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SIMULATION OF URBAN RUNOFF
AND POLLUTANT LOADING
FROM THE GREATER LAKE CALUMET AREA

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SIMULATION OF URBAN RUNOFF
AND POLLUTANT LOADING
FROM THE GREATER LAKE CALUMET AREA

PART1. THEORY AND DEVELOPMENT
PART *2.* AUTO_QI USER'S MANUAL

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EXECUTIVE SUMMARY

Features from the ILLUDAS model and the Q-ILLUDAS model were combined and modified to provide a new model known as AUTO_QI. The model provides for a continuous simulation of soil moisture based on a continuous hourly rainfall record, evapotranspiration, and soils parameters provided by the user. The soil moisture is used to determine the antecedent moisture condition for the simulation of runoff volumes for events exceeding a rainfall amount specified by the user.

The runoff volumes and buildup/washoff parameters for user-selected pollutants are then used to generate pollutant loadings and event mean concentrations (EMCs) for each event. The event results may be examined individually or combined to produce annual loadings. Event results may also be examined for one outfall or combined by receiving water. Critical events are also identified by the model.

Best management practices (BMPs) may be identified by the user and applied to any portion of the basin being simulated. Multiple BMPs may be specified and these may overlap on one or more subbasins. BMPs are applied by the model as a percent reduction for each of the water quality parameters requested. The user must provide this BMP "efficiency" for each parameter.

A sample data set is provided with the program and may be modified by the user through a menu system (QEMENU). QIMENU is used to enter or edit data, run the program, and generate output from the model. A complete user's manual is provided for QIMENU. When BMPs are employed, output is provided with and without BMP results. The program is designed to run on an IBM PC/AT or compatible.

An optional geographic information system (GIS) interface is provided to generate the necessary input files relating to land use, soils, and BMP distribution. The user must provide automated coverages of the entire basin for land use including percent impervious surface, soils, BMP distribution and effectiveness, and subbasin boundaries. The interface is provided as part of the AUTO_QI program and is designed to run on ARC/INFO on a PRIME computer. The interface produces two input files for the model that may be downloaded directly into QIMENU.

Observed rainfall, runoff, and water quality data were used to verify AUTO_QI on the Boneyard Creek basin in Champaign, Illinois, using literature values for the buildup and washoff of pollutants. The model was also applied to the Greater Lake Calumet area south of Chicago to determine annual pollutant loadings to the Calumet and Little Calumet Rivers.

Part 1 of this report describes the theory and development of the model as well as the results of verification and application. Part 2 is a detailed manual for users of the program.

PART 1. THEORY AND DEVELOPMENT

1.0 - INTRODUCTION

Models for simulation of urban runoff hydrographs such as the Illinois Urban Drainage Area Simulator, ILLUDAS (Terstriep and Stall, 1974), Stormwater Management Model, SWMM (Metcalf and Eddy, Inc., et al., 1971; Huber et al., 1975) and Storage, Treatment, Overflow, Runoff Model, STORM (Hydrologic Engineering Center, 1975) have been used for some time. They are considered reliable for stormwater drainage design and are widely used. Models that incorporate urban runoff water quality are available, but are less frequently used. The main reasons are: (1) the water quality component is less reliable; (2) the models require extensive input data; and (3) the models lack verification. This is unfortunate since urban water quality modeling is a convenient tool for assessing pollutant loadings. Considering the high cost of monitoring and the lack of extensive data for using a statistical approach, the proper model with field data verification is a logical and feasible method for water quality assessments.

The principal investigators have developed an approach (Terstriep and Lee, 1989) that greatly reduces the cost of applying a deterministic model (Q-ILLUDAS, Noel and Terstriep, 1982) to a relatively large area by incorporating the ARC/INFO geographic information system (GIS) for data management. The main savings comes from automation of input files. Readily available automated data include the USGS LUDA level II land use data and the U.S. Census Bureau's "DIME" or "TIGER/LINE" file for population, housing and street density. The streams, soils, and other data are also available in the Illinois and other state and federal GIS databases. This method is very effective for simulating regional urban runoff loadings where large databases and multiple outfalls are involved. The model and GIS interface developed is known as AUTO_QI.

The general goal of this project is to incorporate the GIS database and to make the Q-ILLUDAS model available for regional water quality analysis. The specific objectives of this project are to:

1) Modify the existing Q-ILLUDAS model to meet regional modeling needs.
2) Develop a user-friendly interface program for handing input and output.

3) Greate a GIS computer macro which can assist with Q-ILLUDAS input.

4) Apply the model to the Greater Lake Calumet Area near Chicago, Illinois.

This report is divided into two parts. Part 1 is a technical reference describing some of the problems associated with urban water quality simulation, the development of the AUTO_QI model, the Geographic Information System (GIS) interface, and an application of the model to the Greater Lake Calumet Area. Part 2 is a user's manual for the model. It describes the menu system in detail, defines variables, and leads the user through a sample problem.

1.0.1 - Acknowledgments

The principal investigators of this report were Michael L. Terstriep and Ming T. Lee. Thomas Davenport, U.S. Environmental Protection Agency regional Nonpoint Source Coordinator, reviewed the early versions of this report and provided a number of helpful comments and suggestions. Douglas Noel developed the program for the original Q-ILLUDAS model, consulted on this project, and provided a general outline for the revised computer program. M. Razeur Rahman wrote the LOAD and BMP portion of the model. Evan P. Mills wrote the menu-driven program QIMENU for handling the inputs and outputs. Amelia V. Greene wrote the AML program to handle the GIS interface. John Brother prepared the graphical work.

1.1 - LITERATURE REVIEW

The special hydrologic problems of urban runoff are described by Shaw (1983) as follows:

The problem of estimating the runoff from the storm rainfall is very much dependent on the character of the catchment surface. The degree of urbanization (extent of impervious area) greatly affects the volume of runoff obtained from a given rainfall. Retention of rainfall by initial wetting of surfaces and absorption by vegetation and pervious areas reduces the amount of storm runoff. These surface conditions also affect the time distribution of the runoff. Thus the computational method used to obtain runoff from the rainfall should allow for the characteristics of the surface area to be drained.

Thus, the first efforts in urban runoff modeling were to relate runoff from storm rainfall to the catchment characteristics.

The first storm water sewer design method was the rational method (Kuchling, 1889). The unit hydrograph method was introduced by Sherman (1932). After the development of digital computers, early urban hydrologic models were developed, such as those by James (1965), Papadakis and Preul (1973), Terstriep and Stall (1974), and McPherson and Schneider (1974). One of the main characteristics of urban runoff is that during the early minutes of a storm, urban runoff is mainly derived from the impervious surfaces. Contributions from the pervious portion of the basin are highly variable and more difficult to define. Other research results may be found in Novotny and Chesters (1981), Harm et al. (1982) and Shaw (1983).

Early urban runoff water quality modeling research was conducted by Sartor and Boyd (1972), Hydrologic Engineering Center (1977), McPherson (1978), Sutherland and McCuen (1978), Huber and Dickinson (1988), Noel and Terstriep (1982), Geiger and Dorsh (1980), Johanason et al. (1980), and numerous other researchers. A comprehensive review of modeling of nonpoint source water quality in urban and non-urban areas was prepared by Donigian and Huber (1990). Other reviews that consider surface runoff quality models include: Feldman (1981), Huber and Heaney (1982), Eibler (1982), Whipple et al. (1983), Barnwell (1984, 1987), Huber (1985, 1986), Bedient and Huber (1989), and Viessman et al. (1989).

A partial list of urban water quality models is shown in Table 1.1.1.

Table 1.1.1. Urban Runoff Quality Model

Name of the model	Authors	Year
QUAL-II	Hydrologic Engineering Center	1975
SWMM	Huber et al.	1975
STORM	Hydrologic Engineering Center	1977
MUNP	Sutherland and McCuen	1978
Q-ILLUDAS	Noel and Terstriep	1982
QQS	Geiger and Dorsh	1980
HSPF	Johanason et al.	1980

A detailed description of each of the models can be found in the respective references. The following section will be limited to a discussion of the deposition and accumulation of pollutants on impervious surfaces and removal of solids from the street surface.

As reported by Sonnen (1980), the state of the mathematical urban water quality model was fairly dismal a decade ago. Little has changed since then since the physical processes are so complex as to defy efforts to reduce them to mathematical statements. Consequently, semi-empirical methods are often used.

1.1.1 - Deposition and Accumulation of Pollutants on Impervious Surfaces

As described by Novotny and Chesters (1981), the primary sources of pollutants are wet and dry atmospheric deposition, litter, and traffic. Pollutants deposited on the surface during a dry period can be carried by wind and traffic and accumulate near the curb or median barrier. Thus many studies report the street pollutant loading by unit length of curb.

The street refuse washed by runoff to storm sewers contains many contaminants. Significant amounts of organics, heavy metals, pesticides, and bacteria are commonly associated with street refuse. The pollutant accumulation rates are affected by atmospheric fallout, wind, traffic, litter deposition, vegetation and particle size distribution.

Pollutant accumulation in an urban area has a significant random component and no mathematical model will yield totally reliable results. Consequently, one common concept used is the storage-input-output

schematic approach which assumes that the amount of accumulated pollutants on a surface can be described as a simple mass balance formula:

$$dP/dt = A - rP \qquad (1)$$

where

A = the pollutant accumulation rate in pounds per day

r = the pollutant removal rate

P = the amount of street refuse or dust/dirt present on the street

t = time in days

Integrating Equation (1), then

$$P = A/r \, [1 - \exp(-rt)] + C \qquad (2)$$

where

exp = exponential function

C = undefined constant

Using the empirical data from Shaheen (1975), the parameters were defined for the Washington, DC, area as follows:

A = (ATMFL + LIT) (SW/2) +1.15 TD

r = .00116 exp [.0884 (TS + WS)]

C = 0

where

ATMFL = atmospheric fallout rate$(g/m^2/day)$

LIT = litter deposition rate $(g/m^2/day)$

SW = street width (meters)

TD = traffic density (thousand axles/day)

TS = traffic speed (km/hr)

WS = wind speed (km/hr)

Another attempt was made by Sutherland and McCuen (1978), who developed a set of refuse accumulation functions by using average daily traffic volume, and pavement condition expressed by the present serviceability index (PSI). The results are a set of accumulation equations in terms of these input factors.

The accumulation of street refuse is the main pollution source in urban areas. Typical urban street refuse was reported by Novotny and Chesters (1981) and is shown in Table 1.1.2.

Table 1.1.2. Street Refuse Accumulation

| Land use | Solids Accumulation | | | |
| | Chicago* Dust and Dirt | | Eight American Cities ** Total Solids | |
	(g/curb meters/day)	(lb/ac/day)	(g/curb meters/day)	(lb/ac/day)
Single family	10.4	2.1[+]	48	9.5[+]
Multiple family	34.2	6.8[+]	66	13.1[+]
Commercial	49.1	9.7[+]	69	13.7[+]
Industrial	68.4	13.5[+]	127	25.1[+]

   * American Public Works Association report (1969)

  ** Sartor et al. (1972; 1974)

   + The curb density in Chicago and eight American cities was assumed by the authors to be 90 meters/ac

The Chicago results indicated that the multiple family areas generate about three times more street dirt than the single family areas. The commercial and industrial areas generated about 5 and 7 times more than the single family areas.

The street refuse accumulation rate based on the eight American cities (Sartor et al., 1972, 1974) is 2 to 4 times higher than the Chicago dust/dirt accumulation rate. This shows the wide variations in pollutant accumulation rates in existing measured field data for different cities.

1.1.2 - Refuse Washoff by Surface Runoff

When surface runoff occurs on impervious surfaces, the splashing effect of rain droplets and drag forces of the flow put particles in motion. Many hydraulic models have appeared in sedimentation literature which are potentially applicable to the problem of particle suspension and transport. Two models used frequently in urban runoff modeling are described below.

1) *Yalin Equation.* Of numerous equations published in the literature, the Yalin equation (1963) is considered as one of the best for describing suspension and transport of particles by shallow flow typical for rills and street gutters. The equation has been reported in the following form.

$$p = 0.635 \text{ s } [1 - \text{In } (1 + as)/(as)] \qquad (3)$$

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where

p = particle transport per unit width of flow (g/m-sec)

$s = (Y / Ycr)-1$

$$a = 2.45\ \rho_s^{-0.4} \sqrt{Ycr}$$

In = natural log function

The variables are defined as follows:

Y = particle bed load tractive force

$$= \frac{\mu^*}{[(\rho_s - 1)\,gD]}$$

ρ_s = particle density (g/cu-cm)

Ycr= the critical tractive force at which sediment movement begins.

D = particle diameter (m)

μ^* = shear velocity (m/sec)

g = gravity acceleration (m/sec^2)

Based on Yalin's equation, Sutherland and McCuen (1978) developed a washoff model which is based on the relationship between percentage removal of total solids in a particle range due to a total rainfall volume of 1/2 inch and correlation factor Kj such that:

$$TSj = Kj\ (TSi) \tag{4}$$

where

TSj = the percentage removal of total solids in a particle range due to total rainfall volume j measured in mm

Kj = a factor relating TSj and TSi

TSi = the percentage removal of total solids in the particle range due to a total rainfall of 1/2 inch.

2) *Sartor et al. (1972 and 1974) Approach.* The Sartor et al. washoff function is based on the first-order washoff function:

$$dP/dt = -\,K\,u\,r\,P \tag{5}$$

where

P = amount of solids remaining, pounds

t = time, in days

Ku = a constant depending on street surface characteristics (called urban washoff coefficient)

r = rainfall intensity, inches/hour

The constant Ku was found independent of particle size within the studied range of 10 to 1000 micrometers. The integrated form of the equation can be expressed as:

$$P_t = P_o [1-exp(-Kurt)] \qquad (6)$$

where:

P_o = initial mass of solids in the curb storage

P_t = mass of material removed by rain with duration t

exp = exponential function

In spite of its highly empirical nature and arbitrarily chosen constants, the Sartor concept has been incorporated in many urban runoff models such as SWMM (Metcalf and Eddy, Inc., et al., 1971; Huber et al., 1975) and STORM (1977).

1.2 - AUTO_QI MODEL
1.2.1 - Model Overview

AUTO_QI is actually three programs known as HYDRO, LOAD, and BMP. These programs run in series, each using output from the previous program as input along with additional information from the user. HYDRO performs a continuous simulation of soil moisture based on a daily and hourly rainfall record provided by the user. It also computes runoff volume for each event above some user-specified rainfall amount. LOAD uses these runoff volumes and additional pollutant accumulation and washoff information to calculate pollutant loadings for each runoff event. The BMP program then reduces these loadings in accordance with user-specified best management practices (BMPs) and reports the results both with and without BMP conditions. The simulation process may be examined by looking at wet and dry periods.

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1.2.2 - Wet Periods

Runoff may only occur during a "wet period," a day during which rainfall occurs. During these potential runoff periods hourly rainfall amounts are required. The basin is assumed to have three types of area: directly connected paved area, supplemental paved area, and contributing grassed area. As the name implies, runoff from the directly connected paved area flows directly to the storm system. Runoff from the supplemental paved area flows first across the grassed area and is subjected to infiltration losses. The remainder of the basin is assumed to be grassed area and all rain falling on this surface is also subjected to infiltration losses. The runoff process is described below.

