]
683002	01-05-76	Automatic	660	3	0.11	0.078	0.75	0.29	2.0	340	70	12
		Grab	664	4	0.11	0.068	0.73	0.37	2.2	342	70	12.5
413005	02-02-76	Automatic	1,146	14	0.28	0.18	0.36	2.3	1.5	300	375	10.0
		Grab	1,158	14	0.30	0.19	0.28	2.5	1.5	302	360	10.0
413007	02-09-76	Automatic	3,162	39	0.30	0.027	2.06	0.25	0.64	252	2,050*	9
		Grab	3,232	38	0.31	0.030	2.26	0.26	0.64	250	1,400*	46

* Duplicate sampler deviating more than 20% from the mean.

parameters associated with particulate matter, care has been used to prevent using sampling procedures that might affect suspended solids concentration. Since the same automatic sampling procedure was used for other types of water quality parameters not included in the regular baseline river surveys or event samplings, the same good data quality should have been obtained for these parameters.

Important water quality parameters not analyzed in the regular baseline river survey and estuary samples are metals, organics and bacteria. Samples were obtained for these parameters on two dates during baseflow conditions.

The total coliform, fecal coliform and fecal streptococci counts almost always exceeded accepted standards by a wide margin. Most of the samples collected on June 11 and September 9, 1975 for pesticides and PCB's had concentrations below detection limits. In a few isolated instances, aldrin, lindane, heptachlor epoxide, and methoxychlor showed significant concentrations above detection limits for the June 11, 1975 survey. Most phenol concentrations for samples taken June 24 and September 3, 1975 were above detection limits (October, 1975 Semi-Annual Report).

Many of the stations had measurable total metal concentrations in the June 25 and September 3, 1975 surveys (Appendix A Table 3). The concentrations of cadmium, selenium, arsenic and nickel were below detection limits for both dates and were not included in Appendix A Table 3. The concentrations of copper, lead, zinc, chromium and mercury were observed to increase significantly at and below Underwood Creek (station 413007) for both dates. This apparent trend in total metal concentrations for both dates might reflect the influence of industry and high population densities in the lower part of the watershed. The unexpectedly high lead concentration (520 mg/l) at station 413005 on June 25, 1975 was probably due to water from a recent runoff event discharging from a storm sewer pipe directly above the station. A similar high concentration of lead discharged from a combined sewer system was observed at station 413009 (880 mg/l on June 25). A similar increase in concentration was not observed for iron, aluminum and manganese, which are usually high because of their geological abundance. The magnitude of the concentra-

Appendix A. Table 8. Comparison of metal concentrations at the 12 river stations for baseflow conditions on June 25* and September 3, 1975

Station	Cu	Pb	Zn	Cr	Hg	Fe	Al	Mn
	μg/l							
				June 25, 1975				
673001	<3	<3	<20	<3	<0.2	800	330	60
683002	3	<3	<20	<3	<0.2	1,500	85	100
683001	11	7	40	<3	<0.2	4,200	80	200
463001	3	<3	<20	<3	<0.2	1,600	372	130
413011	3	5	<20	<3	<0.2	1,000	332	40
413008	5	6	<20	<3	<0.2	3,200	1,220	120
413007	13	28	110	3	0.4	6,900	85	220
413006	18	35	130	7	0.2	5,700	940	120
413005	10	520	60	9	<0.2	4,700	1,520	120
413010	6	30	40	4	0.2	4,500	570	70
413009	12	880	170	36	0.3	2,200	640	40
413004	13	22	80	5	<0.2	4,800	880	150
				September 3, 1975				
673001	<3	<3	<20	<3	<0.2	1,520	712	90
683002	<3	<3	<20	<3	<0.2	1,520	656	100
683001	<3	<3	30	<3	<0.2	2,900	860	130
463001	7	<3	<20	<3	<0.2	1,080	272	100
413011	5	<3	<20	<3	<0.2	360	176	70
413008	<3	<3	<20	<3	0.4	2,500	910	140
413007	9	21	50	7	<0.2	1,680	688	140
413006	9	35	130	11	<0.2	1,700	768	160
413005	5	10	30	5	<0.2	1,800	440	90
413010	4	11	20	<3	<0.2	4,600	1,280	60
413009	21	560	180	80	0.3	1,360	272	60
413004	10	10	50	7	0.9	1,480	440	180

* Samples obtained below confluence with Little Menomonee River were on the descending side of a rain event hydrograph. Parts of the watershed received at least 0.2 inch rain on June 24 and a trace on June 25.

tions for most metals was similar for both the June 25 and September 3, 1975 surveys at all the stations. The low levels of most of the parameters during the baseline metal and organic survey sampling increased the importance of determining these parameters during runoff events.

The total concentrations of most metals increased significantly during the August 20, 1975 runoff event at both the Schoonmaker and 70th Street stations (413010 and 413005, respectively) and again during the November 29 through December 1, 1975 runoff event at 70th Street (station 413005) (Appendix A Tables 4, 5 and 6). The levels of selenium and arsenic did not change at all. Most of the metals reached concentrations substantially higher than the concentrations observed for the baseline metal survey samples on June 25 and September 3, 1975 at the same stations (Appendix A Tables 4, 5 and 6). The exception was the high baseline lead concentration observed on June 25, 1975 at the 70th Street station and the similarity between baseline and event concentrations for aluminum and manganese during the November 29 through December 1, 1975 runoff event. The lead concentration on June 25, 1975 was probably the result of water from an antecedent event discharging from a storm sewer outfall just above the 70th Street station. The average event concentration of lead, copper and chromium usually exceeded the concentration for these metals during the baseline quarterly sampling at the same stations (Appendix A Tables 4, 5 and 6). The average metal concentration for an event was calculated by dividing the total water loading for the event into the total loading for the metal. The average concentration on August 20, 1975 was higher for copper and chromium at the 70th Street station than at the Schoonmaker Creek station except for lead which was about the same concentration for both stations. A higher average metal concentration would be expected at 70th Street since it represents the combined Menomonee River drainage from many different areas while Schoonmaker Creek is a small tributary to the Menomonee River draining an older high-density residential area. However, it was interesting to observe that many individual concentrations of copper, lead, zinc and cadmium were similar at both stations, and the peak concentrations for lead and zinc were higher at Schoonmaker Creek. The average concentrations of copper, lead and cadmium at the 70th Street station were higher on August 20, 1975

Appendix A. Table 4. Comparison of metal concentrations during August 20, 1975 runoff event at 70th Street and baseflow conditions on June 25 and September 3, 1975

Time or date	Cu	Pb	Zn	Cr	Ni	Cd	Fe	Al	Mn
	μg/l								
				Event (Aug. 20, 1975)					
1330	58	53	60	14	<20	1.3	2,100	900	120
1415	76	320	320	31	140	1.7	13,600	4,000	440
1500*	110	550	320	50	48	3.1	25,500	11,200	550
1545	65	400	230	24	27	2.1	22,000	8,700	430
1630	97	146	180	25	<20	1.5	13,800	4,900	350
1715	58	130	160	27	<20	1.4	10,600	4,900	260
Ave. Conc.**	87	370	-	35	-	-	-	-	-
				Baseflow					
June 25	10	520	60	9	<20	0.2	4,700	1,520	120
Sept. 3	5	10	30	5	<20	<0.2	1,800	440	90

* Peak flow.

** Average concentration is the total loading of metal divided by total water loading for event.

Appendix A. Table 5. Comparison of metal concentrations in Schoonmaker Creek during the August 20, 1975 runoff event and baseflow condition on June 25 and September 3, 1975

Time or date	Cu	Pb	Zn	Cr	Cd	Fe	Al	Mn
	μg/l							
				Event (Aug. 20, 1975)				
1240	120	272	130	25	2.7	5,500	2,200	110
1255*	48	550	220	15	2.5	10,000	4,700	230
1325	45	320	120	9	1.2	4,400	2,800	120
1340	20	174	100	8	0.9	5,000	2,000	120
1355	140	640	270	20	2.4	10.800	5,000	350
1405*	50	368	220	16	1.8	12,000	4,200	330
1420	54	140	900	9	0.7	8,200	4,000	260
1430	36	85	80	7	0.6	4,400	3,500	150
1440	21	63	80	9	0.8	3,800	2,800	120
1445	17	68	360	5	0.6	4,000	2,200	140
Ave. Conc.**	60	410	-	10	-	-	-	-
				Baseflow				
June 25	6	30	40	4	<0.2	4,500	570	70
Sept. 3	4	11	20	<3	<0.2	4,600	1,280	60

* Peak flow.

** Average concentration is the total loading of metal divided by total water loading for event.

Appendix A. Table 6. Comparison of metal concentrations for 70th Street during the November 29, through December 1, 1975 runoff event with baseflow values on June 25 and September 3, 1975

Time or date	Cu	Pb	Zn	Cr	Cd	Fe	Al	Mn
	μg/l							
				Event (Nov. 29, 1975)				
0445	84	18	80	8	0.7	700	300	<40
0845*	106	126	120	21	2.1	2,700	1,080	130
1245	72	104	110	40	1.3	3,700	1,000	100
1640	72	84	100	21	1.4	3,900	120	110
2040	58	76	100	14	1.9	3,400	1,100	110
				Event (Nov. 30, 1975)				
0040*	72	108	100	12	1.0	3,800	1,150	120
0445	58	80	100	9	1.0	5,200	1,280	110
0845	40	54	80	8	0.7	4,200	1,560	100
1240	36	38	70	12	0.6	4,600	1,100	110
1640	44	27	60	5	0.7	3,400	1,080	90
2040	42	19	50	7	0.8	2,900	960	80
				Event (Dec. 1, 1975)				
0040	46	15	50	4	0.8	2,200	860	90
0040	35	12	40	3	1.1	1,800	600	70
0840	36	10	40	4	1.2	1,700	560	70
Ave. Conc.**	58	66	-	13	-	-	-	-
				Baseflow				
June 25	10	520	60	9	0.2	4,700	1,520	120
Sept. 3	5	10	30	5	<0.2	1,800	440	90

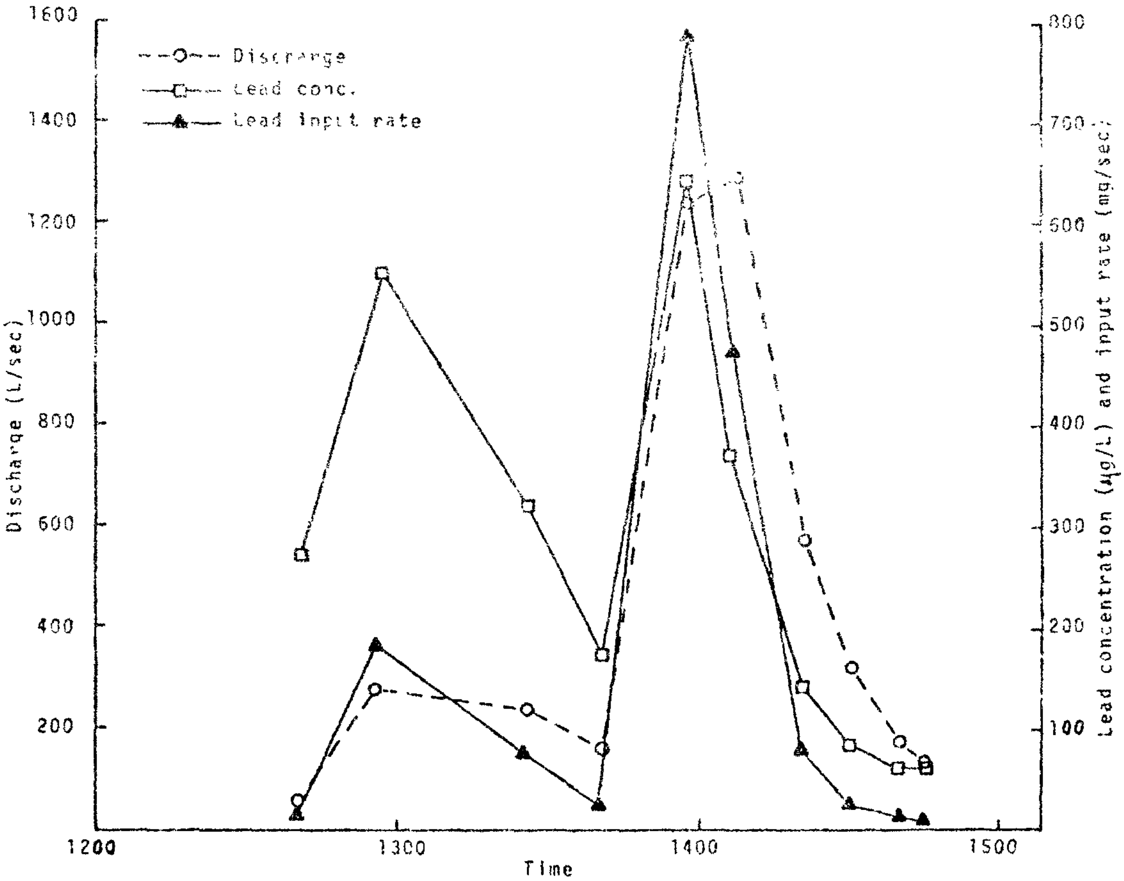
* Peak flow.

** Average concentration is the total loading of metal divided by total water loading for event.

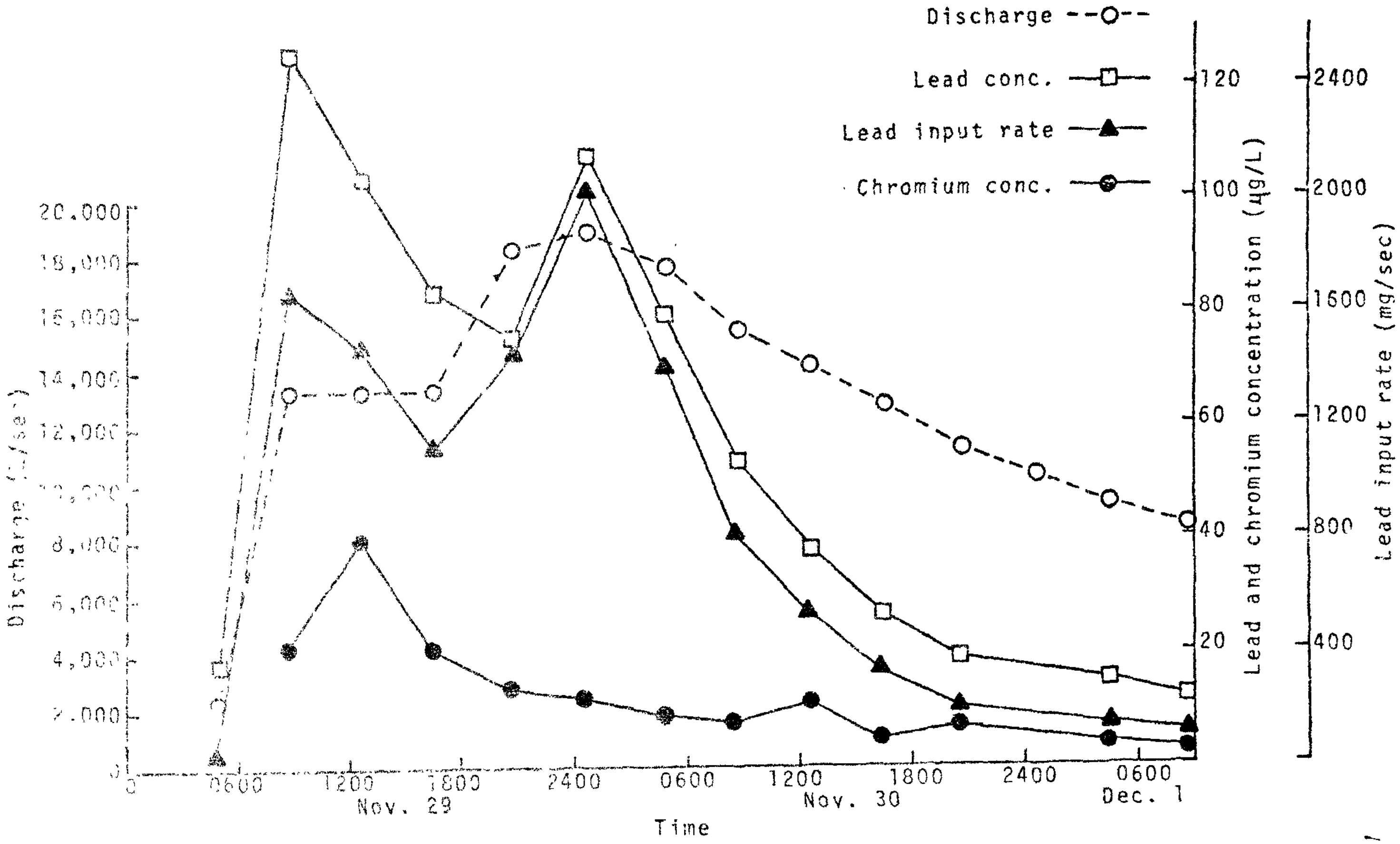
than for the November 29 through December 1, 1975 event. Also, the individual concentrations were generally higher, and peak concentrations were higher at 70th Street on August 20, 1975 than for the November 29 through December 1, 1975 event for all the metals except cadmium and copper. The higher metal concentrations on August 20, 1975 at 70th Street were probably due to the greater rain intensity of the August 20, 1975 event, intensifying the rate of metal flushing from the watershed. Approximately 0.7 inches of rain fell in about 3 hours on August 20, and 1.0 inches of rain were recorded for the 3-day November 29 through December 1, 1975 event, most of which fell throughout the first day. The peak flow rate for the August 20 event (34,000 l/sec) at 70th Street was almost twice the peak flow rate for the November 29 through December 1 event (19,000 l/sec).

The peak flow at 70th Street during the August 20, 1975 event coincided with the peak total metal concentration for all the metals except nickel (Appendix A Table 4). Two peaks were observed on the Schoonmaker Creek hydrograph during August 20, 1975. Most metals showed a peak concentration at the first peak, but the peak metal concentration was about 10 minutes before the second peak for most of the metals (Appendix A Fig. 10 and Table 5). However, the shape of the hydrograph around the second peak indicated the actual peak flow might not have been recorded. Although the lead concentration at Schoonmaker Creek was similar for both peaks, the pollutograph or input rate curve indicates the loading during the first discharge peak was small compared to the second discharge peak (Appendix A Fig. 10).

The hydrograph for the November 29 through December 1, 1975 event had an initial plateau followed by a distinctive peak. Most of the metals reached a peak concentration at the beginning of the plateau, but cadmium reached a peak before chromium, iron and aluminum after the distinctive peak following the plateau. Copper, lead, zinc and manganese concentration peaks coincided with the flow peak following the flow plateau (Appendix A Fig. 11 and Table 6). The usually less distinct and noncoinciding nature of the second metal concentration peak for most of the metals was probably due to the relatively low intensity of the event. An example of this was the peak concentration observed for chromium (Appendix A Fig. 11). The higher concentration of lead in the first concentration peak (126 μg/l) as compared to the second (108 μg/l) was typical of many of the metals and was



Appendix A Fig. 10. Discharge and lead concentration at Schoonmaker Creek during August 20, 1975 runoff event.



Appendix A Fig. 11. Discharge, lead and chromium levels, and lead input rates at 70th Street station for November 29 through December 1, 1975 runoff event.

probably due to the first flush of the watershed (Appendix A Fig. 11). The lead pollutograph mirrored the rapid rise of the hydrograph to a value just under the second flow peak and indicated the loading of lead in the first concentration peak was a significant part of the total loading. This was in direct contrast to the relatively small lead loading for the first peak at Schoonmaker Creek on August 20, 1975. This was a result of the discharge in the final peak being small compared to the second even though the concentrations were similar.

Another parameter from the baseline quarterly surveys measured during an event was organics. Contrary to the metal results, the organic concentrations did not increase during the November 20 and 21, 1975 event at the 70th Street station. All the organics levels were below the limits of detection for the entire event.

Analyses of most of the event samples for regular baseline river survey parameters (nutrients, etc.) will continue. The concentration trends for these parameters during runoff events have been discussed in the October, 1975 Semi-Annual Report. The parameters associated with particulate matter (suspended solids, total P and total organic N) usually increased in concentrations during events at all the stations. The concentrations of dissolved nutrients (dissolved reactive P and (nitrate + nitrite)-N) increased during the events at Noyes Creek (station 413011) and Schoonmaker Creek (413010), but the concentrations of dissolved nutrients at 70th Street (station 413005) remained about the same with slight increases or decreases. Hardness, alkalinity and the concentration of chloride decreased for all stations during the events. Eventually, a sufficient number of events at the automatic river stations will be documented to allow a more detailed analysis of data to compare the stations as to nutrients and other parameters. Also, more detail in regard to related concentration changes during events will be possible after performing statistical correlation analyses for all the listed parameters for one event.

Concentrations of nutrients and other parameters during events are being combined with the discharge data to make pollutographs or loading curves. Examination of the pollutographs for each station under different hydrological conditions reveals a potential for predicting, with very little or no sampling, the loadings for different parameters during

an event. Determination of parameter loadings during events is essential to river monitoring objectives, as loading data for events provide the only means for determining contributions from different land uses. Loading data will be used also to determine the quantities of various parameters in the river system that might affect Lake Michigan water quality.

Copper, lead and chromium loadings were calculated for the August 20, 1975 and the November 29 through December 1, 1975 events (Appendix A Table 7). Both the event loadings and total loadings for metals were greater for the August 20, 1975 and November 29 through December 1, 1975 events at the 70th Street station than at the Schoonmaker Creek station due to the greater water volumes in the former station. Also, due to the greater water volume for the November 29 through December 1, 1975 event than for the August 20, 1975 event, the 70th Street station experienced a greater total metal loading for the November 29 through December 1, 1975 event.

The baseflow loading for a month was calculated by excluding the discharge from runoff events and combining baseline survey data with the mean monthly discharge. Average monthly baseline metal loadings were larger in June than in September. Most total metal loadings for events were greater than the approximate baseflow loadings (Appendix A Tables 7 and 8). Large loading rates for events when compared to average monthly baseline loadings emphasize the importance of recording event loadings for metals (Appendix A Table 8).

The event loadings for total P, dissolved reactive P (DRP) and suspended solids were calculated for the June 17, July 18, August 18 and 20, and September 5, 1975 runoff events (Appendix A Table 9). The total event loadings for these parameters varied significantly from one event to another at the same station and corresponded to the variation in concentrations of these parameters and the water volume.

In most instances, the total event loadings of total P, DRP, and suspended solids at Schoonmaker and Noyes Creeks exceeded or approximated the total baseline monthly loadings (Appendix A Table 11). The ratios of the event loadings to the total monthly baseflow loadings at 70th Street station were low in most instances. The suspended solids loadings on August 20 and September 5, 1975 were the exceptions for the 70th Street

Appendix A. Table 7. Metal loading at 70th Street and Schoonmaker Creek during storm events and baseflow

Sampling location	Sampling date, 1975	Metal loading* Cu	Pb	Cr	Water loading**	Sampling duration, hr.	Rainfall, in.
		—— kg ——					
					EVENT LOADING		
Schoonmaker Cr.	August 20	0.2	1.4	0.05	3.4×10^6	2.08	0.7
	August 20	21	89	8	2.4×10^6	3.75	0.7
	November 29 through December 1	139	158	31	2.4×10^9	32	[illegible]
					BASEFLOW+		
Schoonmaker Cr.	June 25	0.002	0.01	0.001	4	-	-
70th Street	June 25	1.2	65	1.1	1,448	-	-
Schoonmaker Cr.	September 3	0.0002	0.0005	-	0.5	-	-
70th Street	September 3	0.43	0.87	0.43	1,011	-	-

* Loading measurements for event sampling in kg/event; baseflow loading in kg/day.
** Water loading during event is recorded in liters; baseflow water loading in 1/sec.
\+ Baseflow parameters determined on a average monthly basis.

