INTERNATIONAL JOINT COMMISSION

MENOMONEE RIVER
PILOT WATERSHED STUDY

SEMI-ANNUAL REPORT

COOPERATING AGENCIES

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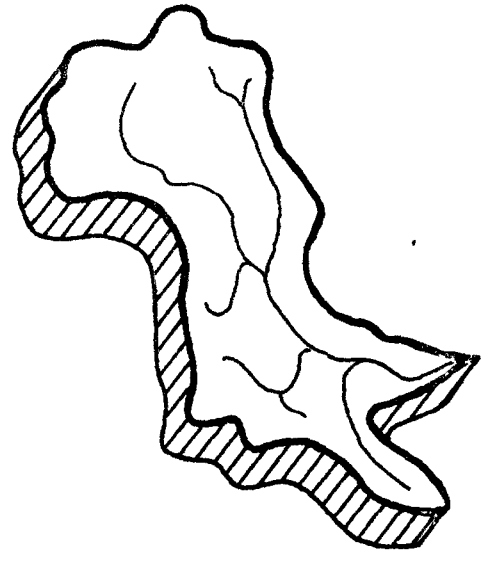
OCTOBER 1975



City of Milwaukee showing Menomonee River flood plain

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TABLE OF CONTENTS

Page No.

SUMMARY SEMI ANNUAL REPORT..... 1

APPENDIX

A. River Monitoring Activities..... 7

B. Specific Land Use Studies..... 21

C. Land Data Management System..... 28

D. Atomspheric Monitoring..... 33

E. Remote Sensing..... 36

F. Proposal of Modeling Output Objectives..... 40

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 uses 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 was selected as the site for studying the effects of rapidly changing land use patterns in an urban setting. A unique facet of the Menomonee River watershed stems from the proposed plan to remove all municipal point sources of pollution by 1976, at which time the effects of land use on water quality will arise primarily from non-point sources. Thus, of the six major watersheds chosen for intensive study, the Menomonee River watershed will serve as the focus of investigations on the impact of urban land uses on water quality and this 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 made towards achieving the specific objectives of the study since the January, 1975 semi-annual report.

The river monitoring activities are currently achieving the goals of the first objective. Scheduled weekly water quality sampling at twelve automatic monitoring stations and three harbor area grab stations has been underway since January, 1975 (refer to January, 1975 semi-annual report for location of sites). Beginning in March, two grab sampling stations were added on the Menomonee River in the long unsampled reach between the confluence of the Menomonee and the Little Menomonee Rivers and the 70th Street station. The parameter list for weekly scheduled monitoring includes nutrients, solids, hardness, alkalinity, color, conductivity, temperature, DO and pH. Two sets of samples were collected for organic, trace metal and bacteriological analysis as part of the quarterly sampling effort. Continuous *in situ* electronic sensor monitoring of pH, DO, conductivity and temperature began in the spring at five automatic monitoring stations. Discharge is monitored continuously at eleven of the 12 automatic monitoring stations, and recording rain gauges are operating at seven of the stations and at Greenfield High School. Sediment samples are collected by the U.S. Geological Survey (USGS) on a continuous basis at the 12 stations. Event sampling was initiated in June at four automatic stations (463001, 413011, 413010 and 413005) with the intention of obtaining better yearly loading estimates and providing data essential for the overland flow and river transport models. Data from the weekly sampling activities were edited and stored on computer mass storage to allow for reporting, statistical analysis and plotting.

The principal method used in achieving objective 2 is an inventory of land use characteristics and their impact 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. 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 aerial extent. Eight land data types are presently coded for the entire watershed, one type is in progress, and two are planned.

The Specific Land Use Study program is designed to investigate the

impact of various land uses on water quality. Thirteen study areas, representing major homogeneous land uses in the watershed, have been identified as storm event sampling sites for the Specific Land Use Studies. Detailed surveys have been completed for seven of the sites and stations will be operable by midwinter. Each station will consist of a control structure, stilling well, stage recorder, sequential sampler and protective enclosure. The parameter list will include those in the "core" list suggested by the Tack C technical committee. The data will be incorporated into the overland flow model.

An additional source of pollutants to the watershed arises from atmospheric fallout. The nature and quantity of the pollutants is determined by the types of land use in and around the watershed and the climatological characteristics of the area. An air and rain water monitoring program is presently being established in the watershed in support of objective 2. The primary objective of the atmospheric monitoring project is to determine the relative contribution of different land uses to the total weight and chemical composition of the aerosols measured over the watershed. The atmospheric study will also attempt to quantify the mass of aerosols entering the watershed from rain and dry fallout deposition. Presently, seven high-volume air samplers are being calibrated and will be mounted permanently on existing monitoring stations along with modified (Wong) rain samplers. Two cascade impactors will be used periodically to size-fractionate aerosols. The target date for initial sampling is January 5, 1976.

Also in support of the second objective is a recently initiated remote sensing project. The intent of this project is to develop techniques for mapping land use and hydrologically-active source areas in a watershed from small scale color-IR imagery. The technique involves measuring the film density on the image for the area of interest and with the aid of a computer, interpreting and mapping the area. It is anticipated that the automatic processing of digitized photography will accelerate the land cover interpretation process. Statistical summaries of the aerial extent of each land cover category can be obtained within any given area. This data should be useful input to the hydrological modeling effort. Density measurements on the film and ground checking of the results are being accomplished at the University of Wisconsin-Madison, while the

computer interpretation and mapping are being undertaken at The Pennsylvania State University.

Objective 3 is being supported 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. A computer model--"STORM"--has been acquired to model overland flow and quality of runoff water. Preliminary testing of the model has been performed on three small subwatersheds and subroutines of the model are being developed. In addition, conceptual models of soil adsorption applicable to agricultural chemicals, nutrients, pesticides and other pollutants transported in the soil are being prepared and will be added to the STORM model. Ouput from the overland flow and quality model will be used in the river transport model. The river transport model will account for in-stream and benthic processes over a range of flows (i.e., a dynamic model) and deliver the derived loadings to an estuary model. It is anticipated that DO/BOD, sediment and nutrient/algae interactions and quantifications will be derived from extensively modifying existing models.

A model is being developed to relate surface runoff quality to the ultimate nonpoint sources, namely, atmospheric fallout, precipitation, land and management practices and natural geological weathering. However, this model requires extensive data collection and for this reason will not be of general applicability. Thus, an attempt is being made to derive empirical relationships describing the quality of surface runoff to land use and meteorological parameters.

In their cooperative effort with the IJC Project, including coordination with their programs supported by Section 208 funds under Public Law 92-500, the Southeastern Wisconsin Regional Planning Commission (SEWRPC) is developing several watershed models. It is likely that an amended form of the Hydrocomp Simulation Watershed Model--which contains both overland flow and river transport components--will be capable of satisfying the requirements of objective 3 of the Menomonee River Pilot Watershed Study.

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 Menomonee River Pilot Watershed Study were divided into the

the three aforementioned specific objectives. Since January, 1975 the river monitoring activities in support of objective 1 have been fully implemented and will continue to be conducted at the present level for the duration of the project. Most of the projects designed to accomplish the second and third objectives have been initiated recently and will progress significantly towards meeting these objectives within the next 6 months. Eight land types already have been coded into the Land Data Management System and progress has been made in identifying special study sites and defining better the modeling activities.

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 reaching or moving in the Menomonee River and its principal tributaries. The parameter list includes the "core" list determined by the Task C Technical Committee of the Pollution from Land Use Activities Reference Group (PLUARG), plus others likely to affect the quality of Lake Michigan water. 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 handled 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 major tributaries began in January, 1975 after the site selection and construction of 12 automatic monitoring stations.

Progress

Sampling frequency for baseflow water quality at the river monitoring stations was seasonally adjusted to accomodate times of rapid changes in discharge such as in the spring. Bi-weekly water quality samples were obtained from the 12 automatic stations from January until the end of March 1975, and from the end of March until the end of June samples were obtained twice a week. Since the end of June the stations have been sampled once a week. Beginning in March two grab samples stations on the Menomonee River, 413061 and 413062, were included in the regular river sampling schedule. These two stations provide water quality data in the long reach between stations 683001 and 413005 on the Menomonee River (refer to pages 17 and 18 in January 1975 semi-annual report for location of monitoring stations). Starting in March the scheduled weekly samples at

the automatic monitoring stations were collected when the gauge height permitted. A quality control program was initiated in April to compare grab samples with samples obtained from the automatic samplers. Grab sampling stations 413004, 413013 and 413012 in the Menomonee River harbor area were sampled bi-weekly between January and the end of March, and once a week from the end of March until the end of May when bi-weekly sampling was resumed. The parameter list for the scheduled weekly sampling at all stations included the basic nutrient scan, solids, total alkalinity, hardness, color, chloride, conductivity, pH, DO and temperature. Total organic carbon was added to the list on July 28. Temperature, DO, pH and conductivity have also been measured continuously at five river stations (413004, 413005, 683001, 413008 and 673001) equipped with an electronic sensor-type monitor. Data from the weekly sampling activities have been edited and stored on computer mass storage to allow for reporting and statistical analysis. The data may be accessed through batch processing or terminal input and output. To further assist in the interpretation of the water quality data, the stored information is presently being programmed for mechanical plotting in terms of concentration and loading and will be included in the April 15 report. The above calculations will include the parameters from quarterly sampling.

Two quarterly samplings for metals, organics and bacteria at the 12 automatic stations were accomplished this year. Samples were obtained under baseflow conditions in June and September. The total coliform, fecal coliform and fecal streptococci counts almost always exceeded accepted standards by a large margin. Most of the samples collected on June 11th and analyzed for organics showed concentrations below detection limits. In a few instances, aldrin, lindane, heptachlor epoxide and methoxychlor demonstrated a significant concentration above detection limits. Most phenol levels for samples taken June 24 and September 3 were above detection limits. Phenol concentrations varied considerably between two different sampling dates at the same station. Many of the metals sampled on June 25 had concentrations below detection limits at all the stations. Levels of copper, lead, zinc and chromium appeared to be higher at stations below station 413007 (Appendix A Table 1). Previous investigators have shown a significant increase in metal loadings during runoff events. Therefore, an attempt is being made to

Appendix A Table 1. Metal and phenol concentrations in quarterly samples collected at automatic monitoring stations of the Menomonee River Pilot Watershed Study

Metal	Metal and phenol concentrations, µg/l, at the following monitoring stations: 673001	683002	683001	463001	413011	413008	413007	413006	413005	413010	413009	413004
							Metals					
Copper	<3	3	11	3	3	5	19	18	10	6	12	13
Lead	<3	<3	7	<3	5	6	28	35	520	30	880	22
Zinc	<20	<20	40	<20	<20	<20	110	130	60	40	170	80
Chromium	<3	<3	<3	<3	<3	<3	3.4	7	9.2	4	36	4.6
Arsenic	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10
Selenium	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5
Nickel	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20
Cadmium	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	0.2	<0.2	<0.2	<0.2
Mercury	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	0.4	0.2	<0.2	0.2	0.3	<0.2
Iron	800	1500	4200	1600	1000	3200	6900	5700	4700	4500	2200	4800
Aluminum	330	85	800	372	332	1200	85	940	1520	570	640	880
Manganese	60	100	200	130	40	120	220	120	120	70	40	150
Sampling Date							Phenols					
6/24/75	1	1	3	-	1	3	11	21	14	9	4	12
9/3/75	5	3	4	3	31	4	6	3	1	6	11	5

collect quarterly metal samples during runoff events. A plan to sample for organics during an event is also being investigated. A more accurate estimate of monthly loadings of quarterly parameters will be made by combining base flow and runoff event concentrations with the continuous discharge data.