1.2.3 - Paved Area Runoff

The model distinguishes between directly connected paved area, and supplemental paved area. The losses from directly connected paved area consist of initial wetting and depression storage. These losses are combined and treated as an initial loss to be subtracted from the beginning of the rainfall pattern. After subtracting these losses from the rainfall pattern, the remainder of the rainfall will appear as effective rainfall and thereby as runoff from the paved area.

1.2.4 - Grassed Area Runoff

Computation of grassed area runoff includes runoff from the supplemental paved area since both are subjected to infiltration. As in the case of paved-area runoff, rainfall is the primary input for grassed areas. The modifications that must be made in changing the rainfall pattern to grassed area runoff are much more complex than in the paved area case. The procedure followed here is first to add in supplemental paved area runoff and then to subtract initial and infiltration losses.

In this model, rainfall on the supplemental paved area is simply distributed by linear weighting over the entire grassed area, therefore modifying the actual rainfall for grassed areas such that:

$$R' = R\,(1.0 + SPA/CGA) \qquad (7)$$

where

R' = effective rainfall on the grassed area

R = actual rainfall

SPA = supplemental paved area

CGA = contributing grassed area

In an urban basin, the area that is not paved is most often covered with bluegrass turf. When rain falls on this turf, there are two principal losses, the first being the depression storage and the second being infiltration into the soil. In this model depression storage is filled and maintained and infiltration is satisfied before any runoff takes place. Depression storage is normally taken to be 0.20 inches, but provision is made in the model for this to be varied.

The dominant and far more complex loss of rainfall falling on grassed areas is that caused by infiltration. The theoretical approach to evaluating infiltration rates is based on using the physical properties of the soil to estimate the water storage available in the soil mantle and evaluating the role of this water storage as rain water infiltrates into and through the soil mantle. Details of water storage in soil and infiltration rates through soil are given in the original ILLUDAS manual. Only brief descriptions are provided here.

1.2.4.1 - Water Storage in Soil

The amount of water that can be stored in the soil mantle is dependent upon the total pore space available in the soil between the soil particles. In this model, the total water in storage in the soil mantle is divided into two principal parts. The first of these is gravitational water. This is the water which will drain out of soil by gravity. The second is evapotranspiration (ET) water.   It is the water which can be removed by plants through evapotranspiration.

Soil moisture storage capacity varies with soil type and may be classed by hydroiogic soil group. In this model, seven hydrologic soil groups can be

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considered; A, AB, B, BC, C, CD and D. The U.S. Soil Conservation Service describes the hydrologic soil groups as follows:

> A = low runoff potential, high infiltration rate (consists of sand and gravel)
>
> AB =   soil having properties between soil types A and B
>
> B   =   moderate infiltration rate and moderately well drained
>
> BC =   soil having properties between soil types B and C
>
> C   =   slow infiltration rate (may have a layer that impedes downward movement of water)
>
> CD =   soil having properties between soil types C and D
>
> D   =   high runoff potential, very slow infiltration rate (consists of clays with a permanent high water table and high swelling potential)

Default values of soil moisture storage capacity for different soil types are supplied in Appendix B. Users can change these values to suit their own experience. For further references see Eagleson (1970) and Richey (1961).

1.2.4.2 - **Infiltration Rate**

Knowledge of the water storage available for infiltration within a soil mantle makes it possible to compute the infiltration rate at any time t from the Horton equation as given by Chow (1964):

$$f = f_c + (f_o - f_e)\exp(-kt) \tag{8}$$

where

> f_c = final infiltration rate, inches per hour
>
> f_o = initial infiltration rate, inches per hour
>
> k = shape factor
>
> t = time from start of rainfall
>
> exp = exponential function

This equation is solved by the Newton-Raphson technique for given f_c and f_o values that depend on soil properties supplied by the user. A shape factor (k) of 2 was used to provide the shape best reflecting natural conditions.

The total amount of infiltration during a storm event depends upon the total amount of soil moisture (ET water and gravitational water) in storage. The higher the amount of available soil moisture, the lower the amount of infiltration and vice versa. In this model the total amount of infiltration is distributed among ET storage and gravitational storage in a preassigned 60/40 ratio. AUTO_QI continuously simulates soil moisture so that a reliable soil moisture is available at the beginning of any event.

1.2.5 - Dry Periods

During dry periods the model operates on two different time steps: daily if there is no rainfall on the current day and hourly if there is rainfall at some time during the current day.   During dry periods depression storage and soil moisture depend on: 1) evaporation, at a user supplied rate from depression storage; 2) infiltration from depression storage, with the infiltration volume separated in a 60/40 ratio into ET water and gravitational water; 3) evapotranspiration, at a user specified rate, from ET water storage; and 4) percolation at a constant rate, f_c, from gravitational water storage.

1.2.6 - Spatial Distribution of Runoff Processes

All of the wet period and dry period processes are assumed to be spatially distributed, and are simulated by the use of a triangular distribution. Figure 1.2.1(a) shows that the distribution is assumed to vary linearly from zero to twice the user-specified mean value over the subcatchment area. DEPG, as an example, is the mean pervious depression storage. Figure 1.2.1(b) shows the concurrent processing of depression storage and infiltration potential. Although both filling of depression storage and infiltration are assumed to be spatially distributed as in Figure 1.2.1, they are assumed to be totally independent of one another physically. Depression storage may therefore be considered to have a uniform distribution with respect to infiltration potential.

The concurrent processing of infiltration and depression storage, Figures 1.2.1(c) and 1.2.1(d), assumes that infiltration potential, varying from
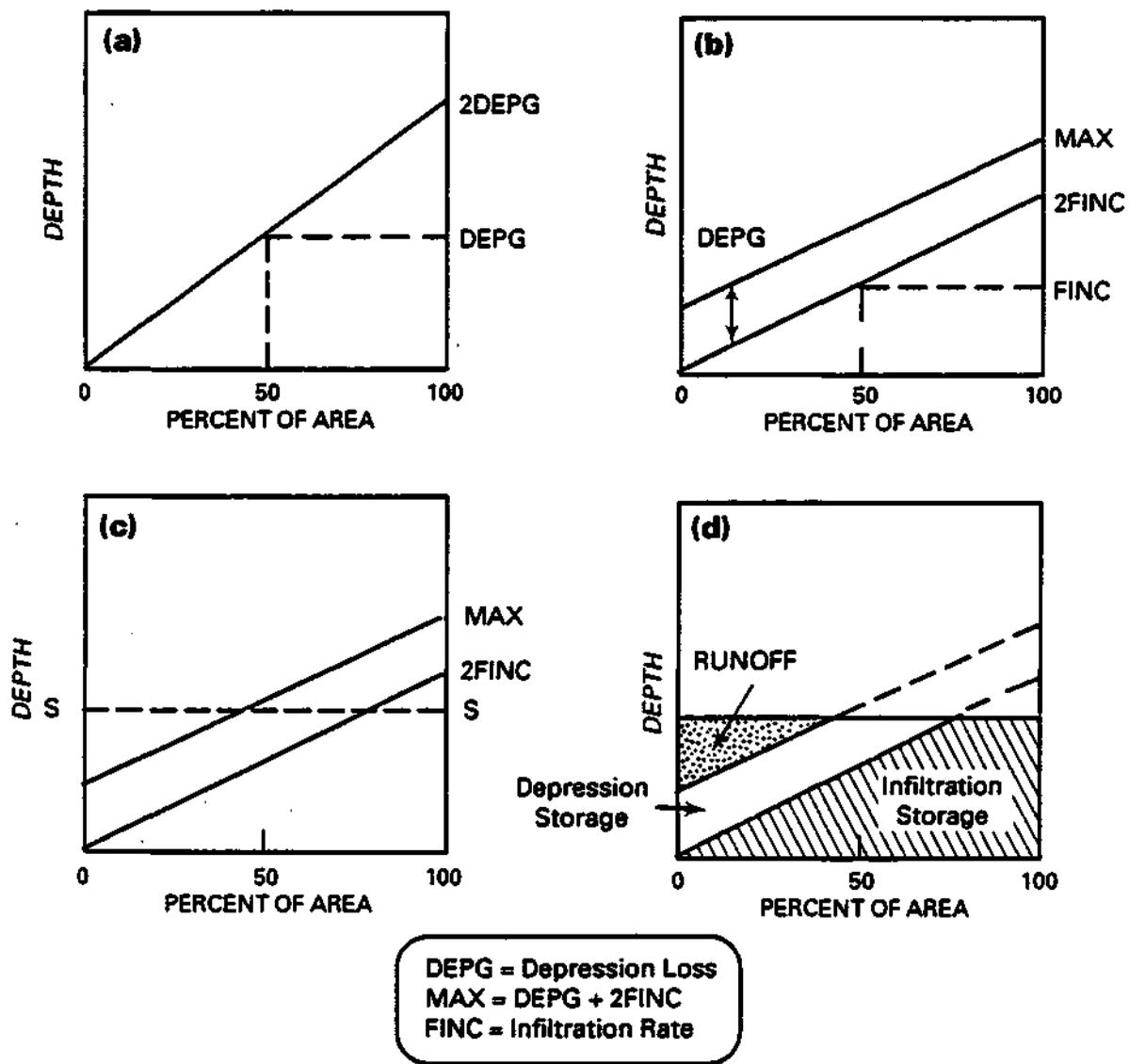
Figure 1.2.1. Triangular spatial distribution

zero to 2FINC, is satisfied for a particular level of supply, S, before considering depression storage. The supply rate, S, is defined as the sum of the rainfall and the uniformly distributed volume of depression storage at the start of the interval. The volume below S and between curves 2FINC and MAX represents the moisture supply to depression storage in the interval, D, and is processed according to the above discussion of Figures 1.2.1(a) and 1.2.1(b). The volume remaining below S and above the curve bounded by MAX is the surface runoff volume for the hour.

1.2.7 - Volume of Pollutant Generation

Once an effective hyetograph has been generated for both pervious and impervious areas, these rainfall depths are supplied as input to the program LOAD which in turn generates the washoff of different pollutants from the storm event. LOAD utilizes linear accumulation and exponential washoff equations. The number of pollutants and their different characteristics such as daily accumulation rate, daily removal rate, etc., are supplied by the user.

L2.7.1 - Dry Periods

One form of mass balance formula in discrete form is the linear accumulation equation which generates the antecedent pollutant load at the beginning of an event as follows:

$$P_t - P_{t-1} (1-r) + A \tag{9}$$

where

P_{t-1} = initial load at time t-1

P_t = load at time t

r = background removal rate

A = daily accumulation rate

1.2.7.2 - Wet Periods

At the start of rainfall, the amount of a particular pollutant on surfaces which produce runoff will be P_o, in lb/acre. Assuming that the pounds of pollutant washed off in any time interval, dt, are proportional to the pounds remaining on the ground, P, the first order differential equation is:

$$- dP/dt = kP \qquad\qquad (10)$$

which when integrated converts into the exponential washoff function for the removal of the surface loads as follows:

$$P_o - P = P_o(1-\exp(-kt)) \qquad\qquad (11)$$

where:
$P_o - P$ = washoff load, lb/acre
k = proportionality constant
t = storm duration, hours

In order to determine k, the model uses the same assumption as the SWMM model, that k varies in direct proportion to the rate of runoff such that:

$$k = iB$$

where:
i = runoff, in./hr
B = constant

To determine B it was assumed that a uniform runoff of 1/2 inch per hour would wash away 90 percent of the pollutant from paved areas and 50 percent of the pollutant from grassed areas in one hour. That leads to a value of B of 4.6 for paved areas and 1.4 for grassed areas. These are default values and can be modified by the user.

Washoff load is determined by applying each constituent's loading parameters to the buildup function to determine the initial load (by land use), and then applying the exponential washoff equation for impervious and pervious areas. The event mean concentration (EMC) is determined by dividing the total washoff loads by the runoff volume for each land use.

1.2.8 - Best Management Practices (BMP)

Best Management Practices (BMPs) are the measures implemented to reduce pollutants from source areas, or in streams and receiving waters. The mechanisms of pollutant removal by BMPs may be simple or complicated. There are many factors which govern their pollutant removal ability.

Schueler (1987) outlined three primary interrelated factors: 1) the removal mechanisms used, 2) the fraction of the annual runoff volume which is efficiently treated, and 3) the nature of urban pollutants being removed.

The AUTO_QI model does not model specific BMP processes, but represents the effectiveness of BMPs by a removal efficiency factor. The model can handle one or more BMPs in a catchment or portion of a catchment. A detailed description of preparing input data for the BMP component can be found in Part 2 of this report. The determination of the pollutant removal factor may be inferred from field performance monitoring, laboratory experiments, modeling analyses, or theoretical considerations. Most model users, however, must rely on literature values as a starting point.

The particulate related pollutants, such as sediment and lead, are relatively easy to remove by common removal mechanisms such settling. Soluble pollutants, such as nutrients, are much more difficult to remove. The settling mechanism has little or no effect, and biological mechanisms, such as uptake by bacteria, algae, rooted aquatic plants or terrestrial vegetation, are often used. A detailed description of individual BMPs can be found in Schueler (1987) and Novotny and Chesters (1981).

Table 1.2.1 shows typical BMP pollutant removal efficiencies (Schueler, 1987). The model allows users to test the potential enhancement of water quality by implementation of one or more BMPs in a catchment or group of catchments. The user specifies what portion, in percent, of a catchment will be affected by the desired BMP(s) and the removal efficiency of the BMP(s). The model output lists the load and event mean concentration (EMC) without BMPs, followed by the load and EMC expected with BMPs. This same procedure can be applied to reflect existing conditions if one or more BMPs are already in place.

Table 1.2.1. Urban BMP Pollutant Removal Efficiency

BMP	Suspended Sediment	Total P	Total N	Oxygen demand	Trace metal	Bacteria	Over-capability
			Chemical Constituents				
Extended pond	80-100%	40-60%	20-40%	40-60%	60-80%	UN	Moderate
Wet pond	60-80%	40-60%	20-40%	20-40%	60-80%	UN	Moderate
Infil-tration	80-100%	40-60%	40-60%	60-80%	80-100%	60-80%	High trench
Infil-tration	80-100%	40-60%	40-60%	60-80%	80-100%	60-80%	High basin
Porous pavement	80-100%	60-80%	60-80%	60-80%	80-100%	80-100%	High
Water quality inlet	0-20%	UN	UN	UN	UN	UN	Low
Filter strip	20-40%	0-20%	0-20%	0-20%	0-20%	0-20%	Low (20 ft wide turf strip)
Grassed swale	0-20%	0-20%	0-20%	0-20%	0-20%	UN	Low (high slope)

Note: UN = unreported.

1.3 - DATA PREPARATION
1.3.1 Interfacing the GIS Database and AUTO_QI

Urban runoff quantity and quality are highly dependent upon the land use and hydrologic soil type. To tabulate the land use/soil complex for a large basin is a time consuming process. To simplify the data collecting process, an optional ARC Macro Language (AML) program was developed to retrieve the land use/soil layers in a format suitable for model input.

The AML includes a menu driven data review feature with two windows on the screen. The right window shows an index map of the whole drainage basin and the subbasin boundaries. The user can select a subbasin and display the land use, soil layers, streets, and storm sewers. If the user wants the land use input file of a specific subbasin, the AML will retrieve the attribute data and generate an ASCII file for the model input.