Appendix A. Table 8. Ratio of event metal loadings for floowing dates to the June and September approximate baseflow loadings

Sampling location	Sampling month, 1975	Parameters		
		Cu	Pb	Cr
		August 20, 1975 event		
Schoonmaker Creek	June	2	4.67	1.25
	September	40	140	-
70th Street	June	0.57	0.05	0.24
	September	1.62	3.42	0.62
		Nov. 29 through Dec. 1, 1975 event		
70th Street	June	3.76	0.08	0.91
	September	10.69	6.08	2.38

Appendix A Table 9. Total P, dissolved reactive P and suspended solids loadings for runoff events at Noyes Creek, Schoonmaker Creek and 70th Street in 1975

Sampling location	Sampling date, 1975	Parameters								
		Total P, kg	Reactive P, kg	Suspended solids kgx10³	Rainfall, in	Sampling duration, hr	Water loading, l	Ave. total P conc., mg/l	Ave. DRP conc., mg/l	Ave. susp. solids conc., mg/l
Noyes Creek	June 17	17	5	17	0.75	2.25	2.5×10^7	0.7	0.2	706
	July 18	1	0.2	0.8	0.50	3.5	3.2×10^5	0.3	0.05	250
Schoonmaker Creek	August 18	0.2	0.03	0.1	0.20	0.5	5.7×10^5	0.4	0.10	260
	August 20	1	0.2	1.1	0.70	2.08	3.4×10^6	0.3	0.06	320
70th Street	August 18	9	3.6	1.8	0.20	2.5	3.1×10^7	0.3	0.12	58
	August 20	165	14	152	0.70	3.75	2.4×10^8	0.6	0.05	633
	September 5	54	23	19	0.4	6.5	1.5×10^8	0.4	0.15	127

Appendix A Table 10. Total P, dissolved reactive P and suspended solids loadings for baseflow at Noyes Creek, Schoonmaker Creek and 70th Street during the summer of 1975

Sampling location	Sampling month, 1975	Parameters: Total P, kg/day	Total P, mg/l*	Diss. reactive P, kg/day	Diss. reactive P, mg/l*	Suspended solids, kg/day	Suspended solids, mg/l*	Ave. discharge, l/sec
Noyes Creek	June	0.2	0.16	0.1	0.10	19	16	14
	July	0.1	0.09	0.04	0.03	25	21	14
	August	0.2	0.11	0.07	0.04	34	20	20
	September	0.06	0.08	0.02	0.03	5	6	9
Schoonmaker Creek	June	0.1	0.30	0.06	0.20	3	9	4
	July	0.02	0.14	0.01	0.11	0.30	2	2
	August	0.04	0.14	0.02	0.10	3	11	3
	September	0.005	0.11	0.003	0.08	0.04	1	0.5
70th Street	June	44	0.35	20	0.16	22**	0.17	1,448
	July	30	0.29	23	0.23	28**	0.27	1,191
	August	25	0.25	13	0.13	17**	0.17	1,175
	September	26	0.30	18	0.21	12**	0.14	1,011

* Average concentration.
** Values are x10^2.

Appendix A. Table 11. Ratio of event total P, dissolved reactive P and solids loading and water loading for following dates and stations to the approximate monthly baseflow loadings

Sampling location	Sampling month, 1975	Parameters			
		Total P	Diss. reactive P	Suspended solids	Water loading
Noyes Creek	June 17	2.83	1.25	29.31	0.69
	July 18	0.33	0.20	1.05	0.09
Schoonmaker Cr.	August 18	0.02	0.30	1.18	0.07
	August 20	1	0.20	12.94	0.44
70th Street	August 18	<0.01	0.01	0.03	0.01
	August 20	0.22	0.04	2.94	0.08
	September 5	0.07	0.04	0.52	0.06

station. The low event water volume combined with average total P and DRP concentrations that were similar to the average monthly baseflow concentrations probably accounted for the low loading ratios at the 70th Street station for these events (Appendix A Tables 9 and 10). Since the relative contribution of total monthly nutrient and suspended solids loadings from runoff events was only based on one or two events in a month, a more accurate estimate of the relative significance of runoff events to total monthly loadings will be possible when the loadings are calculated for more events.

Future loading calculations will include all the water quality parameters determined during event and baseline surveys. Loading calculations will be done for all important events and summarized along with the baseline loadings on a monthly and seasonal basis for each station. These calculations will provide more accurate estimates of the event-to-monthly loading ratios and indicate possible seasonal trends. The loading data will be interpreted in terms of land use activities by the land use-water quality models presently being developed.

Problems Encountered during Field Activities

The following is a listing of the various types of field activity problems that were encountered in the 1975 field year and some suggested solutions.

Sample collection

U.S. Geological Survey (Ps-69) automatic pumping samplers were used to collect water samples during storm events as well as during baseline sampling periods. Problems associated with this sampler follow.

Problem: Partial or complete clogging of the intake pipe by heavy debris, causing one of three sampler fuses or one of two 110-12 volt power converter fuses to blow.

Solution: No reliable method of screening the intake has been found to date. Switching to "slow blow" fuses has allowed, at times, the sampler to complete its pumping cycle even though partially clogged; it then may clear itself during the purging cycle which follows.

Problem: At times, light debris (leaf or macrophyte fragments) would clog the swing-arm nozzle, thereby cutting off water delivery to the sampler bottles.

Solution: A medium mesh screen positioned above the swing-arm funnel collected all debris that might otherwise clog the nozzle.

Problem: Sampler pumps sustained worn-out impellers and control box malfunctions.

Solution: Pump mountings were improved to reduce vibration, and control box circuitry was improved.

Problem: Calibration of sampler efficiency and sample diversity.

Solution: During each sampling survey of all river sample sites, one site was chosen, on a rotating basis, from which to collect two simultaneous grab samples and a sampler sample. The grab samples were collected as close as possible to the sampler intake and at the precise moment the sampler was collecting. Both of these grab samples are defined as simultaneous samples and are analyzed separately to determine the amount of natural diversity found in the water quality of two essentially like samples. The sampler sample taken at the same time as the two grab samples is defined as the comparison sample since its analysis is compared to that of the grab samples to aid in determining the effects that the pumping action of the sampler may have on the water being sampled. Location of the sampler intake in reference to stream width and water depth should also be field calibrated. This involves the comparison of analyses of sampler samples with those of depth- and point-integrated grab samples.

Sample handling

All water samples are packed with ice in insulated containers and sent via U.S. mail to the water quality laboratory of the Laboratory of

Hygiene at the University of Wisconsin-Madison (a distance of 70 miles) for analysis.

Problem: Delays sometimes occurred in mailing iced samples to the laboratory.

Solution: Samples in containers which are prestamped and marked for special handling may be delivered directly to the loading dock of the main post office to be sent via U.S. mail-parcel post. This procedure prevents delays since the containers are loaded directly from the loading dock to a delivery truck and do not enter the post office. An additional advantage is that the loading dock is never closed, so samples can be mailed at any time.

Continuous monitoring

Five selected sites along the Menomonee River watershed are equipped for continuous monitoring of water temperature, dissolved oxygen, pH and conductivity. *In situ* water quality monitors (Surveyor Model 6D), manufactured by Hydrolab Corporation, Austin, Texas, are used for this monitoring.

Problem: How to place the *in situ* water quality monitoring probes (contained inside a protective sonde) in the river.

Solution: Probe sondes were fastened to steel posts driven into the riverbed. Attachment was by means of a small "s" hook attached to the sonde top, which allowed the sonde to be hung from a "u" bolt attached to the post. The height of the sonde in the water could easily be adjusted by raising or lowering the "u" bolt on the post. The sonde was then hooked to the "u" bolt and strapped tightly to the post with nylon webbing and a rachet. Caution signs were placed directly upstream of each sonde post to warn canoeists or snowmobilers and ice skaters of the obstruction.

Problem: Vandalism to equipment.

Solution: On-shore equipment is housed in a locked building. *In situ*

equipment is submerged and locked to the posts. The sonde power cable from the river to the equipment building is buried.

Problem: How to efficiently work with the *in situ* equipment which is usually located in the middle of the river.

Solution: Anchoring a 5-foot plastic boat alongside the sonde while working on it has proved to be a convenience. The boat serves as a platform to hold tools and the sonde itself while the operator (standing in the water) is attaching or separating it from its power cable. When the sonde is disconnected from the cable for cleaning and calibration, the cable connections are cleaned and secured inside the boat to keep them dry.

Problem: How to efficiently clean and calibrate the probes.

Solution: Weekly calibration has been found to be sufficient to assure reasonably accurate data. The sondes (with probes) are raised from their underwater positions and disconnected from the power cable. The watertight cable connections are carefully cleaned with alcohol, cotton swabs and pipe cleaners, and are secured inside the boat to dry. The sonde and probes with their connections are then taken inside the equipment building and thoroughly cleaned in detergent solution. Additional cleaning of the pH reference probe, which has a porous teflon surface, is accomplished using a stiff wire brush and kitchen cleanser. An extremely soiled pH reference probe may be brought back to life by carefully scraping off the soiled surface film of the teflon with a sharp knife. However, this procedure should be classed as drastic and used only when absolutely necessary. The Clark type dissolved oxygen probe, when cleaned, is replaced by a like probe which has had a new membrane installed the previous day. On rare occasions the silver anode of this probe becomes discolored and adversely affects the probe's performance. Cleaning is accomplished by immersing the probe, with membrane off to expose the anode, in an ultrasonic cleaning tank which contains a 50% solution of ammonium hydroxide and distilled water along with a fine grade detergent (e.g., Alconox). After approximately ten minutes the anode should regain its white color, and the probe is then ready to be thoroughly rinsed and soaked overnight in distilled

water. The probe should then be prepared for normal use. When cleaning the conductivity probe, it is helpful to disassemble it into its two main sections. After thorough cleaning, the sections are reassembled, making sure the two sections are tightly seated against each other. Seating is made easier if the two sections are first moistened to allow the "O" rings, which seat the two sections, to easily slip into place. After cleaning and rinsing, all probes and sonde connections are then cleaned with alcohol, dried and coated with a light film of O-ring grease. All probes are then inserted into the sonde and connected to the surface monitoring unit by a spare power cable. (The main power cable is semi-permanently installed from the building to the sonde location in the river.) The sonde is then calibrated before leaving the building, using standard buffer solutions, standard conductivity solutions, and an air calibration tube and internal calibration techniques as per operators' manual instructions. After calibration, probes are disconnected from the spare cable and installed with the sonde to the main cable in its river location.

APPENDIX B

MENOMONEE RIVER DATA BASE SYSTEM

Introduction

The primary purpose of the Menomonee River Data Base System is to provide ready access to, and analysis of, data from a small watershed study. Emphasis has been put on allowing an interactive user to use the data. This emphasis is one of the primary determinants of the architecture for the system. Also, of major importance were: the types and amount of data; the keys which would be used to access the data; and the types of analyses, summaries, and forms of reporting that users would expect. Each of these determinants and its subsequent effects are analyzed after a discussion of the general approach used.

General Notes on Systems Design

Most of the main routines of the system are written in ASCII ANSI Cobol. This language was chosen for two reasons: it is readable, even by a noncomputer-oriented person, and thus is relatively self-documenting; and second, it is relatively efficient at data manipulation. Many of the support or driver-level routines are written in Fortran V, a relatively efficient numerical algorithm language. There are a relatively small number of routines that are written in Univac Assembler Language. These routines assign and free files and perform input and output on several files.

In addition to a breakdown by language type, the various routines of the system can be separated into the main program, primary functional routines and support routines. This breakdown is indicative of the "top down," semi-structured approach to programming that was used.

In "top-down" programming, the main program is made fully operational first and calls dummy routines which simulate the later-developed secondary routines. These routines are then written one by one, with their lower level routines simulated until all higher levels are operational. This approach was followed with the exception that certain common i-o routines and other common "slave" routines were written first.

The semi-structured approach implies that the long functional routines

are also hierarchically organized. There is a common entry. The user is asked which of the program's options should be executed (possibly after some initial explanation and common initialization). Control is passed to a routine which is short or organized hierarchically. Control flows in as linear a fashion as practical within a routine except when a sub-level is performed. The routines always end at a common point or return to the start.

The main routine follows this approach: first, i-o is initialized and the user is (optionally) given an explanation of choices available; then, the choice of a function causes branching to another program in most cases. Passwords are sometimes verified before control passes.

The function-handling routines that handle a specific type of request are largely of the same format. The primary exceptions are the main data input and report listing programs. The input program is primarily linear within the structure of Cobol sort section flow. The report program is cascading--that is, linear loops overflow into the next outer level of looping only when input changes according to one of the primary keys.

The support programs are generally short, linear, easily understood and have only one primary purpose. The i-o initializer "STRTIO" follows the switchboard approach as does "A53302," the primary i-o controller.

Primary Determinants of Design

The desire to make the program interactive gave rise to severl dominant features of the system. An attempt was made to make the programs usable by people who have little or no familiarity with computers. Files are automatically assigned, freed and sent to output devices. Other files can be set up that contain the job control and data for plotting or statistical analyses (both of these are best done in separate steps).

The programs are made as self-explanatory as possible. Messages are generated explaining use of the system. The user needs to refer to documentation only for the most complex of usages.

The desire for rapid access of the data, which caused interactive capability to be designed, also controlled aspects of the data files structure. The primary data file is set up as "hashed" directory access,

multiple-linked file. "Hashing" is a random access technique explained in Addendum I. The multiple linkings are set up as data is entered in order to allow access to data sorted in various ways without the necessity of actually re-sorting data. The increase in overhead is more than compensated for by lowered handling costs.

The data was grouped into sets or "types" (such as nutrients, metals, etc.) which consist of logically associated kinds of physical or chemical analyses. The "type" grouping gives rise to the association of data on a line of a report and also, thereby, to the establishment of one logical record in a file. The other alternative was to put in one record all analyses performed on one sample. This route was not taken, not only because one record could not then be listed succinctly, but also because of the great variability in the number of analyses done on one sample. Instead, all records associated with one sample are linked through a record that is "type" 19, there being eighteen possible types of analyses.

In addition to type of analysis, a user could be expected to desire retrieval of data based on where and when it was taken or because it could be logically associated in some fashion with other data. The keys for retrieval thus become: station (which is a geographic location), depth, and time at which the samples were taken, as well as type.

As indicated above, "type" 19 records are used to link records from the same sample. "Type" 19 records are also linked to each other according to several sort sequence combinations of station, time and depth. The data records are also sequentially chained, as they are input, by another sort sequence.

The usual method of retrieving a group of data would be to request a specific starting and ending point and a sort sequence. There is no great difficulty in this method for a user except for the necessity of picking an exact set of times (to the minute) that corresponds to an actual sampling event. To eliminate this difficulty, a file has been established containing the keys and record addresses of certain records. These are the information for the first and last (by time) records for each half month

for each station (maximum fifty) and for all stations (the "51st" station).

The types of analyses, summaries and modes of data presentation for which users expressed a desire are the primary determinants of the sort sequences. They also caused the establishment of an ancillary comments file, and control the design of plotting and other analysis programs.

File Structure and Layouts

There are five primary files (see layouts in Addendum II). They are the system file, the main data file, the directory file for the main file, the associated comments file, and the link table file. The link table file has been analyzed above; the directory file is discussed in Addendum I; and the comments file is self-explanatory (see notes in Addendum II.C). The main data file consists of data and link records.

The link record consists of six binary zeros, record keys other than type, link addresses for the eighteen associated types, and link addresses for logically adjacent "type" 19 records. The data record consists of a link address to the record next in the primary sort sequence, deletion or modification code, record keys, sixteen sets of sign and value (K stands for <-), links to two comment records, and the address of the type 19 record.

The system file contains conversion factors for: each analysis; a change of status code; a count of the number of stations and types, the start of miscellaneous types; the beginning year; the number of decimal points for each type; the next available data record space; a set of counts for each station and month combination that tell the number and change status of analyses; an array for each parameter group containing a list of parameter codes and the number of codes, a set of headings or descriptions and a description of the group; three system passwords; the next available comment record space; a set of user passwords and user counts; the first deleted record space; two numbers for calculating the hashing efficiency; and information for octal dumps of files.

Addendum I

The "hashed" main data file actually consists of two files: the data file itself and its directory. The purpose of this addendum is to explain the use of the directory in accessing data records.

Hashing is a technique used for storage and retrieval of data that is sparsely spread throughout a large matrix. By using a smaller matrix and indexing the data through an arithmetic recombination of its original indices, the computer program can greatly reduce the required storage space. There does arise the possibility of several entries being referenced to the same matrix position. To eliminate possible destruction of records, an overflow area is provided. Each record in the directory maintains space to point to records in this area if there are "collisions." Thus, a directory entry consists of three logical parts: 1) a master file address, 2) an overflow pointer area, and 3) a set of keys for verification of which entry is being referred to in the original matrix.

It is also necessary to maintain a record of the next empty spaces in the master file and the overflow area. These records are kept in the "zero" entry of the matrix.

Example

The keys we use are:

1. Station or geographic location--a sequence number from 1 to 50,
2. Depth--from 0 to 9 meters,
3. Data group type--a sequence of numbers from 1 to 19,
4. Date and time--a 5-year period recorded to the minute.

This matrix is obviously made sparse by the large number of possible times of sampling.

The arithmetic recombination is the following algorithm:

Key 1 = (((Y-1973)*100+M)*100+D)*10000+100*H+MIN

Key 2 = ((S-1)*19+T)*10+DP

Yields two keys for storage that represent original position

Hash value = Mod (Key 1 + Key 2, 20011)

20011 is a prime number. Modulus is the remainder function. The hash file directory is thereby 20012 entries plus any overflows. The extra record is derived from the record of next available spaces.

where

Y-1973 ≡ years from beginning of project

M ≡ number of months from start of recording

D ≡ day

H ≡ hour

MIN ≡ minute

S ≡ station sequence number

T ≡ group type number

DP ≡ depth in meters

This algorithm is used because it will compress the original matrix in such a fashion as to minimize "collisions," thus maintaining relative efficiency in data storage and retrieval.

ADDENDUM II

A.

```
01  LINK-ARRAY.
    05  PERIOD-INFO OCCURS 12 TIMES.
    10  PERIOD-DEPTH           PICTURE 9.
    10  PERIOD-DATE.
    15  PERIOD-YEAR            PICTURE 9.
    15  PERIOD-MNTH            PICTURE 99.
    15  PERIOD-DAY             PICTURE 99.
    15  PERIOD-HOUR            PICTURE 99.
    15  PERIOD-MIN             PICTURE 99.
    10  LINK-POSITIONS USAGE IS COMPUTATIONAL PICTURE 9(6).
```

B.1.

```
01  UPDATE-BODY.
    05  FILLER                 PICTURE X(7).
    05  KEY-PART               PICTURE X(15).
    05  BODY-1                 PICTURE X(64).
    05  BODY-2                 PICTURE X(64).
    05  CMNT-L1                PICTURE 9(6).
    05  CMNT-L2                PICTURE 9(6).
    05  CMNT-L3                PICTURE 9(6).
01  UPDATE-RED REDEFINES UPDATE-BODY.
    02  SOME-NAME.
    05  RECORD-POSITION  PICTURE 9(8) SYNC RIGHT USAGE
        IS COMP-4.
    02  RECORD-REST            PICTURE X(162).
    02  REST-RECORD REDEFINES RECORD-REST.
    03  NOT-TIME.
    05  RECORD-DELETE          PICTURE 9.
    03  RECORD-TIME.
    05  RECORD-YEAR            PICTURE 99.
    05  RECORD-MNTH            PICTURE 99.
    05  RECORD-DAY             PICTURE XX.
    05  RECORD-HOUR            PICTURE XX.
    05  RECORD-MIN             PICTURE XX.
    03  NOT-TIME-EITHER.
    05  RECORD-STATION         PICTURE 99.
    05  RECORD-TYPE            PICTURE 99.
    05  RECORD-DEPTH           PICTURE 9.
    05  RECORD-BODY            PICTURE X(128).
    05  RCD-BODY REDEFINES RECORD-BODY.
    10  REC-PART OCCURS 16 TIMES.
    15  REC-SIGN               PICTURE X.
    15  REC-ITEM               PICTURE X(7).
    05  CMNT-ASSN.
    10  CMNT-ASSOC OCCURS 3 TIMES PICTURE 9(6).
```

B.2.

```
01 LINK-RECORD.
   05 LINK-VERIFY  PICTURE 9(8) USAGE IS COMP-4 SYNC RIGHT
     VALUE IS 0.
   88 LINK-VALID VALUE 0.
   05 FILLER                 PICTURE X(5).
   05 LINK-STATION           PICTURE 99.
   05 LINK-DEPTH             PICTURE 9.
   05 LINK-TIME              PICTURE 9(10).
   05 LNK-TME REDEFINES LINK-TIME.
   10 LINK-YEAR              PICTURE 99.
   10 LINK-MNTH              PICTURE 99.
   10 LINK-DAY               PICTURE 99.
   10 LINK-HOUR              PICTURE 99.
   10 LINK-MIN               PICTURE 99.
   05 REC19-POS-N OCCURS 24 TIMES PIC S9(8) SYNC RIGHT
     USAGE IS COMP-4.
```

C.

```
01 COMMENTARY.
   05 LINE-REF               PICTURE 9(6).
   05 CMNT-1                 PICTURE X(60).
   05 CMNT-2                 PICTURE X(60).
   05 COMMENT-NUMBER         PICTURE 9(6).
```

D.

```
01 SYSTEM-STATUS RECORD.
   02 MOST-SSF-LAYOUT.
   05 TYPE-CONSTANT OCCURS 19 TIMES.
   10 TYPE-CONVERSIONS OCCURS 16 TIMES PICTURE 9(4)V9(4)
     USAGE IS COMP-4.
   05 STATUS-FILE-LENGTH     PICTURE 99.
   05 CURRENT-STATIONS       PICTURE 99.
   05 NUMBER-OF-TYPES        PICTURE 99.
   05 MISC                   PICTURE 99.
   05 REPORT-YEAR            PICTURE 99.
   05 EDIT-PARM-FIELDS OCCURS 19 TIMES.
   10 PARM-EDITOR OCCURS 16 TIMES PICTURE X.
   05 NEXT-RECORD            PICTURE 9(6).
   05 STATION-RELATNS OCCURS 50 TIMES.
   10 STATIONS               PICTURE 9(6).
   10 STATION-DESCR          PICTURE X(30).
   10 REPORT-COUNTS OCCURS 60 TIMES.
   15 REPORTED-PREVIOUSLY    USAGE IS COMP PIC 9(6).
   15 UNREPORTED-YET         USAGE IS COMP PIC 9(3).
   15 REPORT-CHANGES         USAGE IS COMP PIC 9(3).
   15 REPORT-DELETES         USAGE IS COMP PIC 9(3).
   15 LEVEL-OF-ACTIVITY      USAGE IS COMP PIC 9(3).
   05 CURRENT-TYPES OCCURS 19 TIMES.
   10 PARM-NUMBERS OCCURS 16 TIMES  PICTURE X(5).
   10 NUMBER-OF-PARMS        PICTURE 99.
   10 HEADINGS.
   15 HEADING-1.
   20 FILLER                 PICTURE XXXX.
```

D. continued

```
        20 HEADING-1-1           PICTURE X(64).
        20 HEADING-1-2           PICTURE X(64).
        15 HEADING-2.
        20 FILLER                PICTURE XXXX.
        20 HEADING-2-1           PICTURE X(64).
        20 HEADING-2-2           PICTURE X(64).
        15 HEADING-3.
        20 FILLER                PICTURE XXXX.
        20 HEADING-3-1           PICTURE X(64).
        20 HEADING-3-2           PICTURE X(64).
        15 HEADING-4.
        20 FILLER                PICTURE XXXX.
        20 HEADING-4-1           PICTURE X(64).
        20 HEADING-4-2           PICTURE X(64).
        10 TYPE-DESCR            PICTURE X(13).
        05 PASSWORD1             PICTURE XXX.
        05 PASSWORD2             PICTURE XXX.
        05 PASSWORD3             PICTURE XXX.
        05 NEXT-COMMENT          PICTURE 9(6).
        05 NUMBER-OF-INITIALS    PICTURE 999.
        05 INIT-ACCT OCCURS 100 TIMES.
        10 INITIALS              PICTURE XXX.
        10 INIT-USAGE            PICTURE 99.
        05 NEXT-DELETE           PICTURE 9(6).
        05 FILLER                PICTURE XXX.
        05 MEAN-EFF  PICTURE 9(4)V9(4) SYNC RIGHT USAGE IS COMP-4.
        05 MAX-EFF USAGE IS COMP-4 SYNC RIGHT PIC 9(8).
        02 TABLE-OF-FILES.
        05 FILLER VALUE 'LNKFLE  '   PICTURE X(12).
        05 FILLER VALUE 'RETEMP  '   PICTURE X(12).
        05 FILLER VALUE 'CONFILE '   PICTURE X(12).
        05 FILLER VALUE 'SSF-MR  '   PICTURE X(12).
        05 FILLER VALUE 'DUMB    '   PICTURE X(12).
        05 FILLER VALUE 'CMNTS   '   PICTURE X(12).
        05 FILLER                PICTURE X(72).
        05 FILLER VALUE 96       PICTURE 99.
        05 FILLER VALUE 96       PICTURE 99.
        05 FILLER VALUE 0        PICTURE 99.
        05 FILLER VALUE 96       PICTURE 99.
        05 FILLER VALUE 96       PICTURE 99.
        05 FILLER VALUE 0        PICTURE 99.
        05 FILLER                PICTURE X(12).
        05 FILLER VALUE 5        PICTURE 99.
        05 FILLER VALUE 29       PICTURE 99.
        05 FILLER VALUE 28       PICTURE 99.
        05 FILLER VALUE 15       PICTURE 99.
        05 FILLER VALUE 8        PICTURE 99.
        05 FILLER VALUE 22       PICTURE 99.
        05 FILLER                PICTURE X(12).
        02 TABLE-DEFINITION REDEFINES TABLE-OF-FILES.
```

D. continued

```
473:      05  TABLE-NAME OCCURS 12 TIMES      PICTURE X(12).
474:      05  TABLE-CONSTANT OCCURS 12 TIMES  PICTURE 99.
475:      05  TABLE-FACTOR OCCURS 12 TIMES    PICTURE 99.
476:      02  UNUSED-YET-SPACE.
477:      05  FILLER                          PICTURE X(288).
```

APPENDIX C

LAND DATA MANAGEMENT SYSTEM

Introduction

The Land Data Management System (Land DMS) is a digital computer-based system designed to store, retrieve, analyze and display--in tabular or graphic form--land data for the Menomonee River watershed. The term "land data" as used in the context of the Land DMS is a comprehensive concept in that it denotes all those watershed characteristics that have an areal extent. For example, land data encompass land use, soil type and civil division information but do not include water quality or stream flow data.