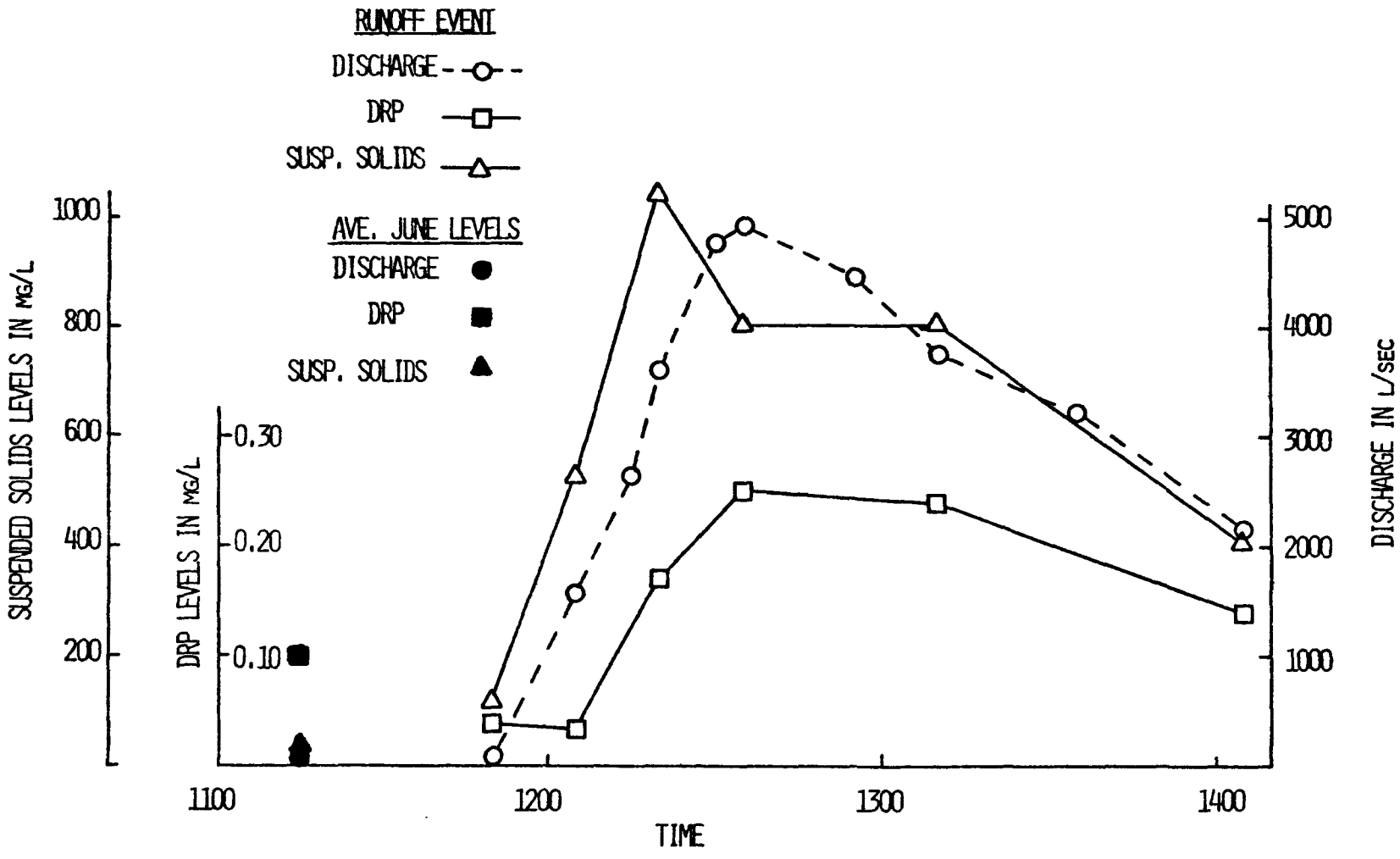
The stage heights that have been monitored continuously since November, 1974 at 10 of the 12 automatic monitoring stations (station 413009 was operational in May) will be available from the U.S. Geological Survey (USGS) in completed form later this year.

Starting in December, 1975 the USGS will provide primary discharge data every 6 weeks with three seasonal updates as a check on the accuracy of the primary data. The primary summer flow data is expected to be accurate to within 10% of the corrected flow data, while primary winter data is expected to be less accurate. Corrected flow data will be received in discharge units on magnetic tape, which will be programmed to be compatible with the stored water quality data. The above procedures will provide more immediate estimates of loadings and interpretation of river flow conditions. Due to the delay in obtaining corrected flow data the USGS will not be able to provide sediment loading data until later this year. The USGS has been monitoring continuously sediment concentration using the automatic samplers at the 12 automatic monitoring stations since March 1975. In the future, sediment concentrations and loading values will be provided monthly on data two months old. During September, 1975 the USGS completed the installation of rain gauges at seven of the automatic monitoring stations (673001, 683002, 683001, 463001, 413011, 413007 and 413005) and an eighth gauge at Greenfield High School in Greenfield. The availability of rain data will be valuable for present efforts in modeling overland flow during runoff events.

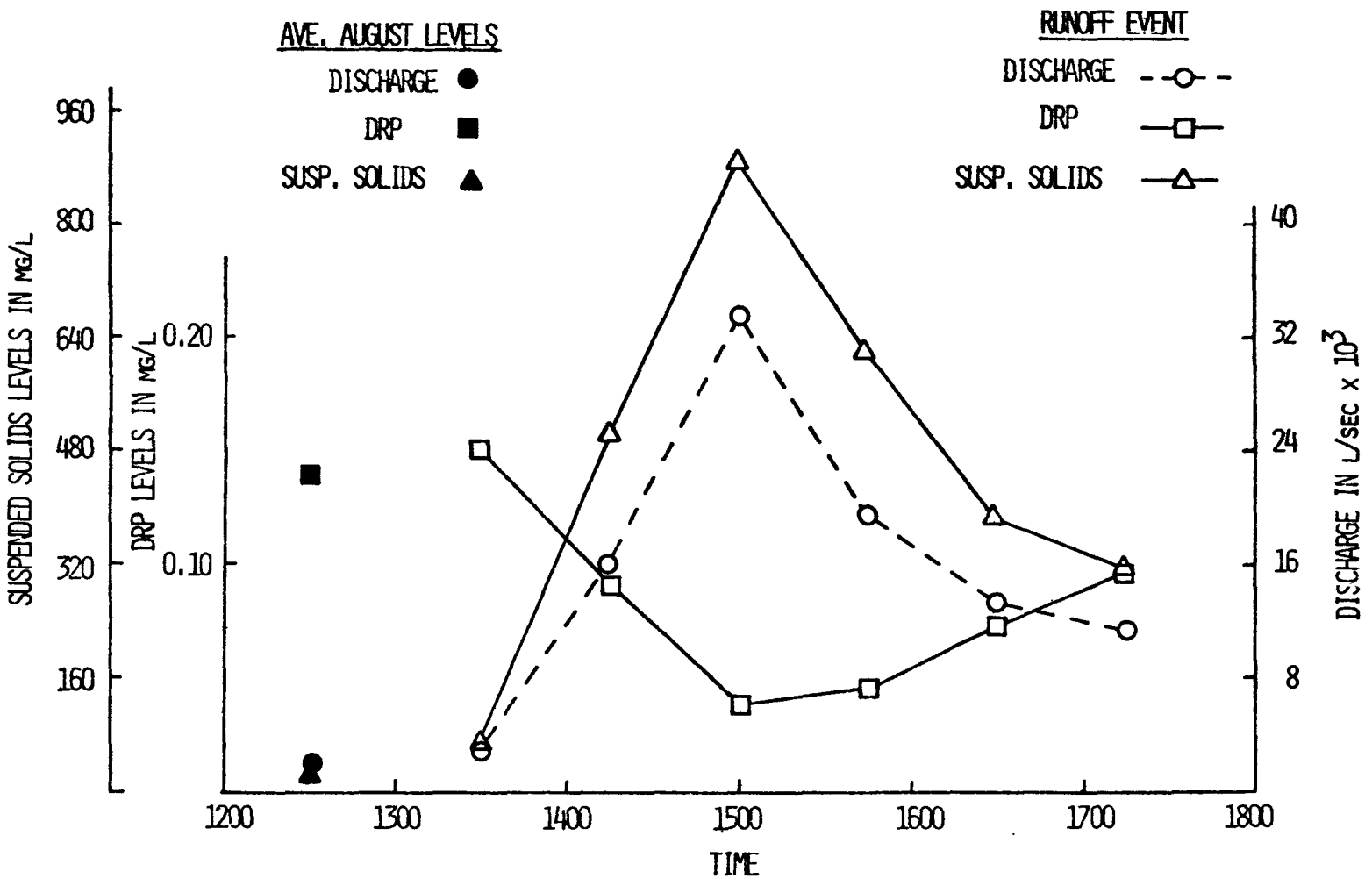
As an important part of the overland flow and river transport modeling effort, a program was initiated in June 1975 to monitor numerous runoff events at river stations 463001, 413011, 413010 and 413005 for the same water quality parameters determined in scheduled weekly samplings. The first 3 stations were chosen based on the homogeneous nature of the land use in their drainage area. Station 413005, which was not sampled until

the third event, provided water quality data for the Menomonee River at a downstream location. Four runoff events (June 17, July 19, August 18 and August 20) have been sampled so far with six or more samples collected at any one station during an event. Due to equipment failure and the uneven distribution of rainfall throughout the Menomonee River watershed, only one of the stations (413011) was sampled during the first 2 events (June 17 and July 18) and two of the 4 stations (413010 and 413005) were sampled in the last two events (August 18 and August 20). A significant increase in the concentration of most of the parameters was observed during the runoff events at stations 413011 and 413010 ; the average dissolved reactive phosphorus (DRP) and suspended solids levels at station 413011 during the month of June were 0.10 mg/l and 25 mg/l, respectively, while the average concentration during the runoff event were 0.20 mg/l and 6,800 mg/l, respectively (Appendix A Fig. 1). The increasing concentration with increasing discharge rates during a runoff event suggest the watershed around station 413011 was a possible nonpoint source of such parameters as dissolved nutrients and particulate matter. Hardness, alkalinity and chloride concentrations decreased with increasing discharge rates at stations 413010 and 413011 for all events, suggesting these parameters were contributed at a relatively constant rate by a source such as groundwater and were present in relatively low quantities in the watershed. Chloride levels are expected to increase with increasing discharge rates if an event occurs during or soon after road salting season.

Trends in parameter concentration at station 413005 during runoff events differed from those observed at stations 413010 and 413011. Concentrations of most of the dissolved nutrient species for the August 18 event tended to increase only slightly with increasing discharge rates, while the dissolved nutrient species levels for the August 20 event decreased with increasing discharge rates. The parameters measuring particulate species increased with increasing discharge water for both events. The DRP levels decreased from 0.15 mg/l to a low of about 0.035 mg/l and the suspended solids increased from a monthly average of about 18 mg/l to a peak concentration of 880 mg/l (Appendix A Fig. 2) for the August 20 event. The same decrease in hardness, alkalinity and chloride with increasing discharge rate, observed at stations 413011 and 413010, also occurred



Appendix A Fig. 1. Discharge, dissolved reactive P and suspended solids levels in Noyes Creek during the June 17, 1975, runoff event.

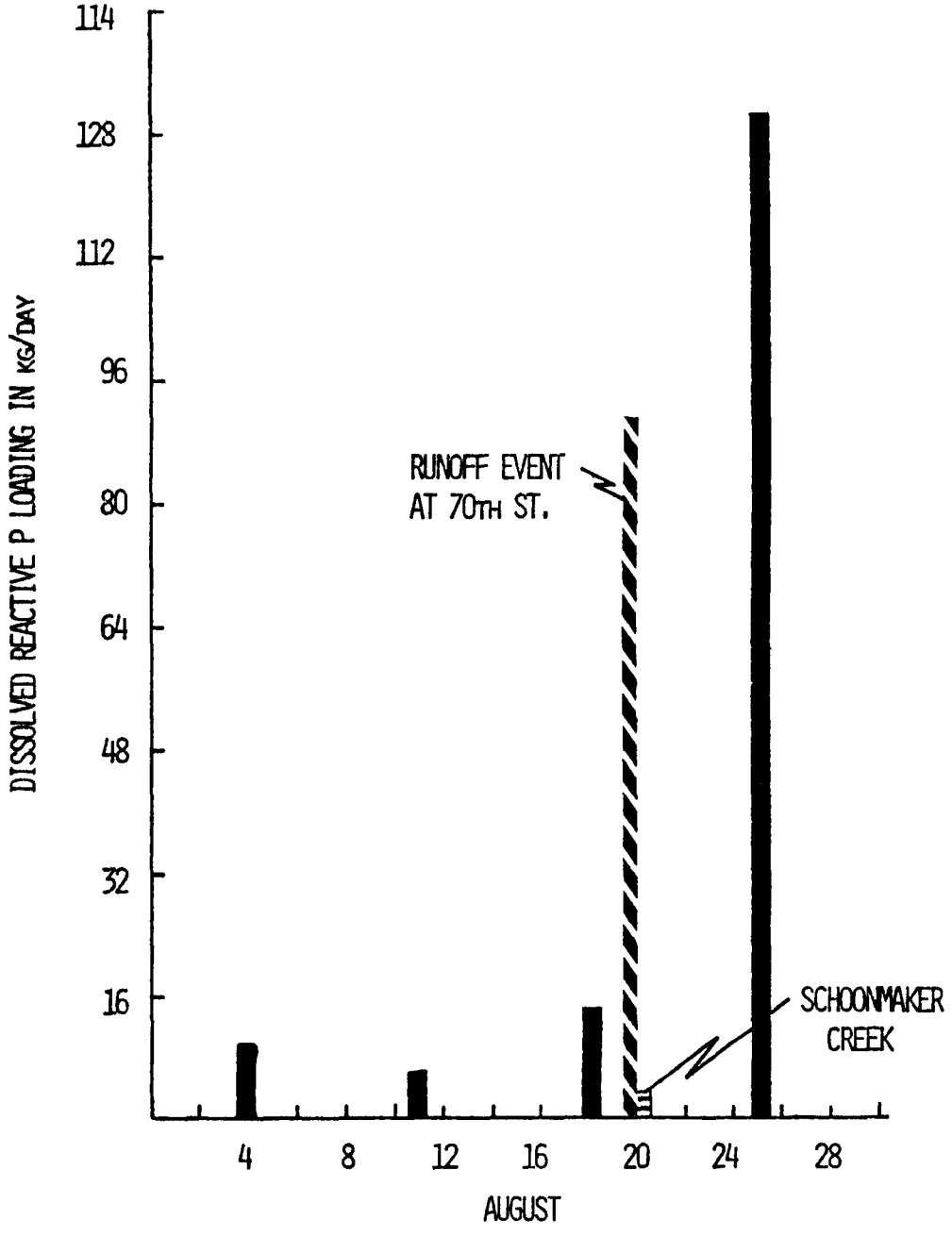


Appendix A Fig. 2. Discharge, dissolved reactive P and suspended solids levels at 70th Street during August 20, 1975, runoff event.