1.3.2 - AML Programs

The AML programs provide the link and user interface between the GIS running on a PRIME and the AUTO_QI program running on a PC. These programs process the data for use by AUTO_QI and also enable the user to view the graphic data at the subbasin level via a menu. The programs are to be used with ESRI's ARC/INFO software on a PRIME computer and are grouped into two functions: the preprocessor programs and the menu system programs.   PREPROCESSORLANDSOIL.AML, PREPROCESSORBMP.AML and RUNIT.AML are the names of the three main programs.

PREPROCESSORLANDSOIL.AML uses the soil, land use, and BMP coverages to create a soil-land use file that can be input to the AUTO_QI model.   BMP.AML uses land use and BMP coverages to create BMP application files for the AUTO_QI model. RUNIT.AML is a program which accesses the ARC/INFO menu system to view the coverages and INFO data. This menu also allows the users to choose and view individual subbasins and their data layers. The detailed descriptions of these three programs can be found in Part 2 of this report.

1.4 - MODEL VERIFICATION

1.4.1 - Introduction

Due to the lack of observed data in the Lake Calumet area, the AUTO_QI model was verified by using the Boneyard Creek Basin in Champaign-Urbana, Illinois. This station has been continuously gaged by USGS since 1948.

The location of the Boneyard Creek streamgaging station is shown in Figure 1.4.1. The watershed area was reduced from 4.7 to 3.6 square miles in 1960 by a diversion. The basin contains a portion of Urbana, the commercial center of Champaign, and the University of Illinois campus. The central business district of Champaign makes up 7.5 percent of the drainage area, and is nearly 100 percent impervious. Other city properties, including predominantly residential, some commercial and light industrial, make up an additional 81.2 percent of the basin. The remaining 11.3 percent of the basin is in parks, open space and other land use classes. The basin has been measured to be approximately 44.1 percent total paved area, which includes 23.3 percent of direct connected paved area,. 13.1 percent of supplemental paved area and 6.7 percent of non-connected paved area. The soils of the basin are predominantly Flanigan silt loam of hydrologic class B (Terstriep and Stall, 1974).

1.4.2 - Runoff Simulation

The rainfall data for three years which represent low (25 percent), average (50 percent) and high (75 percent) annual exceedence of rainfall were chosen for runoff simulation. These years and total rainfall are shown in Table 1.4.1.

Table 1.4.1. Selected Years and Total Annual Rainfall

Year	Total rainfall (inches)	Chance of exceedence (percent)	Comments
1959	35.94	50	average year
1976	32.63	75	dry year
1977	42.44	25	wet year
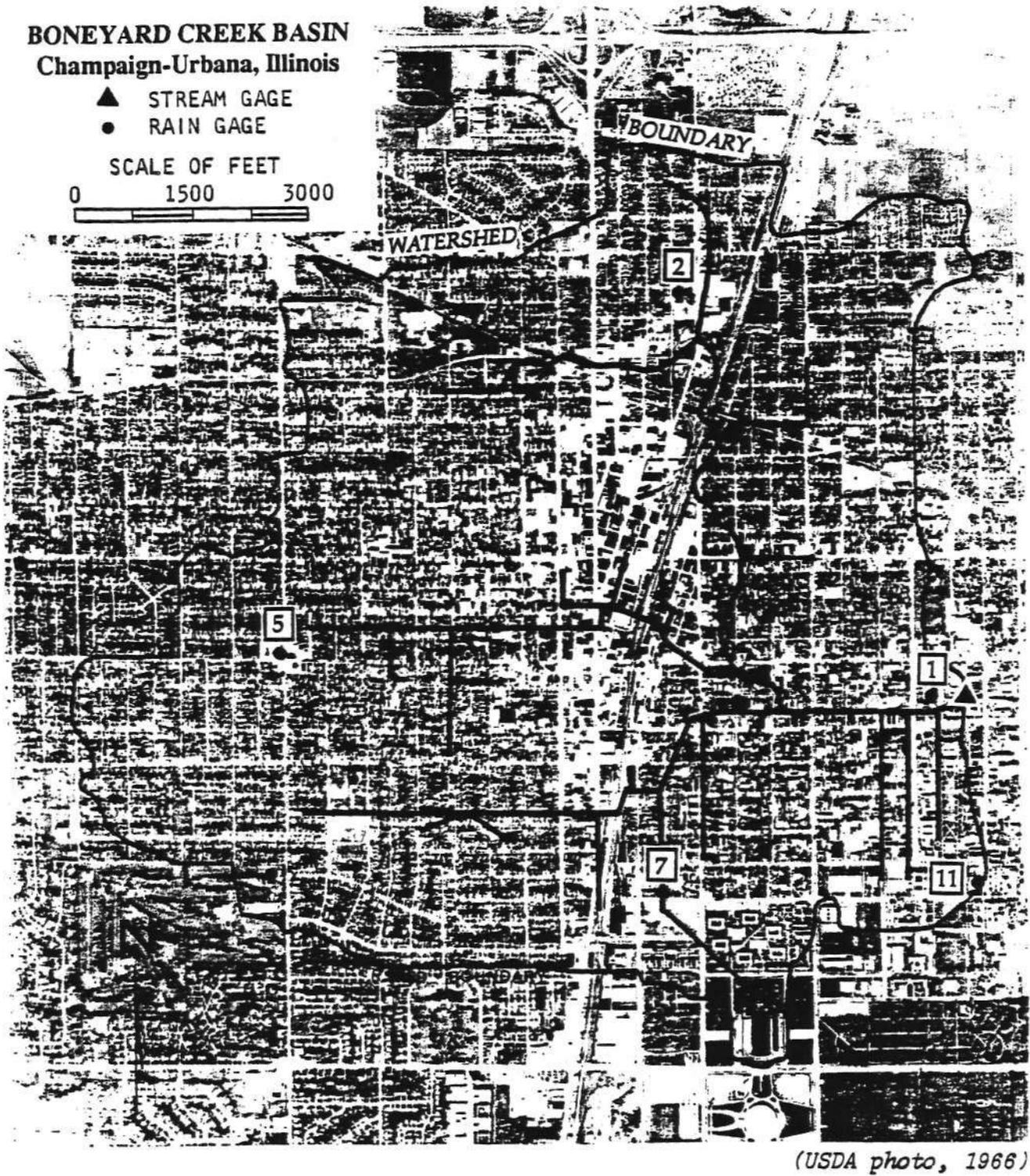
Figure 1.4.1. Boneyard Creek drainage basin and main storm sewer network

Land uses in the basin were simplified into two categories. The land use parameters for these categories that were used to verify the model are shown in Table 1.4.2.

Table 1.4.2. Land Use Parameters

Land use	USGS land use Level 2 code	%PA	%SPA	DEPI (inch)	DEPG (inch)
Residential	11	15	20	.1	.1
Commercial	12	90	5	.1	.1

Note: %PA= paved area in percent
%SPA= supplemental paved area in percent
DEPI= impervious depression storage depth
DEPG= pervious depression storage depth

1.4.3 - Results of Runoff Simulation

Events were selected for which the actual event runoff volume could be distinguished with reasonable confidence from the continuous runoff data. The events are tabulated in Tables 1.4.3, 1.4.4 and 1.4.5 respectively.

Table 1.4.3. Summary of Runoff Simulation for Selected events in 1977

Date	Dry days	Rain-fall (inches)	Event duration (hours)	Observed runoff (inches)	Simulated runoff (inches)	Simulated grass runoff (percent)
1/13/77	3.04	.21	10.00	.006	.022	1
2/23/77	4.29	.33	4.00	.046	.05	2
8/28/77	5.13	1.43	11.00	.43	.32	1
9/24/77	2.13	.83	2.00	26	.18	5.4
10/05/77	.79	1.19	18.00	.31	.23	2
10/22/77	7.17	1.54	12.00	.40	.34	3.4

Table 1.4.4. Summary of Runoff Simulation for Selected Events in 1959

Date	Dry days	Rain-fall (inches)	Event duration (hours)	Observed runoff (inches)	Simulated runoff (inches)	Simulated grass runoff (percent)
7/23/59	3.21	.51	6.00	.07	.08	3
7/27/59	3.17	.80	5.00	15	.16	4
8/29/59	6.00	.23	5.00	.02	.03	3
9/01/59	2.63	.39	6.00	.035	.07	1
9/09/59	8.00	.18	2.00	.024	.02	2
10/10/59	3.63	2.52	9.00	.51	.60	7
11/04/59	0.08	.82	8.00	.185	.19	4
11/13/59	0.13	1.39	23.00	.32	.31	2
12/10/59	5.67	.68	15.00	.106	.11	1

Table 1.4.5. Summary of Runoff Simulation for Selected Events in 1976

Date	Dry days	Rain-fall (inches)	Event duration (hours)	Observed runoff (inches)	Simulated runoff (inches)	Simulated grass runoff (percent)
5/06/76	10.25	.71	15.00	.15	.14	1
6/15/76	14.83	.22	1.00	.025	.03	4
7/15/76	12.58	.32	4.00	.043	.05	2
7/22/76	.33	.98	3.00	.175	.22	4
8/05776	5.67	1.84	9.00	.57	.41	6
9/01/76	6.96	.94	1.00	.16	.22	12
9/09/76	7.42	.93	6.00	.187	.20	2.5
9/19/76	10.4	.98	2.00	.30	.23	10
10/05/76	8.92	1.95	16.00	.53	.44	4
10/19/76	13.00	.21	13.00	.036	.02	0
10/23/76	3.58	.32	6.00	.052	.05	0
10/30/76	6.33	.42	13.00	.11	.07	0
11/25/76	.04	.55	15.00	.12	.09	0
12/06/76	4.00	.17	11.00	.018	.01	0

From Figure 1.4.2, it is seen that AUTO-QI does a reasonably good job in reproducing runoff volumes for dry, average and wet years. The simulated runoff/rainfall ratio for these three years is approximately 20 percent, which is consistent with the observed data and with what has been found previously (Terstriep and Stall, 1974).

1.4.4 - Water Quality Simulation

Water quality data for Boneyard Creek were available for eight events in 1982 from a study done by Bender et al. (1983). Simulated water quality data were compared with those 1982 data.

1.4.4.1 - Water Quality Parameters

The pollutant accumulation/decay parameters required by the model and used in this study are tabulated in Table 1.4.6.

Table 1.4.6. Water Quality Parameters

	ARi (lb/acre/day)	ARp (lb/ac/day)	RRi (percent)	RRp (percent)
For residential land use:				
Suspended solids	7.6300	3.9900	4.50	4.50
Phosphorus	0.0138	0.0070	6.00	5.00
Lead	0.0100	0.0053	6.00	5.00
For commercial land use:				
Suspended solids	9.5500	5.5500	3.00	4.50
Phosphorus	0.0100	0.0053	4.50	4.50
Lead	0.0110	0.0060	6.00	5.00

Note: ARi = the Accumulation Rate for impervious area
RRi = the Removal Rate for impervious area
ARp = the Accumulation Rate for pervious area
RRp = the Removal Rate for pervious area

The accumulation rate and removal rate were selected on the basis of typical midwest urban runoff basins. No attempt was made to adjust these parameters to fit the observed data.

The comparisons between simulated washoff and actual washoff of total suspended solids (TSS), phosphorus (P) and lead (Pb) are summarized in Figure 1.4.3 and Table 1.4.7.
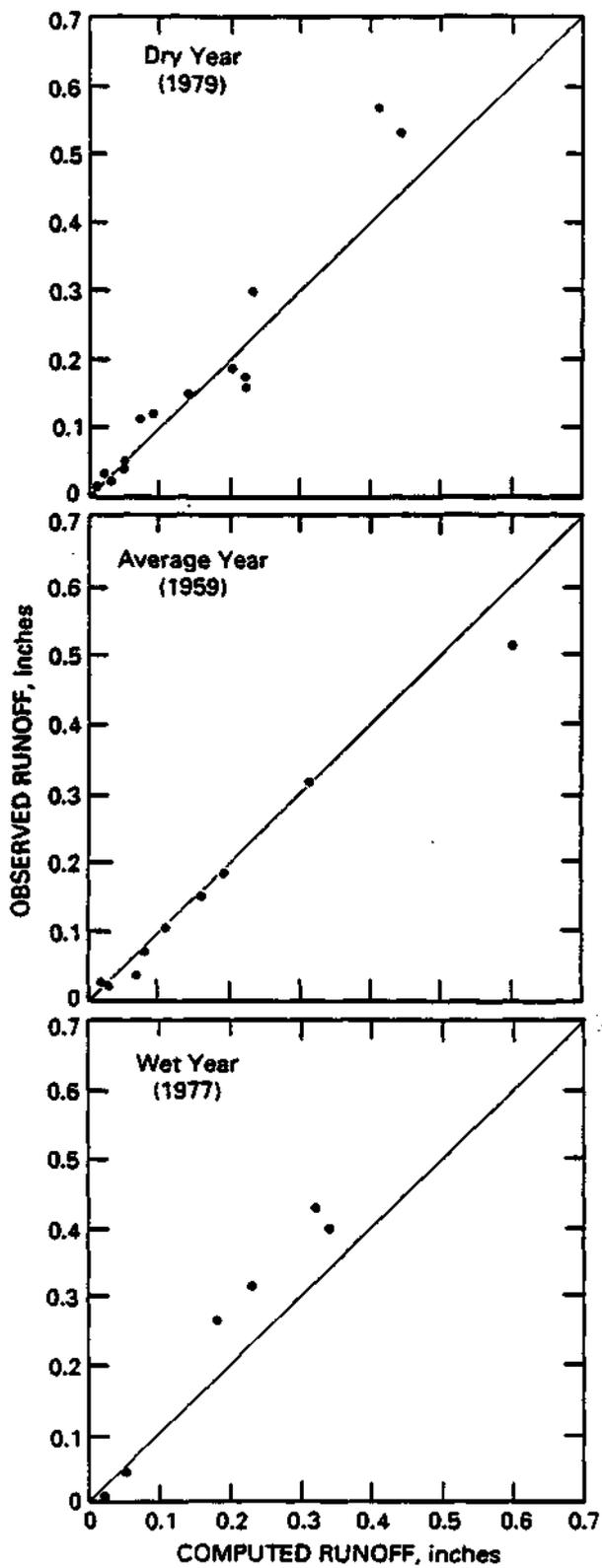
Figure 1.4.2. Comparison of observed and computed runoff volumes
in Boneyard Creek basin, Champaign-Urbana, Illinois