Uses of the Land DMS

The Land DMS has two principal uses in the Menomonee River Pilot Watershed Study:

1. Interpretation of water quality and quantity data acquired from routine long-term monitoring activities as well as that obtained from short-term specific land use studies.
2. Input to hydrologic-hydraulic-water quality models.

In addition to meeting the above two needs of the Menomonee River Pilot Watershed Study, the Land DMS was designed to be consistent with the recommendation of the Ad Hoc Data Handling and Processing Work Group of the PLUARG Task C Technical Committee.

Description of the System

The basic areal unit for storing, retrieving, analyzing and displaying land data is a cell having a nominal area of 1.0 hectare (2.5 acres). The corners of each cell may be referenced to the State Plane Coordinate System, to latitude and longitude, and to the Universal Transverse Mercator System. The digital computer system--hardware and software--needed to support the Land DMS is broken into four phases: the input phase, the data management phase, the data base phase, and the output phase. Under the input phase, data are entered into the Land DMS

on either magnetic tape, magnetic diskettes or punched cards. The second or data management phase is composed of a set of computer programs that perform contingency checks on the incoming data, provide for the maintenance and updating of the Land DMS, and perform analysis of the data as requested by the user. The third or data base phase of the Land DMS is the actual storage of the areal characteristics of each cell in a computer file which is maintained on magnetic tape or on magnetic disc. The fourth or output phase provides transfer of land data from the Land DMS to the user in a variety of media including magnetic tape, punch cards, on-line printer, and plotter.

Work Elements Completed since October 1975

1. A computer program having capability to convert cell corner coordinants from the Wisconsin State Plane Coordinate System to the Universal Transverse Mercator System was obtained from the National Geodetic Survey and added to the data management phase of the Land DMS.
2. The coding of soils data was completed for the watershed and work was initiated on the coding of ground elevation data and land use data by cell.
3. Work was initiated on the software additions needed to determine the characteristics of the total area tributary to each of the monitoring stations established in the watershed.
4. At the request of study participants, the Land DMS was used to prepare a tabular summary of soil types for each of the 244 subbasins in the watershed. In addition, the system was used to prepare a 1" = 2000' scale watershed map showing dominant soil type by cell.

Land Data Contained in the Land DMS

Appendix C Table 1 summarizes the status of land data within the Land DMS. Nine data types have been coded for the entire watershed, and the coding of two data types is in progress. Other land data types will be added in response to the needs of the Menomonee River Pilot Watershed Study.

Appendix C Table 1. Status of land data in the Land Data Management System

Data type	Status: Completed	Status: In progress	Type of coding: Dominant characteristic	Type of coding: Percent of cell	Type of coding: Other
1. Civil division	x		x		
2. Sub-basins and subwatersheds	x		x		
3. Wildlife habitat (with value ratings)	x		x		
4. Woodland-wetlands (with value ratings)	x		x		
5. Park and outdoor recreation sites	x		x		
6. Floodlands	x		x		
7. Perennial streams	x				x
8. Conservancy, flood-land and related zoning	x		x		
9. Soils	x			x	
10. Ground elevation		x			x
11. Land use		x		x	

APPENDIX D

SPECIFIC LAND USE STUDIES

Introduction

The specific land use studies are an attempt to define more precisely the quality and quantity of stormwater from homogeneous and/or predominant land use areas in the watershed. The study sites are representative of the major land uses in the watershed, and data gathered at the stations complement data gathered at the major river monitoring stations. The data will be used to calibrate an overland flow model.

Study Sites

Construction of the sampling stations continued through the winter months and is now complete at the sites listed in Appendix D Table 1. The two residential sites, high density and developing, are part of the major river monitoring system and have been operational since January 1975. The freeway right-of-way site is part of a U.S. Department of Transportation study conducted by Envirex, Inc.--a Rexnord Company--in Milwaukee. Arrangements have been made to receive the study data and findings. Negotiations are presently underway with the Milwaukee County Park Commission for establishment of sampling stations at the Greenfield Park and Golf Course. The Greenfield site likely will contain two sampling stations: one for the park and golf course drainage and another for drainage from the Town of New Berlin, a medium density residential area.

Equipment

Sealed bids were opened in December 1975 for the purchase of water-level recorders and samplers. Low bids were submitted by Leupold and Stevens, Inc., for type A model 71 water-level recorders and by the Instrumentation Specialities Company for model 1680 water samplers with high speed pumps.

The flow proportional circuitry of the 1680 samplers has been modified to provide at least 50 ma. output to drive a relay/event marker

Appendix D Table 1. Completed specific land use study sites

Land use	Location
	Transportation
Airport	Timmerman Airport at W. Appleton Ave., Milwaukee
Freeway, right-of-way	Highway 45 between Blue Mound and Underwood Creek
Freeway, interchange	Stadium Interchange (I-94--USH 41) near Milwaukee County Stadium, Milwaukee
	Commercial and Industrial
Retail and services	Brookfield Square Shopping Center at N. Moorland, Brookfield
Manufacturing, heavy	Allis Chalmers at S. 70th St., West Allis
	Residential
High density	Schoonmaker Creek at W. Milwaukee Ave., Wauwatosa
Low density	Underwood Parkway at Wrayburn Rd., Elm Grove
Developing	Noyes Creek at 91st St., Milwaukee

system which is attached to the level recorders and marks the time a sample is taken.

The "1680" samplers have two actuation modes:

1. During spring snowmelt, when the stage rises slowly during the day, the samplers are actuated, in the "Time" mode, by a micro switch on the moving pen assembly of the water-level recorder.
2. During the remainder of the sampling season (rainstorm periods), the samplers are actuated, in the "Flow" mode, by a reed switch mounted opposite the float wheel of the water-level recorder. Magnetics, mounted near the circumference of the float wheel, close the switch and actuate the sampler for a predetermined change in water level.

At the present time, work is continuing on the installation of the electronic switching devices.

Sampling and Laboratory Analysis

Laboratory space at the Water Chemistry Laboratory, University of Wisconsin-Madison has been equipped to handle analysis of Group C (inorganic and organic) parameters. Procurement of an atomic absorption spectrophotometer with graphite furnace and a gas-liquid chromatograph is underway, and an analytical chemist has been hired.

Preliminary grab sampling of runoff arising from snowmelt was started on March 18, 1976, at selected specific land use study sites to scan for the predominant Group C parameters (airport, Stadium interchange, Brookfield Square Shopping Center and Allis Chalmers Corporation). An attempt is being made to separate the suspended sediment from the water and scan it for heavy metals and organics, since it plays a major role in the transport of pollutants.

APPENDIX E

BIOLOGICAL STUDIES

Objectives

A biological sampling program has been designed to provide the data necessary for correlating biotic composition of the community with the chemical and physical parameters being measured in the stream. This program is designed to provide samples which are not necessarily representative of the natural community at each site. Instead, the samples will provide data useful for both intersite and intrasite comparisons spanning the entire sampling period. The standardized artificial substrate being used affords a suitable and uniform habitat for organisms drifting down from the upstream reaches. The use of modified Hester-Dendy samplers also provides control over habitat available for colonization at sites differing greatly in their riverbed composition. In addition, chemical analyses of the organisms for heavy metals and pesticides will provide information on concentrations and locations of these substances within the food chain.

Sampling Program

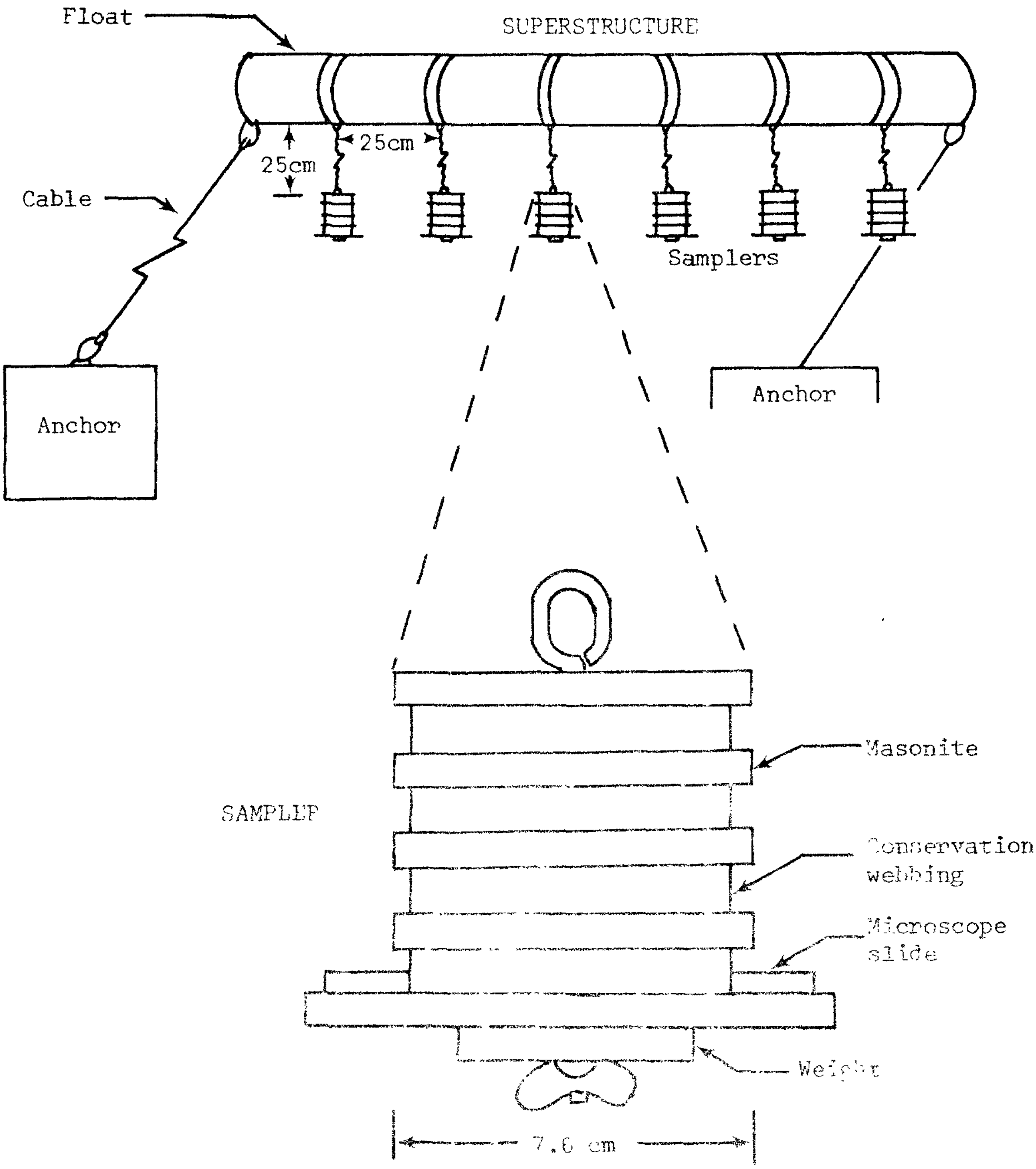
Five sites have been selected for biological monitoring. Four of these sites coincide with continuous monitoring stations (413005, 683001, 413008, 673001) and one is an additional upstream station (683002). Each station will be equipped with a floating structure from which are suspended six modified Hester-Dendy samplers made of Masonite and Conservation Webbing (Wards Natural Science Establishment, Inc., Rochester, N.Y.). Sampler colonization will be six weeks in length, with a sampler overlap of four weeks. Two samplers will be removed and replaced every two weeks from each site for the duration of the sampling period. This continuous and rotating sampling program provides the data necessary for multivariate analysis of species composition as related to the chemical parameters being measured in-stream. Field sampling will continue from early April 1976 to November 1976. All samples will be analyzed for macroinvertebrates and periphyton community composition at the Water Resources

Center. The preserved specimens may be analyzed later for content of heavy metals and pesticides.

Progress

To date, several methods of sampling have been tried and considered. Artificial substrate sampling was chosen because of the control over an important environmental factor which it provides. The modified Hester-Dendy (Appendix E Fig. 1) was chosen for ease of handling and replicate sampling.

Superstructure floats (Appendix E Fig. 1) are being built by the machine shop of the Zoology Research Department at the University of Wisconsin and the Masonite-Conservation Webbing samplers are being assembled by hourly helpers at the Water Resources Center.



Appendix E Fig. 1. Modified Hester-Dendy sampler.

APPENDIX F

ATMOSPHERIC MONITORING PROGRAM

Introduction

The input of atmospheric substances, in the form of wet and dry deposition, may play an important role in the movement of materials through both terrestrial and aquatic ecosystems (Biggs et al., 1973; Andren et al., 1975). The Menomonee River watershed, which is presently being hydrologically calibrated, provides an ideal site for studying the influence of atmospheric processes in the cycling of elements. A watershed can also act as a source of atmospheric materials to surrounding areas via resuspension of soil dust by wind and anthropogenic activities. The Menomonee River watershed may thus act as both a source and a sink for atmospheric substances. The primary objectives of this program are: 1) quantification of elemental input into the watershed through the atmosphere; 2) identification of atmospheric elemental sources; 3) determination of the relative contribution of different land use practices to the total weight and chemical composition of the elements measured in the atmosphere above the Menomonee River watershed; 4) quantification of watershed-derived atmospheric elements into Lake Michigan; and 5) evaluation of methods available for determining the effect of elemental atmospheric input on the chemical composition of the Menomonee River.

Prior to rain and aerosol collections in the Menomonee River basin we have evaluated collection methodologies for aerosols. This report will deal with the evaluation of high-volume air samplers and inherent sampling difficulties. Specifically, it is useful to know the sources and magnitude of errors involved in: 1) filter paper weighing (using Whatman-41 filters), 2) high-volume sampler performance, 3) sample division, and 4) sample digestion and analytical procedures.

Weighing

Two types of filter papers are generally available for high-volume air sampling. One--the glass fiber filter--is used widely by many researchers including the U.S. Environmental Protection Agency (EPA) for total suspended particulate (TSP) measurements. However, glass fiber

filters contain a large amount of impurities, making them unsuitable for trace element analysis. The cellulose Whatman-41 filter contains fewer impurities and has been selected for this study.

Unfortunately, paper filters are extremely hydroscopic. An 8"x10" sheet indicates a change in weight of up to 1% with every 2% change in relative humidity at room temperature. Consequently, it is critical to weigh each filter before and after collection at the same humidity.

The USDA Forest Products Laboratory, Madison, Wisconsin, has provided weighing facilities for the project. These facilities include a large room which is temperature- and relative humidity-controlled to ±0.5% at 50% relative humidity. An equilibration chamber for the filter paper was built from plexiglass. Inside, the paper filters equilibrate for 24 hours before the tare weighing and again for 24 hours before weighing of the collected material.

The chamber is virtually airtight except for two holes cut in the ends covered by glass fiber filters. A vacuum pump (with exhaust filters) draws air out of the chamber; consequently, humidified, filtered air is constantly entering the end portals and flowing across the filter paper for the 24-hour period. The scale used reads to ±0.1 mg.

Calibration of High-Volume Air Sampler

Each sampler has a flow gauge (ft^3/min) at the exhaust orifice below the motor. The air flow gauge must be calibrated to standard conditions, namely, Standard Cubic Feet/Minute (SCFM) normalized to a pressure of 29.92 in. of Hg at 298°K. Using a National Air Surveillance Network (NASN) type orifice calibration assembly, the flow rate in SCFM can be obtained as follows.

First, the orifice calibrator is screwed onto the intake of the sampler. A flexible hose is connected to the pressure tap on the side of the orifice to a manometer which reads inches of water. Under a given set of temperature and pressure conditions, flow rate is proportional to the change in inches of water.

$$Q_{ind} = k\sqrt{\Delta p}$$

where Q_{ind} is true flow rate at a given temperature and pressure

Δp is inches of water difference on manometer

k is 17.66 for this particular orifice calibrator

The true flow can be corrected to SCFM by the formula:

$$Q_s = \sqrt{(Pa/Ps \times (Ts/Ta)} \times Q_{ind}$$

where Q_s is flow rate corrected to SCFM

Ps is 29.92 inches of Hg

Ts is 298°K

Pa is ambient pressure in inches of Hg

Ta is ambient temperature in °K

or simplified to:

$$Q_s = \sqrt{(Pa/Ta)} \times 3.156 \times Q_{ind}$$

To compare the flow gauge to SCFM it must also be corrected for temperature and pressure variations from standard.

$$I_s = \sqrt{(Pa/Ta)} \times 3.156 \times I_a$$

where I_a is flow gauge reading at given temperature and pressure

I_s is flow gauge reading corrected for temperature and pressure

Pa is temperature at pump exhaust.

Finally, I_s is related to Q_s graphically by assuming the relationship is linear. Each flow gauge must be calibrated in this manner and recalibrated with the installation of each new set of brushes for the motor.

Points for the graph of I_s against Q_s are obtained by varying the flow rate in one of two ways. A continuously variable rectifier in the line between the vacuum pump motor and the power source can change motor speed and, thus, flow rate. Resistance plates can be placed within the orifice calibrator above the pump intake to slow the flow. It was thought that

the latter method best simulated clogging in the field and should be used to obtain points for the calibration curve. However, for each pump two calibration curves were obtained experimentally: one at about 90 volts and one at about 66 volts. These two curves agreed well when extrapolated to common points. Calibration of all seven high-volume air samplers has been completed.

Collection

One important test was to compare simultaneously running samplers and note the collection by each. For this experiment, four samplers were anchored 10 feet apart in a square formation atop the Helen White building, University of Wisconsin-Madison. At this location there are no obstructions to the wind from any direction. Each sampler was connected to a rectifier.

Appendix F Table 1 compares TSP measurements for three sampling periods, and Appendix F Table 2 represents a similar experiment run by Neustadter et al. (1975).

Some of the differences in procedure which might account for the greater variation between samples in the Helen White experiment include a larger sample size and the fact that Neustadter was able to record flow rate continuously whereas the Helen White data represent periodic flow measurements averaged over time.

Flow rates actually decreased significantly and in different magnitudes for each sampler over the sampling period. The reason for the decrease was thought to be primarily due to clogging. It was also noted that, in general, those samplers measuring the highest TSP values also experienced the greatest drop in flow rate during the experiment. If the decrease in flow rate is due to clogging, and clogging is a function of the concentration of TSP, then the measured differences in TSP may be, in part, real. Although the samplers were only 10 feet apart, there was no basis from the numbers to suspect effects of one sampler upon another. Wind directions were noted during each run, but downwind samplers did not generally measure less than upwind samplers.

Appendix F Table 1. Factorial experimental TSP data using Whatman-41

Date (1976)	Sampling period	High volume sampler pump no. 1007	1009	2968	2970	95% limits
		--------TSP in µg/m³--------				
26 Jan.	30.0 hrs	30.2	32.9	30.2	27.5	±11.61%
09 Feb.	36.0 hrs	32.3	31.7	32.5	27.5	±12.09%
13 Feb.	66.5 hrs	32.9	29.6	36.4	31.0	±14.42%
Mean		31.8	31.4	33.0	28.7	

From Stolzenburg (1976)

Appendix F Table 2. Factorial experimental TSP data using Whatman-41

Date (1972)	Sampling period	High volume sampler serial no. 14	29	63	68	71	95% limits
		------------TSP in µg/m³------------					
24 Jan.	24 hrs	61.3	62.7	66.0	63.2	67.0	±4.62%
25 Jan.	24 hrs	47.7	52.4	56.5	60.0	55.2	±10.56%
26 Jan.	24 hrs	69.0	71.3	74.2	72.0	64.8	±6.32%
27 Jan.	24 hrs	45.3	43.5	50.5	47.2	47.2	±6.93%
Mean		55.8	57.5	61.8	60.6	58.5	

From H. E. Neustadter et al. (1975)

Division of Sample

The analysis program will include halides of interest such as Cl and Br. Most wet digestion procedures would produce a loss of these volatile elements. The 8"x10" filter paper must be divided, therefore, prior to dissolution so that a portion of it can be analyzed directly by neutron activation analysis for those elements plus some rare earths.

If the filter is cut after collection there would be no direct means for measuring the tare weight. By knowing the area of the cutout portion, the tare weight can be indirectly calculated from the tare of the whole piece. Similarly, the collected weight of a portion could be calculated. To assure equal and known portions, a circular die was made from stainless steel tubing.