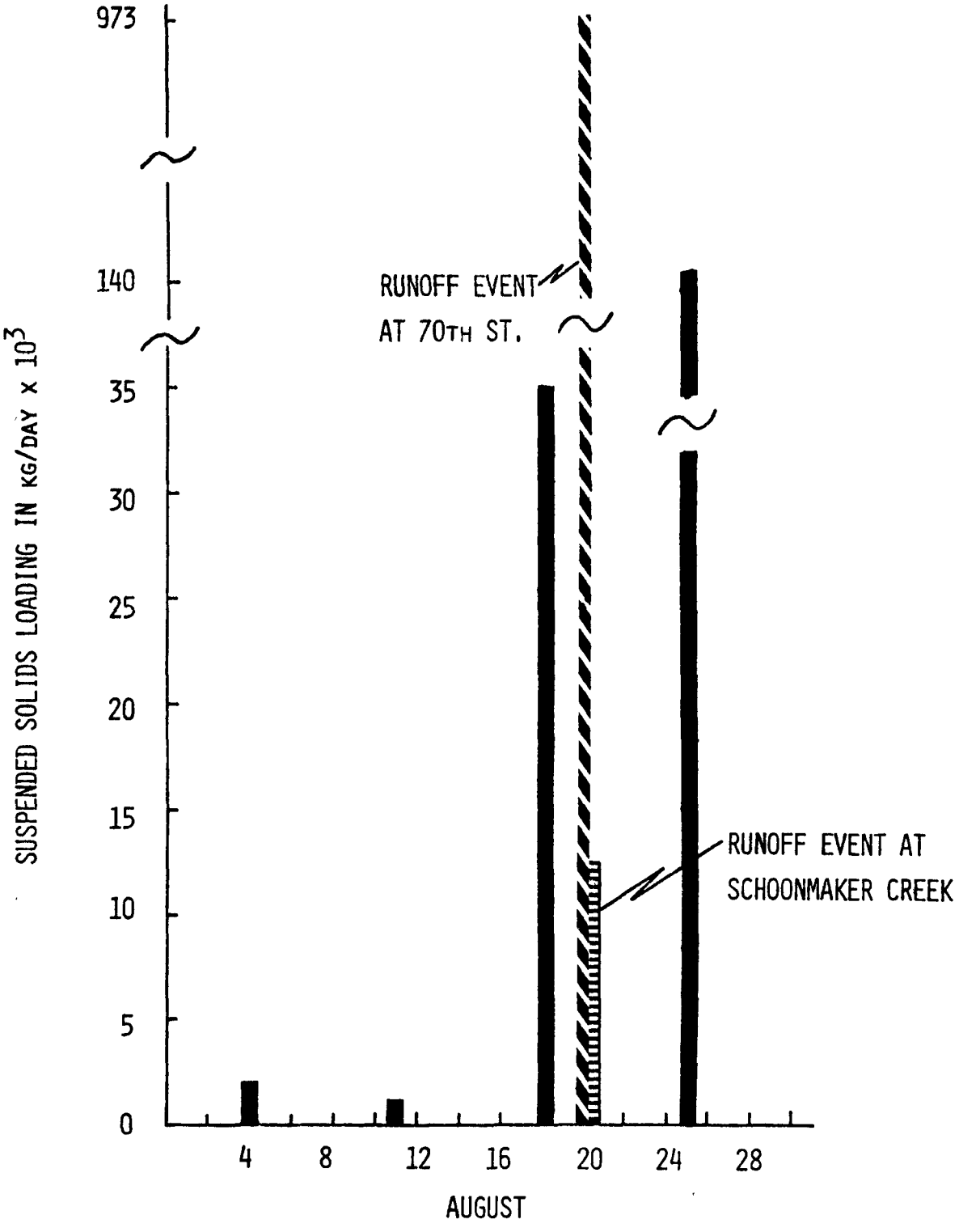
at station 413005 on August 18 and 20. The August 20 data at station 413005 suggest that the Menomonee watershed contained low quantities of dissolved nutrients relative to the volume of runoff and river discharge. The result was dilution of the dissolved nutrients in the river. However, a discussion of concentration changes, large or small, in the various parameters during a runoff event at any of the stations may lead to an incorrect judgment on the full impact of a runoff event until the concentration data is combined with the discharge data to obtain loading values.

The DRP loadings for the days of the scheduled weekly sampling station 413005 during the month of August were found to be about nine times smaller (10 Kg/day vs 90 Kg/day) than the loadings for DRP observed during the August 20 runoff event. The August 25 scheduled weekly sampling had a higher DRP loading because of a storm event that had occurred prior to sampling. The DRP loading for station 413005 was found to be about 22 times (90 Kg/day vs 4 Kg/day) greater than that for station 413010 during the same event (Appendix A Fig. 3). Similar results were found for suspended solids loading on August 20 at station 413005, where the loading was about 28 to 973 times greater (1 to 35 Kg/day vs 973 Kg/day) than the loading observed for the scheduled weekly sampling (Appendix A Fig. 4).

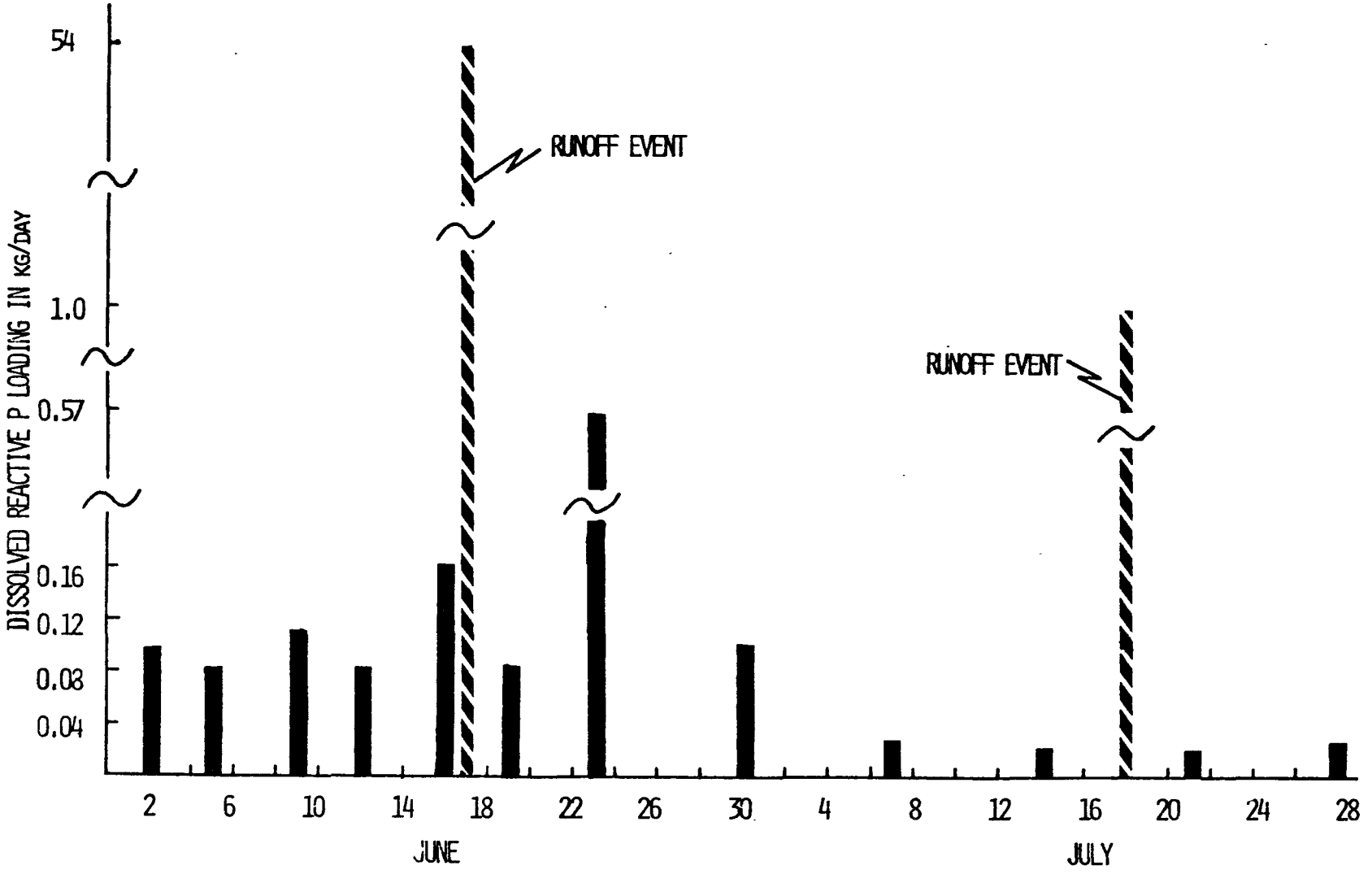
Suspended solids loading at station 413005 was 80 times greater 973 Kg/day vs 12.5 Kg/day) than at station 413010 (Appendix A Fig. 4). Station 413011 was monitored twice during runoff events which allows a comparison of event loading and loading for weekly scheduled sampling, plus loading difference between two separate events. The DRP loadings during the June 1 and July 18 events at station 413011 were 5,400 (540 Kg/day vs 0.10 Kg/day) and 50 (1 Kg/day vs 0.02 Kg/day) times greater than the average loading for weekly scheduled sampling, respectively. Also the average DRP loading for the weekly scheduled sampling was higher (0.1 Kg/day vs 0.02 Kg/day) in June than in July (Appendix A Fig. 5). This was a result of both a decrease in DRP levels and discharge in July. The DRP loading for the June 11 event was 540 times greater (540 Kg/day vs 1 Kg/day) than the July 18 event. This difference is directly correlated to the higher average DRP levels in the June 17 event of about 0.20 mg/l compared to 0.05 mg/l for the July 18 event and a water loading of 2.5×10^7 liters vs



Appendix A Fig. 3. Loadings for 70th Street and Schoonmaker Creek during the August 20, 1975, runoff event compared to loading for samples obtained weekly at 70th Street.



Appendix A Fig. 4. Suspended solids loading during August 20, 1975, runoff event at Schoonmaker Creek and 70th Street station and for weekly sampling at 70th Street.



Appendix A Fig. 5. Dissolved reactive P loadings for Noyes Creek during runoff events and on days of weekly samplings.

3×10^6 liters, respectively. Differences in water loading were partly related to rainfall intensities, which were 0.5 inches in one hour for July 18 and 0.70 inches in one and half hours for June 17, while the DRP concentration differences could be partly influenced by seasonal changes in the watershed. All the above loading data indicate the important contribution of runoff events to total pollution from a watershed irrespective of the parameter concentrations during a runoff event. A better understanding of the factors affecting runoff loadings, such as seasonal changes and rain intensity, will be obtained by future monitoring of runoff events. Further event monitoring might also allow the development of sufficient pollutographs to predict storm loading based mainly on hydrographs.

In Situ Continuous Monitoring Equipment

Five of the river network sampling stations are equipped with electronic sensor-type monitors for *in situ* continuous monitoring of dissolved oxygen, pH, conductivity and temperature. These sites are 1. Menomonee River above 27th Street at Falk Corporation (413004), 2. Menomonee River at 70th Street Bridge (413005), 3. Menomonee River at 124th Street (Hwy. M) (683001), 4. Little Menomonee River at Appleton Avenue (Hwy. 175) (413008) and 5. Menomonee River at River Lane Road (Hwy. F) (673001).

Equipment partially consists of a subsurface sensor probe unit housed in a protective semi-open sonde. The sonde is supported in a subsurface location at mid-stream by attachment to one or more steel posts driven into the stream bed. Attachment of the sonde to the post(s) using a ratchet tightening nylon web belt allows for easy removal of the sonde unit for cleaning and calibration. The sonde unit is connected by water tight neoprene connectors and a urethane cable to monitoring and recording equipment located inside the site building.