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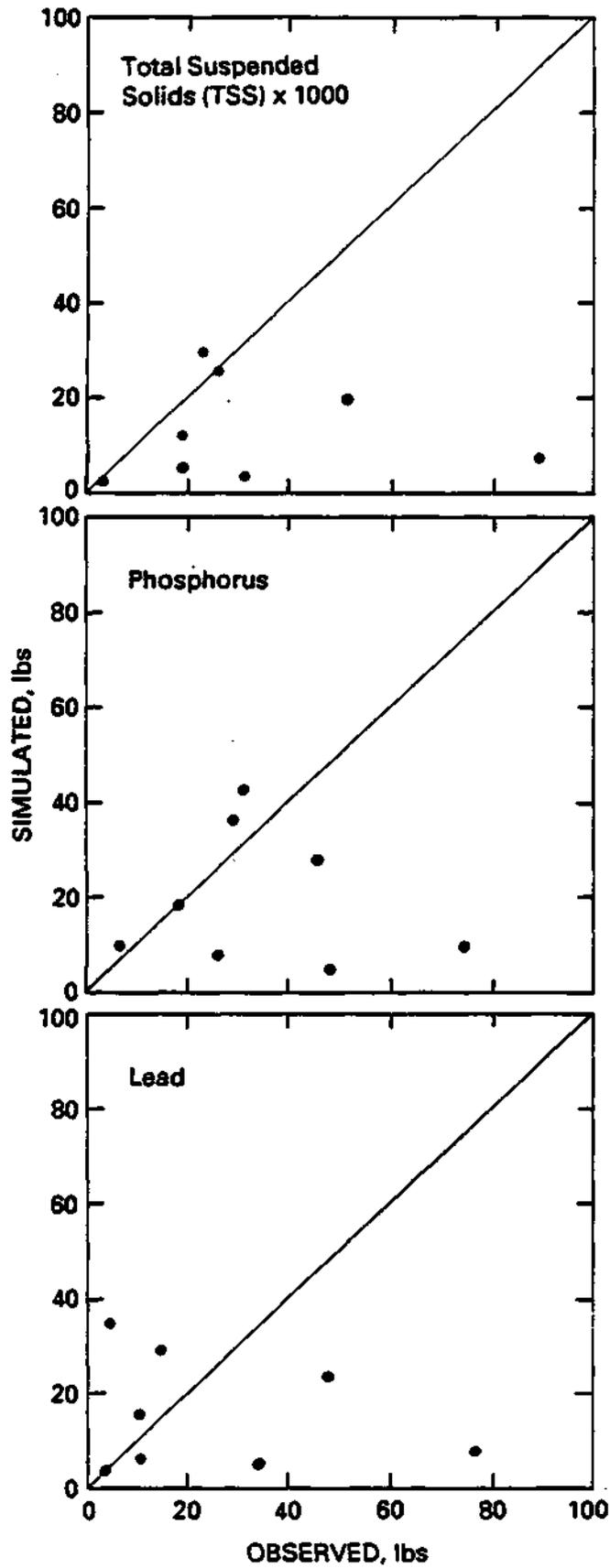
Figure 1.4.3. Comparison of observed and computed water quality loadings in Boneyard Creek basin, Champaign-Urbana, Illinois

The results of this verification are disappointing, but demonstrate the problems of water quality simulation without data for verification and calibration. The buildup and washoff factors in the model could be adjusted to "calibrate" the model to this data set and produce better results, but that was not the intent here.

Table 1.4.7. Washoff Load Simulation for Selected Events of 1982

			TSS		Phosphorus		Lead	
Date	Rainfall (inches)	Runoff (inches)	Sim. (in	Obs. pounds)	Sim. (in	Obs. pounds)	Sim. (in pounds)	Obs.
3/19/82	.52	.08	12,312	18,777	18	18	15	11
4/02/82	.66	.11	6,954	89,179	10	75	8	77
4/15/82	.12	.01	2,388	3,332	10	7	3	4
4/16/82	.60	.10	19,549	52,087	28	46	23	48
5/15/82	.43	.07	25,409	25,857	36	29	29	15
6/15/82	1.17	21	3,302	30,969	5	48	5	35
6/28/82	.98	.16	29,808	22,931	43	31	35	5
7/18/82	1.14	.30	5,070	19,001	8	26	6	11

1.5 – HYDROLOGIC AND POLLUTANT LOADINGS IN THE GREATER LAKE CALUMET AREA

1.5.1 - Introduction

Until the late nineteenth century, the Lake Calumet area southeast of Chicago was primarily a shallow marshy land abundant with wildlife. Rapid urbanization and industrialization since then, however, have left little of the original wetland as shown in Figure 1.5.1. Detailed descriptions of the study area can be found in numerous previous field reports (Colten, 1985; Ross et al., 1988; USHEW, 1965; USACE, 1983). The following sections describe the GIS databases which are needed for urban pollutant loadings.

1.5.2 - GIS Database Layers

1.5.2.1 - Soil Layer

The Statewide "General Soil Map of Illinois" was digitized for the Illinois GIS system in 1985 with funding from the Illinois Department of
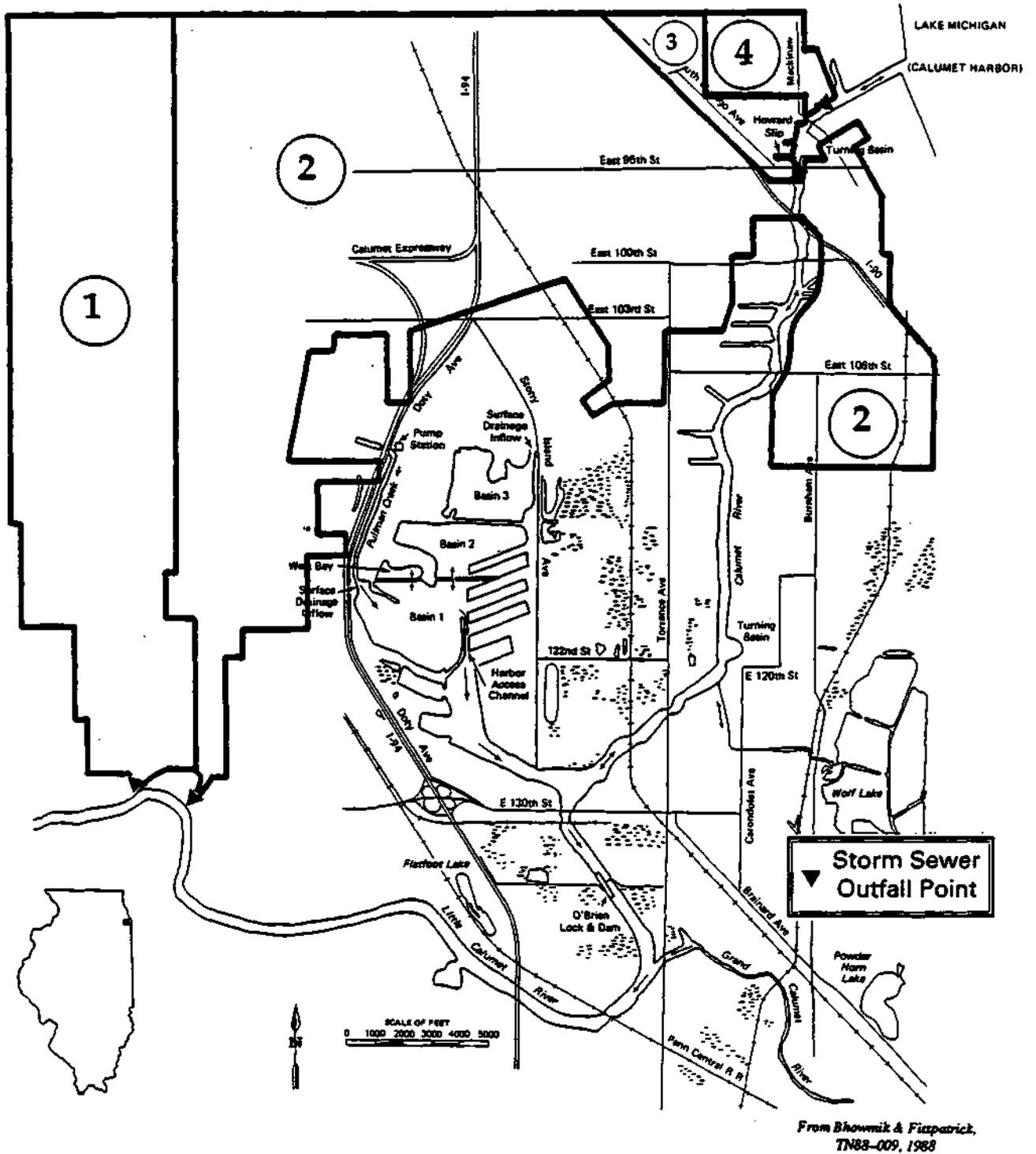
Figure 1.5.1. General location map of four urban drainage basins
in the Greater Lake Calumet Area, Chicago, Illinois

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Mines and Minerals (IDMM). This map contains 57 general soil associations in Illinois. The attribute data include the soil surface color, surface code and the hydrologic class (well drained, moderately well drained, somewhat well drained, and poorly drained). This hydrologic soil class is needed hydrologic modeling in the AUTO_QI model. The source map scale for the soil associations was 1:500,000.

1.5.2.2 - Land Use Layer

The statewide land use maps are available from the USGS LUDA digital data base (Anderson et al., 1976). The land uses are classified based on LUDA Level II containing 37 land use categories (Appendix D). Land use/cover information has been updated by using digital Landsat image data or by scanning aerial photographs (Hsu, 1978; King, Lee and Singh, 1989; Lee and Ke, 1990; Lee, Kao and Ke, 1990). The Illinois State Water Survey has developed image analysis capability using the ERDAS image processing package (ERDAS, 1989). The results of a classified land use can easily be transferred to the ARC/INFO system. Figure 1.5.2 shows the LUDA land use map of the study area.

1.5.2.3 - Street Layer (DIME file/Tiger LINE file)

The street coverage may be obtained from the 1980 DIME file or the 1990 TIGER/LINE files which were created by the U. S. Census Bureau. The DIME/TIGER files are composed of street segment records. A segment is defined as the length of a street feature between two distinct vertices or nodes. Other features are political boundaries and topologic features (rivers, shorelines, canals, railroads, airports). Additional demographic information is also available in the attribute data. This includes state, county and standard metropolitan statistical area codes, aggregate family income, aggregate rental cost for occupied dwelling units, and numerous other demographic statistics. The data can be plotted by census tract. The source map is 1:100,000. This layer is valuable for estimating the pollutant accumulation rate and the imperviousness of the drainage basin. Figure 1.5.3 shows the street map of the study area.
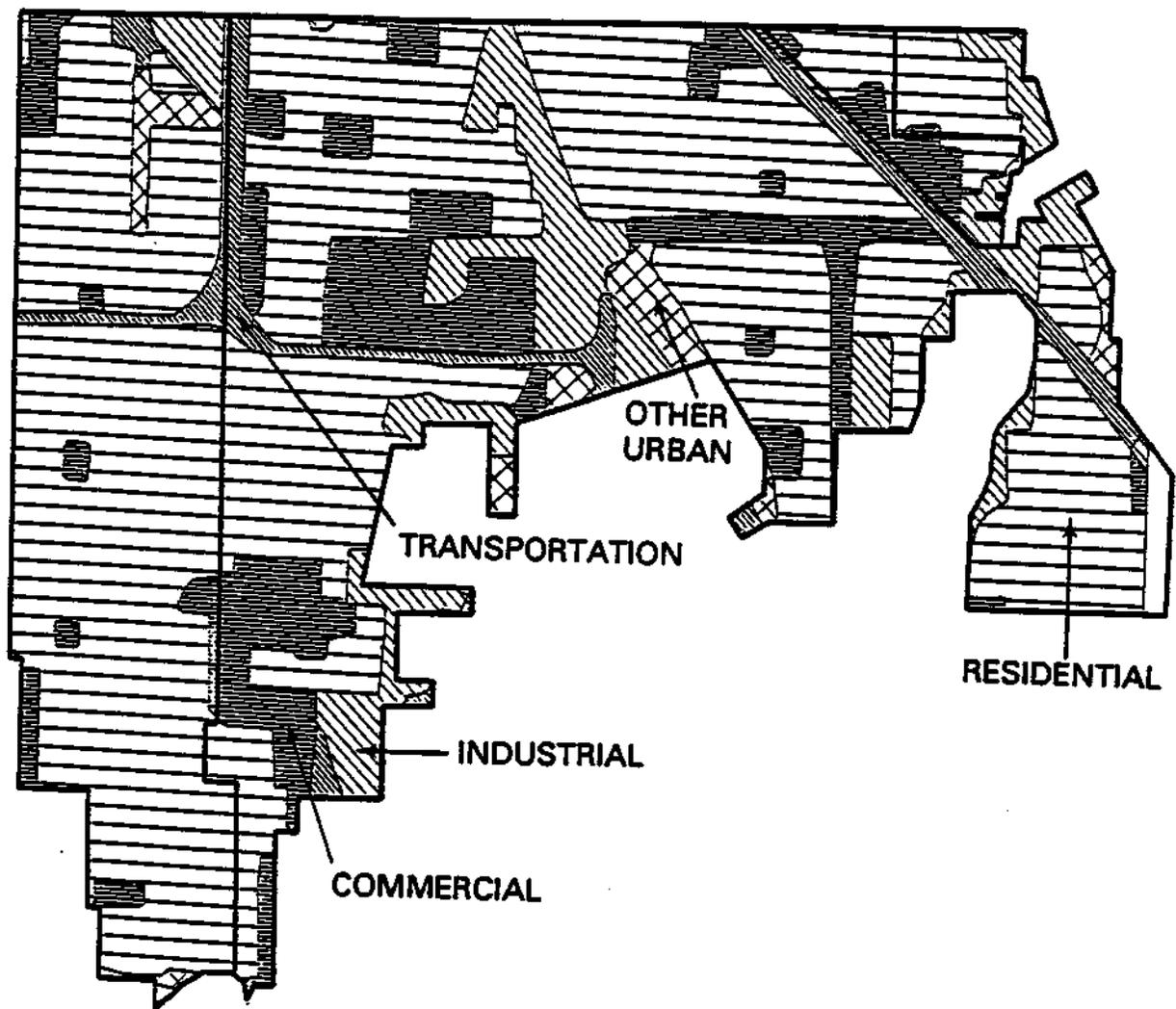
Figure 1.5.2. Land use coverage of the study area
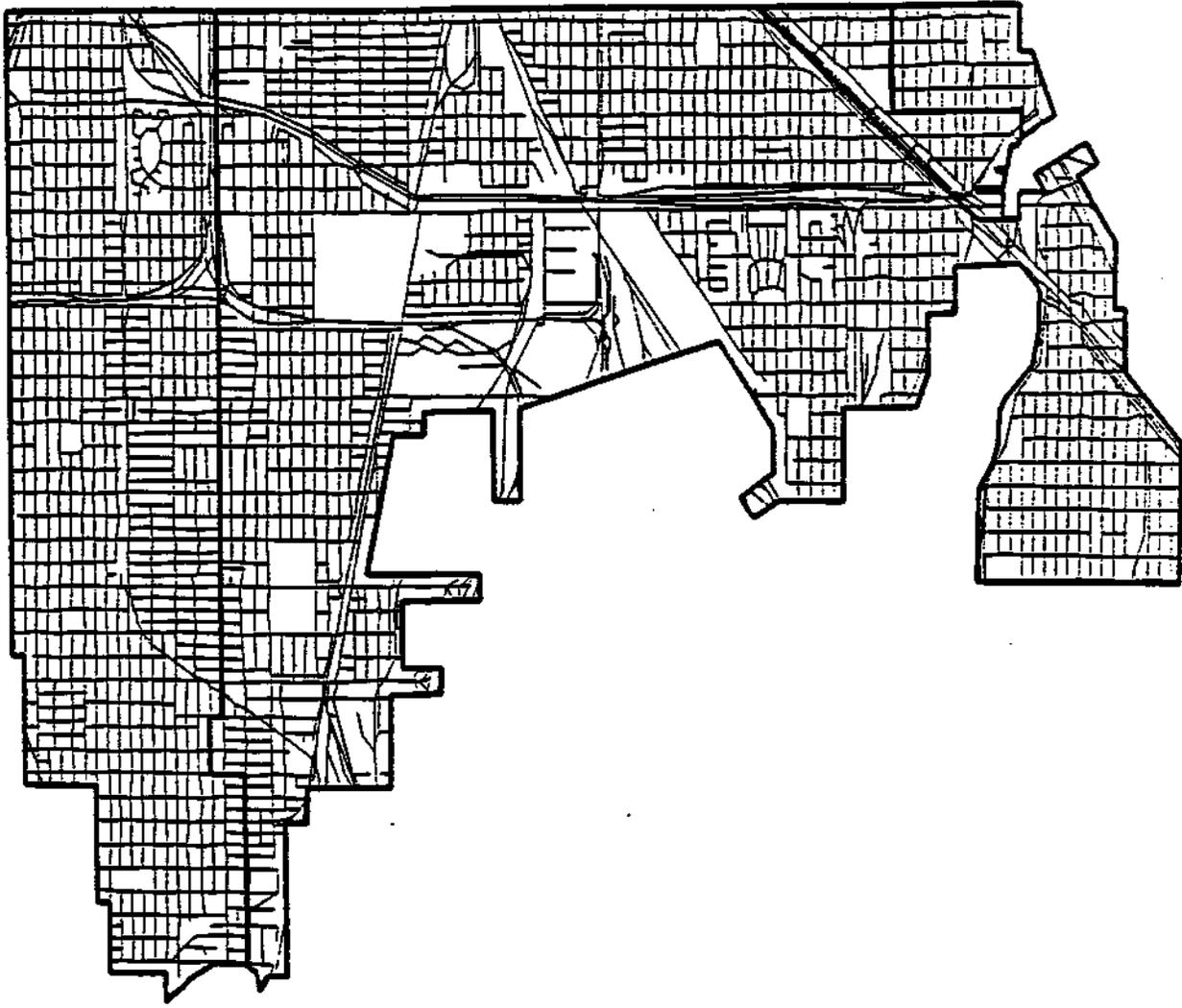
Figure 1.5.3. Street coverage of the study area