Two questions arise concerning this procedure: 1) Is the filter paper uniform in terms of weight per unit area? and 2) Does collection occur uniformly across the filter sheet? The first deals with the precision of the calculated tare weight, and the second with the precision of the calculated collected weight.

To answer the first question, a whole 8"x10" filter was weighed and then eight circles were cut out of it with the die. An area calculation of the weight of one circle equalled the average measured weight of the eight circles to the fourth decimal place. It was calculated that 95% of the time a randomly cut circle from this filter paper would fall within ±0.677 mg of the average weight. The range of circle weights was from 0.0809 g to 0.0829 g. The data appear below.

Variation of Whatman-41 weight - die cut

Actual		Calculated
Die-cut area =	$1.56\ in^2$	Whole area = $80\ in^2$
Die-cut weight:	0.0812 g	Whole weight = 4.1945 g
	0.0822 g	$\frac{1.56\ in^2}{80\ in^2} \times 4.1945\ g = 0.0818\ g$
	0.0816 g	
	0.0826 g	
	0.0809 g	
	0.0817 g	
	0.0829 g	
	0.0815 g	
Mean =	0.0818 g	
95% limits:	±0.677 mg (±0.827%)	

Initially this error appears small. Unfortunately, the amount of collected material on a circle may be relatively small (5.30 mg) compared to the weight of the filter itself (81.8 mg). Therefore, the error on the calculated collected weight may be as large as ±13%. This error can be reduced significantly (to about 1%) if an effectively larger portion of the filter paper (four circles) is cut out.

<u>Resulting error to weight of collected material</u>

TSP Annual Mean (NW part of Menomonee River basin) $\sim$ 35 $\mu g/m^3$

Flow Rate $\sim$ 30 ft^3/min

Time $\sim$ 5 days

$$\text{Total Collected Wt.} = \text{Flow Rate} \times \text{Time} \times \text{Conc.} = \frac{0.2141\ g}{(63\ in^2)^*}$$

<u>Assume even distribution of collected material</u>:

$$\text{Collected Wt. on (1) Circle} = \frac{1.56\ in^2}{63\ in^2} \times 0.2141\ g = 5.30\ mg$$

$$\begin{array}{c}\text{Error in Collected Wt.}\\ \text{for (1) Circle}\end{array} = \frac{\pm 0.677\ mg}{5.30\ mg} \times 100 = \boxed{\pm 12.8\%}$$

\- - - - - - - - - - -

$$\begin{array}{c}\text{Error in Collected Wt.}\\ \text{for the Sum of (4) Circles}\end{array} = \frac{\pm 0.2296\ mg}{4(5.30)\ mg} \times 100 = \boxed{\pm 1.08\%}$$

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*Actual collecting surface of filter paper.

The error discussed above may not be totally attributable to filter uniformity variations. Other factors contributing to the differences include nonuniform die cuts and humidity changes (even at the ±0.5% level) between measurements.

Probably of more concern is the question of collection uniformity. The analytical scheme does not involve weighing the die-cut circles. Instead, that weight will be calculated by area after the whole filter paper is weighed. If the tare weight varies, the result should be insignificant as long as the blank values for analyzed elements are well below

the collected values. However, if collection is nonuniform, variations will have a large effect on the calculated "true" value of the concentrations of the elements in the air. Furthermore, the tare value errors and reweighing errors would be reintroduced if the circles had to be weighed.

Collection uniformity is difficult to assess. Weighing die-cut circles is not a good method to use since there are so many other factors contributing to the variation. It may be possible, however, to determine an overall error which would include contributions from filter nonuniformity, collection nonuniformity, humidity changes, balance sensitivity, and analytical error, if elemental analysis is carried out on the circles.

An experiment was undertaken with a set of four filters from one run. Eight circles were cut from each filter, four from the center and four from the corners.

For each filter, first the four corner circles were combined and analyzed for Na, Ca and Mg; and, secondly, the center circles were combined and similarly analyzed. Absorbances are compared between the inside and outside sets in Appendix F Table 3. Absorbances are proportional to concentrations, so the percent variations are expressions of the final elemental concentrations in air due to all possible error sources listed above. These variations are topped by an 18.2% difference in the sets from filter no. 4 (Appendix F Table 3) for the Na analysis.

The initial trend of higher concentrations toward the center of the filter paper evidenced in the Na analysis seems to be reversed in the Ca analysis. An arbitrary goal before field sampling might be to reduce the final error to below 15%, recalling that this error represents reproducibility within one collected filter paper, not between samplers.

Digestion and Analysis

Preliminary digestion and analytical procedures are outlined below.

Appendix F Table 3. Absorbance comparisons between materials deposited on the centers and corners of Whatman-41 filter papers for Na, Ca and Mg

		Filters			
		1	2	3	4
	Center	0.3439	0.3233	0.5229	0.5272
Na	Corner	0.3363	0.3107	0.4976	0.4461
	% Diff.	2.26	4.06	5.08	18.2
	Center	0.1073	0.1051	0.0799	0.0721
Ca	Corner	0.1180	0.1073	0.0820	0.0655
	% Diff.	9.97	2.09	2.63	10.1
	Center	0.1752	0.1752	0.1772	0.1580
Mg	Corner	0.1878	0.1733	0.1691	0.1580
	% Diff.	7.19	1.10	4.79	0.0

Divide sample

- → Neutron activation analysis (direct analysis)
- → Flameless atomic absorption (LTA and HNO_3, HF dissolution).
- → Flame atomic absorption

Digestion

Mixture of HNO_3 & $HClO_4$ (2:3) + heat → Silica residue with. . .K, Na, Mg, Ga, ?, ?

Alternatives:

1) Analyze directly
2) Filter
3) HF addition (LaF_3 ppt)

Dilute

DDW + LiCl or CsCl + La reagent

Analyze

Optimize operating conditions

Flameless atomic absorption is intended to be the main analytical tool. Currently, only a flame atomic absorption unit is available and procedures for its use are being worked out. A mixture of HNO_3 and $HClO_4$ (2:3) is added to filter paper circles in a quartz digestion flask. The mixture is heated slowly at first to decompose the easily oxidizable materials. Then, at a higher temperature the $HClO_4$ is brought to boiling and the solution clears. This procedure does not remove solid silicates which may contain significant quantities of K and Na and possibly some Mg and Ca.

Analyzing the samples directly might result in interferences due to scattering from undecomposed silicates. Filtration might remove soluble elements of interest or those associated with the silica. Addition of HF should solubilize the silicon to $SiF_6^{=}$. However, excess Fl^- will react with the lanthanum reagent (added for control of PO_4^{-3}, Al, and Si

interferences in the determination of Ca and Mg) to form a precipitate LaF_3. Investigation is underway to circumvent these problems. Ionization control is effected by the addition of LiCl or CsCl.

Summary

A literature review indicated that little attention has been paid to minimizing errors involved in gathering aerosol data. In addition to considering errors inherent in the physical manipulation of filter papers, the high-volume collection performance, and subsequent chemical analysis, one has to consider the collection efficiency of the filter papers for various size classes of aerosols. Lockhart et al. (1963) reported that Whatman-41 cellulose filter papers collect aerosols down to 0.3 μm with a greater than 99% efficiency. The collection efficiency for particles less than 0.3 μm is presently uncertain. Furthermore, there is a lack of experimental work on the collection efficiency of both Whatman-41 and glass fiber filters and the change in relative ambient humidity.

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APPENDIX G

REMOTE SENSING PROGRAM

Introduction

This is a joint project between The Pennsylvania State University, Office for Remote Sensing of Earth Resources (ORSER), and the University of Wisconsin-Madison, Water Resources Center and the Civil Engineering Department, to determine the applicability of remote sensing data in hydrological modeling efforts.

Objectives

The objectives of this study are twofold:

1. To develop techniques for converting aerial imagery into digital representation which can be interpreted by a computer. This work is being undertaken at the University of Wisconsin-Madison.
2. To prepare, at The Pennsylvania State University, land cover maps and data summaries using automatic data processing procedures on digitized color infrared aircraft photography and to compare them with land use maps and data summaries prepared by the Southeastern Wisconsin Regional Planning Commission (SEWRPC).

Methods and Materials

Data

Low altitude 70 mm color infrared photography is being acquired with the cooperation of the Wisconsin Department of Natural Resources (DNR). The imagery is taken by a two-camera system mounted in the DNR's DC-3 aircraft. Both color and color infrared imagery (Kodak types 5257 and 2443, respectively) are taken on each mission. Photographic missions have been flown approximately once per month during the summer and fall months of 1975. Photographic coverage of the Menomonee River Basin will continue to be flown in the spring and summer months of 1976. Imagery from each flight is calibrated and developed at Precision Photo Laboratories in Dayton, Ohio.

The photographic imagery is converted into a digital representation by using an Optronics P-1000 scanning microdensitometer. This instrument is capable of measuring the film density everywhere on a 4.5" x 6.3" transparency every 25 (0.025mm) to 100 (0.1mm) microns. The instrument will create a computer-compatible magnetic tape with numerical information that is related to the film density on the scanned transparency. This digital tape can be processed on a computer.

The research this year has been directed at improving the density measurements from the microdensitometer and on preprocessing of the numbers from the microdensitometer to make possible the interpretation at ORSER.

Since the films used are multi-emulsion films, some type of color separation process must be employed in the microdensitometer. From previous research, it was decided that narrow-band interference filters must be inserted in the optical path when density measurements were made with the microdensitometer. Since the filters decreased the intensity of the light in the system, operational problems were encountered, but an acceptable method of operating the microdensitometer was found. Further work on improvement of the operation of the microdensitometer will be continued.

Once density measurements have been acquired from the microdensitometer, calibration procedures must be employed. Because of film processing and other problems, film density is not proportional to the energy incident on the film when it was exposed. Procedures have been developed to correct the film measurement for these nonlinear effects. Programs were written to enable this correction to be performed on the University of Wisconsin's Univac 1110 computer.

Another problem in the analysis of aerial imagery is the radiometric changes on the film due to the geometric properties of the lens. Due to geometric considerations, an image is always darker at an edge relative to its center. Density measurements must be corrected for this effect before digital interpretation. Work is progressing on this correction. Corrections for atmospheric absorption, scattering, and uneven scene illumination are also being considered.

Thus far, two scenes near Menomonee Falls in Waukesha County, Wisconsin, dated 16 July and 6 October 1975, have been digitized in the wavelength intervals 4450-4550 Å (red), 5450-5550 Å (blue) and 6450-6550 Å (green) using a 100 micron spot size representing a pixel size of 7.5 meters on a side. Approximately 377 hectares (930 acres) of the July 16 data and 334 hectares (825 acres) of the October 6 data were digitized.

Analysis of the digital tape is undertaken utilizing The Pennsylvania State University's IBM System 370, Model 168 computer and ORSER's programs for analyzing remote sensing data (Borden et al., 1975). Land cover maps were developed and output on conventional paper printouts was provided as well as being displayed on ORSER's RAMTEK color cathode ray tube system.

Ground truth information consisted of 35 mm color slides of the digitized photography, U.S.G.S. 7.5 minute quadrangle topographic maps, Soil Conservation Service soil survey maps (USDA, 1971), and telephone communications with University of Wisconsin and SEWRPC personnel.

Analysis procedures

The first step in the analysis procedure was to run the ORSER program called SUBSET. Each wavelength interval or channel comprising a separate file on the source tape was run using SUBSET which reformatted the data into the standard ORSER format. The three channels for the July 16 data and the three channels for the October 6 data could not be merged due to scale differences between the two digitized photographs. Therefore, each date was analyzed separately.

The initial display for each date was produced using the NMAP program which yields a brightness map similar to a grey-scale map. These maps are useful for initial target location and verification of general location. The NMAP program requires no *a priori* knowledge of target spectral signatures or other characteristics.

The UMAP program is employed to identify areas of local spectral uniformity. Each element is compared with its near neighbors, using the euclidean distance between spectral signatures as the measure of

similarity or dissimilarity. One or more categories of uniformity can be mapped according to distances specified by the user. All elements with distances from their neighbors smaller than those specified are mapped as uniform, while those with distances greater than specified are mapped as contrasts. The output shows the pattern of uniformity and contrasts from which the user can designate coordinates of training areas for input to supervised classifying routines. High contrast boundaries between uniform areas may also be determined.

Signatures and associated statistics are obtained from the STATS program, which computes the multivariate statistics for one or more training areas obtained from UMAP or a similar output. The user designates, for each identifiable category, a training area by line and element coordinates, and the program computes the statistics for all of the data which fall within the boundaries. The mean and standard deviation vectors for each category are calculated and the correlation and variance-covariance matrices are computed. If desired, the eigenvalues and eigenvectors of these matrices, and histograms for selected channels, can also be computed.

Using statistics from the STATS program, for the targets of interest, supervised classification and mapping can be done with the CLASS program. By specifying either the ACLASS or DCLASS option, one of two operational modes can be selected. Under the ACLASS option, the data are normalized and are classified according to their angle of separation in a multidimensional geometric sense, with classification made into the category for which the angle is smallest. Under the DCLASS option, the data are not normalized and are classified according to their euclidean distance of separation from each of the categories. The output of these programs is a digital character map with each category of classification represented by a unique symbol assigned by the user.

Frequently, it may not be possible to accurately define or locate training areas, or a sample target may not be of sufficient size or area to lend itself to categorization using the supervised STATS-CLASS sequence. Such targets may be linear features, such as streams, or a series of small scattered features which are not large enough to be represented as uniform areas by UMAP. In such cases, these areas are defined for analysis by an unsupervised classifier, CLUS, which develops its own set of spectral signatures and statistics using a clustering algorithm, outputting a character map based on these parameters. The spectral signatures developed using CLUS can then be used in the CLASS program along with the signatures developed from the STATS program.

Classification maps can be produced on conventional line printers or displayed on a color cathode ray tube device.

Results and Discussion

July 16 data

To date, 29 signatures have been developed for the July 16 data representing five categories of land cover (Appendix G Table 1). Appendix G Table 1 lists the category name, number of signatures required for each category and the percentage of the area classified as that category. More than one signature is usually required for each category to account for within-category variability. For example, several types of vegetation may be apparent in a scene with each one having a unique signature and, if the investigator is only interested in vegetation in general, he combines them into a single category by assigning them the same symbol or color. Approximately 93 percent of the area was classified. Grassland and pastureland represent a variety of vegetation and required many more signatures than other categories. It is suspected that these areas are no longer in use as commercial agricultural lands but merely are in a state of vegetative cover awaiting industrial and/or residential development. As a result, management of the vegetation is probably minimal, which allows natural soil fertility variations to manifest themselves in the vigor and health of the vegetation. The various physiological conditions of the vegetation result in more variable reflectance values than would normally occur with crops grown under an adequate commercial agricultural management program.

Some confusion was apparent between the categories of roof tops, roads and highways, and disturbed lands because of their apparent simi-

Appendix G Table 1. Classification results of the digitized photography collected on July 16, 1975

Category	No. of signatures	Area mapped, %	Area, Ha
Grassland and pastureland	16	74	279.0
Disturbed land	2	3	11.3
Roof tops	4	6	22.6
Roads and highways	3	8	30.2
Trees	4	2	7.5
	Unclassified*	7	26.4

*Since development of land cover maps is an iterative procedure, unclassified areas are those areas which have not been assigned a specific land cover category using the signatures developed to date.

larities in reflectance. Only slight confusion between trees and other categories was apparent. Tree shadows did have a tendency to moderate the specificity of the tree signatures, resulting in some confusion with other vegetation.

Residential areas consist of a highly variable group of small targets, such as roof tops, trees, lawns, and streets. Thus, because it is difficult to accurately delineate categories within residential areas, it may be necessary to use a spot size smaller than the 100 micron spot size presently used on the digitizer.

October 6 data

A total of 39 signatures representing six categories of land cover has thus far been developed for the October 6 data (Appendix G Table 2). Approximately 80 percent of the area was classified. Appendix G Fig. 1 shows the classification results of the October 6 data as displayed on the color cathode ray tube system.

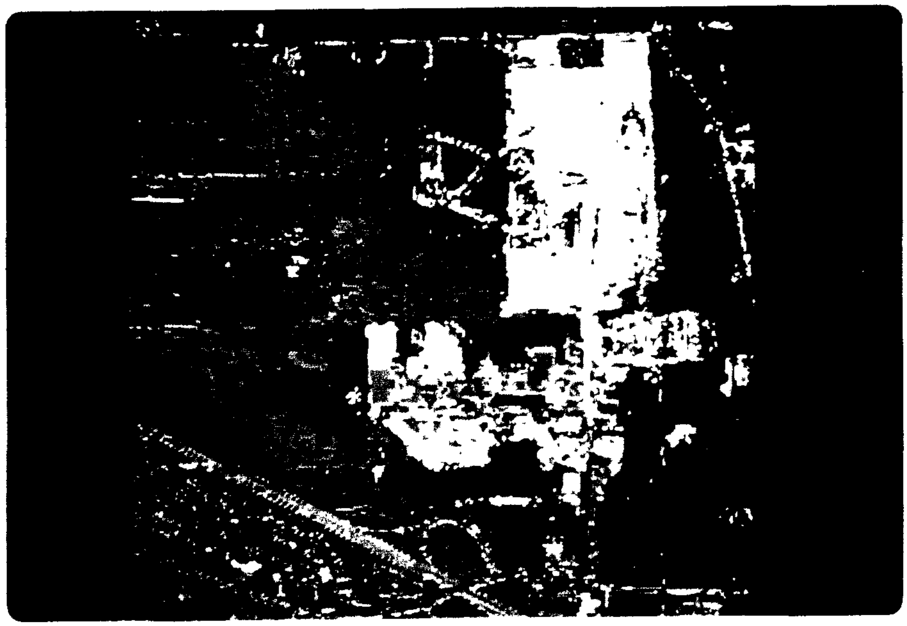
The yellow area in the upper right of Appendix G Fig. 1 represents the disturbed land category which is classified as clayey land by the Soil Conservation Service (Soil Survey Staff, 1971). Clayey land is defined as a miscellaneous land type that consists of fill areas and of cut or borrow areas occurring mainly within or near cities or towns and areas used for housing developments or related purposes. The yellow areas of Appendix G Fig. 1 (disturbed land category) are cut or borrow areas where the entire solum of the soil has been removed, exposing the raw underlying material. The underlying material is variable, consisting of silty clay loam glacial till that contains pockets of loamy or silty material and is generally compacted and relatively impervious. Due to the variable reflectance of these areas, several signatures were required to adequately classify them.

The blue areas and the pale green areas of Appendix G Fig. 1 represent the roof tops and roads-highways categories. Some confusion between these two categories is readily apparent. The purple and brown areas of Appendix G Fig. 1 represent the trees and grassland-pastureland categories, respectively. Considerably more areas are misclassified as trees on this

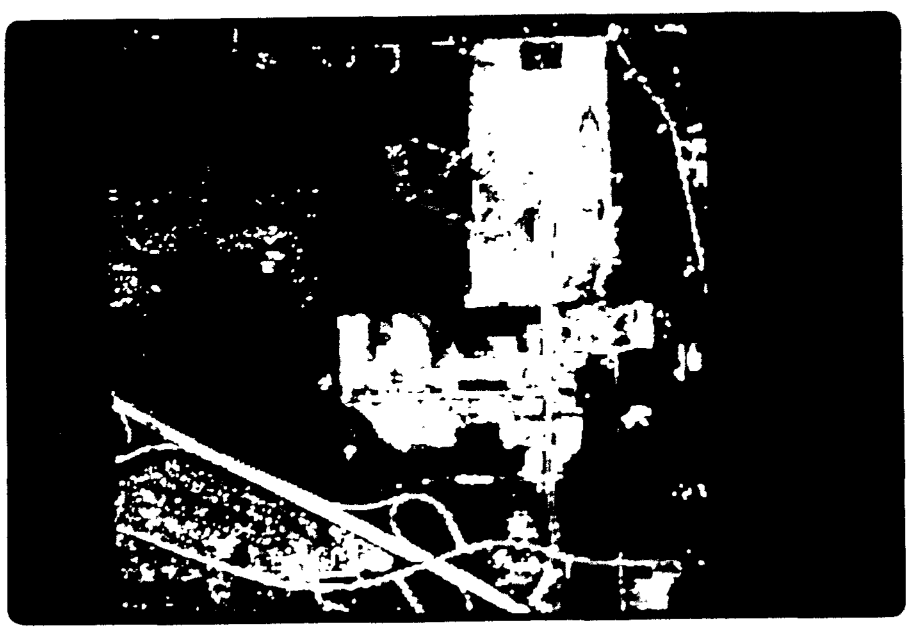
Appendix G Table 2. Classification results of the digitized photography collected on October 6, 1975

Category	No. of signatures	Area mapped, %	Area, Ha
Grassland and pastureland	22	50	167.0
Disturbed land	4	10	33.4
Roof tops	5	6	20.0
Roads and highways	4	5	16.7
Trees	3	6	20.0
Parking lots	1	3	10.0
	Unclassified*	20	66.8

*Since development of land cover maps is an iterative procedure, unclassified areas are those areas which have not been assigned a specific land cover category using the signatures developed to date.



Appendix G Fig. 1. Classification results of the October 6 data as displayed on the RAMTEK color monitor system.



Appendix G Fig. 2. Categories of roads and highways (light green), roof tops (brown), and disturbed lands (light blue), as displayed on the RAMTEK color monitor system.

date than on the land cover maps developed using the July 16 data. This was caused by some of the trees taking on their autumn colors, resulting in tree signatures with a larger variation than the tree signatures obtained using the July 16 data.

The residential area in the lower left of Appendix G Fig. 1 is inadequately classified since many of the targets are quite small and highly variable.

Appendix G Fig. 2 is a display on the color cathode ray tube device depicting those categories which could be considered impervious surfaces. The light blue areas represent the disturbed land category, light green represents roads and highways, and the brown areas represent the combination of the roof tops and parking lot categories.

Comparisons of the July 16 and October 6 data

Comparison of the area mapped as disturbed land, using the July 16 data (3% as shown in Appendix G Table 1) and using the October 6 data (10% as shown in Appendix G Table 2), shows a distinct temporal change. In the interval between July 16 and October 6, a large area was disturbed by removing the entire solum of the soil (upper right of Appendix G Figs. 1 and 2) in preparation for development. This illustrates the valuable temporal change detection for which remote sensing is particularly well-suited.

In general, the October 6 data were superior to the July 16 data for classification of roof tops, roads and highways, and disturbed lands, whereas the July 16 data were more suited for detection of trees since in October the trees were beginning to take on their autumn colors. Both data sets appeared equally suited to the classification of grassland and pastureland.

The 20% unclassified area of the October 6 data (versus 7% for the July 16 data) was due mostly to additional areas of vegetation for which signatures have yet to be developed. Thus, major differences between Appendix G Tables 1 and 2 can be attributed to temporal changes.

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APPENDIX H

LAND USE-WATER QUALITY MODELING

This appendix is divided into four sections which describe the progress to date by the modeling participants. Sections I to III address the modeling effort as it pertains to meeting objective 3 of the Menomonee River Pilot Watershed Study, i.e., developing an integrative and predictive capability with respect to the impact of land use on surface water quality. Section IV is an evaluation of an empirical model relating runoff quality to watershed characteristics. This model is likely to be useful in watershed/water quality studies where extensive financial and time support is not available and where the detail being included in the Pilot Watershed Studies is not essential. Compared to the other modeling efforts, this model does not require a great amount of data for calibration.