The above water equipment consists of a surface unit which allows instantaneous reading of all parameters, a data scanner which separates data impulses and a strip chart recorder which records separate parameter data on an alternate time basis. (Data collection via tape deck units in place of the scanner and strip chart is available.) Strip chart data is collected monthly and digitized for computer input.

The entire continuous monitoring system is battery-powered by a 12 volt direct current system and internal mercury batteries. This set-up provides a reliable power supply independent of electrical line power. Electricity is used, however, to provide heat and light to the sites and to charge periodically the batteries.

Calibration frequency of the system is dependent on rate of probe fouling, which in turn is dependent on general water quality. A weekly or twice-a-week cleaning and calibration schedule is usually sufficient to ensure accurate data.

APPENDIX B

SPECIFIC LAND USE STUDIES

Introduction

The nature of river sampling and the heterogeneity of land use in the Menomonee River watershed precludes the use of most of the river sampling stations as specific land use stations. Defining the character of storm-water from homogeneous and/or predominant land use areas in a rapidly urbanizing watershed requires the establishment of stations at the outlets of these areas. In selecting sites, an attempt must be made to select areas that are representative of major land uses in the watershed. Data generated by the stations will give us an insight into the types and amounts of pollutants associated with land drainage. In addition, the data will be used to support an overland flow modeling effort.

Study Sites

Presently, thirteen study areas have been identified and are listed in Appendix B Table 1. Over the past few months, seven of the areas have been emphasized and are listed in Appendix B Table 2 along with some pertinent information. Two additional areas, Schoonmaker Creek and Noyes Creek, which are part of the river network sampling system, will be used. Detailed surveys have been completed for the seven sites and stations will be operable by mid-winter. We had originally expected a starting date in late fall but have been frustrated by delays in obtaining permission to access areas. The rationale for concentrating on seven sites rested with the inability of the laboratory to handle a larger station load.

Equipment

Each station will consist of a control structure, stilling well, stage recorder, sequential sampler and protective enclosure. See Appendix B Table 3 for more details.

During rain events stage will be recorded and the sequential sampler

Appendix B Table 1. Sites selected for the special land use studies

Land Use	Location
	Transportation
Airport	Timmerman Airport at W. Appleton Ave, Milwaukee
Railroad	Milwaukee Road switching and maintenance yard at W. Canal, Milwaukee
Freeway, right-of-way	Segment of Stadium Freeway (USH 41) between W. State St. and W. Washington Blvd., Milwaukee
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	Elm Grove at Wrayburn Rd., Elm Grove
Developing	Noyes Creek at 91st St., Milwaukee
	Recreational
Golf course	Currie Park Golf Course at N. Mayfair, Wauwatosa
Park	Greenfield Park at S. 124th, West Allis
	Land Disposal
Landfill	Germantown Sanitary Landfill at County Line Rd., Menomonee Falls
	Wetland
Swamp	Germantown swamp

Appendix B Table 2. Some characteristics of selected areas and status of obtaining permits to install sampling equipment and control structures

Land Use	Location	Estimated area (ha*)	Imperviousness (%)	Estimated Peak discharge** (cms***)	Control structure required	Permit status
Airport	Timmerman Airport at W. Appleton, Milwaukee	134	15	3.3980	Palmer-Bowlus(P-B) flume	Permit issued
Freeway, interchange	Stadium Interchange (I-94--USH 41) near Milwaukee County Stadium, Milwaukee****	79	51	8.3535	P-B flume	Permit issued
Commercial, shopping center	Brookfield Square Shopping Center at N. Moorland, Brookfield****	58	42	2.6901	P-B flume	Negotiation nearing completion
Industrial, heavy	Allis-Chalmers at S. 70th St., West Allis	43	92	6.7394	H-flume	Permit issued
Residential, high density	Schoonmaker Creek at W. Milwaukee Ave., Wauwatosa	201	75	19.4254	Bubble gage	Permit issued
Residential, low density	Elm Grove at Wrayburn Rd., Elm Grove	39	23	1.9822	H-flume	Negotiation nearing completion
Residential, developing	Noyes Creek at N. 91st St., Milwaukee	543	30	12.6576	Bubble gage	Permit issued
Landfill	Germantown Sanitary Landfill at County Line Rd., Menomonee Falls	28	0	2.6335	H-flume	Negotiation nearing completion

* 1 ha = 2.471 acre.
** Assume 4" rainfall for 10-year 24-hr rainfall (estimation based on: SCS-USDA. 1975. Urban hydrology for small watersheds. Tech. Release No. 55).
*** 1 cms (m^3/sec) = 35.31467 cfs.
**** See Appendix B, page 24 for air photographs.

Appendix B Fig. 1. Brookfield Square Shopping Center - looking south, drainage to the north.

Appendix B Fig. 2. Stadium Interchange - looking south, drainage to the east.

Appendix B Table 3. Station Equipment

Control Structure:	H-flume for open channel conditions - Palmer-Bowlus for stormsewer pipes
Stilling Well:	Corrugated drain pipe
Stage Recorder:	Leupold and Steven digital tape stage recorder with event marker
Sequential Sampler:	ISCO 1680 sampler with extended timer for drawing larger sample volumes
Protective Enclosure:	Precast cement sewer pipes approximately 3' x 3 ' with a locked steel top. Pipes can be added to increase the height.

will be actuated by a liquid level switch. This switch starts and stops the sampler when the stream reaches a predetermined level. Stage recording and sampling times will be determined by the hydrology of the area. Sampling will not be proportional to flow due to the large variations in flows and heads that will be experienced at the sampling sites.

Laboratory analysis will be handled by the Wisconsin State Laboratory of Hygiene for Groups A, B and D parameters and the USGS for Groups E and F. For Group C inorganic and organic, a special laboratory will be established at the University of Wisconsin-Madison. Negotiations are presently underway for laboratory space and we expect to have an analytical chemist on the staff by November 1, 1975.

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. 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 encompasses land use, soil type and civil division information but does not include water quality or streamflow data.

Uses of the Land DMS

The Land DMS has two principal uses under 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 special 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 so as to be consistent with the recommendations of the Ad Hoc Data Handling and Processing Work Group of the Task C Technical Committee.

Data Storage Unit: The Cell

The basic areal unit for storing, retrieving, analyzing and displaying land data is the cell. The Menomonee River watershed was subdivided into about 35,000 cells by partitioning U.S. Public Land Survey system quarter sections. Each of the four sides of each quarter section was equally divided into eight parts and the grid marks on opposite sides of the quarter section were connected resulting in 64 cells per quarter section each having a nominal area of 1.0 hectare (2.5 acres). The use of cells

that are partitions of quarter sections has one principal advantage: It facilitates the geo-referencing of each cell since horizontal survey control has been established for a large number of quarter-section corners in the watershed using field survey methods and control is directly transferrable, by computation, to the centers and corners of each cell.

Geo-referencing

An accurate geo-referencing procedure is required to permit computation of the area of each cell or of groups of cells and to facilitate display in map form, of selected land data. The corners of each cell were accordingly referenced to the State Plane Coordinate System. Plane geometry was then used to calculate, within the Land DMS, the State Plane Coordinates of each corner and of the center of each cell. The Land DMS can also readily convert the cell corner coordinates to latitude and longitude and software is being developed to convert the coordinates to the Universal Transverse Mercator System.

The Supporting Computer System

The digital computer system--hardware and software--needed to support the Land DMS can be 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, analyze the data and transfer it--on request--back to the user. The analysis capability of the data management phase utilizes an overlay technique to identify cells having specified combinations of land data types. The third or data phase of the Land DMS is the actual storage of the areal characteristics of each cell in a computer file, maintained on magnetic tape or on a magnetic disc. The fourth or output phase, provides transfer of land data from the Land DMS to the user in a variety of tabular and graphic formats. For example, land data can be ouput on a cell

basis or aggregated by subwatershed or some other geographic area of interest. System output can be obtained on several media including magnetic tape, punched cards, on-line printer, and plotter.

Land Data Contained in the Land DMS

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

Appendix C Table 1. Land data in the land data management system

Data Type	Status			Type of Coding		
	Completed	In Progress	Planned	Dominant Characteristic	Percent of Cell	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, Floodland and Related Zoning	x			x		
9. Soils		x			x	
10. Ground Elevation			x			x
11. Land Use			x		x	

APPENDIX D

ATMOSPHERIC MONITORING

Objectives

As part of the overall Menomonee River watershed study, an air sampling network will be set up within the boundaries of the watershed. Objectives of the research are listed below:

1. The primary objective is to determine the relative contributions of different land uses to the total weight and chemical composition of the aerosols measured over the watershed.
   a. To characterize "background" aerosols, i.e., the particulate matter not injected from sources within the watershed.
   b. Identify sources of aerosols, i.e., land uses or point sources.
2. To attempt to quantify the mass of aerosols entering the watershed from rain and dry deposition.
   a. To correlate frequency and duration of rainfall with total and elemental concentration of aerosols.
3. To determine size distribution of total particulate and individual elements as a function of relative humidity.
4. To study collection efficiencies of water surfaces, snow surfaces, leaves, etc.

Sampling and Analysis

Seven high-volume air samplers along with modified (Wong) rain samplers will be set up on river monitoring stations 673001, 683002, 683001, 463001, 413011, 413007 and 413005. An additional rain sampler will be built at Greenfield High School, Greenfield. Meteorological data will be obtained from stations in the area operated by the Air Pollution Control Section of the Wisconsin Department of Natural Resources. Data from on-site rain gauges will also be used.

In addition to total suspended particulates, two cascade impactors will be used periodically to size-fractionate the collected aerosols. Analysis of about 25 elements will be done by neutron activation, flameless atomic absorption, and flame atomic absorption on all air and rain samples.

Rain samples will be freeze-dried prior to neutron activation analysis (N.A.A.). The Whatman 41 cellulose filter paper from the high-volume air samplers will be cut to size and along with the nucleopore filter paper from the impactors will be directly analyzed by N.A.A. Prior to flameless atomic absorption analysis, the remaining cellulose filter will be dissolved in acid. In the case of the nucleopore filter only one of the analyses can be performed. If flameless atomic absorption is chosen for the nucleopore filter the filter is dissolved in chloroform.

Progress to Date

Presently the seven air samplers are being calibrated in Madison. The next step will be to make test runs to compare collection efficiencies between them, due to motor differences and filter paper variations. Some equipment on order has still not arrived (Wong rain samplers, flameless A.A. system, and silicon controlled rectifiers for voltage reduction on the high volumes). The target date for initial sampling in the watershed is January 5, 1976.

APPENDIX E

REMOTE SENSING

The intent of this project is to develop techniques for mapping land use and hydrologically active source areas in a watershed from small-scale color-IR imagery. The technique involves measuring the film density on the image for the area of interest and with the aid of a computer, interpret and map the area. The tasks of density measurements on the film and ground checking of the results are being accomplished at the University of Wisconsin-Madison, while the computer interpretation and mapping are being done at The Pennsylvania State University.

The imagery used by this project will be high altitude color-IR imagery flown by the National Aeronautics and Space Administration (NASA) (scale 1:120,000) and low altitude 70 mm imagery acquired with the aid of the Wisconsin Department of Natural Resources (WDNR) DC-3 (scale 1:72,000). Densities on selected portions of the imagery will be measured with an Optronics P-1000 scanning microdensitometer. This instrument can measure the density every 25, 50 or 100 microns in the areas of interest on the film imagery. The imagery will be scanned through three different colored intereference filters in order to perform a color separation of the photographic imagery. The best choice of filters to perform this color separation is under investigation. The output from the scanning densitometer is a nine-track computer tape on which is written the film densities at each point in the area of interest. The film densities on the computer tape must be transformed before the data is used in the computer interpretation programs. This transformation depends on the properties of the microdensitometer,properties of the three dyes in the film, and radiometric calibration of the roll of imagery of interest. Once this transformation has been determined, a computer tape of the transformed film densities will be generated and sent to The Pennsylvania State University for processing through the data processing system of the Office for Remote Sensing of Earth Resources.

This system is couched in a multivariate framework. Each observation, identifiable by scan line and element number consists of a vector composed of three response values (one each for the response in the blue, green and

red portions of the electromagnetic spectrum). Spectral signatures will be determined for selected training areas. A variety of classification programs will then be used to classify the data into discrete land cover classes.

It will be possible at this time to determine if there are any problems with data registry. The photography has to be scanned three successive times and it is essential that each scan exactly overlays the previous scan. Computer techniques will probably have to be developed to align and register the data.

The output from the computer processing will result in the form of digital maps showing the spatial distribution of various land cover types. Most of these maps will be in black and white grey scale. Combinations of grey scaling and four colored ribbons may also be used to produce a colored output map.

Several other output modes will also be used. One of these modes would be to output the land cover types using the CalComp plotter. Another method will be to display the results on a color monitor and to photograph this color display.