1.5.2.4 - Sewer Network

For the Greater Lake Calumet area, the sewer outfall points were identified from existing city storm sewer maps and field investigation. These maps were obtained from the City of Chicago Public Works Department. The sewer lines were highlighted, the outfall points were identified, and drainage boundaries were delineated. The maps were then digitized and attribute data were added. The source map is 1:2,400. This layer provides drainage boundaries and is also used to estimate the parameters of washoff functions.

1.5.2.5 - **Aerial Photographs**

Two sets of aerial photos were obtained for the Lake Calumet area. The positive films of the National Aerial Photographic Program series (NAPP) with the scale of 1/40,000 were purchased for the study area. The second set of photographs was the 1" = 500 ft detailed low altitude color aerial photographs which were taken for the U.S. Army Corps of Engineers, Chicago District 1987. These two sets of photographs were valuable for determining the percent of pervious and impervious areas in the drainage basin.

1.5.3 - Preparation of Input Data

Lake Calumet is currently surrounded by and receives runoff from an urban-industrial complex (Figure 1.5.1). The Lake Calumet area was subdivided into four subbasins according to the positions of the outfall points (Figure 1.5.1). The AUTO_QI model was used to determine the runoff and pollutant loading from each subbasin of the watershed. The breakdown of land use characteristics for each subbasin is given below in Table 1.5.1.

Table 1.5.1. Breakdown of Land Uses in Each Subbasin

Land uses	Land use code	Area in acres in subbasin #			
		1	2	3	4
Residential	11	2,885.52	4,257.3	163.91	193.21
Commercial	12	213.15	1,361.15	111.72	6.37
Industrial	13	83.33	1,016.65	50.51	82.55
Transportation	14	131.80	439.39	0.00	0.00
Other urban or built-up area	17	93.54	53.59	0.00	0.00
Deciduous forest area	41	11.84	29.00	0.00	0.00
Nonforest	62	0.00	124.29	0.00	0.00
Barren	76	0.00	35.04	0.00	0.00
Total		3,419.18	7,319.41	326.14	282.13

The soil of the Lake Calumet area is thick, sandy, Wisconsinan outwash and Aeolian materials (Agricultural Experiment Station, 1982). This type of soil has a moderate infiltration rate and drainage capacity and therefore is of hydrologic class B.

1.5.4 - Runoff Simulation

The land use categories and the related soil parameters used for the study area are shown in Table 1.5.2.

Table 1.5.2. Different Land Use Parameters

Land use	Land use code	%PA	%SPA	DEPI (inches)	DEPG (inches)
Residential	11	15	10	.1	.1
Commercial	12	60	5	.1	.1
Industrial	13	35	0	.1	.1
Transportation	14	80	1	.2	.1
Other urban	17	20	1	.2	.2
Forest	41	2	0	.25	1.0
Barren	76	2	0	.25	.2

%PA is paved area in percent
%SPA is supplemental paved area in percent
DEPI is impervious depression storage depth
DEPG is pervious depression storage depth

The runoff was simulated for each subbasin for rainfall in years 1955, 1959 and 1971. Thirty-seven inches of rainfall in 1959 has approximately 25% chance of exceedence; 32.5 inches of rainfall in 1955 has approximately 50% chance of exceedence; and 29 inches of rainfall in 1971 has approximately 75% chance of exceedence (Neely and Heister, 1987).

A summary of the simulated rainfall/runoff ratios for various subbasins is shown in Table 1.5.3.

Table 1.5.3. Rainfall-Runoff Ratios for the Greater Lake Calumet Area

Year	Total rainfall (inches)	Annual rainfall /runoff ratio for subbasin #			
		#1	#2	#3	#4
1955 (Average)	32.5	.159	.30	.323	.27
1959 Wet year)	37	.15	.282	.308	.255
1971 (Dry year)	29	.146	.277	.30	.25

The annual average rainfall-runoff ratios range from 15 to 30 percent. The higher rainfall-runoff ratios are mainly due to larger percentages of land uses in commercial, industrial, and transportation categories which have a high percent of imperviousness. The majority of runoff was contributed from the paved areas.

1.5.5 - Water Quality Simulation

The water quality parameters for each land use were assumed to be the same as the parameters that were used for verification in the Boneyard Creek basin in Urbana. The parameters are presented in Table 1.5.4.

Table 1.5.4. Water Quality Parameters

Chemical const.	ARi (lb / acre / day)	ARp (lb / acre / day)	RRi (percent)	RRp (percent)
For residential land use:				
Suspended solids	7.6300	3.9900	4.50	4.50
Phosphorus	0.0100	0.0053	6.00	5.00
Lead	0.0106	0.0053	4.00	3.00
For commercial land use:				
Suspended solids	9.5500	5.5500	4.50	4.50
Phosphorus	0.0085	0.0040	6.00	5.00
Lead	0.0075	0.0025	4.00	3.00
For industrial land use:				
Suspended solids	8.3300	6.0000	4.50	4.50
Phosphorus	0.0100	0.0055	6.00	5.00
Lead	0.0125	0.0055	4.00	3.00
For transportation land use:				
Suspended solids	8.0000	4.7500	4.50	4.50
Phosphorus	0.0075	0.0040	6.00	5.00
Lead	0.0250	0.0150	4.00	3.00

ARi is the Accumulation Rate for impervious area
RRi is the Removal Rate for impervious area
ARp is the Accumulation Rate for pervious area
RRp is the Removal Rate for pervious area

The pollution accumulation rates for total suspended solids increase from residential areas to commercial and industrial areas. The lead accumulation rate for the transportation area was assigned about two-fold higher than that of the residential areas.

Subbasins 1 and 2 discharge to the Little Calumet River and subbasins 3 and 4 discharge to the Calumet River as shown in Figure 1.5.1. Table 1.5.5 shows the loadings discharging to the Little Calumet River (subbasins 1 and 2). Table 1.5.6 shows the loadings discharging to the Calumet River (subbasins 3 and 4).

Table 1.5.5. Summary of Pollutant Loadings to the Little Calumet River
(Subbasins 1 and 2)*

Year	Constituent	Yearly total load 1000 lb	Average EMC(mg/l)	Max event* load 1000 lb
1955	Suspended solids	3,644.2	369.0	252.0
	Phosphorus	6.6	0.5	2.3
	Lead	6.4	0.5	0.9
1959	Suspended solids	2,904.9	440.0	205.0
	Phosphorus	5.9	0.8	1.4
	Lead	5.3	0.7	0.6
1971	Suspended solids	3,646.0	373.8	366.0
	Phosphorus	5.0	0.8	.69
	Lead	5.9	0.6	.60

* Drainage area: 10,172 acres (15.9 sq mi)

Table 1.5.6. Summary of Pollutant Loadings to the Calumet River
(Subbasins 3 and 4)*

Year	Constituent	Yearly total load 1000 lb	Average EMC(mg/l)	Max event* load 1000 lb
1955	Suspended solids	437.24	412.0	21.34
	Phosphorus	0.77	0.6	.19
	Lead	0.63	0.5	.08
1959	Suspended solids	352.55	488.0	19.00
	Phosphorus	.70	0.9	.10
	Lead	.54	0.7	.04
1971	Suspended solids	436.10	417.0	31.30
	Phosphorus	.58	0.8	.06
	Lead	.58	0.7	.05

* Drainage area: 793 acres (1.23 sq mi)

At the Little Calumet River outfall points, as shown in Table 1.5.5, the average annual total suspended solids loadings range from 2,904,000 to 3,646,000 pounds. These amounts are equivalent to about 0.17 tons per acre. At the Calumet River outfall points as shown in Table 1.5.6, the average

annual total suspended solids loadings range from 352,000 to 437,000 pounds. This is equivalent to about 0.27 tons per acre, which is higher than that of the Calumet outfall points. This can be attributed to the higher percent of impervious areas in the commercial and industrial land-use areas. For comparative purposes, this amount is slightly lower than suspended sediment yields from a typical rural watershed.

The annual phosphorus loadings for the simulation for the selected three years range from 580 to 784 pounds at the Calumet River outfalls and 5,000 to 6,600 pounds at the Little Calumet River outfalls. The average EMCs range from 0.6 to 0.9 and 0.5 to 0.8 at the Calumet River outfalls and the Little Calumet outfalls, respectively.

The annual lead loadings for the simulation for the three years range from 5,300 to 6,400 pounds at the Little Calumet outfalls and 541 to 631 pounds at the Calumet River outfalls. The EMCs range from 0.5 to 0.7 mg/l at both the Little Calumet River and the Calumet River outfalls.

It is worthwhile to note that the variations of the event loadings and EMCs among the events are large. However, the variation of annual total loadings of the three-year simulation is relatively small.

1.6 - SUMMARY AND CONCLUSIONS
1.6.1 - Summary

A new comprehensive computer package was developed on the basis of the two proven models for urban water quantity/quality assessment, ILLUDAS and Q-ILLUDAS. The package consists of three main parts: (1) water quantity/quality model, called AUTO_QI, which is an abbreviation of automated Q-ILLUDAS; (2) a convenient menu system called QIMENU for preparing and editing inputs, viewing the outputs, running the model and assisting users; and (3) a GIS interface called RUNIT, and other GIS processing programs.

The AUTO_QI model, which provides continuous simulation, consists of three main components: (1) HYDRO, (2) LOAD, and (3) BMP. HYDRO uses a runoff/soil moisture accounting procedure, pervious and impervious depression storage, interception, Horton infiltration curves, and water storage in the soils to generate runoff volumes for each event in the record. LOAD is the water quality simulator which uses the output from HYDRO along with the pollutant accumulation and exponent washoff functions to

generate loads and EMCs. BMP is the best management practices simulator which handles numerous separate or overlapping best management practices and produces the model output. The impacts of pollution reduction may be simulated at multiple stormwater outfall points. The results can be viewed at one outfall point or multiple outfall points.

QIMENU aids users with preparation of input files, selection of parameters, running the model, testing the BMPs and viewing the output.

The GIS interface uses the ARC macro language (AML) and automates the generation of the major input files for AUTO_QI. It also provides the user with a menu driven program to review GIS coverages on the screen.

The model was verified by using data from the Boneyard Creek drainage basin in Urbana, Illinois. Three sets of rainfall data were selected to represent wet, average and dry years. The input data consist of daily and hourly rainfalls, percent impervious and supplemental paved areas, depression storage, initial and final infiltration rates, gravitational and evapotranspiration soil storage, pollution accumulation and removal rate, and washoff factor. The outputs were compared with the observed data for the Boneyard Creek basin. The results indicated that the model performed well for runoff volume. The simulations of pollutant loadings using the uncalibrated model were poor and indicate the need for further testing and calibration.

After the verification process in the Boneyard Creek basin, the model was used to simulate the Greater Lake Calumet Basin. Four subbasins were delineated based on the storm sewer maps obtained from the Chicago Public Works Department. Three sets of one-year rainfall data were selected to present the wet, average, and dry years. The input data were prepared to present the local conditions for each land use. The model was run for all the rainfall events which had rainfall exceeding 0.1 inches.

The results indicated that the annual average runoff-rainfall ratios varied from 15 to 30 percent. The land use with high imperviousness generated higher runoff-rainfall ratios, which was as expected. The annual total suspended solids loadings for all three years ranged from 352,000 to 437,000 pounds at the Calumet River outfalls and 2,900,000 to 3,644,000 pounds at the Little Calumet River. The phosphorus annual loadings ranged from 584 to 775 pounds at the Calumet River and 5,000 to 6,600 pounds at the Little Calumet River. The lead annual loadings ranged from 541 to 631

pounds at the outfalls of the Calumet River and 5,300 to 6,400 pounds at the outfalls of the Little Calumet River.

1.6.2 - Conclusions

1) An urban model (AUTO_QI) has been produced that simulates volumes of storm runoff, pollutant loading, and event mean pollutant concentrations from a continuous rainfall record and basin parameters.

2) An optional geographic information system (GIS) interface has been developed that generates the required model input files relating to land use, soils, and BMP distribution.

3) Very limited verification of the model has shown good results for runoff simulation and poor results for pollutant simulation.

4) No calibration of the model was attempted and only literature values were used for the buildup and washoff of pollutants.

5) The model was applied to the Greater Lake Calumet area, Chicago, Illinois, and pollutant loadings were generated for the Calumet River and the Little Calumet River.

6) Creation of input files for the Lake Calumet area on the geographic information system did save significant office time. Additional office time was required to automate the subbasin boundaries in the area.

7) The model and interface have the potential for generating runoff volumes and pollutant loadings from a large urban area with multiple outfalls discharging to more than one receiving water. Both annual and event loadings including maximum event loadings are determined.

8) Output from the model can be used for subsequent frequency analysis to determine the probability of various event loads.

9) The model provides for the application of multiple and overlapping BMPs and all results are shown with and without BMPs in place.

10) Observed rainfall, runoff, and pollutant loadings should be used to verify the model before application.