I. Evaluation of a Continuous Simulation Model

Since October 1975, work has continued on the evaluation of an existing continuous simulation model to determine if that model could--with modification--satisfy objective 3 of the Menomonee River Pilot Watershed Study which calls for developing an integrative and predictive capability with respect to the impact of land use on surface water quality. The overall approach in this model evaluation is to determine the effectiveness of the model in reproducing historic hydrologic-hydraulic data and then to determine model capability with respect to water quality phenomena. This procedure is based on the premise that successful water quality simulation is contingent upon effective hydrologic-hydraulic modeling since runoff from the land and flow in the streams provide the transport mechanisms for water quality constituents.

Model description

The digital computer model selected for evaluation is based on a hydrologic-hydraulic model that originated at Stanford University in the early 1960's and is now available--with a water quality feature--from the

consulting firm of Hydrocomp, Inc. The model continuously simulates hydrologic-hydraulic and water quality processes for an indefinite period of time in response to a full spectrum of meteorological conditions. The model consists of three submodels: the hydrologic submodel, the hydraulic submodel, and the water quality submodel. The principal function of the hydrologic submodel is to determine the volume and temporal distribution of runoff from the land to the stream system. The function of the hydraulic submodel is to accept as input the runoff from the land surface as produced by the hydrologic submodel, to aggregate it, and to route it through the stream system, thereby producing a continuous series of discharge values at predetermined locations along the surface water system of the watershed. The water quality submodel simulates the time-varying concentration of water quality indicators throughout the surface water system. Operating on a reach-by-reach basis, this submodel continuously determines water quality as a function of reach inflow and outflow, dilution, and biochemical processes.

Data base development

Data base development consists of the acquisition, verification and coding of data needed to operate, calibrate and apply the model. The data base consists of a large, readily accessible file of information subdivided into five distinct categories: meteorological data, land data, channel data, diffuse source data, and point source data. Work had been completed on the first two types of data in the data base at the time of the October 1975 semi-annual report, and since that time data base development efforts have concentrated on completing channel data and on developing diffuse source and point source data.

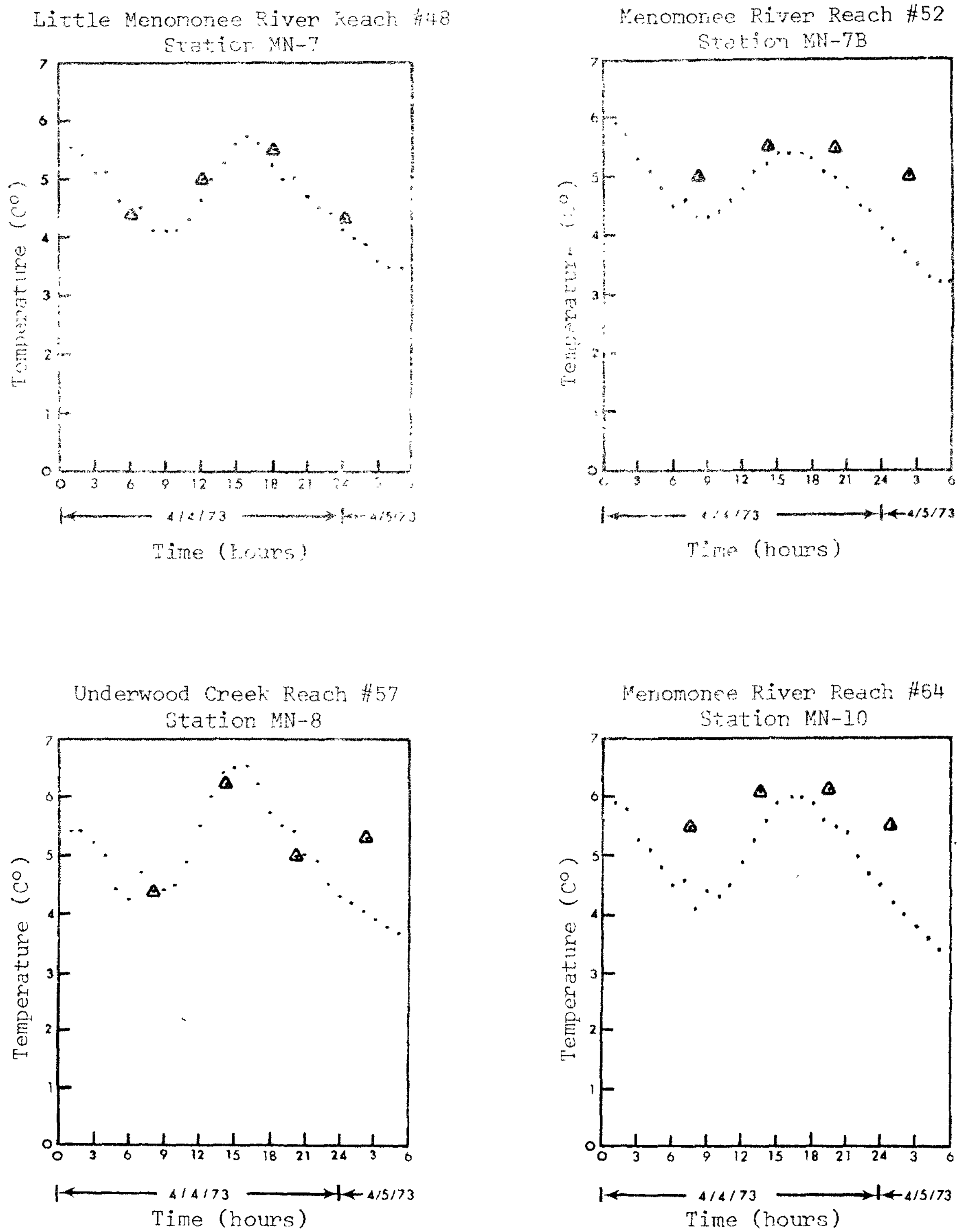
Initial water quality submodel calibration runs

Calibration consists of comparing simulation results with historic fact and, if significant differences occur, making parameter adjustments so as to tailor the model to the natural and man-made features of the watershed. Since the October 1975 semi-annual report, a successful

calibration of the hydrologic submodel and the hydraulic submodel was accomplished, and calibration efforts have concentrated primarily on achieving a preliminary calibration of the water quality submodel.

Inasmuch as the water quality-quantity monitoring data being obtained under the Menomonee River Pilot Watershed Study are not yet available, the initial calibration of the water quality submodel was based on field data obtained as a result of three 24-hour watershed-wide field surveys carried out under the Menomonee River Watershed Planning Program of the Southeastern Wisconsin Regional Planning Commission. In each of these surveys, streamflow measurements were made at five locations on the stream system, while physical, chemical, and biological quality indicators were measured at 17 stream sampling sites. In addition, the surveys involved the conduct of water quality analyses on the effluent from five municipal sewage treatment plants and two industrial facilities, and on the runoff from four watershed sub-basins, each exhibiting a different type of land use. One 24-hour synoptic water quality survey was conducted during the spring, on April 4-5, 1973, and two during the summer, on July 18-19, 1973 and on August 6-7, 1974.

For each of the three synoptic surveys, the calibration process was initiated by concentrating on the station farthest upstream in the watershed and achieving an acceptable correlation between the observed water quality at that location and the results obtained with the water quality submodel. After achieving a successful calibration with emphasis on six parameters--temperature, dissolved oxygen, orthophosphate, nitrogen forms, fecal coliforms, and carbonaceous biochemical oxygen demand--the calibration effort was then focused on the next downstream station. This process of calibration at successive stations down through the watershed was continued until a watershed-wide calibration was achieved with data from the first survey. The calibration procedure was initiated with the one spring event, after which summer survey data were used to complete the initial calibration of the water quality submodel. An example of the results obtained with the water quality submodel calibration are presented in Appendix H Fig. 1, in the form of a graphical comparison of recorded and simulated water temperatures at four locations in the watershed during the April 4-5, 1973 synoptic survey.



Source: SEWRPC

Legend: ▲ Recorded temperature
• Simulated temperature

Appendix H Fig. 1. Comparison of recorded and simulated temperatures for the Menomonee River watershed for April 4, 1973.

Model selection

Participants in the Menomonee River Pilot Watershed Study have tentatively selected the Hydrocomp Model as the basic simulation tool for the study, recognizing that some supplementary modeling may be required to meet the study objectives. This selection was based on consideration of available hydrologic, hydraulic and water quality models including--but not necessarily limited to--the Hydrocomp Model, the Wisconsin Hydrologic Transport Model (WHTM), the U.S. EPA Storm Water Management Model (SWMM), the Corps of Engineers Storage, Treatment and Overflow Model (STORM), and experience with the Hydrocomp Model, SWMM, STORM, and a new model called LANDRUN. (See Section II for further discussion.)

Work elements planned

Modeling efforts in the immediate future will concentrate on refining the above initial calibration of the Hydrocomp Model and on identifying and proceeding with the necessary supplemental model development. Monitoring data obtained under the pilot study will soon be readily available for use in this refined calibration effort. The use of that data will permit a significant improvement in the calibration, inasmuch as the monitoring data cover relatively long periods of time and include extensive streamflow measurements as well as data on water quality parameters.

II. Land Use-Water Quality Models

Since the beginning of Marquette University's participation (March, 1975) in the Menomonee River Pilot Watershed Study, the major effort has been focused on an evaluation of existing land use-water quality models and development of a land use-water quality model which would satisfy the objectives of the program.

Evaluation of existing models

From the variety of models available in the United States for modeling runoff from urban and nonurban areas, only a few include pollutant transport. Most of the available models are either general hydrological models estimating runoff quantity from rainfall excess or models that are used for the design of stormwater overflows in sanitary sewers.

The following models were evaluated by the Marquette University team as carrier models for the land use-water quality modeling:

"STORM"

This program represents a method of analysis for estimating the quantity and quality of runoff from small, primarily urban, watersheds. Nonurban areas may also be considered. Land surface erosion for urban and nonurban areas is computed in addition to the basic quality parameters of suspended and settleable solids, BOD, total nitrogen, and orthophosphate. The model considers the interaction of seven stormwater parameters, namely,

1. Precipitation and air temperature for rainfall/snowmelt. The program utilizes the degree-day method to estimate the amount of runoff from the snowmelt.
2. Runoff which is computed by a simple Rational formula as follows:

$$R = C(Pr - f)$$

where R is runoff
Pr is precipitation
f is available depression storage and
C is the runoff coefficient.

3. Pollutant accumulation on a daily basis accumulation is entered as input and is cumulated during the dry period. The washout of pollutants is computed using an exponential washout formula:

$$\Delta P = P_o(1 - e^{-E_u R \Delta t})$$

where ΔP is the amount of pollutants washed from the watershed

P_o is the initial amount of pollutants at the beginning of the storm

E_u is the urban washouf decay coefficient and

Δt is a fixed time interval.

4. Land surface erosion is computed by the Universal Soil Loss Equation:

$$A = EI \times K \times (LS) \times C \times P$$

where A is the soil erosion rate

EI is the rainfall factor

K is the soil erodibility factor

LS is the length of slope factor

C is the cropping management factor and

P is the erosion control practice factor.

The dust and dirt washout and surface erosion provide estimates of the amount of suspended materials (washload) in the runoff. All other pollutants are considered as fractions of the suspended load.

5. Other procedures relevant to the land use-water quality modeling include: treatment rates estimation, storage computation and overflow from the storage/treatment system.

The program is available from the Hydrologic Engineering Center, Corps of Engineers, U.S. Army, 609 Second Street, Davis, California 95616.

The following steps have been used in evaluating STORM:

1. Input data for three experimental watersheds in the Menomonee River basin have been prepared according to the format of STORM. The experimental watersheds included:

   Schoonmaker Creek

   Noyes Creek

   Little Menomonee River at Donges Bay Road.

2. The program was run with the above data and varying storm intensities.
3. The outputs were plotted against rainfall intensities and compared visually with available historical data.

The results for the Schoonmaker Creek, which did not include surface erosion, (the area is classified as medium density residential with a high percent of imperviousness) seem to be adequate. The outputs for Noyes Creek and Donges Bay revealed a serious logical discrepancy in the erosion portion of the model. The suspended solids load (in tons) decreased with increasing rain intensity, as indicated in Appendix H Fig. 2 for Noyes Creek. The numerical estimates did not agree with the historical data.

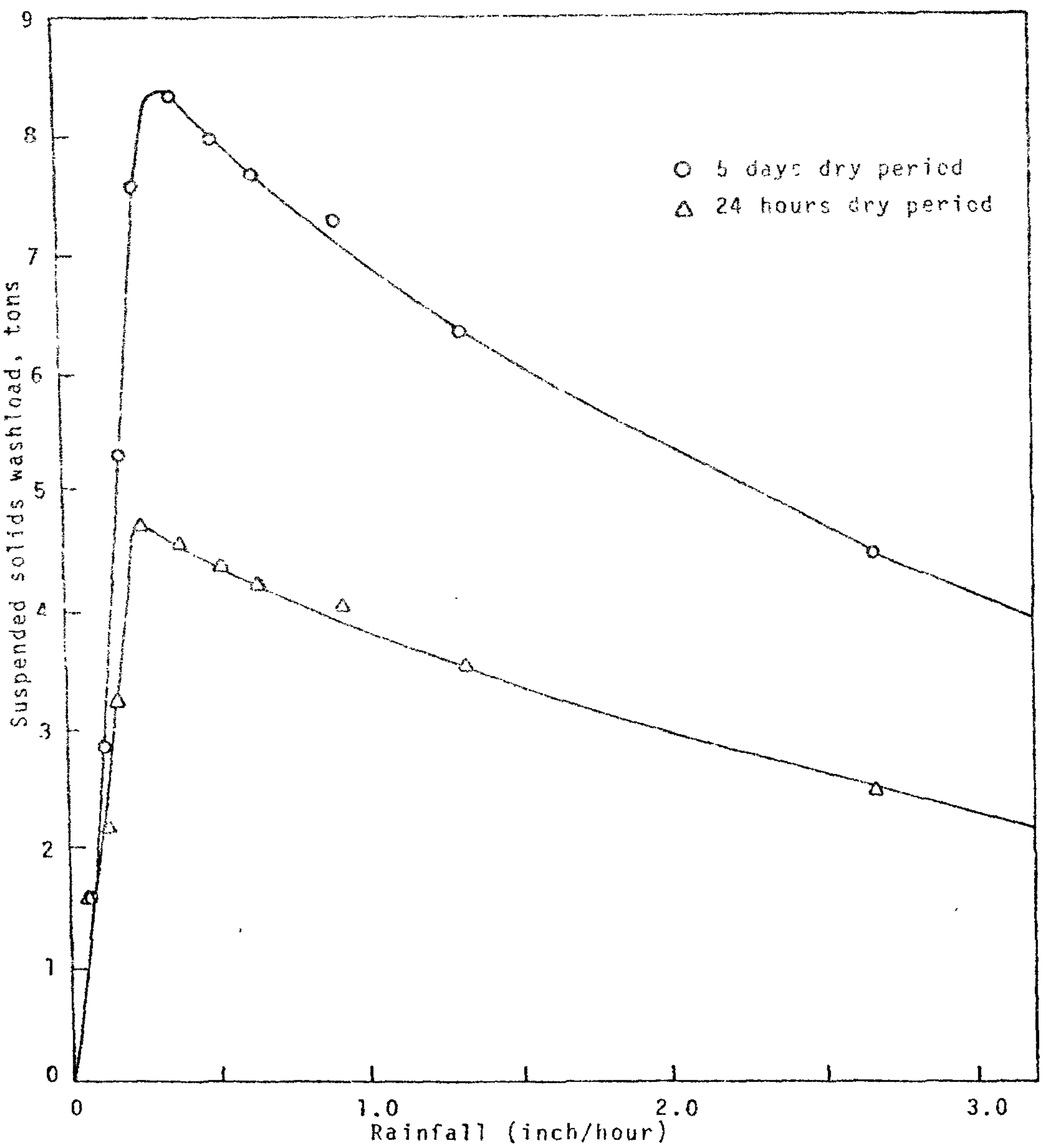
In conclusion, it is felt that the program STORM is not adequate for the land use-water quality modeling for the following reasons:

1. The model relies heavily on inputted information. The model is not dynamic; each hourly interval represents an isolated event.
2. The major shortcomings include:
    a. Inadequate description of the runoff information which relies solely on estimation of the coefficient of runoff.
    b. No account is taken of soil characteristics and soil adsorption.
    c. Pollutant washout is computed as a fraction of the suspended solids, and not from a mass balance.
    d. An error exists in the erosion subroutine.

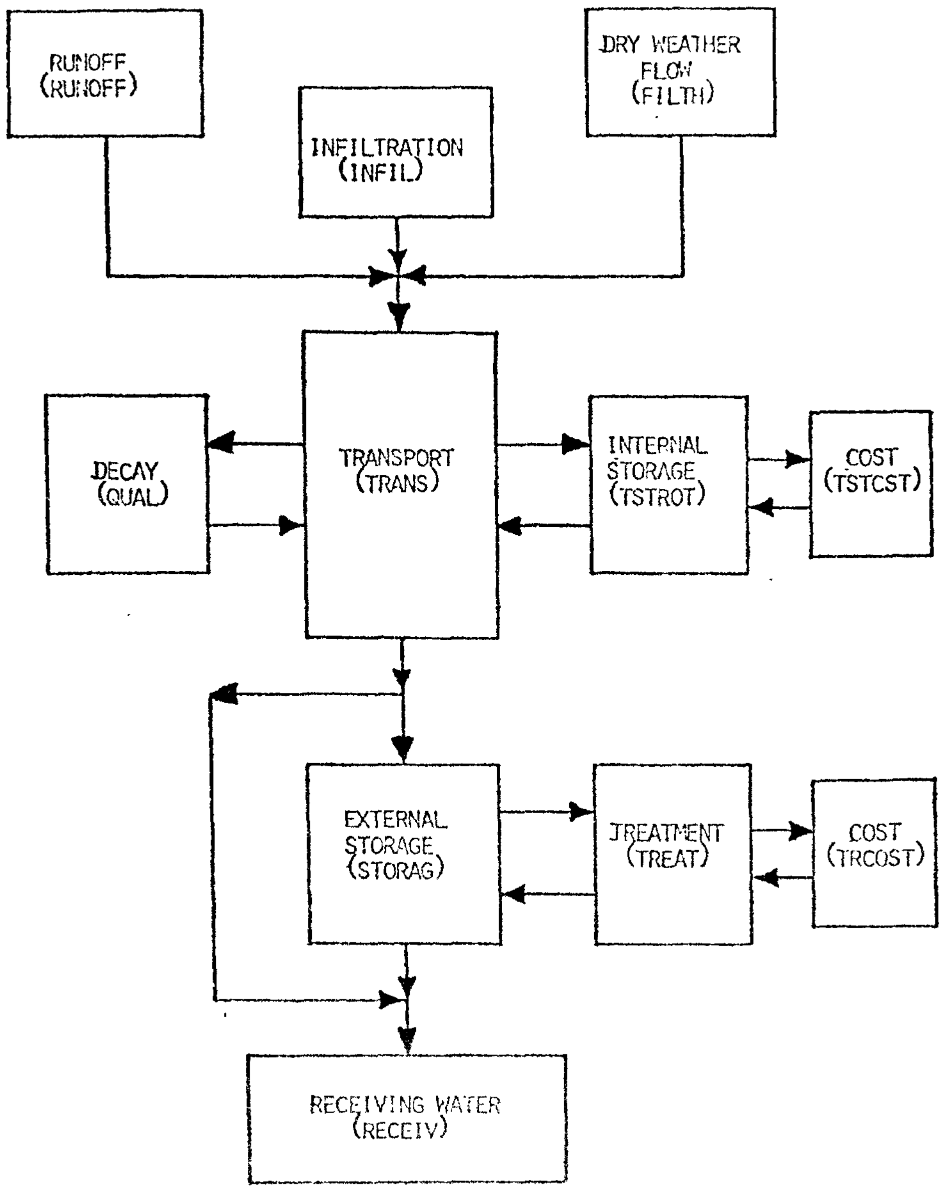
Stormwater management model - "SWMM"

The evaluation of "SWMM" is based on the past experience of the Marquette team with the model rather than from a direct application to the Menomonee River Project.

The model was developed under the sponsorship of the U.S. EPA by a consortium of contractors--Metcalf and Eddy, Inc., the University of Florida, and Water Resources Engineers, Inc. The model is comprehensive in that it is capable of representing urban stormwater runoff and combined sewer overflow phenomena. The major components of the model are illustrated in Appendix H Fig. 3.



Appendix H Fig. 2. Predicted washload for Noyes Creek using the STORM model.



Note: Subroutine names are shown in parentheses.

Appendix H Fig. 3. Major components of the Stormwater Management Model (SWMM).

The model assumes a series of subcatchments. A rainfall hydrograph is applied and infiltration computed using Horton's equation as a function of time, and the average depth of rainfall excess over the catchment is calculated. If this depth exceeds a specified depression storage depth, overland flow outflow is calculated with Manning's equation. Overland flow enters the gutters, and gutter outflow and flow in conduits is again calculated with the Manning equation and continuity. The model is thus a simple infiltration model with kinematic routing of overland, gutter, and conduit flow. The receiving water portion is based on the finite difference approximation of the St. Venant flow equation.

Quality is simulated similarly to "STORM." The quality constituents are derived from the dust and dirt fallout during a specified dry period preceding the storm and from surface erosion represented by the Universal Soil Loss Equation. Other pollutants are again estimated as fractions of the suspended load.

The model is not continuous and can be used only for runoff quantity and quality simulations for events. The processes taking place between the events are ignored. The model also ignores all transformation occurring in soil and neglects interflow and groundwater runoff. In addition, the model requires enormous computer storage capacity (in excess of 350K) and very detailed input information describing the hydraulic elements of the system. The primary purpose of the model is to design stormwater conveyance systems. Due to its size and complexity, the program is extremely difficult to modify or adapt for any other use.

Development of "LANDRUN"

The objectives of Task C call for a modeling technique to estimate pollutant loadings to the Great Lakes Basin which would be related to land use in the basin. In the Work Plan it was anticipated that two modeling methods would be employed for estimating the loadings, i.e., a statistical regression analysis of the effect of various land uses on water quality of the runoff, and a deterministic land use-water quality model capable of simulating the overland flow portion of the runoff, including the effect of soil and soil interactions on pollutant transformations and transport.

Due to the failure of "STORM" and serious reservations about attempting the necessary modifications and amendments of large computer programs (e.g., "SWMM"), the only feasible alternative was to develop a medium-size hydrologic and sediment transport model.