The various types of output will be compared to the land use mapping that was done by the Southeastern Wisconsin Regional Planning Commission.

It is anticipated that this automatic processing of digitized photography should greatly speed up the land cover interpretation process. Statistical summaries of areal extent of each land cover category can be obtained within any given area. This data should be useful input to the hydrological modeling efforts.

APPENDIX F

PROPOSAL OF MODELING OUTPUT OBJECTIVES

For greatest effectiveness, water-quality modeling must respond to the overall project objectives within the confines of relevant model outputs. Many previous water-quality models have focused on dissolved oxygen as a sole parameter. Perhaps the first significant precedent for a DO model occurred with the 1966-70 Delaware Estuary Water Quality Modeling Project. Although this model included five physical, six mineral, four nitrogen, three oxygen, three bacteriological, five metal and four miscellaneous parameters, predictive use of the time-varying model was focused almost entirely on DO, and on salinity which was considered to be a conservative substance. The continuing narrowing of focus doubtless arose from such statements as:

> "The system developed during the research being reported here is based on the assumption (underlinings added) that there exists a single measurable attribute that is indicative of the river water quality. It is also assumed that there is a minimum (or maximum) value of this attribute beyond which it is undesirable to go. Further, it is assumed that there is a causative relationship between the amount of materials being introduced into the river and the downstream water quality ..." "... therefore, the river presents a reaction system having BOD as its major input and DO as a measure of output. (A River as a Chemical Reactor. Penobscot Tidal Estuary Study, E. G. Bobalek, University of Maine, 1971.)

Taken far beyond its limited context of presentation, BOD/DO fixation--as an end rather than a means--has largely turned concern away from eutrophication-inducing nutrients, bacterial and viral hazards, toxic metals, organic toxicants and sediment as threats to environmental quality and the general public health. Certainly, there is increasing need to re-focus on basic objectives of the environmental clean-up effort (see especially The Uncertain Search for Environmental Quality, Ackerman et al., The Free Press, New York, N.Y.

Lake Michigan has a long retention time and can be described as a "sink" situation in the classical sense. Thus, DO content delivered by the Menomonee River is of small consequence in comparison to the off-shore

processes within the lake. Nutrient content, BOD, fecal and other coliforms, metals, organic compounds and sediments should be of primary concern. Nonetheless, attention to the modeling of DO/BOD constitutes the first step toward the modeling of the other parameters and should serve to check flow rates and as an important guide in determining the reactions of non-conservative substances. The determination will involve extensive literature search and application of University of Wisconsin-Madison technical expertise developed in the International Biological Program supported simulation studies on Lake Wingra. Sediment quantity and size distribution is an important pollutional input not only in its own right, but because it acts largely as a reservoir of potential toxicants. Nutrient inputs--not only nitrogen and phosphorus, but carbon, silica and some trace elements--are important in determining the extent of algae and macrophyte activity and the degree of eutrophication, which doubtless influence the reactions of non-conservative substances. A brief catalogue of parameters for which modeling is important (the order of listing denotes suggested order of priority) is presented (Appendix F Lists 1 and 2).

The Development of Data Input via STSAM

The development of a Statistical and Time-Series Analysis Model is of first importance to the application of the collective expertise of project personnel.

Efforts are impending to analyze long-term precipitation and runoff records for the project vicinity using power-spectra analysis. Median values (and other appropriate confidence levels) will be plotted within the identified cycle periods. Scrutiny of this information allows definition of hydrologic seasons within the study area; model input and output could then be expressed over periods of truest physical significance.

Looking toward good model output, we must examine a basic assumption, namely, is land use an effective descriptor of vegetation and surface imperviousness, occurrence probability of particular parameters, and population/urbanization characteristics, such that runoff water-quality conforms to particular land uses. While land use does provide a good

Appendix F List 1. High-priority parameters

Polychlorinated Biphenyls (PBCs)

*Radium 226/Alpha Radioactivity

Lead

*Barium

Surface Contaminants

Asbestos

Silica

Phthalates

DDT/DDD

Oil and Grease

Streptococci Coliform

Copper and Zinc

Manganese and Iron

Aluminum

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*Suggested additions to Task C "core" parameter list

Appendix F List 2. Moderate-priority parameters

Arsenic

Selenium

*Titanium

*Zirconium

Nickel

Chromium

Vanadium

Chloride

Cadmium

Mercury

Phenolics (and Chlorophenols)

Heptachlor/Heptachlor Epoxide

*Polynuclear Aromatic Hydrocarbons

*Strontium

Molybdenum/Beryllium

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*Suggested additions to Task C "core" parameter list

beginning for categorization, the need to minimize statistical deviations will probably dictate that, to the extent feasible, the classification should be expanded in three particular areas, namely, agricultural, residential, and manufacturing areas.

Specific information on farm-type and class of crop within the "cell" will be determined to better describe vegetation and water quality parameters. Similarly, zoning classifications from planning sources might quantify better the extents of surface imperviousness and population/urbanization characteristics and also capture some "essence" of the consequent dependence of land use on vegetation and fallout-derived parameters. Hydrologically, it is probably acceptable to categorically-unify single and two-family homes. However, it would also be important to divide the aggregate into perhaps four classifications by plot acreage, as well as to distinguish between low and high-density multi-family units (e.g., garden-apartments vs. high-rises). Furthermore, either planning agency information or an industrial agency's input would allow manufacturing breakdown by Standard Industrial Classification (S.I.C) and further categorization as appropriate to species of pollutants. Thusly, there would be limitation to the enormous heterogeneity of surface imperviousness and occurrence probability of particular pollutants inherent to a single class, e.g., manufacturing. Such category subdivision, where needed, would likely save the Menomonee River Pilot Watershed Study from having to echo the lament of a 1970 San Jacinto River Basin report:

"The results from models were rejected because of the general incompleteness of the predictor data and because the available predictor data were not directly related to water quality..."

<u>A Model Relating Water Quality, Vegetational Structure and Urbanization in the San Jacinto River Basin.</u> Jameson, D. L. Houston Univ., Texas.

Such land-use derived category expansion might require extensive expansion of the special study sites for calibration purposes (Appendix F List 3). The modest site preparation and grab sampling called for would allow the establishment of "a matrix model of the relationship between predictors and water quality," which parallels the San Jacinto Basin Study and which represents elaboration upon the 'location j' dimension of the 'data matrix for monitoring work units' (Fig. 20 of the 1st IJC semi-annual report). The difficulties

Appendix F List 3. Land use category expansions

For purposes of the MRWS Pilot Study it is likely that expansion of the Land Use Categories defined by SEWRPC need expansion into some or all of the sub-categories listed below:

Single Family Residential might be expanded to:

1. One/two family residential - 1/4 acre or less
2. " " " " - 1/2 acre or less
3. " " " " - up to 2 acres
4. " " " " - 2 acres or more
5. Mobile homes

Multi-Family Residential might be expanded to:

6. Multi-family - high rise
7. Multi-family - low rise
8. Residential Under Development, as is
9. Retail and Services (local plus regional), as is

Wholesale and Storage might be expanded to:

10. Wholesale and storage - open
11. " " " - enclosed

Manufacturing and Extracting might be expanded to:

12. Manufacturing - Food and kindred products - general
13. " - " " " " - dairy
14. " - " " " " - beer
15. " - " " " " - meat
16. " - Textile Mill Products
17. " - Paper and allied products - general
18. " - " " " " - de-inked pulp
19. " - Printing and publishing - general
20. " - " " " - newspaper
21. " - Chemicals and allied products - general
22. " - " " " " - organic specialists
23. " - " " " " - non-organic specialists
24. " - " " " " - pharmaceuticals

25. Manufacturing - Energy materials - general
26. " - " " - petroleum products
27. " - " " - coal products
28. " - " " - nuclear isotope products
29. " - Rubber and plastic products - general
30. " - " " " " - rubber
31. " - " " " " - plastics
32. " - Leather and leather products
33. " - Primary metal industry
34. " - Fabricated metal industry
35. " - Machinery except electrical
36. " - Electrical machinery
37. " - Transportation equipment
38. " - Miscellaneous manufacturing
39. Extractive - Quarries - active
40. " - " - inactive
41. " - Mines

Transportation, Communication and Utility Facilities might be expanded to:

42. Transportation, Comm., etc. - Rail, bus and ship terminal
43. " " " - Railroad right-of-way
44. " " " - Railroad yards
45. " " " - Airports (terminal and field)
46. " " " - Local and collector streets right-of-way
47. " " " - Arterial streets & hwy right-of-way
48. " " " - Freeway & expressway right-of-way
49. " " " - Truck terminals
50. " " " - Off-street parking
51. " " " - Communication and utility facilities

Governmental and Institutional might be expanded to:

52. Institutional (local and regional)
53. Government (local and regional)

Park and Recreation might be expanded to:

54. Public recreation area (local and regional) - open
55. " " " " " " - enclosed
56. Private and other recreation areas - natural intensive use
57. " " " " " - artificial intensive care

Croplands and Rotation Pasture might be expanded to:

58. Croplands - general
59. " - grains (including oats)
60. " - truck farm (i.e., vegetables)
61. " - corn
62. " - alfalfa and hay
63. Pasture - general
64. " - dairy
65. Barnyard

Orchards and Nurseries might be expanded to:

66. Orchards - general
67. " - stone fruits (e.g., cherries, plums, prunes, almonds,peaches)
68. " - seed fruits (e.g., apples and pears)
69. Nurseries - quantity
70. " - specialty

Fowl and Fur Farms might be expanded to:

71. Fowl (i.e., poultry)
72. Fur

73. Lakes, Rivers, Swamps and Canals, as is
74. Swamps, Marshes and Wetlands, as is
75. Unused Lands, as is
76. Land Fill and Dumps, as is
77. Woodlands, as is

Categories for application elsewhere in Great Lakes Basin as necessary:

15a. Tobacco manufacturers
16a. Apparel and related products
16b. Lumber and wood products
16c. Furniture and fixtures
32a. Stone, clay and glass products
37a. Instruments and related products
68a. Vineyards

An evaluation of the relative importance of the sub-categories is presently being undertaken to allow the project to be conducted within manageable limits.

introduced by additional sampling are not to be ignored, but neither can the experiential record of past modeling disasters. Careful choice of sampling sites, field techniques, simplifications derived from hydrologic season awareness and correlation data for the more sophisticated continuous monitoring sites could provide the matrix which could markedly assist in the solution of the modeling objectives (Appendix F Tables 1 and 2).

Overland Flow Element

Literature Review of Modeling Techniques for Overland and River Transport Systems

Modeling techniques and mathematical models applicable to the land use-water quality model have been reviewed and evaluated for possible use. The following areas of the land use-water quality transformation have been covered:

- Rainfall - Runoff Relationship
  - Rational formula
  - Unit hydrograph - linear systems
  - Variable unit hydrograph - nonlinear systems
  - Kinematic wave models
- Flow Routing Methods
  - Numerical solutions of St. Venants equations
  - Muskingum method
  - Hydrograph method
- Infiltration and Groundwater Storage
  - Exponential decrease of infiltration
  - Soil moisture dependence models
- Interception and Depression Storages
- Evaporation and Evapotranspiration
- Snow Melt and Snow Storage
- Erosion and Sediment Transport
  - Universal soil loss equation (USLE)
  - Transport of cohesive sediments
  - Sediment saturated flow
  - Deposition and scour of cohesive sediments

Predictor (Land Use) / Water-Quality Study Site Sub-Basins	NBMR 4,5	NBMR 1-6	UMR 8-10	UMR 8-11	UMR 12,13	WBMR 1-3	WBMR 4-7	WBMR 9	WBMR 1-8	WBMR 1-10	WC 1-4	WC 5,6	WC 1-8	NXWC 1-5	NXWC 6	NXWC 8,9	NXWC 1-10	NXWC 1-11	UMR 31	LC 7	LC 1-6	LC 1-11	UMR 36-40	BD 1-3,8	BD 4-7	BD 1-9	BD 10,11	BD 1-14	LTMR 6	LMC 1-7	LTMR 12,13	LTMR 14	LTMR 24	LTMR 23-26	LTMR 1-29; LMC 1-7	LMR 7,8	LMR 9	LMR 7-10	LMR 15
No	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39
Single-Family Residential		●	●	●	●	●	●		●	●	●	●	●	●	●		●	●	●	●	●	●	●	●	●	●	●	●	●	●	●		●	●	●	●	●	●	●
Multi-Family Residential																		●	●														●	●	●		●	●	●
Residential Under Development			●	●	●	●			●	●	●	●	●	●	●	●	●	●	●		●	●		●	●	●	●	●			●	●		●	●				
Retail and Services														●			●	●			●	●	●	●		●		●						●	●				
Wholesale and Storage									●	●							●	●					●											●	●				
Manufacturing and Extracting						●						●	●								●	●	●			●	●	●		●				●	●				
Transp., Communication + Util. Fac.						●	●		●	●			●	●		●	●	●					●										●	●	●	●		●	●
Government and Institutional			●	●																					●	●	●	●		●			●	●	●	●	●	●	●
Park and Recreation											●		●										●											●	●	●		●	●
Croplands and Rotation Pasture	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●		●	●				
Orchards and Nurseries								●		●		●	●	●			●	●												●		●			●				
Fowl and Fur Farms																																			●				
Lakes, Rivers, Swamps + Canals														●			●	●					●	●	●	●		●							●				
Swamps, Marshes + Wetlands			●	●		●	●	●	●	●	●	●	●	●	●		●	●					●	●	●	●	●	●		●	●				●				
Unused Land		●	●	●							●		●						●		●	●	●	●		●	●	●		●	●		●	●	●	●		●	
Landfill and Dumps																							●												●				
Woodlands	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●		●	●	●	●	●	●	●	●		●		●		●	●	●			●				

Appendix F Table 1. Preliminary predictor/land use vs. water quality calibration matrix - up-stream section (Final matrix envisaged to incorporate land use category expansions and to enter number of cells).