PART 2. AUTO_QI USERS MANUAL

2.0 - INTRODUCTION

This user's manual is intended to provide all of the information necessary for the user to create and edit the data files necessary to run AUTO_QI, run the program, and examine the output on screen and in printed form. Internal functions of the model are described in Part II, the Technical Manual.

The user is provided with Automatic Macro Language (AML) files that will generate the LU.nnn and BMPAPP.nnn files from digital information. These AMLs are specifically for use with the ARC/INFO Geographic Information System (GIS). They were developed because of the potential for great cost savings in the generation of data required to run AUTO_QI on large urban areas. The use of these AMLs is optional and a GIS is not required to run AUTO_QI.

The user interface for AUTO_QI is known as QIMENU. As the name indicates this is a series of menus and help files to assist both the experienced and novice user.

After a description of the distribution Diskettes and installation instructions, the manual will proceed through a description of the input files and menus in the same sequence as the user would to complete a run of the program.

A "Shareware" utility is included with the AUTO_QI package as an option for the user to examine. It is called LIST, a program that provides a convenient method to list, scroll, and read input or output files. Many users will already have a similar program on their system and may disregard this utility. If the user likes LIST and decides to keep it, he or she should comply with the on-line instructions and send an appropriate payment to the developer. Payment for LIST was not included in the payment for AUTO_QI.

2.1 - PROGRAM CAPABILITIES

AUTO_QI is designed to provide quasi-continuous simulation of runoff volume, pollutant load, and event mean concentration

from urbanized watersheds. Soil moisture simulation is continuous on a daily basis but only individual events above a user specified base rainfall are selected for runoff simulation. The simulation may include various Best Management Practices (BMPs). In this case, output will show pollutant levels with and without BMPs in place. Neither peak runoff values nor hydrograph shapes are simulated, only total runoff volume for each selected event.

The basin being simulated may be divided into a number of subcatchments, but the descriptive values such as land use and BMP areas are lumped within each subcatchment. The outputs for each subcatchment may be combined to simulate the total loadings to a given receiving water.

Pollutant loadings are simulated by using exponential accumulation and washoff functions on the impervious and pervious surfaces of the watershed. As such, the user may specify any pollutant for which accumulation and washoff rates are available. These factors are not provided by the model.

Any BMP may be specified by the user if removal efficiency is known by pollutant and land use. These removal efficiencies are not provided by the model.

2.2 - GENERAL CONCEPTS

Several files are required to run AUTO_QI. These may be considered in three groups: rainfall files covering the simulation period, basin description files that apply to the entire basin under consideration, and subcatchment files describing features that apply to individual subcatchments. The file names must be exactly as shown for each run.

RAINFALL DATA - DARAIN.DAT, HRRAIN.DAT
The program requires a file of daily rainfall (DARAIN.DAT) and a corresponding file of hourly rainfall values (HRRAIN.DAT). The daily rainfall file must contain one daily value in inches for each day of the maximum desired simulation period. The hourly rainfall file must contain 24 hourly values for each non-zero rain day in the daily rainfall file. If the daily rainfall was zero, there are no hourly values provided for that day.

BASIN FILES - BASIN.DAT, BMPEFF.DAT, EVAP.DAT
SOIL.DAT, WQLIST.DAT - These files, which will be described
in detail below, include BASIN.DAT which selects the rainfall
period and assigns a title to the run.   The BMPEFF.DAT file
describes BMP effectiveness.   EVAP.DAT provides monthly
evaporation and evapotranspiration values.   Infiltration param-
eters for basic soil types are provided in EVAP.DAT, and
WQLIST tells the model which pollutants will be simulated.

SUBCATCHMENT FILES - BMPAPP.nnn, LU.nnn, WQ.nnn
One each of these files is required for each of the subcatchments.
The value of "nnn" is the subbasin index or ID number.   The
BMPAPP.nnn file describes the extent of BMP application
within each land use.   LU.nnn describes the land use
parameters and soils, and WQ.nnn describes the buildup and
washoff characteristics of each pollutant.

2.3 INSTALLATION
2.3.1 HARDWARE REQUIREMENTS
AUTO_QI is designed to run on a PC or AT compatible computer
with an IBM or EPSON compatible printer connected to LPT1.
Either a color or monochrome monitor may be used.   The
program will run from a floppy disk, but a hard disk is highly
recommended.   Memory should be at least 512K   The program
can be very time consuming if a large number of subbasins or
storms are used in the simulation.   A fast 286 or 386 machine is
preferred.

2.3.2 DISTRIBUTION DISKETTES
The four distribution DISKETTES provided as part of the
AUTO_QI package include the following files:

SYSTEM DISKETTE
The actual AUTO_QI program provided as compiled FORTRAN
files and optional utilities:
HYDRO.EXE
LOAD.EXE
BMP.EXE

MENU DISKETTE
The primary user interface and data editing programs:
QIMENU.EXE   LIST.COM
QIMENU.HLP
QIMENU.INI

SAMPLE DATA DISKETTE
The required data files for a small sample basin with 3 subcatchments:

BASIN.DAT	LU.001	BMPAPP.001	WQ.001
BMPEFF.DAT	LU.002	BMPAPP.002	WQ.002
DARAIN.DAT	LU.003	BMPAPP.003	WQ.003
HRRAIN.DAT			
EVAP.DAT			
SOIL.DAT			
WQLIST.DAT			

ARC/INFO AML DISKETTE
These Automatic Macro Language (AML) files provide a link between the ARC/INFO Geographic Information System (GIS) and the AUTO_QI program. A description of these files and use of the GIS interface will be presented in a separate section of the manual.

2.3.3 - SETUP

Before installing the program make a copy of the distribution DISKETTES. Set the original distribution DISKETTES aside for safe keeping and use the copies for installation.

It will be assumed that the user will be operating from a hard disk and has some knowledge of DOS commands.

It is suggested that the QIMENU files be stored in one directory and the SYSTEM Files and SAMPLE DATA together in a separate directory. The SYSTEM and SAMPLE DATA must reside in the same directory.

1. Create the main directory (md\AUTO_QI) and move to it (cd\AUTO_QI).

2. Insert the MENU diskette into drive A: and copy all of the files to the main directory (copy a:*.* c:).

3. Create a sub-directory for the input data (md\AUTO_QI\QITEST) and move to that directory (cd\AUTO_QI\QITEST).

4. Insert the SYSTEM diskette into drive A: and copy all of the program files to the main directory (copy a:*.* c:).

5. Insert the SAMPLE DATA diskette into drive A: and copy all of the files to the data sub-directory (copy a:*.* c:).

6. Run the program from AUTO_QI directory by typing QIMENU.

The ARC/INFO AML diskette will not be copied to the PC.

2.4 - DATA PREPARATION

This section will describe the preparation of data using the sample problem data provided as an example. It is assumed that the user is preparing the data "manually" rather than with the assistance of a GIS. Use of the GIS will be described in a later section.

2.4.1 - SAMPLE BASIN

The following figures show the FOX Basin for which data in this section and on the SAMPLE DATA diskette were prepared. The first figure shows the subbasin boundaries and names and the second figure shows the distribution of best management practices.
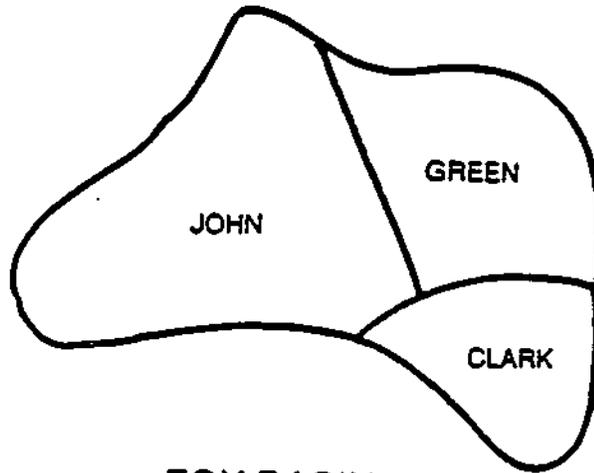
FOX BASIN

SUBBASIN BOUNDARIES
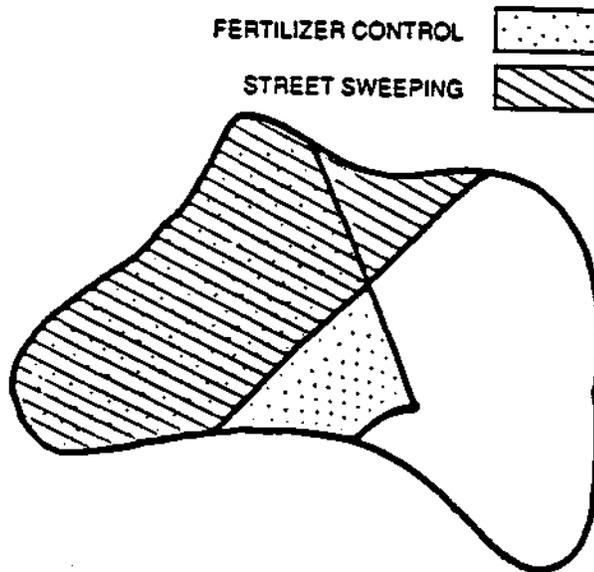
FOX BASIN

BEST MANAGEMENT PRACTICES

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The following physical features were determined for the FOX Basin (363 total acres) and were used to compile the SAMPLE DATA.

Subbasin ID	1	2	3
Subbasin Name	CLARK	GREEN	JOHN
Residential (acres)	0	62	196
Commercial (acres)	40	42	0
Industrial (acres)	23	0	0
TOTAL (acres)	63	104	196

Land Use	Area	Imp acres	Supp %	Soil %
SUBBASIN #1 - CLARK STREET				
Commercial	40	80	10	5
Industrial	23	40	20	5
SUBBASIN #2 - GREEN STREET				
Residential	62	30	10	4
Commercial	42	60	20	3
SUBBASIN #3 - JOHN STREET				
Residential	100	40	20	3
Residential	96	50	20	5

2.4.2 - BASIN-WIDE FILES

2.4.2.1 - GENERAL BASIN DATA - BASIN.DAT
This file is most easily created by modifying an existing file, such as the one provided in the SAMPLE DATA.

BASIN DESCRIPTION
The first line in this menu may contain any information the user wishes to identify the resulting output. The information will appear on all screen and printed output.

START DATE
This is the starting date of the simulation. It is imperative that this date fall within the range of data provided in the daily rainfall file DARAIN.DAT.

END DATE
This is the last date of the simulation period. This date must lie within the range of data provided in DARAIN.DAT.

MINIMUM RAINFALL
This value is the minimum rainfall in inches below which an event simulation will not occur. If you wish to simulate only those events for which the rainfall was at least one half inch, enter 0.5 here.

NUMBER AND NAME OF **SUBBASINS**
These values come from the BASIN menu described below.

FORMAT: **A80/2I7/F7.3/A15/I2**
       A20 (for each subbasin)

SAMPLE DATA:

```
    SAMPLE BASIN - CLARE, GREEN, & JOHN
    060188 063088
     .20
    EVAP.DAT
     3
CLARK STREET
GREEN STREET
JOHN STREET
```

2.4.2.2 - PRECIPITATION

The program will only accommodate one rainfall record. If it is desired to use more than one gage record the user must prepare a weighted rainfall record. All precipitation will be treated as rainfall since the program does not provide a snow melt routine.

The user may decide to use a single rainfall event or a series of events comprising some portion of an historical or simulated period of record. In either case, both a daily rainfall file (DARAIN.DAT) and an hourly rainfall file (HRRAIN.DAT) must be present.

DAILY RAINFALL - DARAIN.DAT

A minimum of one month of daily rainfall values is required in the DARAIN.DAT file using the following format.

FORMAT: **12F6.2/12F6.2/7F6.2** (for each month)

SAMPLE DATA: It is suggested that the month and year be included at the end of the first line of each month's data as shown in the sample data. This is not required by the program but facilitates editing of the data.

```
0.00  0.00  0.00  0.00  1.50  0.00  0.00  0.00  0.00  0.50  0.00  0.00  6/88
2.50  0.00  0.00  0.00  0.00  0.00  0.00  0.00  0.00  0.00  0.00  0.00
0.00  0.00  0.00  0.00  0.00  0.00  0.00  0.00  0.00  0.00  0.00  0.00
```

HOURLY RAINFALL - HRRAIN.DAT

There are three rules for compiling the hourly rainfall file (HRRAIN.DAT). One, there must be hourly rainfall presented for each non-zero rain day in the daily rainfall file. Two, there must be 24 hourly values for each non-zero rain day. Three, no hourly rainfall may be presented for a zero rain day in the daily file.

FORMAT: **12F6.2/12F6.2** (for each day)

SAMPLE DATA: It is suggested that the date be included at the end of the first line of each day's data as shown in the sample. This is not required by the program but facilitates editing of the data.

```
.0   .0   .0   .0   .0   .5   .8   .2   .0   .0   .0   .0   6/05
.0   .0   .0   .0   .0   .0   .0   .0   .0   .0   .0   .0
.0   .0   .0   .2   .3   .0   .0   .0   .0   .0   .0   .0   6/10
.0   .0   .0   .0   .0   .0   .0   .0   .0   .0   .0   .0
.0   .0   .7   .8   .3   .3   .3   .1   .0   .0   .0   .0   6/13
.0   .0   .0   .0   .0   .0   .0   .0   .0   .0   .0   .0
```

2.4.2.3 - WATER QUALITY LIST - WQLIST.DAT

The user should determine and list here the chemical constituents that are required by the simulation. Any constituent may be used for which the user is able to specify the daily accumulation and washoff rate and the removal rate by any BMPs to be used. The model is most reliable for those constituents which are related to suspended solids. Those constituents which are to a large extent dissolved are most subject to question. In any case, it is always desirable to verify the model with real data.

The list of constituents provided here must be the same as that specified later in the BMP Removal Efficiency file and the Water Quality File.

FORMAT: **I2**
            A20 (for each constituent)

SAMPLE DATA:

      3
       SUSPENDED SOLIDS
       NITROGEN
       LEAD

2.4.2.4 - **EVAPORATION - EVAP.DAT**
Evaporation pertains to evaporation from free water surfaces such as standing water on impervious and pervious areas. Typical value for Illinois: 36 inches per year. Evapotranspiration is the combined process of evaporation and transpiration, where transpiration refers to the passage of soil water through the plant system and its vaporization into the atmosphere. Evapotranspiration depletes moisture from the soil. Typical growing season values for corn: 3-5 inches per month.

EVAP.DAT of the SAMPLE DATA provided with the AUTO_QI package and listed below shows typical values for central Illinois. The topic is also discussed in more detail in Appendix A.

For further information and formulas to calculate evaporation and evapotranspiration, see "Agricultural Engineers' Handbook," by C.B. Richey, editor-in-chief, McGraw-Hill, 1961.

FORMAT: **12F6.2 (12 monthly ET values)**
12F6.2 (12 monthly Evap values)

SAMPLE DATA:

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
(Headings are not part of the data)
1.10	1.37	3.10	5.10	6.82	7.80	8.06	6.82	5.40	3.72	2.10	1.16
0.94	1.17	2.34	5.06	6.19	7.30	6.78	6.02	4.47	2.74	1.80	0.99

2.4.2.5 - SOIL - SOIL.DAT
An important function in the model as part of the HYDRO program is the simulation of soil moisture and the resultant infiltration losses. One line is required for each soil classification. The required parameters are defined below.