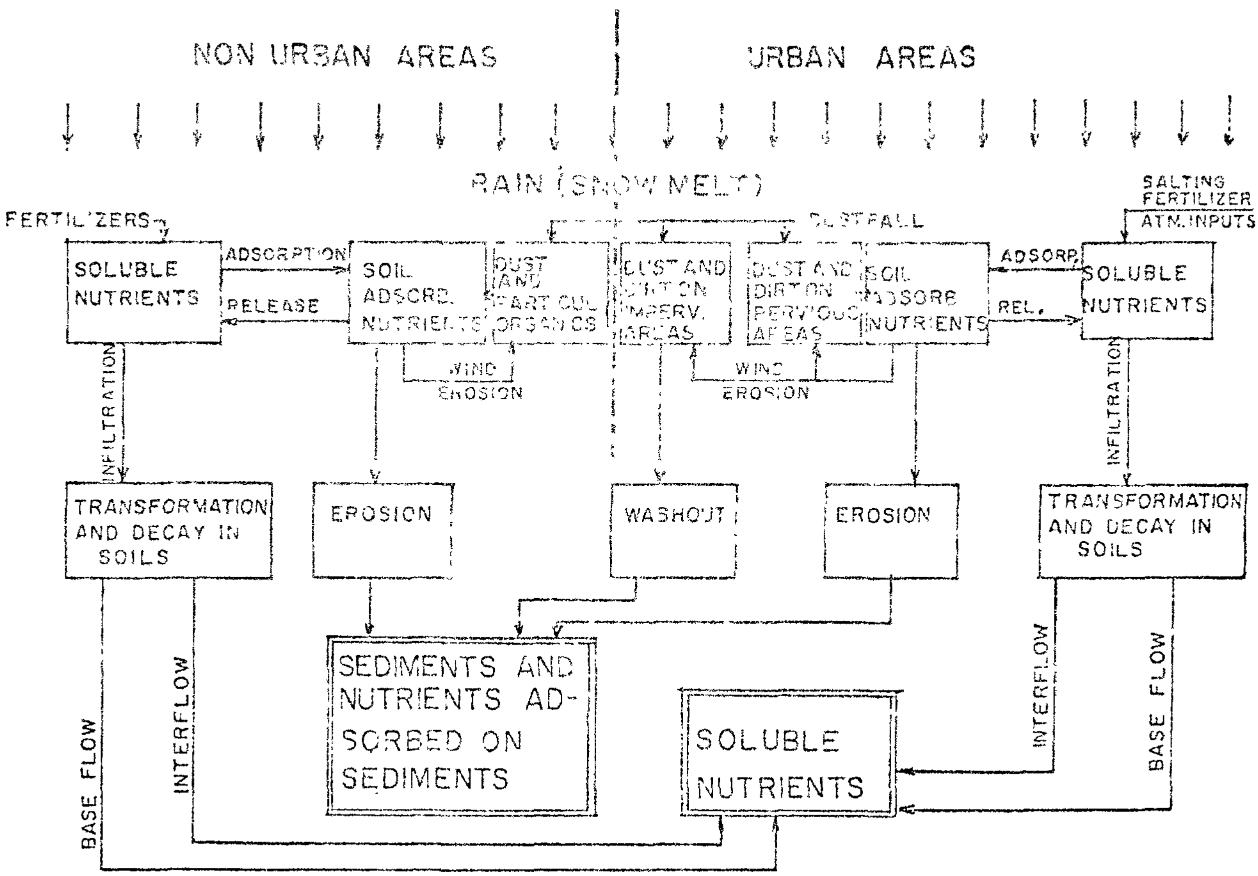
The present version of the model developed at Marquette University under the working code "LANDRUN" represents a dynamic hydrologic transport model which transforms precipitation into surface runoff, interflow and groundwater aquifer recharge quantity and quality. A schematic conceptual flow diagram of the model is shown in Appendix H Fig. 4. Most of the model parameters and some inputs are related to land use within the modeled watersheds.

The present version of "LANDRUN" includes modeling the following processes:

1. Snowpack-snowmelt by the degree-day method.
2. Infiltration by the Holtan or Philip models.
3. Excess rain from precipitation, minus evaporation, infiltration and depression and interception storage.
4. Routing of the excess rain by an Instantaneous Unit Hydrograph (IUH) method based on a kinematic wave formula or the empirical IUH formula of Sarma, Delleur and Rao.
5. Dust and dirt cumulation in urban areas and washout.
6. Surface erosion by a modified Universal Soil Loss Equation which includes effects of both rainfall energy and street runoff energy erosion.
7. Routing of the sediment.

A soil adsorption model applicable to phosphorus, pesticides, and toxic elements transport has been developed, tested, and is being incorporated as a subroutine into "LANDRUN." The parameters of the model are related to such soil characteristics as pH, and clay and organic matter contents and the inputs are infiltration rate, soil moisture content, evapotransportation (based on the potential evaporation and crop growth stage), fertilizer application and amount of the modeled substance removed by harvesting.

The output from the subroutine is the amount of pollutants adsorbed on the top soil particles, quantity of dissolved pollutants removed from the



Appendix H Fig. 4. Schematic conceptual flow diagram of the "LANDRUN" model.

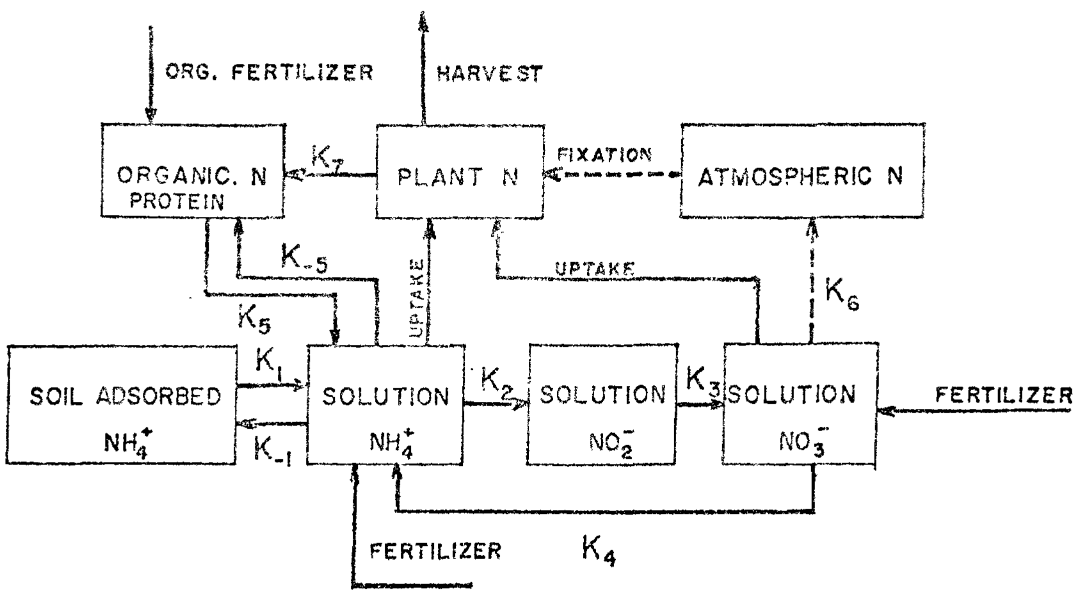
top soil and the amount of dissolved pollutants in the interflow and groundwater recharge. A separate report covering phosphorus modeling has been prepared.

Soil nitrogen model

Nitrogen transformations in soil represent a complex system consisting of several processes. The major nitrogen transformation processes are:

1. Atmospheric N fixation by soil bacteria,
2. Adsorption and release of NH_4 by soil particles,
3. Nitrification,
4. Denitrification,
5. NO_3 and NH_4 uptake by plants,
6. NH_4 uptake by soil bacteria, and
7. Ammonification of organic N.

The schematic of the soil nitrogen model is shown in Appendix H Fig. 5. A report covering the formulation of the model and estimating its parameters is being prepared and will be available in the near future.



Appendix H Fig. 5. Schematic flow diagram of the nitrogen model showing various transformations of N species.

III. The MRBS Modeling Strategy

The modeling effort of the MRBS has progressed from a general strategy to the awareness of specific factors relating to the Pollution from Land Use Activities Reference Group (PLUARG) modeling objectives. The accessory programs which might be used to undertake these considerations are:

1. A hydrologic season/event-baseflow tendency plot
2. A wet/dry fallout proportioning (relative to total fallout)
3. A native-state effect deduction
4. Coefficient initialization determination
5. Loading rate determination
6. Channel influence assembly
7. Loading rate adjustment matrices

It is seen that programs 2, 3 and 6 focus on specific factors, while the others are elements within a framework-design which applies generalized program tools, e.g.: LANDRUN, as under development at Marquette University; HSPII--Hydrocomp Simulation Program II, the forthcoming improved version of a program in use at the Southeastern Wisconsin Regional Planning Commission (SEWRPC); to the specific output needs of the program. Detailed descriptions of the accessory programs are presented in Appendix H Table 1, while two alternatives for the total framework-design are outlined in Appendix H Figs. 6 and 7.

These networks are proposed as approaches toward meeting PLUARG modeling objectives. Determination of water quality, its relationship to land use, and transferability of results to the entire Great Lakes Basin are accomplished by correlation analyses of water quality to discharge quantity/unit area, by pollutant and contributory land use. Determination of the land use related coefficients "a" (land use activity effects) and "b" (an exponent governing precipitation effects) would allow essential quantification of event/baseflow pollutant addition, i.e., loading rates, by the relation aq^b. Recent development of defined event criteria by the Wisconsin Department of Natural Resources (WDNR), however, now opens the possibility that aq^b analyses might be further divided into runoff and groundwater, as well as dissolved/suspended solid cross-

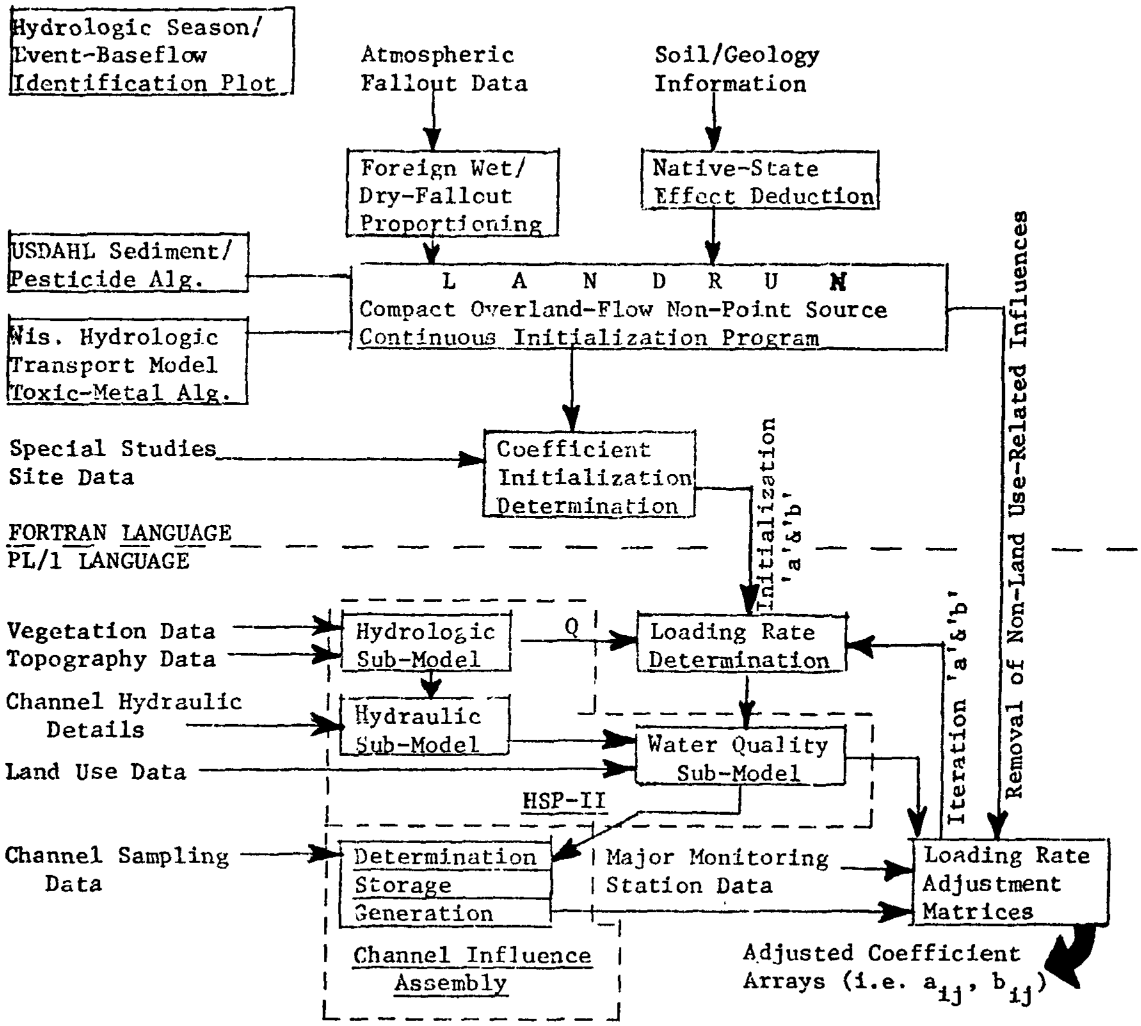
Appendix H Table 1. Detailed descriptions of accessory programs

1. A Hydrologic Season/Event-Baseflow Tendency Plot--derived via arithmetic/geometric mean operations (i.e., correlation ensemble establishment) on 12 years of U.S.G.S. Wauwatosa gauge streamflow data, and arithmetic mean operation on the relative standard deviations thereof. Breakdown is to weeks in order to reassemble periods of self-stationarity (i.e., hydrologic seasons) and event-baseflow (i.e., high-low relative standard deviation) for detailed planning of future monitoring efforts.
2. A Foreign Wet/Dry-Fallout Proportioning--required to reduce observed loading values by such non land use related components. The algorithms-of-choice have not yet been ascertained pending discussion. A statistical "Wind-Rose" treatment might be extracted from aviation-technology, while application of algorithms from the ATM atmospheric transport submodel of the Unified Transport Model is another possibility for future model sophistication. However, fallout dissolution proportioning is a more immediate concern.
3. A Native-State Effect Deduction--required to reduce observed loading values by a non land use related component. It is envisioned that Betson's "Nonpoint Mineral Model" approach (within the program) will be used, probably in concert with Cherkauer's assistance and special studies site installations at wetland, sparsely-vegetated upland, and highly-vegetated upland locations.
4. Coefficient Initialization Determination--believed best handled by a linear-correlation of loadings (corrected by accessory programs 2 and 3--as processed through the LANDRUN correction-initializing program) with runoff. By this method, coefficients "a" (land use activity effect) and "b" (exponent portion of precipitation effect) would be determined for input to accessory program 5, i.e., to formulate aq^b and $a(1-e^{-bt})$.
5. Loading Rate Determination--to be the application of the land use data to the prior-determined coefficients "a" and "b" and flow "q" (runoff quantity/unit area, as determined by the hydrologic submodel of the HSPII master program). Thus, areal loading rates of focus parameters

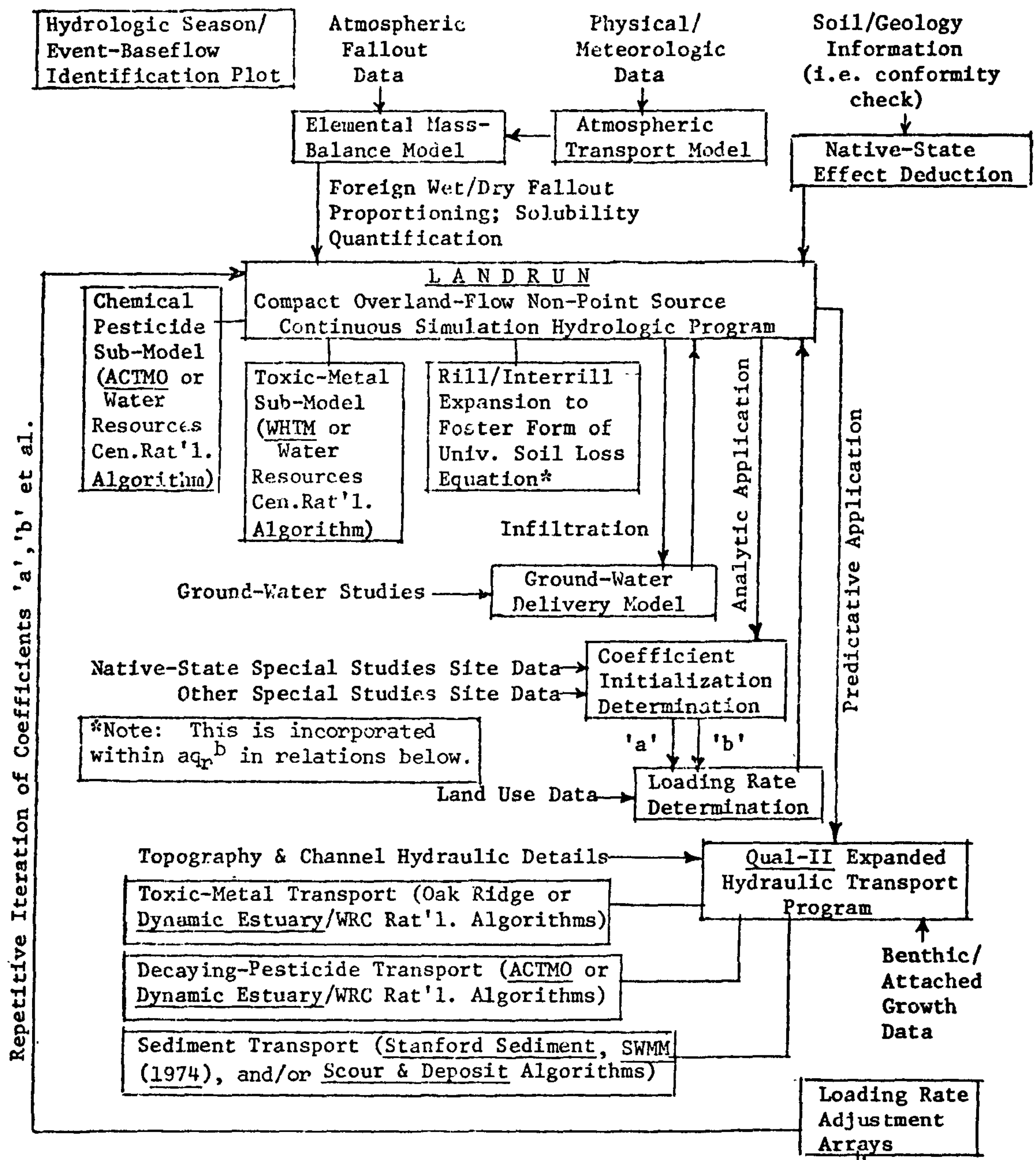
Appendix H Table 1 con't.

are determined for input by land use into the water quality submodel of the master program.

6. Channel Influence Assembly--requires the use of semi-seasonal channel samplings to assess in-stream loading value changes (due to non land use related physical and biological/chemical influences) and subsequently to store and appropriately insert such quantifications for approx. two-mile long reaches. A linear correlation of physical effect against discharge velocity might be undertaken following application of a biological/chemical influence estimate. Alternatively, algorithms of the Stanford Sediment subroutine of the Paraquat model (Pesticide Transport and Runoff Model) might be applied in conjunction with the Texas biological and chemical exchange in stream channel component of the Unified Transport Model.
7. Loading Rate Adjustment Matrices--deals with the trial-and-error character of the final iterative aspects of model calibration. The equations comparing theoretical loadings at monitoring sites with observed loadings have been developed, and a Gauss-Jordan solution algorithm is visualized.



Appendix H Fig. 6. Modeling strategy alternative I.



Relation Forms (all in FORTRAN LANGUAGE) for loadings:

Rural Land Use: $L=At(aq_r^b+cf_i^d+g(e^{-\tau})^h+\Sigma_o^t lf_{gwr}^m)$, where aq_r^bKCPSL is the runoff term of the Foster form of USLE; q_r is (Q-f)/A, runoff per area; f_i is interflow; e^{-t} is a transform of ground water; and f_{gwr} is ground water recharge.

Urban Land Use: $L=At(at_1(1-e^{-bRt_2})+cf_i^d+g(e^{-\tau})^h+\Sigma_o^t lf_{gwr}^m)$, where R is q_r in rural.

Appendix H Fig. 7. Modeling strategy alternative II.

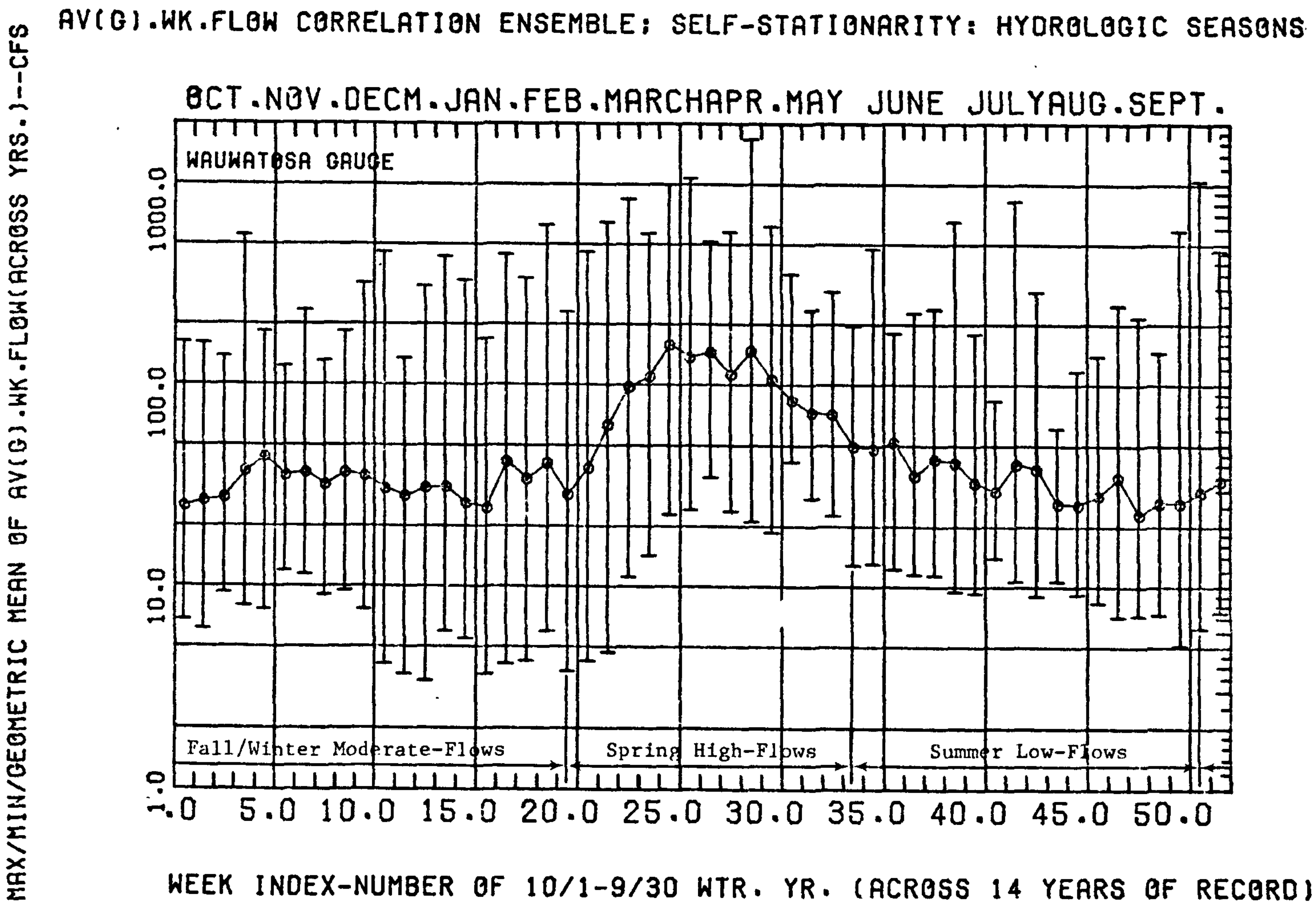
breakdowns. This would conform to "q" apportionment between event and baseflow breakdown by application of the developed criteria to observed hydrographs.

It is to be appreciated, however, that the form aq^b most appropriately describes (essentially) rural areas. Therefore, it would be applied by incorporation into a modified form of the Foster Universal Soil Loss Equation. On the other hand, fallout-accumulation/runoff at work in urban land uses is probably best handled by the formula $at_1(1-e^{-bt_2})$, where "a" represents land use activity effect (i.e., fallout quantity); "b", an exponent constituent reflecting removal efficiency; t_1, baseflow duration; and t_2, event duration. Since infiltration can be expressed in this exponential decay form, consequent interflow and groundwater effects could exploit this format $a(1-e^{-bt})$.