Predictor (Land Use) / Water-Quality Study Site Sub-Basins	SBUC 1	SBUC 2	SBUC 1-3	SBUC 4,5	SBUC 6	SBUC 4-7	SBUC 9	SBUC 13	SBUC 1-14	DD 1-9	UC 1,2	UC 1-4, DD 1-9	UC 5,6	UC 10	UC 1-11, DD 1-9	UC 13	UC 16	UC 1-19, DD 1-9	HC 5	HC 1-4	HC 7	HC 1-6,8	HC 16	HC 1-18	LMR 21	LMR 28	LMR 27	LMR 27-29	LMR 33	LMR 34-37
No.	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69
Single-Family Residential	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●		●
Multi-Family Residential					●	●			●			●		●	●	●	●	●	●	●	●	●		●						
Residential Under Development	●		●			●		●	●	●	●	●	●	●	●		●	●	●	●	●	●	●	●	●				●	●
Retail and Services										●		●			●		●	●				●		●		●		●	●	●
Wholesale and Storage									●									●						●		●		●		●
Manufacturing and Extracting				●		●			●						●			●						●		●		●		●
Transp., Communication + Util. Fac.	●		●	●		●	●	●	●	●		●		●	●		●	●	●	●	●	●	●	●		●	●	●	●	●
Government and Institutional	●		●		●	●			●	●	●	●	●		●		●	●	●	●	●	●		●		●	●	●	●	●
Park and Recreation				●		●		●	●	●		●			●	●		●		●	●	●	●	●						●
Croplands and Rotation Pasture	●	●	●			●			●	●	●	●	●	●	●			●		●		●		●						
Orchards and Nurseries														●	●			●												
Fowl and Fur Farms																														
Lakes, Rivers, Swamps + Canals																		●												
Swamps, Marshes + Wetlands							●		●	●	●	●	●		●			●	●	●		●		●						
Unused Land				●		●			●	●	●	●	●		●		●	●	●	●		●		●						
Landfill and Dumps					●	●			●							●	●	●		●		●		●						
Woodlands				●	●	●	●		●	●	●	●	●	●	●			●	●	●		●		●						

Appendix F Table 2. Preliminary predictor/land use vs. water-quality calibration matrix - downstream section (Final matrix envisioned to incorporate land use category expansions and to enter number of cells).

Soil Adsorption

Solubility of soil phosphate compounds

Phosphate adsorption process and isotherms

Soil water adsorption models

Over 100 references have been reviewed. A special review report covering hydrological problems of transport has been prepared. Similar reports on erosion and sediment transport, and on soil adsorption processes will be issued in the near future.

Testing of Existing Models

A computer model "STORM" has been acquired and preliminary testing of the model has been performed on three small subwatersheds.

1. Schoonmaker Creek - a mostly single family residential area in the southeastern part of the Menomonee River watershed.
2. Noyes Creek - a mixed open (park) and residential subwatershed in the Little Menomonee River watershed.
3. Donges Bay Road in the most northern part of the watershed draining farm and agricultural areas.

The model computes the runoff in hourly intervals by a method similar to the Rational Formula and erosion using USLE. Other quality parameters are related to the sediment content. The model is adequate for very rough estimations of sediment originating from dust and dirt accumulation in urban areas. The results using the erosion portions are unsatisfactory.

The Hydrocomp Simulation Watershed Model, based on the Stanford Watershed Model is now being tested by the Southeastern Wisconsin Regional Planning Commission. Several other models have been reviewed but rejected as not meeting the objectives of the IJC - land use-water quality modeling task.

Model Development

Presently, subroutines of the proposed overland flow and quality model are being developed and combined together under a working name "LANDRUN". The model which has been formally debugged contains the following sections:

a. rain editing, snow melt and snow pack computation
b. depression and interception storage
c. infiltration
d. excess rainfall - surface runoff transformation
e. erosion by the USLE
f. dust and dirt accumulation
g. sediment transport and deposition during the overland flow

The model is now being tested and delineated.

In addition, conceptual models of soil adsorption applicable to agricultural chemicals, nutrients, pesticides and other pollutants transported in the soil, are being prepared and will be added to the prepared model.

Parameters of the Land Use

Hydrological Model

Water is the primary carrier of pollution in a watershed. Thus, the knowledge of the hydrology of the watershed, rainfall runoff transformation, turbulence and residence times in channels, are the primary parameters to be estimated by the models.

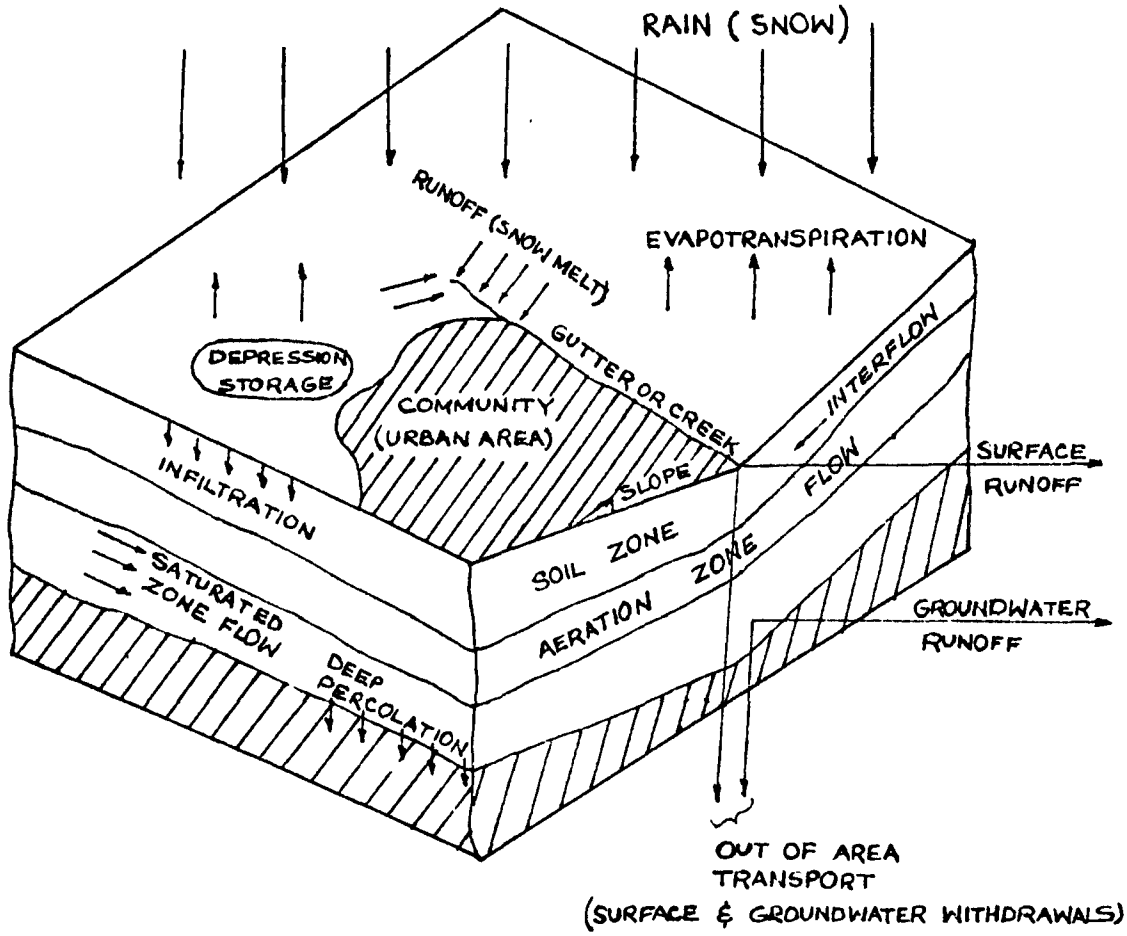
Overland Flow Model Hydrology

A schematic picture of a watershed hydrology model is shown in Appendix F Fig. 1. This schematic can be translated into a complex computer model such as the Stanford Watershed Model (Crawford, Linsley - 1966). The flow chart of the proposed hydrologic model for the Menomonee River sub-drainage areas is shown in Appendix F Fig. 2.

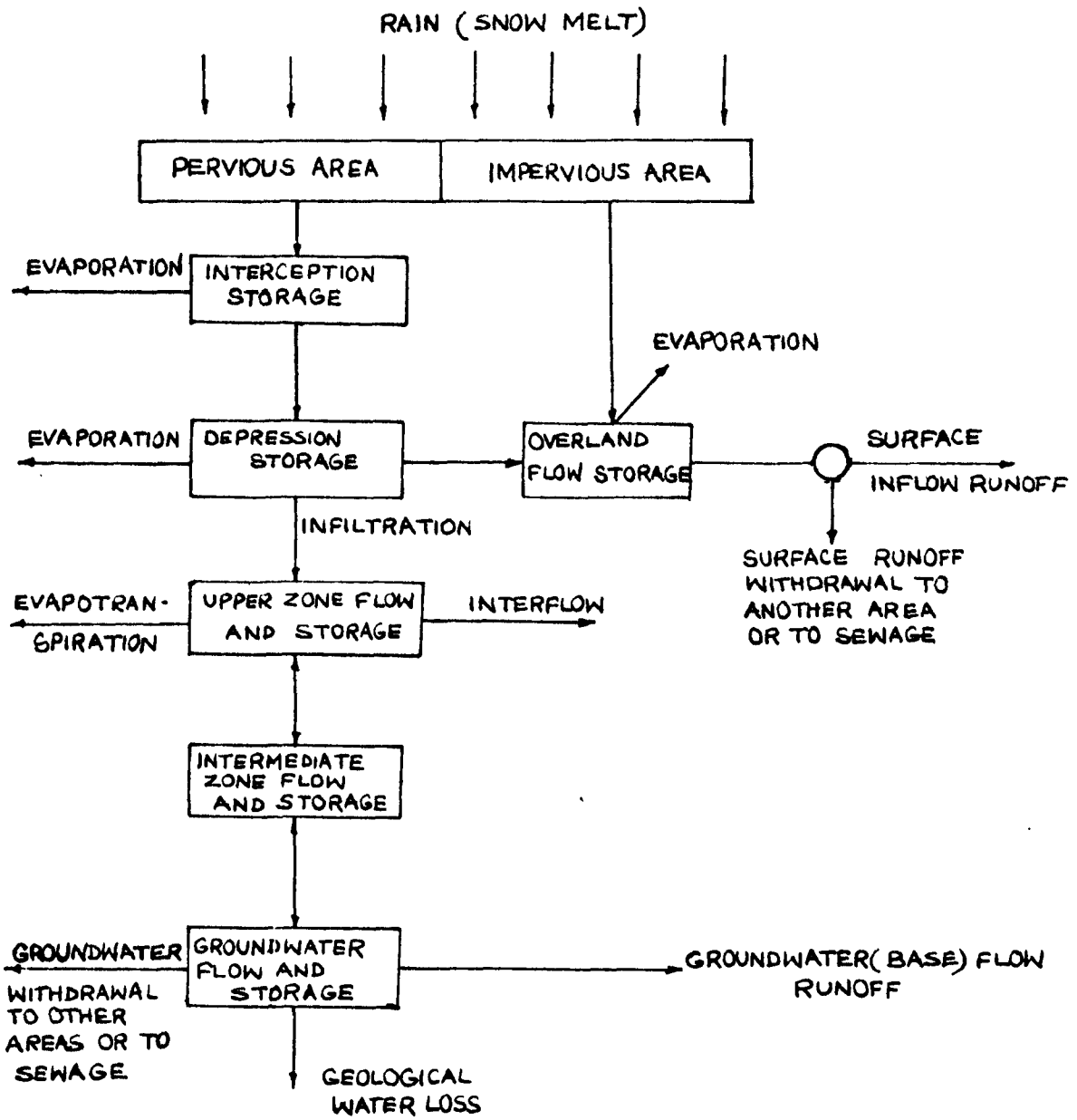
Hydrologic Parameters of the Overland Flow Model

The necessary parameters for the model are:

Major Inputs: a. rain intensity mm/hr (in hourly or shorter intervals)



Appendix F Fig. 1. Overland flow model.