F_O - The initial infiltration rate (in./hr) in the Horton equation.

F_C - The final infiltration rate (in./hr) in the Horton equation.

Emax - The amount of storage available in the soil mantle for evapotranspiration water in inches.

Gmax - The amount of storage available in the soil mantle for gravitational water in inches.

Further information on these parameters is available in Appendix B. For a more detailed description of the above terms see also "The Illinois Urban Drainage Area Simulator, ILLUDAS," by Michael L. Terstriep and John B. Stall, Bulletin 58, Illinois State Water Survey, Urbana, 1974.

FORMAT: **20X/20X**
          10X, 4F7.4 (for each soil type)

SAMPLE DATA: The first line of table headings and the following blank line are required.

SOIL TYPE	FO	FC	EMAX	GMAX
1	10.000	1.000	2.700	12.600
2	9.000	0.750	3.410	11.050
3	8.000	0.500	4.120	10.500
4	6.500	0.375	5.000	7.650
5	5.000	0.250	5.100	4.800
6	4.000	0.175	4.650	4.650
7	3.000	0.100	4.200	4.500

2.4.2.6 - BMP REMOVAL EFFICIENCY - BMPEFF.DAT

The program always assumes that BMPs will be considered as part of the analysis. These may be proposed for evaluation, or they may be existing practices that must be included in the simulation if reasonable results are expected. The list of BMPs should be determined prior to coding any data, and the list of BMPs provided here must be the same as that specified in the Water Quality File and the BMP Application File.

For typical values see "Controlling Urban Runoff: A Practical Manual for Planning and Designing Urban BMPs," Dept. of

Environmental Programs, Metropolitan Washington Council of Governments, 1987.

The file contains the number of BMPs to be used followed by a line for each BMP and its anticipated removal rate in percent for each chemical constituent and in the same order as shown in the Water Quality Constituent file.

FORMAT: **I2**
         A20,10F4.2 (for each BMP)

SAMPLE DATA:

```
 2
STREET SWEEPING          .30      .15      .20
FERTILIZER CONTROL       .0       .25      .00
```

2.4.3 - SUBBASIN FILES

The preceding files were applicable to the entire basin and must therefore also be appropriate for each subbasin. The following three files accessed from the lower portion of the MAIN - DATA portion of the menu describe specific aspects of each subbasin. There must be one of each of these 3 files for each subbasin.

2.4.3.1 - LAND USE - LU.nnn

The land use file contains the number of land uses in the specific subbasin and a line of data describing each land use. The legal land uses are limited to those included in the USGS LUDA Level II Land Use Codes. A list of these is provided in Appendix D. The list of land uses must also be compatible with those in the following Water Quality File and BMP Application File. Definitions of the variables on each line of the file follow.

CODE - The Level II Land Use Code as defined in the USGS LUDA data. These codes are used for convenience with the GIS interface which uses the LUDA data.

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DESCRIPTION - The description of the CODE. Not an input field; it is supplied automatically when a CODE is entered.

%IMP - The percentage of the current subbasin that is impervious and directly connected to the drainage system, such that runoff is not subject to infiltration losses.

%SUPP - The percent of the current subbasin that is impervious but from which runoff is subject to infiltration losses. An example would be rooftop runoff that flows across grassed areas before reaching the drainage system.

DSi - The depression storage depth available on the impervious area. This depth is subtracted from rainfall before producing any runoff. Typical value: 0.1 inch.

DSp - The depression storage depth available on the pervious area. This storage must be maintained by rainfall before runoff can occur. Typical value: 0.2 inches.

AREA - The total area of the current subbasin in acres.

SOIL - The U.S. Soil Conservation Service hydrologic soil group. Conventional values are: A, AB, B, BC, C, CD, and D. These values were referred to as 1 through 7 in the input data code.

%MOIST - The percentage saturation in the soil at the start of the simulation.

FORMAT: **I2**

        I2,A20,4F4,F10.2,I2,F4.2

         (for each land use)

SAMPLE DATA:

LUDA		IMP	Supp	DS_i	DS_p	Area	Soil	Moist.
(Headings are not part of the data)								
2								
11	**"Residential"**	**.30**	**.10**	**.10**	**.20**	**82.00**	**4**	**.5**
12	**"Commercial"**	**.60**	**.20**	**.10**	**.20**	**22.00**	**3**	**.5**

2.4.3.2 - WATER QUALITY - WQ.nnn

The water quality file contains information about the buildup and washoff of pollutants for each constituent to be simulated for each land use in the specific subbasin. Values of the various parameters shown in the sample data are compiled from various sources including "Storm Water Management Model," U.S. Environmental Protection Agency, 1971. Additional information is also presented in Appendix C. These parameters are highly variable and should be determined by verification of the model with real data. Definitions of the parameters are as follows:

ARi - The daily pollutant accumulation rate on the impervious area. (lb/acre/day)

ARp - The daily pollutant accumulation rate on the pervious area. (lb/acre/day)

RRi - The pollutant removal or decay rate from the impervious area. (%)

RRp - The pollutant removal or decay rate from the pervious area. (%)

Pi - The pollutant load on the impervious area at the beginning of the simulation. Gb/acre)

Pp - The load in the pervious area at the beginning of the simulation. (lb/acre)

EXPi - The shape factor in the exponential washoff equation for the impervious area. A typical value is 4.6 assuming that 90 percent of the pollutant should be washed off by 0.5 inches of rainfall.

EXPp - The shape factor in the exponential washoff equation for the pervious area. A typical value is 1.4 assuming that 50 percent of the pollutant would be washed off by 0.5 inches of rainfall.

FORMAT: **8F7.4** (for each constituent, the number of lines in the file will be the number of land uses times the number of soils)

SAMPLE DATA: The land uses and water quality constituents must be compatible with their use in related files. Although not used by the program, it is advisable to add the land use at the end of the first line of each land use sector to aid in data editing.

SAMPLE DATA:

AR_i	RR_i	AR_p	KR_p	P_i	P_p	EXP_i	EXP_p	
			(Headings not part of data)					
2.3100	.0500	1.1600	.0450	6.9300	3.4800	4.6000	1.4000	RESIDENTIAL
.0142	.0600	.0070	.0500	.0526	.0210	4.6000	1.4000	
.0030	.0300	.0015	.0300	.0090	.0045	4.6000	1.4000	
10.000	.0450	5.0000	.0450	30.000	15.000	4.6000	1.4000	COMMERCIAL
.0100	.0600	.0060	.0500	1.0000	1.0000	4.6000	1.4000	
.0100	.0300	.0050	.0300	.0300	.0150	4.6000	1.4000	

2.4.3.3 - BMP APPLICATION - BMPAPP.nnn

This file is most easily created by modifying an existing file using QIMENU. It provides information to the program about the distribution of BMPs in each of the subbasins. There may be no BMPs in a given subbasin or multiple BMPs that may or may not overlap. The SAMPLE PROBLEM has examples of both of these situations in a simple configuration of 3 subbasins and 2 BMPs.

Each subbasin is divided into regions with each region described by a distinct land use. An example subbasin is shown below:

```
═══ Edit BMP Application File - BMPAPP.002 ═══
                        Pct of Land Use in Sector for Land Use:
    BMPs in Sector:     11  12

    ┌─────────────────────────────────────────────────────┐
    │  1                 51   0                            │
    │  --                49 100                            │
    │                                                      │
    │                                                      │
    └─────────────────────────────────────────────────────┘


    11 Residential
    12 Commercial


    Enter   Modify entry      Ins    Insert entry
                              Del    Delete entry
```

Now consider the distribution of BMPs in the subbasin. Each BMP can be applied on any portion of the basin. A BMP may cover only part of Land Use #1 or it may cover parts of all three land uses. In addition, in cases when more than one BMP is being applied, the BMPs may overlap, as the following diagram illustrates:

BMP #1   BMP #2

BMP #2 & #3   NO BMP
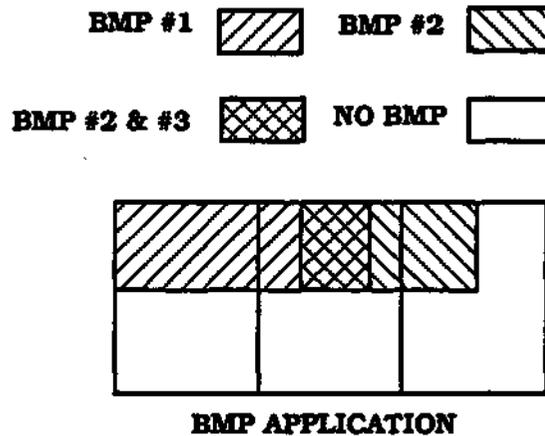
BMP APPLICATION

Each line in the BMP Application File is a unique combination of one or more BMPs called a sector. In this example there are four sectors: one is the region covered by BMP #1; another is covered by BMP #2; the third is covered by BMPs 1 and 2; and the fourth has no BMPs. There must be a line in the BMP Application File (BMPAPP.nnn) for each sector in the subbasin.

One way to visualize sectors is to think of them as pieces of dough cut by a cookie cutter. Roll the dough out into the shape of the subbasin. Now take a cookie cutter in the shape of BMP #1, and cut (but do not remove) the area covered by BMP #1. Now cut a region in the shape of BMP #2. Remember the two cutouts can overlap. Repeat this process for each BMP. When you have cut all the BMP regions, separate the individual pieces. Each piece represents a sector.

In the above example, BMP #1 was cut, then BMP #2. The first sector is the piece of dough from BMP #1 which was not also cut

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by BMP #2. The second sector is the piece of dough cut by BMP #2 which was not also cut by BMP #1. The third sector is the intersection of the dough cut by BMPs 1 and 2. Finally, the fourth sector is the dough which remains after the cutting, that not covered by either BMP 1 or 2.

Each sector, or line, contains an entry for each land use. This entry is the percentage of the land use which is covered by the sector. For instance, if sector one occupies 35% of land use 1, then a 35 will appear in land use 1's entry for the sector. Here is a sample BMP Application file:

. PERCENT OF LAND USE

SECTORS	LU#1	LU#2	LU#3
1	50	40	0
2	0	35	25
1&2	0	25	0
NO BMP	50	50	75
TOTAL	100	100	100

Looking at the column for LU#2 and the previous diagram, BMP #1 occupies $40% of land use #2, BMP#2 occupies 35%, BMPs #1 and #2 overlap on 25%, and 50% is covered by no BMP. The numbers in each column must add to 100%.

FORMAT: **Free Format** (BMP and % of each land use under that BMP separated by blank spaces)

SAMPLE DATA:

1	.51	.00	1	0
2	.49	1.0	0	0

2.5 - QIMENU

After installation is complete, start the user interface by typing **QIMENU** and pressing ENTER. After the disclaimer statement, the *MAIN* Menu shown below will appear.

2.5.1-MAIN MENU
Basin Data Run Output Misc   Fl=Help eXit

The menu items will be discussed from left to right. To access these items, scroll to the desired item with the arrow keys and press ENTER or press the first letter of the desired item.

2.5.2-BASINMENU

```
┌══════ Edit Subbasin List - BASIN.DAT ══════┐
│                                            │
│   Index  Description                       │
│  ┌──────────────────────────────────────┐  │
│  │   1    CLARK STREET                   │  │
│  │   2    GREEN STREET                   │  │
│  │   3    JOHN STREET                    │  │
│  │                                       │  │
│  │                                       │  │
│  │                                       │  │
│  │   .                                   │  │
│  └──────────────────────────────────────┘  │
│ ─────────────────────────────────────────  │
│  Enter  Modify entry      Ins   Insert entry│
│                           Del   Delete entry│
└════════════════════════════════════════════┘
```

The *BASIN* Menu is used to edit the list of subbasins found in the basin. Each record (line) in the Menu is a subbasin index and its associated description. The index number will be required later to select the current subbasin in the *DATA* Menu and in the *RUN* Menu.

Subbasin descriptions can be modified by pressing the Enter key. Modify the description using the usual editing keys (press F2 for a complete list), and press Enter to accept the changes or Escape to discard them.
To insert a new subbasin, press the Insert key. The initial value will be that of the subbasin just below the current one. Simply modify the line and press ENTER to accept the new subbasin or

ESC to discard it. Press DEL to delete the current subbasin. You will be asked to confirm your decision. The indexes associated with the descriptions are automatically renumbered after insertions and deletions.

To exit the subbasin list editing screen, press ESC. If you accepted changes to any of the lines or inserted or deleted any lines, the data will be written out to disk and a message notifying you of this will appear. This menu provides a list of subbasins on which the simulation may be run. It also determines the range of legal subbasin index values for the "Current Subbasin" in the *DATA* Menu.

2.5.3-DATAMENU

```
┌─────────────────────────────────────────┐
│ Current Subbasin                  2      │
├─────────────────────────────────────────┤
│ Datafiles Path                           │
│ ──────── Basin-Wide Files ────────       │
│ General Basin Data                       │
│ Daily Rain Data                          │
│ Hourly Rain Data                         │
│ Water Quality Constituents               │
│ Evaporation Data                         │
│ Soil Data                                │
│ BMP Removal Efficiency Data              │
│ ──────── Files for SubBasin 2 ────────   │
│ Land Use Data                            │
│ Water Quality Data                       │
│ BMP Application Data                      │
└─────────────────────────────────────────┘
```

The *DATA* Menu provides access to all of the required *.DAT files and *.nnn files except the BASIN.DAT file described above and the rainfall files DARAIN.DAT and HRRAIN.DAT to be described later. Any of the files that can be accessed from within *DATA* may also be edited without leaving QIMENU.

2.5.3.1 - DATA, CURRENT SUBBASIN

The value of the "Current Subbasin" is the current subbasin index and will determine which subbasin specific files are selected for editing. Press ENTER to change the value of the current subbasin and ENTER again to accept the value or ESC to reject. The "Current Subbasin" must be one of the subbasins listed in the BASIN.DAT file described above.

To choose from a list of available subbasins and their associated descriptions, enter a value of zero. You will be told that the value is illegal. Press Enter and a scrollable list of subbasins will appear. Use the arrow keys to move to the one you wish to select, then press ENTER. The number will appear in the edit box automatically. Selecting from this list insures a legal value.

2.5.3.2 - DATA, DATAFILES PATH

DATAPATH FILES identifies the drive and directory in which the input data files for QIMENU can be found. Scroll to this option and press ENTER or press "D". A new line will be displayed showing the current path. Make sure that this line may be edited if necessary to identify the correct path name.

2.5.3.3 - DATA, GENERAL BASIN DATA - BASIN.DAT

```
══════════════ General Basin Data File - BASIN.DAT ═════════════
 Basin Description:  SAMPLE BASIN - CLARK, GREEN, & JOHN

 Run from 06/01/88 to 06/30/88

 Minimum Rainfall Value:  .20
────────────────────────────────────────────────────────────────
  F2   List editing keys
```

The *GENERAL BASIN DATA* menu contains four pieces of data applicable to the basin. These are described above under "Data Preparation". Use TAB or arrow keys to highlight an item you wish to change. To accept any changes you've made, press

CTRL-ENTER on any of the fields or ENTER on the last field (Minimum Rainfall). To discard any changes, press ESC.