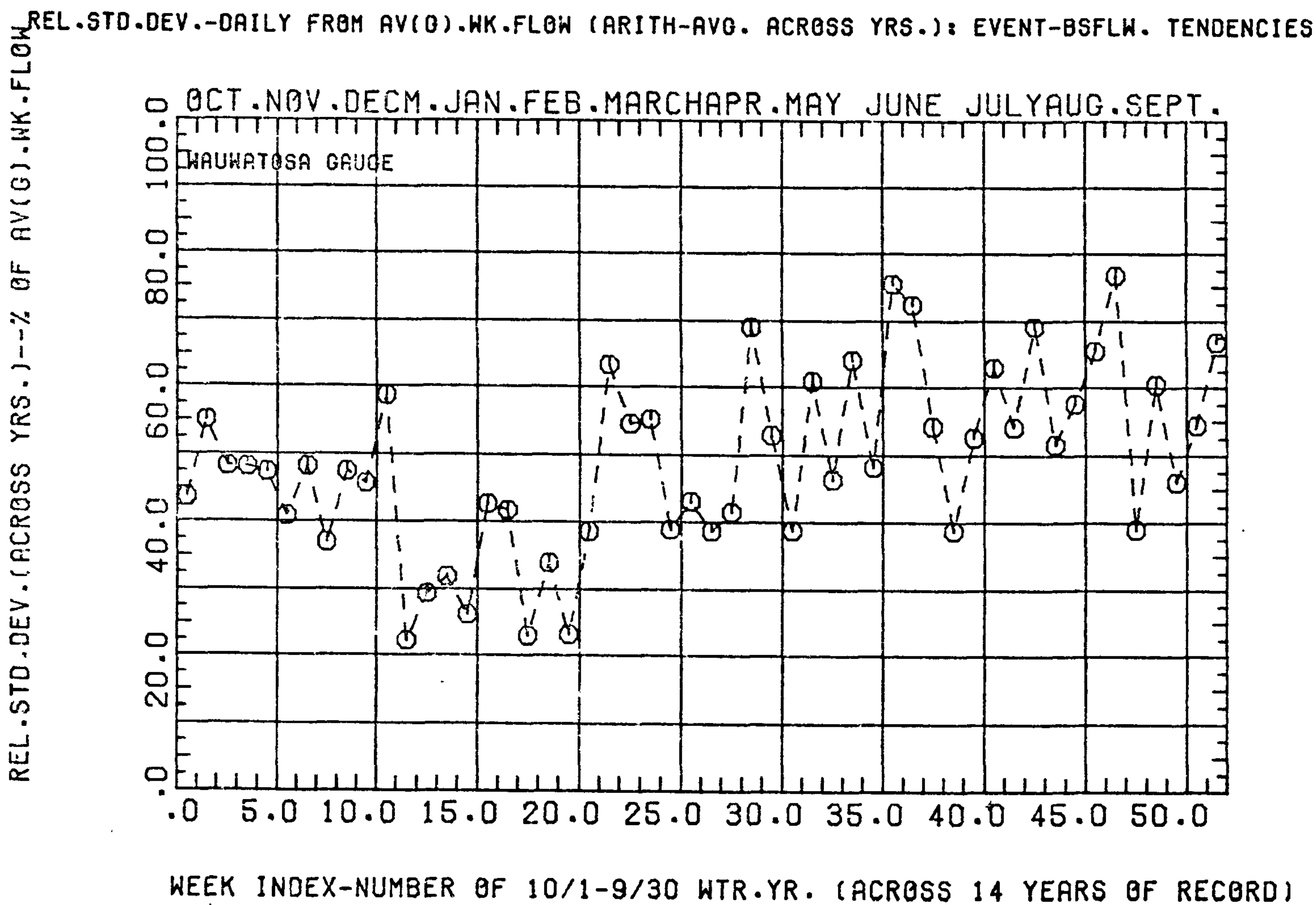
Use of the aq^b and $a(1-e^{-bt})$ approach would enable linkage of the LANDRUN program to a channel program (e.g., a revised Qual II) on a repetitive basis consistent with the actual frequency of sampling and analysis. This would be an alternative to the use of the HSPII program. In any case, the technique should generate, from this pilot study, results transferable to other urban areas and to the entire Great Lakes Basin, thereby interfacing with the objectives of Task D, and lending itself to application of remote-sensing technology.

In the first framework-alternative it is visualized that the first four of the seven accessory programs are to be written in Fortran and the remaining three in PL/1. The use of PL/1 would allow sequentially-linked execution and feedback-looping between these and HSPII. The second framework-alternative would be written in the more universal Fortran. Accessory programs 2 through 7 would likely be developed using an interactive remote terminal with associated tape file creation and mapping.

The isolated and repetitive-statements character of program 1, however, has made batch-run, later supplemented by tape-file creation, an efficient approach. These Hydrologic Season/Event-Baseflow Tendency Plots have been completed and are presented as Appendix H Figs. 8 and 9, with Index-Week breakdown shown in Table 2. In Appendix H Fig. 8, periods of rough self-stationarity within the plot of geometric means of average



Appendix H Fig. 8. Correlation ensemble of average weekly flows superimposed across years (periods of self-stationarity taken as hydrologic seasons).



Appendix H Fig. 9. Relative standard deviation of daily from average weekly flows, as averaged across years (measure of tendency toward event).

Appendix H Table 2. Index-week breakdown with recommended sampling times

Week	Dates	Week	Dates	Week	Dates
1	Oct. 1 to 7	18	Jan. 28 to Feb. 3	36	June 3 to 9
2	Oct. 8 to 14	19	Feb. 4 to 10	37	June 10 to 16
3	Oct. 15 to 21	†#20	Feb. 11 to 17	38	June 17 to 23
4	Oct. 22 to 28	21	Feb. 18 to 24	39	June 24 to 30
*5	Oct. 29 to Nov. 4	22	Feb. 25 to Mar. 3	40	July 1 to 7
6	Nov. 5 to 11	23	Mar. 4 to 10	41	July 8 to 14
7	Nov. 12 to 18	24	Mar. 11 to 17	42	July 15 to 21
8	Nov. 19 to 25	25	Mar. 18 to 24	43	July 22 to 28
9	Nov. 26 to Dec. 2	26	Mar. 25 to 31	†44	July 29 to Aug. 4
10	Dec. 3 to 9	†27	Apr. 1 to 7	45	Aug. 5 to 11
11	Dec. 10 to 16	28	Apr. 8 to 14	46	Aug. 12 to 18
12	Dec. 17 to 23	*29	Apr. 15 to 21	47	Aug. 19 to 25
13	Dec. 24 to 30	30	Apr. 22 to 28	†48	Aug. 26 to Sep. 1
14	Dec. 31 to Jan. 6	31	Apr. 29 to May 5	49	Sep. 2 to 8
15	Jan. 7 to 13	32	May 6 to 12	50	Sep. 9 to 15
16	Jan. 14 to 20	33	May 13 to 19	*#51	Sep. 16 to 22
†17	Jan. 21 to 27	*†#34	May 20 to 26	52	Sep. 23 to 30
		35	May 27 to June 2		

*Channel/specialized land use studies sampling week (event preferred and probable)

†Channel/specialized land use studies sampling week (baseflow preferred and probable)

#Week of seasonal transition

weekly runoff (between years) indicate hydrologic seasons. In Appendix H Fig. 9 high relative standard deviation of average weekly runoff from daily values (between years) is indicative of a tendency toward events in that index-week (and the converse low relative standard deviation is indicative of undisturbed baseflow). The channel/special studies site sampling suggested in Appendix H Table 2 and Fig. 10 results from these analyses.

The next tasks anticipated to be undertaken are the writing of accessory programs 2, 4 and 7, as well as possible expansion of the LANDRUN program (via: ACTMO--Agricultural Chemical Transport Model--elaborations on the Universal Soil Loss Equation, the ACTMO Chemical Option Submodel for organic-chemical quantification, and WHTM--Wisconsin Hydrologic Transport Model--toxic metal appendages). If, as in Appendix H Fig. 7, LANDRUN is to be used for more than an initialization function, groundwater contributions must be quantified. In any case, the entire assembly (i.e., the Marquette-developed program with appropriate expansions) is to be read into a storage file at the University of Wisconsin-Madison.

It is intended that input and output data be arrayed by land use and pollutants of concern as shown in Appendix H Tables 3 and 4. Coordination with specific land use study sites is underway to cover all uses.

Further sites recommended as essential to accomplishment of project objectives include wetlands, a highly vegetated site and a sparsely vegetated site to obtain the best approximation of native state conditions. Thus, the dual function of representing specific land uses and native-state conditions would be served. Monitoring of sites in Butler (representative of light industry) and in Milwaukee at East Wells and North Milwaukee Streets (representative of the high-density residential/urban downtown land use) might also be needed. The E. Wells-N. Milwaukee Streets site is essential if estuary modeling is to be accomplished.

Some type of monitoring at the 45th Street estuary-limit control structure also is needed. This is dictated by particularly high lake levels often topping the Falk Corporation flood control sheet-piling. The specialized function of the Hawley Road monitoring installation does not provide complete flow records. The stage-discharge correlation at 45th Street and the theoretical reconstruction of records in the vicinity of that site (as based on 70th Street records) would be derived consistent

Hydrologic season	(Late winter)/spring (i.e., generally condensed to "spring")	Summer	Fall/(early winter)
Character of weather	cool/wet	warm/dry	cold/semi-wet
Approximate months	late February March April early May	late May June July August early September	late September October November December early February
Approximate event ranking	highest yield	moderate yield	lowest yield
Approximate baseflow ranking	highest yield	lowest yield	moderate yield
Recommended sampling	Baseflow--mid-Feb. (↔) Baseflow--early April Event--late April	Event--late May Baseflow--early Aug. Baseflow--late Aug.	Event--early Nov. Baseflow--late Jan. Baseflow--mid-Feb. (↔) Event--late September

Appendix H Fig. 10. Recommended sampling scheduling derived from hydrologic season breakdown.

Appendix H Table 3. Land uses

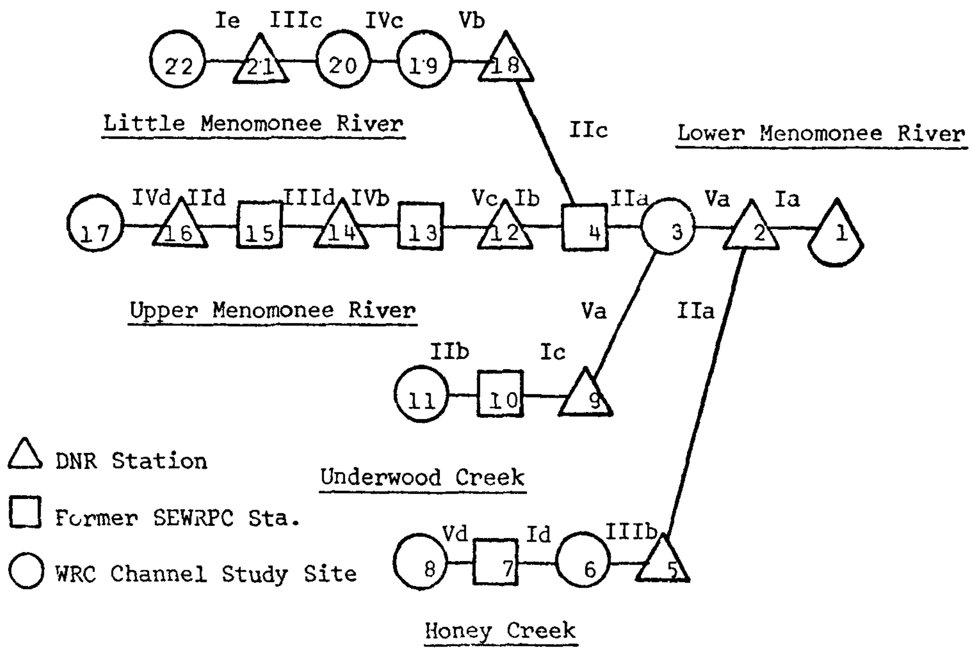
1)	Wetland
2)	Upland
3)	Cropland
4)	Orchard nursery
5)	Animal husbandry
6,7)	Low-density residential
8)	Mid-density residential
9)	High-density residential/urban downtown
10)	Commercial
11)	Light industry
12)	Heavy industry

Appendix H Table 4. Focus pollutants

1)	Carbonaceous B.O.D.
2)	Strept coliform
3)	Kjeldahl nitrogen
4)	Nitrate + nitrite
5)	Total phosphorus
6)	Pesticide
7)	Lead
8)	Zinc
9)	Copper
10)	Total sediment

with hydraulic analysis techniques. Assessment of pollutant velocity and flow peak characteristics, as well as lag-time between flow surges (i.e., stage increases) and the pollutant passage at monitoring sites is needed. To quantify these, the time-of-travel dye studies, presented in Appendix H Fig. 11, may be utilized in concert with general flow quantity and specific flow peak correlations between stations as developed in accord with hydrologic/hydraulic flow principles.

It is anticipated that the Falk Corporation site and the three downstream grab sample sites will prove useful to the subsequent estuary-modeling phase. Use of a Fortran assembly--most desirably Qual II (Alternative 2)--upstream is more compatible with estuarine modeling. At this point, establishment of additional monitoring is recommended, as follows: at the North Ave. dam and at the Wisconsin Ave. bridge on the Milwaukee River; in Kinnickinnic Creek at the railroad embankment culvert (at Cleveland Ave.) and at the mooring basin interface; in Milwaukee harbor; and at the harbor entrance to Lake Michigan.



Day	Segment	Collection Device Req'd. Fixed	Collection Device Req'd. Portable	Device Monitoring Times from Day's Initial Dye Release: Sum. Bsflw.	Device Monitoring Times from Day's Initial Dye Release: Sum/Fall Event	Summer Bsflw.	Summer Event	Fall Event
Monday	Ia		X	030- 730	010- 450	3 pts.	9 pts	11 pt
	Ib		X	400-1100	300- 740	2	7	7
	Ic	X		500-1200	340- 820	1	2	2
	Id		X	600-1300	420- 900	1	1	1
	Ie	X		630-1330	520-1000	1	1	1
Tuesday	IIa	X		030- 730	010- 450	3	9	11
	IIb		X	400-1100	300- 740	1	1	1
	IIc		X	500-1200	340- 820	2	7	7
	IId		X	730-1430	600-1040	1	2	2
Wed'day	IIIa		X	030- 730	010- 450	3	9	11
	IIIb	X		130- 830	030- 530	1	1	1
	IIIc		X	300-1000	230- 710	1	1	1
	IIId	X		400-1100	310- 750	1	2	2
Th'sday	IVa		X	030- 730	010- 450	3	9	11
	IVb		X	400-1100	300- 740	1	2	2
	IVc		X	500-1200	340- 820	2	3	4
	IVd	X		730-1430	550-1030	1	1	1
Friday	Va	X		030- 730	010- 450	3	9	11
	Vb	X		400-1100	300- 740	1	2	2
	Vc	X		500-1200	340- 820	2	3	4
	Vd		X	600-1300	420- 900	1	1	1
						35(x2)	82	94

Density for Rhodamine WT (20% sol.): $\Sigma \approx 246$ pt. @1.19 = 294 lbs.
†Costs from Dupont Co. (1976): i.e. 2-25# lot @$107† + 250# drum @$920†

Appendix H Fig. 11. Time-of-travel study details.

IV. Empirical Modeling of Runoff Quality from Small Watersheds

Small watersheds which contain no point sources of contamination act as natural integrators of the various nonpoint contamination sources which can contribute to streamflow. The quality of runoff from these watersheds is a complex interaction of hydrologic, climatic, geologic, cultural and chemical factors. Runoff quality can be modeled by identifying the role of each of these causative factors and incorporating them into an inclusive digital model. The primary modeling efforts of the Menomonee River Pilot Watershed Study are directed toward this end. However, the digital model to be developed will necessarily be complex. It will have large data input and computer storage requirements and require extensive calibration. In some instances a far simpler--albeit less precise--model might be useful.

This segment of the overall project is designed to develop such a model. It is based on the premise that observing quality of runoff from a variety of small watersheds will enable us to empirically relate that runoff quality to the land use, climatic, hydrologic and other factors which produced it. This model assumes that the concentration of a chemical in surface runoff varies temporally about a mean runoff concentration in a predictable manner. The factors which control the mean concentrations must therefore be identified and an empirical means for predicting mean concentrations must be devised.

After a mean concentration has been developed, a relative concentration, the ratio of the concentration at any time to the mean, can be defined. The model assumes that the relative concentration of runoff from a given watershed will show a temporal variation which is a reproducible function of land use, storm characteristics and season. Development of relative concentration curves for a variety of watersheds allows prediction of the distribution of runoff concentrations during runoff events. Combination of the concentrations with runoff quantities then allows prediction of mass loadings.

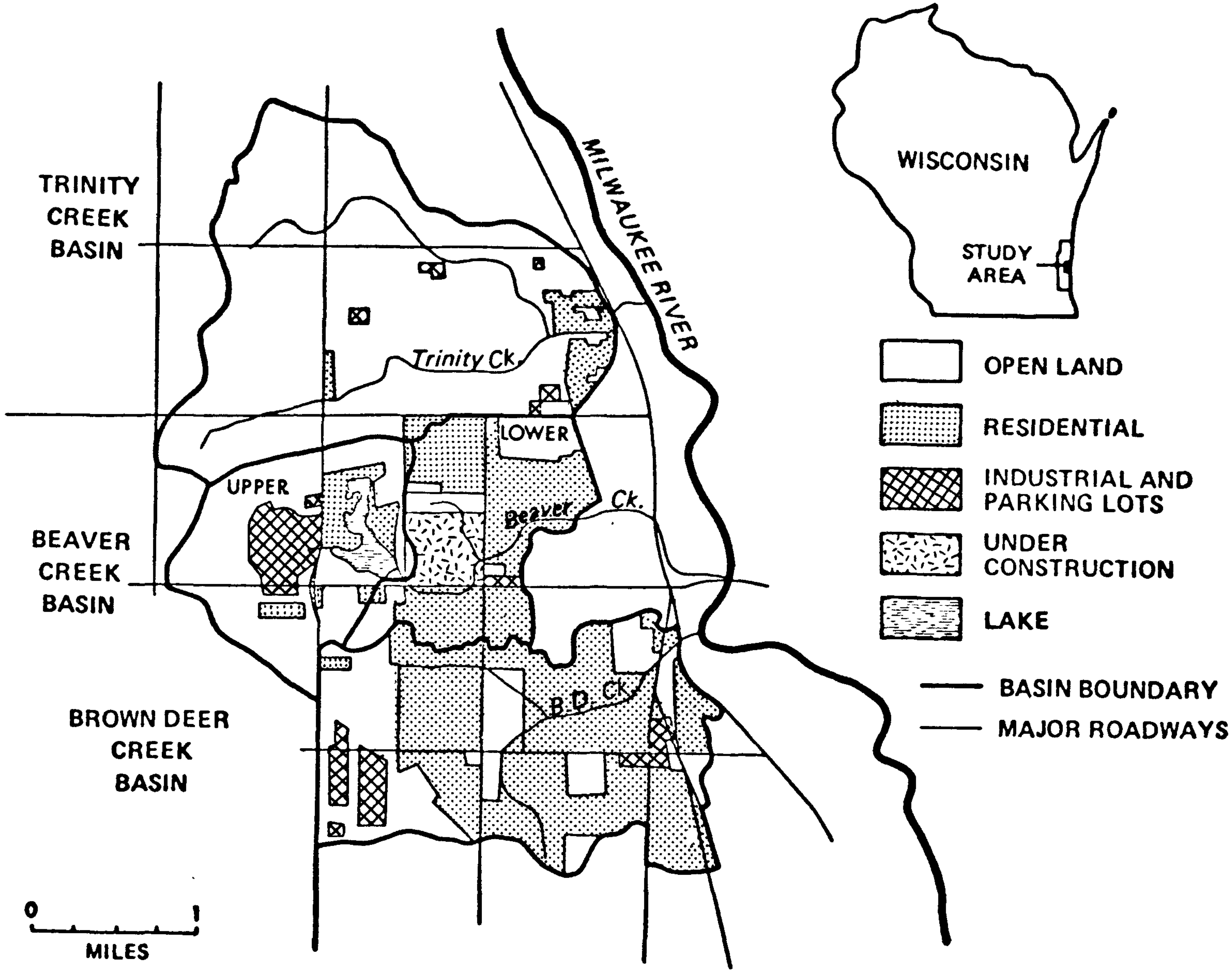
Work on this model began independently in 1974, and was incorporated into the Menomonee River Project in the spring of 1975. As a result, the effort to date has been largely in three small watersheds which are

tributaries of the Milwaukee River, but which are also contiguous with the Menomonee River watershed in the Village of Brown Deer and the City of Mequon (Appendix H Fig. 12). The three watersheds were selected originally for study because, while they are all quite similar in size and natural conditions, they span the zone of active development on Milwaukee's north side. The southernmost is largely developed as a stable light-to-medium density residential area. The northernmost part is still rural-agricultural. The central watershed is undergoing two types of active development: construction and expansion of commercial centers and condominia in the upper watershed, and development of a new medium density residential subdivision in the central reaches. Manual observations of the responses of these watersheds to runoff events have been underway since June, 1974. It was out of these observations that the idea for a simple, empirical model of small watershed overland runoff developed. The work on this model has been divided into three phases, which are described below.

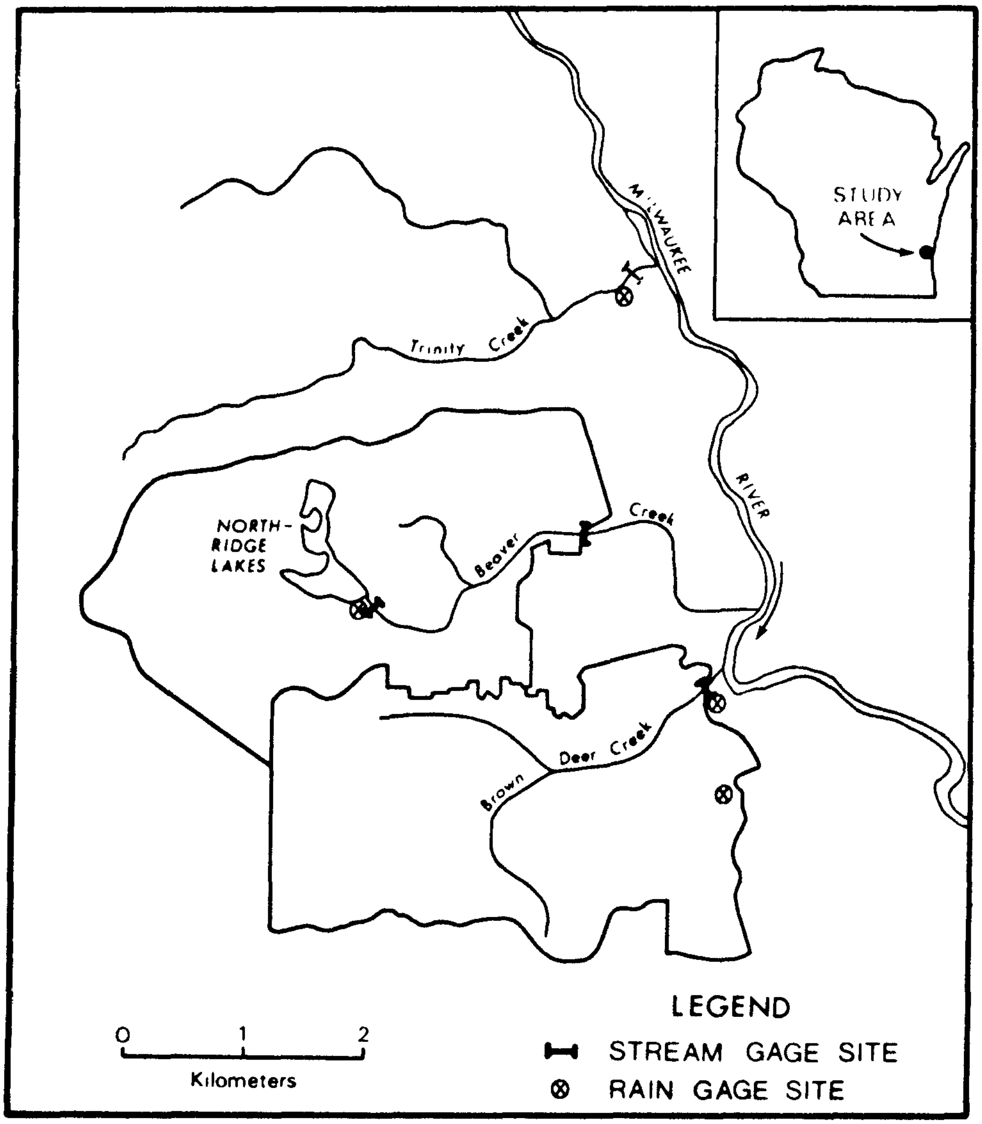
<u>Phase I - Watershed monitoring and initial data analysis</u>

This effort began in June, 1974, and continues. With the aid of one graduate assistant, the principal investigator has monitored the response of the three watersheds to 20 runoff events. Staff gauges and sampling sites have been established at four sites (Appendix H Fig. 13). A rating curve has been developed and is updated continually at each site. Some discharges are measured during runoff events using a pygmy Price meter to recalibrate the rating curves. Baseflow samples are collected at each site prior to runoff, and water samples are taken periodically during the runoff event. Samples have been analyzed *in situ* for pH, electrical conductivity and temperature and in the laboratory for total dissolved solids (TDS), Cl^-, Na, Ca, Mg, HCO_3^- and suspended solids (SS).