Appendix F Fig. 2. Schematic diagram of the overland flow model.

b. temperature °C

c. potential evaporation (daily) mm/day

System Parameters:

a. drainage area - hectares

b. percent imperviousness

c. land use categories

d. roughness of the surface (as Manning's n) for each category

e. curb density m/hectare for urban areas land use categories

f. depression and interception storage for each land use category (mm)

g. surface elevation

h. slope and flow length

Soil Data:

a. hydrologic soil group

b. porosity

c. minimum soil moisture

d. percolation rate

e. depth to water table

f. particle size distribution (% clay, silt and sand)

g. specific gravity of soil particles

Groundwater Data:

a. elevation of the aquifer base and surface

b. hydraulic conductivity

c. porosity

Demographic Data:

a. population density for each land use

Hydraulic Parameters: The River Flow Model

Channel Data:

a. identification of the reaches

b. length (meters) of the reaches

c. bottom elevation of the upper and lower end

d. coefficients for velocity - flow relationship
e. coefficients for stage - flow relationship
f. bottom roughness (Manning's h)

Quality Components of the Model

A preliminary schematic picture of the quality subroutines is presented in Appendix F Fig. 3.

Pollutant Cumulation and Washout in Urban Areas

The pollutant cumulation in urban areas is a function of the land use characteristics and can also be related to air pollution and wind erosion characteristics of the area. In the simplest form, the pollutants cumulation rate can be expressed as

$$\frac{\text{pollutant cumulation}}{\text{time}} = f\ (\text{land use; dust fall})$$

which can be directly inputed or incorporated as a default value in the model. More sophisticated models will use wind speed as a factor affecting the pollutants cumulation rate.

The washout function will utilize the first order decay function in the form

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

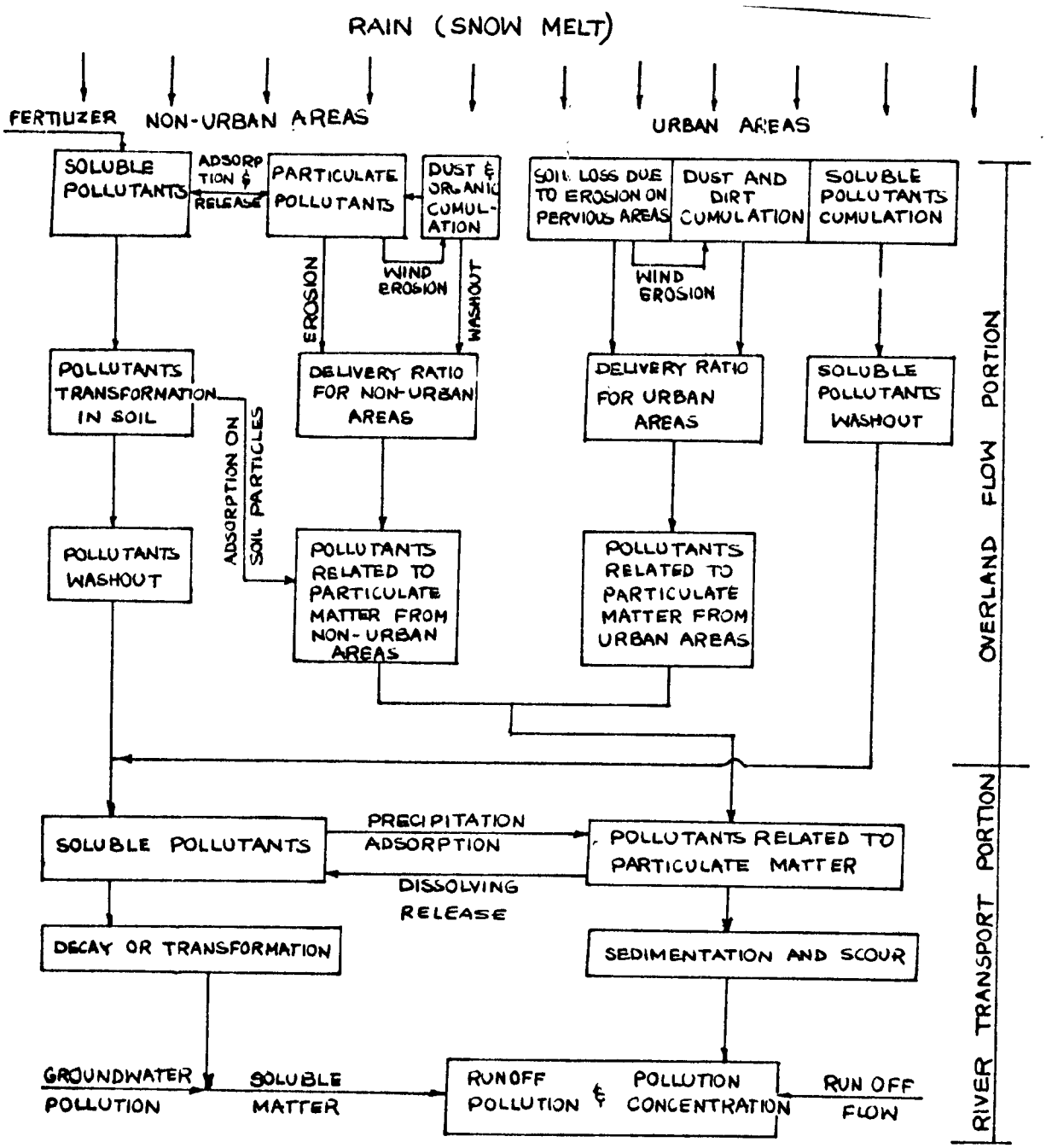
where ΔP = amount of pollutants washed into the runoff during the time period t

P_o = amount of pollutants present on the surface before the beginning of the rain

K_p = a coefficient depending on the rain intensity

Model Parameters

a. Rates of pollutant cumulation in urban areas for each pollutant to be modeled.
b. Coefficient K_p for particulate pollutants.



Appendix F Fig. 3. Schematic diagram of the quality subroutines.

Soil Loss Model

The available modeling techniques for soil loss (erosion) estimation and particulate matter channel routing will be discussed in a separate report.

The estimation of soil loss by erosion will be accomplished by the Universal Soil Loss Equation. The parameters necessary for the soil loss estimation are (in addition to those necessary for the hydrological model):

a. soil erodibility factor
b. cropping management factor
c. erosion control practice factor.

The above parameters are necessary for all soils subject to erosion in the sub-basins.

To estimate the impact of the soil particles on rivers, the information must include:

d. soil delivery ratio.

An attempt will be made to estimate the soil delivery ratios by the model.

Sediment Transport in Streams

The model has not, as yet, been formulated. The following information is deemed necessary for the model in addition to the parameters discussed previously:

a. settling velocity of sediments (can be computed from particle sizes and specific gravity)
b. parameters for the estimation of equilibrium concentration (i.e., concentration of the sediments at which scour ≈ deposition)
c. plasticity limit and liquid limit of sediments.

Nutrient Model in Overland Flow - Phosphorus Model

The phosphorus model will be based on the adsorption kinetic model given as:

Dissolved Phase

$$\frac{\partial C}{\partial t} = D_L \frac{\partial^2 C}{\partial X^2} - v \frac{\partial C}{\partial X} - \rho \frac{\partial S}{\partial t} - \Sigma N$$

Sorbed Phase

$$\frac{\partial S}{\partial t} = K (S_e - S)$$

and

$$S_e = \frac{bQ^oC}{1+bC}$$

where C ... phosphorus concentration in the soil water phase

S ... phosphorus sorbed on soil particles

S_e .. saturated equilibrium of sorbed phosphorus

D_L .. diffusion coefficient

v ... convective downward velocity of infiltration

K ... kinematic coefficient of adsorption

ΣN .. sinks and sources of phosphorus (plant uptake and release and organic phosphorus transformation)

b ... partition coefficient

Q^o .. maximal sorptivity of phosphorus for soil

ρ ... soil density

t ... time

x ... coordinate of flow

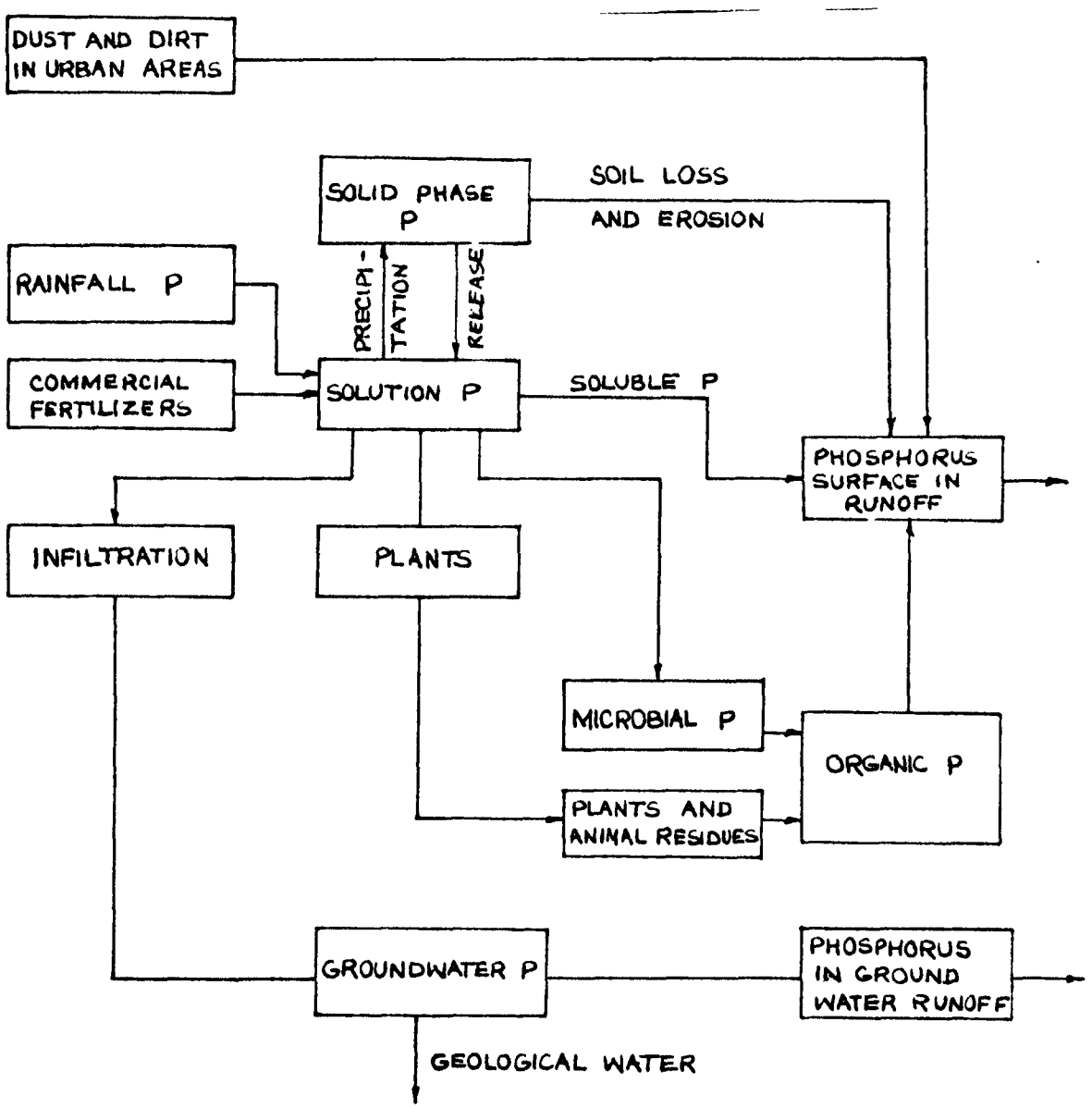
The preliminary structure of the model is shown in Appendix F Fig. 4.

Inputs to the Model

a. phosphorus content of dust and dirt
b. phosphorus content of atmospheric precipitation
c. fertilizers application
d. other phosphorus inputs

Model Parameters

a. soil pH
b. clay and organic carbon content
c. phosphorus loss and release by plants



Appendix F Fig. 4. Phosphorus model in the overland flow model.

d. phosphorus adsorption isotherm and kinetic parameters
e. aluminum and iron content

Phosphorus Movement in Streams

Similarly to soil phosphorus, phosphorus in the aquatic environment is either bound to suspended particles or dissolved. Thus, a similar adsorption sorbed phase-free phase equilibrium model may be formulated. The dissolved phosphorus is in equilibrium with that adsorbed on suspended particles or on the bottom deposits. The release of phosphorus from the bottom deposits is a diffusion process taking place in the bottom boundary layer. The final form of the model has not, as yet, been formulated.

Nitrogen Model - Soil Nitrogen

Soil nitrogen model will consist of the following components:
Nitrogen fixation by soil bacteria
Ammonia adsorption on soil particles
Nitrification
Denitrification
Deamination
Nitrogen uptake of plants
In its final form the model will be based on the simultaneous solution of differential equations describing the above processes in the soil profile.

Pesticides and Heavy Metals Transport

Modelling of the above components will be discussed in a separate report following evaluation of the literature survey.

Determination of the Relation of Surface Runoff Concentrations to Land Use and Meteorological Conditions

The purpose of this project is to develop an empirical means of relating the quality of surface runoff to land use and meteorological conditions

rather than directly to the ultimate nonpoint sources of atmospheric fallout, precipitation, land and road management practices and natural weathering. The direct relation approach requires extensive monitoring of these nonpoint sources. Although these data are being collected in the Menomonee River Pilot Watershed Project, they are relatively rare elsewhere. Thus, it is worthwhile to investigate other means of predicting surface runoff quality.

The method being developed involves analysis of the mass loadings of flow during runoff events from small drainage areas where point sources are minimal. The total mass loadings represent integrations of the inputs from all the nonpoint sources contributing to the area plus the baseflow. Separation of baseflow and baseflow loadings from the event hydrograph and mass loading curves, respectively, leaves the discharge and mass loading of the surface runoff itself. The concentration of a particular constituent in the surface runoff (C_R) is then simply the mass load of that constituent divided by the discharge at the same instant during the event. A dimensionless relative concentration ($C_R/\overline{C}$, where $\overline{C}$ is the mean concentration of the constituent in the surface runoff for a given event) can then be defined. Studies underway on small tributaries to the Milwaukee River, immediately east of the Menomonee River have shown that the relative concentration shows a time distribution during an event that is related to land use.

Runoff event data from Noyes Creek, Schoonmaker Creek and the Little Menomonee River, plus the specific land use sites in the Menomonee Watershed, and the Milwaukee tributaries will be used to determine surface runoff concentrations and relative concentrations. The relation of these relative concentrations to time during the event, and to land use and meteorological conditions, such as rainfall intensity and duration, and antecedent rainfall, will be analyzed statistically. This analysis will provide an empirical relationship between the relative concentration's time distribution and land use and rainfall conditions which will allow prediction of surface runoff concentrations throughout the event. These concentrations can in turn be combined with a unit hydrograph to produce mass loading curves for the event.

River Transport Model

The third element of the modeling, namely, the river transport model, is to pick up the output runoff and sediment of the overland flow model and describe resultant downstream output to the boundary of Lake Michigan. However, closer scrutiny has shown this to be a particularly complex problem. Above the control structure which admits mainstem flow to a channelized section commencing at 45th Street (i.e., approximately 10 blocks downstream of Hawley Road) is conventional streamflow; however, below that point is either potential and (in most cases) actual major influence of seiche from the Lake. Thus, to provide output applicable to lake input quantification the model must consist of two elements: a conventional river transport and an estuarine transport endeavor.

A fully-dynamic model might incorporate in-stream/benthic-effect modifications but more importantly show other benefits. Input of data would be easier and the model could allow for better parameter quantification. The River Transport modeling would also have to address itself to the impending elimination of sewage treatment plant discharges. Similarly, best application of the Army Corps of Engineers Scour and Deposit program and the (extension of the) Stanford Sediment program is critical to the important, bottom-transport aspects of the River Transport Model.

Estuarine focus initially involves definition of limits. The 45th Street flow-control device on the Menomonee River, the large dam below North Avenue on the Milwaukee River and the old railroad culverts adjacent to Cleveland Avenue on the Kinnickkinnick River down to the harbor entrance would probably be the most appropriate definition of estuary limits. This would include extensive cross-correlation potential from industrial acreage, a flushing tunnel from the Lake to the Kinnickkinnick River, sheet pile flow-control devices(s) at the Falk Corporation, a present monitoring installation (413004) and three grab sample sites (413014, 413013 and 413012). Continuity of these sites plus establishment of six more grab-sites (Milwaukee River and Kinnickkinnick River estuary-limits, sites, prior to their entries into the harbor, at the harbor entrance and an inharbor site) along with assessment of dam and tunnel records, application of aerial photography, and attention to the understanding of the

"secondary" seiche mechanisms (i.e., wind-generated, as opposed to barometric pressure) is needed to complete a river transport model. Coordination with an upcoming University of Wisconsin-Milwaukee project to investigate seiche in the Milwaukee Harbor will be effected.

Evaluation of a Continuous Simulation Model

The Southeastern Wisconsin Regional Planning Commission in their role as a prime contractor under the IJC project and as a designated planning commission for receipt of Section 208 (P.L. 92-500) funding play a unique part in coordinating efforts on the Menomonee River Pilot Watershed Study. In this coordinating role work was initiated on the evaluation of an existing continuous simulation model to determine if the model could--with perhaps some modification--satisfy the third objective of the Menomonee River Pilot Watershed Study which calls for developing the predictive capability necessary to extend the findings of the study to other urban settings in the Great Lakes Basin. The overall approach in this model evaluation is to test first 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 mechanism 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, Incorporated. The model is unique in that it continuously simulates hydrologic-hydraulic and water quality processes for an indefinite period of time in response to a full spectrum of meteorological conditions. This is in contrast to the more common discrete event models that generate hydrographs and pollutographs only for major hydrologic events. Continuous process models are most likely to meet the needs of the pilot study

because they permit the computation of total annual transport of potential pollutants from a watershed to the Great Lakes for the complete spectrum of runoff conditions and streamflows and because they facilitate statistical analysis of the manner in which that material is delivered to the receiving waters.

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. Meteorological data and land data constitute the two principal types of input for operation of the Hydrologic Submodel. The key output from the submodel consists of a continuous series of runoff quantities for each land segment in the watershed. The function of the Hydraulic Submodel is to accept as input the runoff from the land surface as produced by the Hydrologic Submodel, to aggregrate 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. Input for the Hydraulic Submodel consists of parameters describing the stream reaches and impoundment sites as well as the output from the Hydrologic Submodel. The Water Quality Submodel simulates the time-varying concentration, or levels, of water quality indicators at selected points throughout the surface water system. Operating on a reach-by-reach basis, the submodel continuously determines water quality as a function of reach inflow and outflow, dilution, and biochemical processes. Input to the Water Quality Submodel consists of output from the Hydrologic Submodel, channel data and diffuse and point source data. Output from the submodel consists of a continuous series of water quality levels at selected points on the watershed stream system.

Data Base Development

Data base development consists of the acquisition, verification and coding of data needed to operate, calibrate and apply the model. The model data base for the watershed and environs is being assembled and when completed will consist of a large, readily accessible computer file of information subdivided into six distinct categories: meteorological data, land

data, channel data, riverine area structure data, diffuse source data and point source data. The meteorological data set is the largest because it contains 35 years of semi-monthly, daily, or hourly information for seven types of meteorological data. The data base is being developed by combining data obtained from the Southeastern Wisconsin Regional Planning Commission with data from the U.S. National Climatic Center.

Initial Calibration Runs

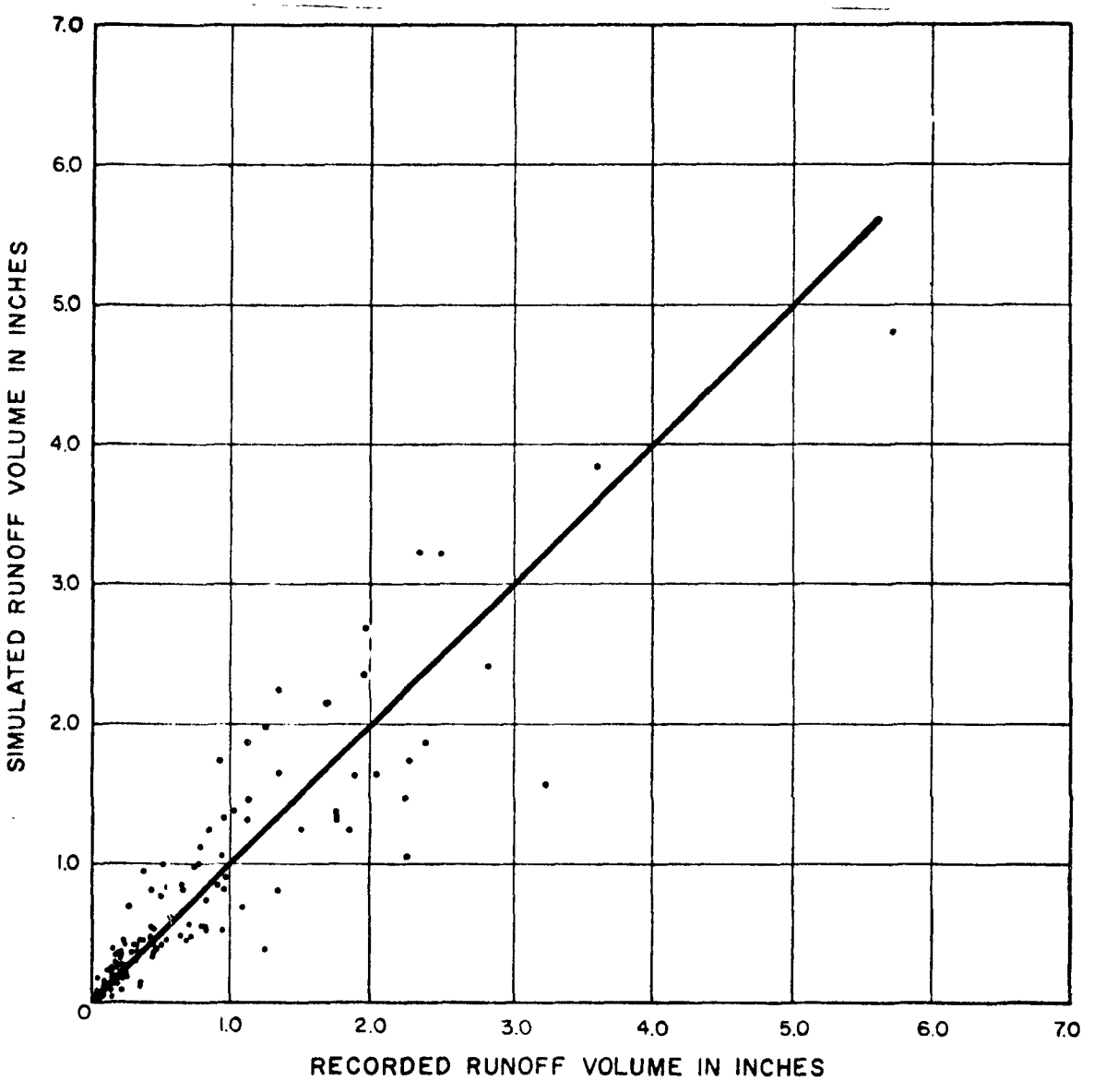
Calibration consists of comparing simulation results with historic fact and, if a significant difference occurs, making parameter adjustments so as to tailor the model to the natural and man-made features of the watershed. The initial calibration of the hydrologic-hydraulic portions of the model were conducted on sub-watersheds outside of but close to the Menomonee River watershed that were essentially spatially homogeneous with respect to soils, slope and land use-cover and had combinations of these three key land characteristics that were similar to those in land characteristics that were similar to those in land segments of the Menomonee River watershed. Gaged subwatersheds outside of the Menomonee River watershed were selected because the monitoring network that exists within the watershed had not yet yielded sufficient streamflow data for calibration purposes. The underlying objective was to use the initial calibration process to determine land parameters for the homogeneous subwatersheds which could in turn be applied to the Menomonee River watershed.

The initial calibration runs on the three test subwatersheds reveals that the combination of the Hydrologic Submodel and the Hydraulic Submodel can effectively reproduce the hydrologic-hydraulic response of a basin to a wide variety of meteorologic inputs. A close correlation was achieved between simulated and recorded annual and monthly runoff volumes, simulated and recorded hydrographs for major runoff events, and simulated and recorded annual instantaneous peak discharges.

Work Elements Planned and in Progress

Upon successful completion of the initial stage of the calibration process,

calibration runs were initiated in the Menomonee River watershed using limited historic stream flow records. An example of the results of that simulation is presented in Appendix F Fig. 5 in the form of a graphical comparison between simulated and recorded monthly runoff volumes. These model runs will be supplemented with calibration runs using precipitation and streamflow data collected under the pilot study monitoring program. After completion of the hydrologic-hyraulic calibration, the model will be tested against the water quality monitoring data.



SOURCE: SEWRPC

Appendix F Fig. 5. Comparison of recorded and simulated monthly runoff volumes for the Menomonee River at the Wauwatosa Gauge, January 1, 1963 to September 31 ,1973.

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