Flood hydrographs are generated from the gauge readings and rating curves. Load hydrographs for each chemical constituent are generated by combining sample concentrations and flow hydrographs. After visual inspection, all hydrographs are digitized, and interpolated, integrated and plotted on a Univac 1110 computer. To date, interpolation and integration are completed on 14 events, and the plotting is underway.



Appendix H Fig. 12. Distribution of land uses in the study area.



Appendix H Fig. 13. Locations of staff gauges and sampling sites in the study area.

On Beaver Creek, three sets of hydrographs were generated: one set for each of the sampling sites, and one for just the lower half of the watershed, i.e., the area under residential development. The latter hydrographs are obtained by routing flow from the upper site downstream and subtracting it from total flow at the lower site. Thus, three data sets will be available: the upper watershed containing commercial development and draining into the Northridge Lakes, the lower watershed containing residential development, and the total watershed.

Appendix H Table 5 provides some of the preliminary runoff concentration values for the suburban, developing residential and rural watersheds. Appendix H Table 6 indicates the magnitude of the load per unit drainage area carried from each watershed for a variety of events. Appendix H Table 7 puts the absolute load magnitude data into a comparative form, i.e., the relative loading. Each number in Appendix H Table 7 is the ratio of the load from a particular watershed to that from the rural watershed. The relative loading then is a measure of the degree of change from rural conditions caused by a particular land use. Data for the remaining events and the additional chemical parameters is being processed currently.

The events monitored have been grouped into two seasonal categories, namely, summer and winter. Summer events are runoff events occurring between May and November, during the time when watershed and channel vegetation have major effects on runoff. Winter events are snowmelt runoff events occurring generally between January and March. Some monitored events, such as March rainstorms, do not fit in either category. However, they are hydrologically unique and cannot be treated except as individual cases.

It was anticipated that watershed runoff would be related to land use as well as affected by the season of the year, the intensity and quantity of precipitation or snowmelt, and the antecedent runoff conditions. The latter is treated here as the number of days since the last runoff event. Summer runoff is shown in Appendix H Fig. 14, where total runoff per unit rainfall is plotted as a function of antecedent flow. As depicted graphically, the data collected thus far indicate that total runoff is related to land use, total rainfall and antecedent conditions. However,

Appendix H Table 5. Quantity and quality of runoff from two suburban watersheds (Brown Deer Creek and Lower Beaver Creek) and a rural watershed (Trinity Creek) during a series of storm events

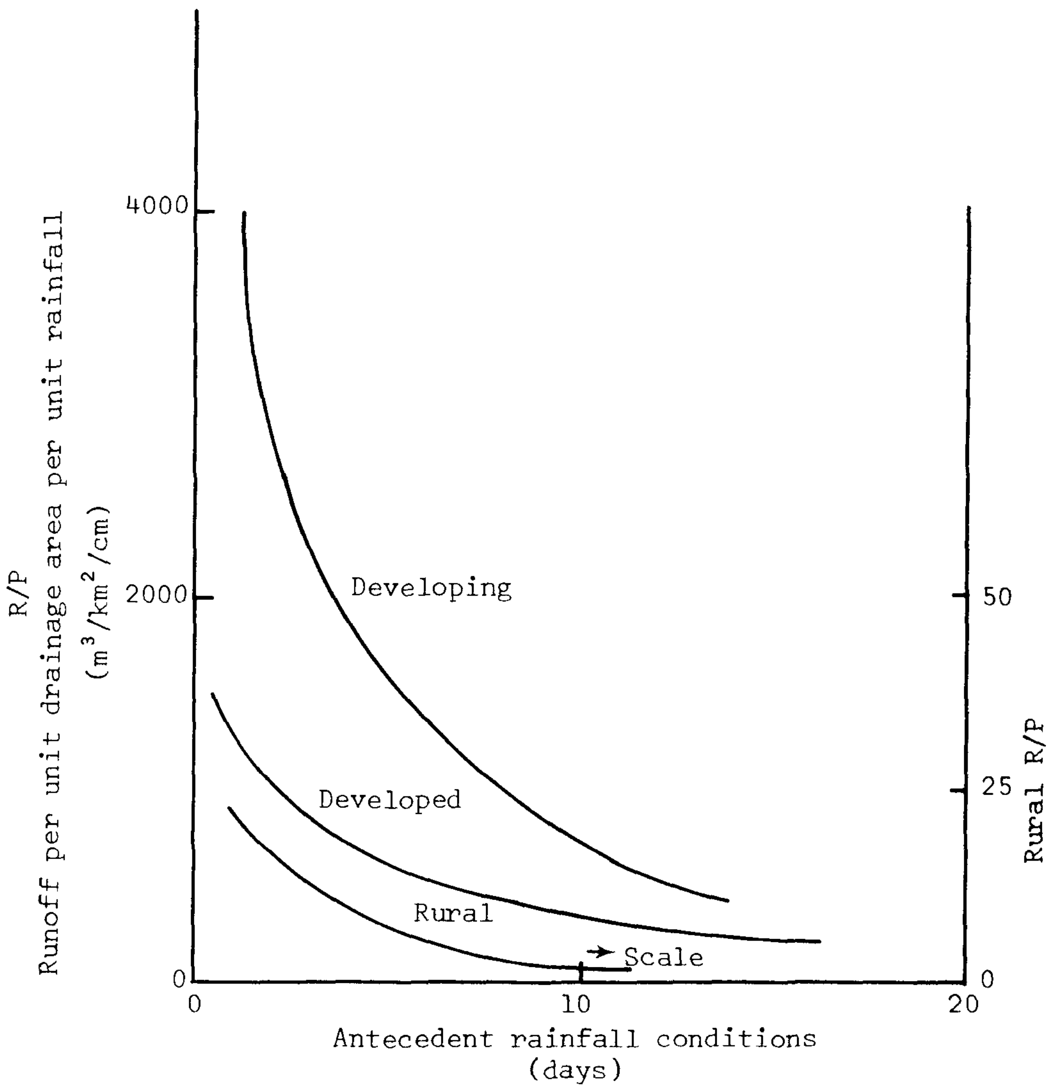
Event	Runoff Amount	Mean concentrations: Total dissolved solids	Mean concentrations: Cl^-	Mean concentrations: Suspended solids
	m^3/km^2	mg/l		
		Brown Deer Creek		
July 25, 1974	972	256	39.9	240
October 6, 1974	1,093	142	24.7	189
May 14, 1975	492	99	30.5	-
July 11, 1975	2,386	168	22.9	-
July 18, 1975	239	644	100.0	-
July 19, 1975	381	161	27.6	-
November 2, 1975	2,290	197	20.3	576
June 9, 1974	2,560	-	-	1,210
July 10, 1974	1,940	-	-	309
Weighted mean concentration		194	27.5	826
Standard deviation		-	88.6	453
		Lower Beaver Creek		
July 25, 1974	-	-	-	518
October 6, 1974	997	107	17.3	240
May 14, 1975	694	94	21.2	-
July 11, 1975	928	120	14.3	-
July 18, 1975	478	122	12.6	-
July 19, 1975	2,480	56	8.7	-
November 2, 1975	1,385	179	19.2	358
June 9, 1974	-	-	-	180
July 10, 1974	-	-	-	266
Weighted mean concentration		105	14.3	309
Standard deviation		45	4.7	132
		Trinity Creek		
July 25, 1974	17.7	405	29.4	-
October 6, 1974	8.3	659	87.2	112
May 14, 1975	0.0	-	-	-
July 11, 1975	4.7	213	15.9	-
July 18, 1975	2.6	319	26.1	-
July 19, 1975	23.1	701	71.6	-
November 2, 1975	8.3	423	39.4	44
June 9, 1974	-	-	-	-
July 10, 1974	18.4	-	-	26
Weighted mean concentration		528	52.1	51
Standard deviation		166	24.0	34

Appendix H. Table 6. Loadings from small watersheds

Land use	Discharge	Total dissolved solids	Cl^-	Suspended solids
	m^3	kg		
		Rainstorms (average of 6 events)		
Suburban developed (Brown Deer Creek)	1,150	270	30	505
Suburban developing (Lower Beaver Creek)	1,170	126	175	965
Rural (Trinity Creek)	7.8	3.6	0.5	0.6
Lake (Upper Beaver Creek)	2,380	1,290	414	-
		Salt-induced flow (1 event)		
Suburban developed (Brown Deer Creek)	386	1,433	840	-
Suburban developing (Lower Beaver Creek)	270	1,070	658	-
Rural (Trinity Creek)	7.5	2.3	0.7	-
Lake (Upper Beaver Creek)	912	276	102	-
		Snowmelt (average of 3 events)		
Suburban developed (Brown Deer Creek)	5,230	1,730	315	-
Suburban developing (Lower Beaver Creek)	6,370	2,600	440	-
Rural (Trinity Creek)	11,900	3,350	110	-
Lake (Upper Beaver Creek)	3,930	4,065	975	-

Appendix H. Table 7. Loadings from small watersheds relative to a comparable rural watershed. Note the rural watershed for all parameters is given a value of one.

Land use	Discharge	Loadings of Total dissolved solids	Cl^-	Suspended solids
	— m^3 —	—	kg	—
		Rainstorms (average of 6 events)		
Suburban developed (Brown Deer Creek)	145	75	60	840
Suburban developing (Lower Beaver Creek)	150	35	35	1,600
Rural (Trinity Creek)	1.0	1.0	1.0	1.0
Lake (Upper Beaver Creek)	305	360	830	-
		Salt-induced flow (1 event)		
Suburban developed (Brown Deer Creek)	51	630	1,225	-
Suburban developing (Lower Beaver Creek)	36	470	960	-
Rural (Trinity Creek)	1.0	1.0	1.0	-
Lake (Upper Beaver Creek)	120	120	150	-
		Snowmelt (average of 3 events)		
Suburban developed (Brown Deer Creek)	0.44	0.52	2.9	-
Suburban developing (Lower Beaver Creek)	0.53	0.78	4.0	-
Rural (Trinity Creek)	1.0	1.0	1.0	-
Lake (Upper Beaver Creek)	0.33	1.2	9.0	-



Appendix H Fig. 14. Relationship of total summer runoff and antecedent flow.

the data show no significant relationship between runoff and rainfall intensity. Incorporation of additional data as Phase I continues will be used to refine these preliminary relationships. Ultimately Phase I data will be combined with that from small watershed monitoring stations within the Menomonee watershed to quantify the relationship of runoff to land use.

Phase II - Interpretation of mean chemical concentrations of runoff

Work on this phase began in December, 1975, when sufficient runoff events had been monitored to provide a significant set of data. The mean concentration of a material in surface runoff is defined as:

$$\bar{C} = Lr/Qr$$

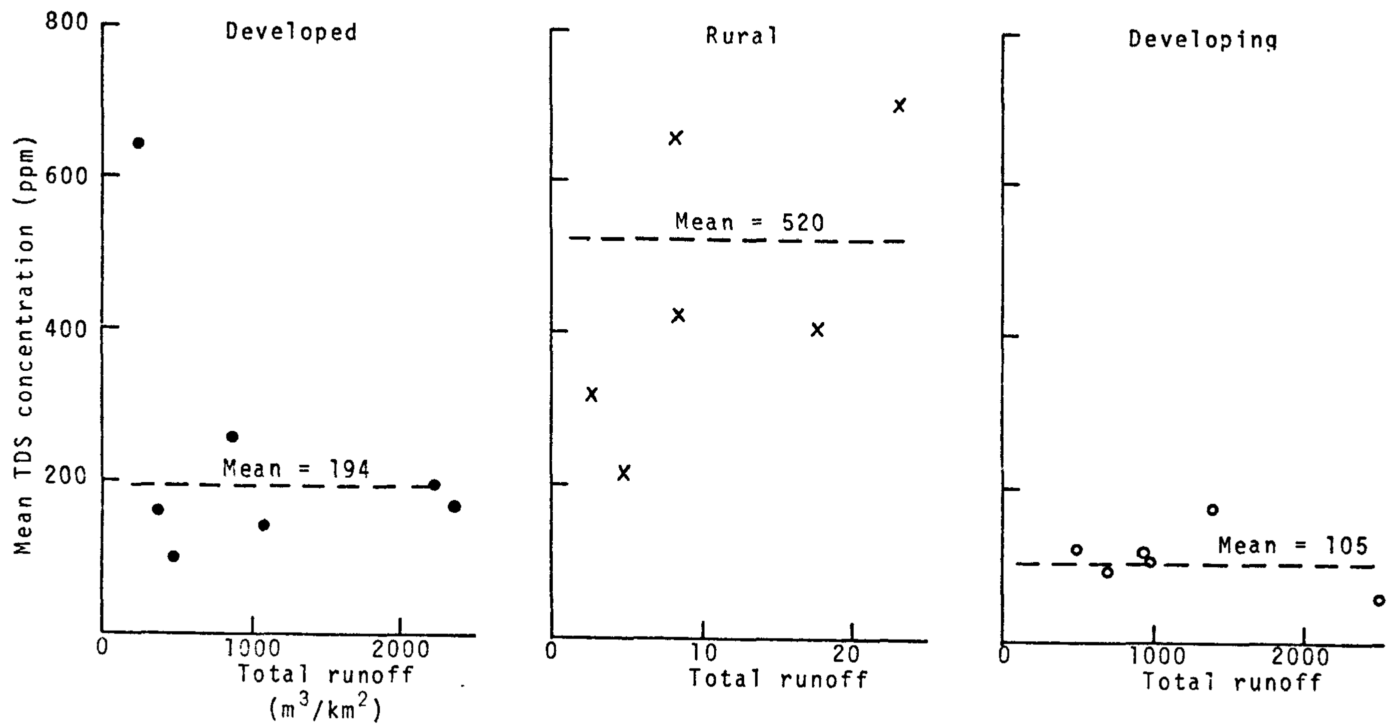
where $\bar{C}$ is the mean concentration (ppm)

Lr is the total load of a material contributed to a stream by surface runoff during an event (in kg), and

Qr is the total quantity of surface runoff during that event (in m^3).

The total flow out of a watershed during a runoff event is a mixture of surface runoff and baseflow. Therefore, it is necessary to delete the baseflow runoff and mass loads from total flow to obtain surface runoff values.

It was anticipated that $\bar{C}$ values would vary seasonally and that within a season they would be affected by the total quantity of runoff and the antecedent runoff conditions. Preliminary findings seem to contradict this assumption, however. Appendix H Fig. 15 shows that $\bar{C}$ values exhibit no visible relationship to the quantity of runoff (Q) for the rural, developing or suburban watersheds. The TDS relationships are representative of the other dissolved chemical parameters. There is no apparent relationship to rainfall intensity or antecedent runoff. In fact, $\bar{C}$ values appear relatively constant for a wide variety of events, particularly in the nonrural watersheds. If $\bar{C}$ is independent of the hydrologic and meteorologic factors, then a single value of $\bar{C}$ can be used for a given watershed for all summer events. A preliminary set of these values is provided in Appendix H Table 8. Additional summer events have not been fully processed. No firm conclusions regarding summer mean concentrations



Appendix H Fig. 15. Relationship of mean concentrations of total dissolved solids and rainfall intensity in three land use areas.

Appendix H. Table 8. Comparison of quality of surface runoff water

Land use	Total dissolved solids	Cl^-	Suspended solids
	mg/l		
	Summer rainstorms (average of 7 events)		
Suburban developed (Brown Deer Creek)	194	27.5	830
Suburban developing (Lower Beaver Creek)	105	14.3	310
Rural (Trinity Creek)	528	52.1	51
	Salt-induced flow (1 event)		
Suburban developed (Brown Deer Creek)	3,710	2,180	-
Suburban developing (Lower Beaver Creek)	3,960	2,440	-
Rural (Trinity Creek)	305	93	-
	Snowmelt (average of 3 events)		
Suburban developed (Brown Deer Creek)	330	60	-
Suburban developing (Lower Beaver Creek)	408	69	-
Rural (Trinity Creek)	282	9.2	-

can be made until these data are included.

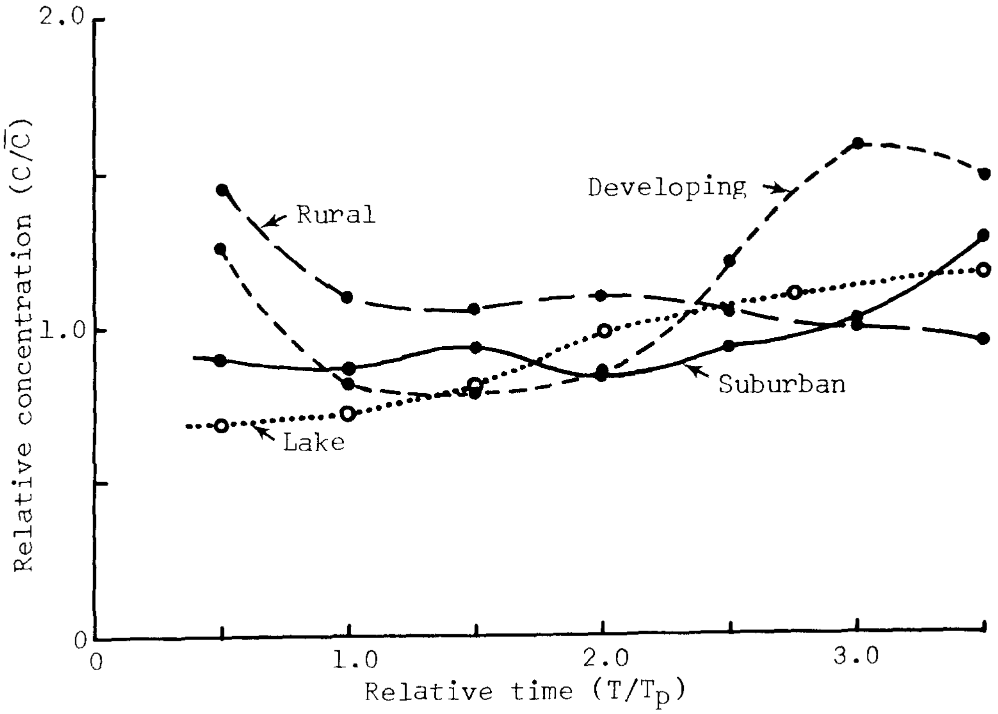
Suspended solids concentrations do show an exponential relationship to total surface runoff in the summer. However, rainfall intensity and antecedent runoff do not seem to affect these concentrations. A second winter monitoring season is now being completed. Analysis of the winter data will not begin until these recent events are processed.

Finally, when the values of mass loadings during runoff become available for small watersheds in the Menomonee watershed, these data will be analyzed to determine the factors controlling their mean runoff concentrations. Combination of Phase II data with the Menomonee data should allow quantification of the role of land use in determining mean concentrations.

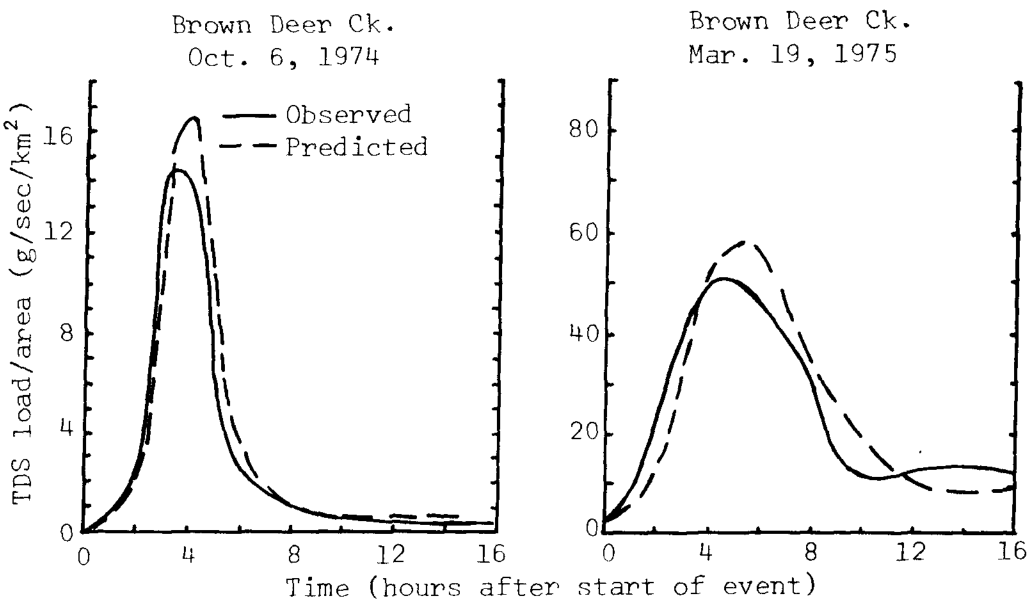
Phase III - Development and testing of relative concentration curves

Plots of relative concentration as a function of a time ratio are being generated by computer for each event. Software is now largely complete and work on this phase is underway.

Appendix H Fig. 16 shows some preliminary curves which are generated by hand. Each is a composite of four events. Relative concentration is plotted against the ratio of hours elapsed since runoff began to length of the storm. These curves were combined with unit hydrographs and predicted $\overline{C}$ values for the Brown Deer Creek watershed to predict the TDS load hydrographs for two events (Appendix H Fig. 17). The similarity between the predicted and actual hydrographs is encouraging. More definitive work on Phase III will be undertaken in June, 1976.



Appendix H Fig. 16. Relative TDS concentration ($C/\bar{C}$) versus relative time (T/T_p) for the study basins. Each line is the average of four events.



Appendix H Fig. 17. Comparison of predicted with observed TDS loads during two runoff events in a suburban watershed.