2.5.3.4 - DATA, DAILY RAIN - DARAIN.DAT

This file, DARAIN.DAT is not accessible from the menu. An external editor is required to create and edit the file. This must be a continuous sequential file of daily rainfall in inches for the longest simulation period desired.

2.5.3.5 - DATA, HOURLY RAIN - HRRAIN.DAT

This file, HRRAIN.DAT is not accessible from the menu. An external editor is required to create and edit the file. See "Data Preparation" above for details.

Having created this file, the user may select any simulation period between the first and last day of DARAIN.DAT. This is done in the *DATA* Menu under "General Basin Data".

2.5.3.6 - DATA, WATER QUALITY CONSTITUENTS - WQLIST.DAT

```
╔══════ Edit Constituent List - WQLIST.DAT ══════╗
║                                                  ║
║        Description                               ║
║     ┌─────────────────────────────┐             ║
║     │ SUSPENDED SOLIDS            │             ║
║     │ NITROGEN                    │             ║
║     │ LEAD                        │             ║
║     │                             │             ║
║     │                             │             ║
║     └─────────────────────────────┘             ║
║                                                  ║
║   ─────────────────────────────────────────     ║
║                                                  ║
║     Enter   Modify entry                         ║
║                                                  ║
╚══════════════════════════════════════════════════╝
```

Each line in the "Water Quality Constituents" file is the name of a chemical constituent. To modify the name of the current constituent, press the Enter key. Type in the new name and press ENTER to accept it or ESC to discard it.

To exit the constituent list editing screen, press ESC. If you accepted changes to any of the lines, the data will be written out to disk and a message notifying you of this will appear.

CAUTION

THIS FILE MUST CONTAIN THE SAME CONSTITUENT LIST AS BMPEFF.DAT, and WQ.nnn. THIS IS THE USER'S RESPONSIBILITY, IT IS NOT CHECKED BY QIMENU.

2.5.3.7 - DATA, EVAPORATION - EVAP.DAT

```
╔══════════════ Evaporation Data File - EVAP.DAT ══════════════╗
║                  Evapotranspiration Rates (inches)            ║
║                                                               ║
║      Jan:  1.10     Apr:  5.10     Jul:  8.06     Oct:  3.72   ║
║      Feb:  1.38     May:  6.82     Aug:  6.82     Nov:  2.10   ║
║      Mar:  3.10     Jun:  7.80     Sep:  5.40     Dec:  1.16   ║
║                                                               ║
║                                                               ║
║                    Evaporation Rates (inches)                 ║
║                                                               ║
║      Jan:   .94     Apr:  5.06     Jul:  6.78     Oct:  2.74   ║
║      Feb:  1.17     May:  6.19     Aug:  6.02     Nov:  1.80   ║
║      Mar:  2.34     Jun:  7.30     Sep:  4.47     Dec:   .99   ║
║                                                               ║
╟───────────────────────────────────────────────────────────────╢
║ F2    List editing keys                                       ║
╚═══════════════════════════════════════════════════════════════╝
```

Evaporation and evapotranspiration values must be provided for all twelve months. To accept any changes you've made to the data, press CTRL-ENTER on any of the fields or ENTER on the last field. To discard the changes, press ESC. See "Data Preparation" above and Appendix A for details.

EDIT EVAPORATION FILENAME
Using this option in QIMENU the user may specify a secondary EVAP.DAT file. This is the only one of the data files for which the filename is not fixed. The user may apply different evaporation values for different simulations and compare the results.

Enter the name of the new file containing the evaporation and evapotranspiration data. Enter only the filename's extension and base (e.g. URBANA.DAT). The full filename is assumed to be [datapath]\evapfname. For example, if you specified the "Datafiles Path" as C:\QIMENU and the evaporation filename as URBANA.DAT, you are describing
C:\QIMENU\URBANA.DAT.

2.5.3.8 - DATA, SOIL - SOIL.DAT

```
═════════════ Edit Soil Data File - SOIL.DAT ═══════════
                        FO        FC       Emax       Gmax
          SOIL GROUP  (in/hr)   (in/hr)    (in)       (in)

              A        10.000    1.000     2.700     12.600
              AB        9.000    0.750     3.410     11.050
              B         8.000    0.500     4.120     10.500
              BC        6.500    0.375     5.000      7.650
              C         5.000    0.250     5.100      4.800
              CD        4.000    0.175     4.650      4.650
              D         3.000    0.100     4.200      4.500

─────────────────────────────────────────────────────────
  F2   List editing keys
```

Each line in the Soil File contains information for one of the seven hydrologic soil groups as defined by the U.S. Soil Conservation Service. There are four parameters per soil group as described above under "Data Preparation." To accept any changes you've made to the data, press CTRL-ENTER on any of the fields or ENTER on the last field. To discard the changes, press ESC.

2.5.3.9 - DATA, BMP REMOVAL EFFICIENCY - BMPEFF.DAT

```
═══════════ Edit Removal Efficiency File - BMPEFF.DAT ═══════════
                        Percent Removal Rate for Constituent:
     BMP Description     A    B    C

   STREET SWEEPING       30   15   20
   FERTILIZER CONTROL     0   25    0


  ───────────────────────────────────────────────────────────────
   A  SUSPENDED SOLIDS
   B  NITROGEN
   C  LEAD
  ───────────────────────────────────────────────────────────────
   Enter   Modify entry    Ins   Insert entry
                           Del   Delete entry
```

The BMP Removal Efficiency File BMPEFF.DAT provides a list of BMPs to be applied to the basin and their removal efficiencies for each constituent being simulated. Each line of the file contains a name describing a BMP (e.g. "Street Sweeping") followed by the removal rate as % of total pollutant removed for each constituent.

The list is presented as a scrollable list of lines, each line containing the name of the BMP and the removal rates for each of the constituents. To modify an existing BMP, press ENTER. The BMP name and the removal rates will turn into editing fields. At the current field, you can type in a new value or, if the value is OK, press TAB to move on to the next field. To accept your changes, press CTRL-ENTER on any of the fields or ENTER on the last field.

To insert a new BMP, press the Insert key. A new entry will appear with the same values as the entry below. Change any of the values using the methods described above to modify an entry. To delete a BMP, press DEL. You will be asked to confirm the deletion. Press ENTER to delete it or ESC to retain it. To exit the removal efficiency editing screen, press ESC. If you accepted changes to any of the lines or inserted or deleted any lines, the data will be written out to disk and a message notifying you of this will appear.

CAUTION
THIS FILE MUST CONTAIN THE SAME LIST OF BMPs AND CONSTITUENTS AS THOSE IN WQLIST.DAT, AND BMP.001. THIS IS THE USERS RESPONSIBILITY, AND DIFFER-ENCES WILL CAUSE AN ERROR IN QIMENU.

2.5.3.10 - DATA, LAND USE - **LU.nnn**
Each line of the Land Use File describes a segment of the current subbasin. Each record must have a distinct land use code and soil group combination.

```
══════════ Edit Land Use File ~ LU.002 ══════════

   CODE  DESCRIPTION        %IMP %SUPP DS1   DSp     AREA SOIL %MOIST
   ┌────────────────────────────────────────────────────────────┐
   │ 11  Residential         30   10  0.10  0.20   82.00   4    50 │
   │ 12  Commercial          60   20  0.10  0.20   22.00   3    50 │
   └────────────────────────────────────────────────────────────┘


  Enter  Modify entry
```

The input is arranged as a scrollable list of land use lines. You can move among the lines by using the arrow keys, the PgUp and PgDn keys, and the HOME and END keys.

Each line contains both a land use and a soil type. The land use code and its description cannot be edited within QIMENU. This must be done externally from DOS or an editor. QIMENU will not allow two lines with the same land use and soil. You may have two lines with the same land use if they have different soils.

CAUTION

THE LU.nnn, WQ.nnn, AND BMPAPP.nnn FILES ARE CLOSELY RELATED. THE LAND USE AND SOIL AND COMBINATIONS AND THE PARAMETERS ASSIGNED TO THEM MUST BE COMPATIBLE IN ALL THREE FILES. ERROR MESSAGES WILL GENERALLY IDENTIFY THESE INCONSISTENCIES.

To modify other parameters in the current land use entry, press ENTER. You can move among these fields by using TAB and SHIFT-TAB (press F2 for a complete list of editing keys). Make a change to a field and then press ENTER. The cursor will move

65

to the next field. If the value is OK, press TAB to move the cursor to the next field.

To accept your changes press CTRL-ENTER at any field or ENTER on the final field, (%MOIST). If you wish to discard your changes, press ESC. After accepting or discarding the line, the data again becomes a scrollable list of land use lines.

To exit the land use editing screen, press ESC. If you accepted changes to any of the lines the data will be written out to disk and a message notifying you of this will appear.

2.5.3.11 - **DATA, WATER QUALITY - WQ.nnn**

```
╔═════════════ Edit Water Quality Data File - WQ.002 ═════════════╗
║                                                                 ║
║  Land Use  1 of 2     11  Residential                           ║
║                                                                 ║
║                                    PARAMETER                    ║
║                     ARi    ARp    RRi   RRp    Pi    Pp    EXPi   EXPp ║
║   CONSTITUENT      lb/acre/day    └─ Pct ─┘   lb/acre    └ constant ┘ ║
║   SUSPENDED SOLIDS 2.3100 1.1600  5.00  4.50 6.9300 3.4800 4.6000 1.4000 ║
║   NITROGEN          .0142  .0070  6.00  5.00  .0526  .0210 4.6000 1.4000 ║
║   LEAD              .0030  .0015  3.00  3.00  .0090  .0045 4.6000 1.4000 ║
║                                                                 ║
║─────────────────────────────────────────────────────────────── ║
║                                  Pg{Up/Dn}   Previous/next land use ║
║    F2    List editing keys   Ctrl-Pg{Up/Dn}  First/last land use ║
╚═════════════════════════════════════════════════════════════════╝
```

The Water Quality Data File WQ.nnn contains parameters relating to the buildup and washoff of each pollutant by land use. For each land use record, this data must be provided for each pollutant in the "Water Quality List File". There must be a record for each of these land use/constituent combinations.

To move to the next land use, press PgDn; pressing PgUp moves you to the previous land use. CTRL-PgUp moves you to the first land use in the list, and CTRL-PgDn to the last.

For a particular page of data, use the Tab key and arrow keys to move from parameter to parameter and from constituent to constituent. To change a field, simply type in a new value.

To accept the changes you've made to the data in any of the land use pages, press Ctrl-Enter. Pressing Escape will discard your changes.

CAUTION

THE LAND USE, SOIL, AND THEIR RELATED PARAME-TERS MUST BE COMPATIBLE IN WQ.nnn, LU.nnn, AND BMPAPP.nnn.

2.5.3.12 - DATA, BMP APPLICATION FILE - BMPAPP.nnn

```
══════════ Edit BMP Application File - BMPAPP.002 ════════════

                          Pct of Land Use Occupied by Sector:
    BMPs in Sector:       11  12
   ┌──────────────────────────────────────────────────────────┐
   │ :                    51   0                                │
   │ --                   49 100                                │
   │                                                            │
   │                                                            │
   │                                                            │
   └──────────────────────────────────────────────────────────┘

   11 Residential
   12 Commercial


    Enter   Modify entry      Ins   Insert entry
                              Del   Delete entry
```

The data is presented as a scrollable list of sectors. Use the arrow keys to move among the entries. To modify a sector, press ENTER. The percentages for each land use will turn into edit fields. You may type in a new value for a field or press Tab to skip it. To accept your changes, press Ctrl-Enter on any field or Enter on the last field. To discard any changes, press Esc. The data will turn back into a scrollable list.

To insert a new sector, press the Insert key. A new entry will appear with values identical to those of the entry immediately

below. Use the methods described above for modifying an entry. Press ENTER or ESC to accept or discard your changes. To delete a sector, press the Delete key. You will be asked to confirm the deletion.

To exit the BMP Application editing screen, press Escape. If you accepted changes to any of the lines or inserted or deleted any lines, the data will be written out to disk and a message notifying you of this will appear.

2.5.4 - RUN MENU

```
         Index    Description

           1       CLARK STREET
    √      2       GREEN STREET
           3       JOHN STREET




   Number of subbasins selected: 1

   Enter    Toggle subbasin
       A    Select all        C    Clear all
  ˆEnter    Run model on selected subbasins
```

The "RUN Menu" is used to create output by running the AUTO_QI programs on a list of subbasins. When the "RUN Menu" is selected, you are presented with a scrollable list of all subbasins. This is the same list which is edited in the "BASIN Menu".

The user may select some set of these subbasins, run AUTO_QI on these subbasins, and display the resulting output. To run a subbasin, use the arrow keys to scroll to the subbasin of interest, and press ENTER to select it. A check mark will appear to the left of the subbasin name. (Under certain conditions, the list may not show a subbasin after it has been selected. Do not worry, moving the arrow keys to it will confirm

that it has indeed been selected.) Pressing ENTER on a selected subbasin will deselect it, and the checkmark will disappear. Typing the letter A will select all of the subbasins. Typing the letter C will deselect all of the subbasins.

Move through the list, selecting the set of subbasins for which you wish to see output. When the set is complete, press CTRL-ENTER to begin the simulation. You will be asked from which program you wish to begin processing. If you select Hydro, then the Hydro, Load, and BMP programs will be run, in that order. If you select Load, then the Load and BMP programs will be run, in that order. If you select BMP, then only the BMP program will be run.

You cannot begin the simulation with Load unless the Hydro program has already been run and the output files exist in your Datapath file space. Similarly, you cannot begin with BMP unless Hydro and Load have been run.

2.5.5 - OUTPUT MENU

```
┌──────────── Select an Event or Summary ───────────┐
║ *** SUMMARY ***                                      ║
║ 06/05/88|          1.50|       4.39| 0.51| 0.34| 4.21| 3.00 ║
║ 06/10/88|          0.50|       1.23| 0.14| 0.28| 4.79| 2.00 ║
║ 06/13/88|          2.50|       7.47| 0.86| 0.34| 2.88| 6.00 ║
║                                                      ║
╙  Date  |   Rainfall   |Runoff (ac-ft)| (in)| R/R | Dry | Dur ┘
```

If you elected to run one subbasin, output will be created for all of the rainfall events for which the rainfall was at least the minimum specified in the "General Basin File". In addition, a summary will be created which computes totals, maxima, and averages for the entire run. If more than one subbasin was selected, output will be combined as if they were one subbasin. This option can be used to show multiple subbasin impact on one receiving water. The user also has the option of printing event or summary output.

After each "Run" of the program, several output files will appear in the Datapath file space. These only exist until the next "Run" of the program, at which point they are replaced by the new

output. If the user wishes to save these output files they should be moved to a new directory or a new path established for the next "Run."

Most of these files contain information already presented in the "Output" portion of QIMENU. The user will find additional information in HYDRDOUT.nnn and HYDLUOUT.nnn, however. The LIST utility described earlier is an excellent way to view these files.

2.5.5.1 - SINGLE SUBBASIN OUTPUT
After AUTO_QI has completed the simulation, you will be presented with a scrollable list containing one entry for a summary and one entry for each event. Scroll to the entry you wish to view and press Enter. A printed version of the output may be generated with "ALT P." When you are done viewing the output, press Escape.

2.5.5.2 - MULTIPLE SUBBASIN OUTPUT
When the simulation has been completed, you will be shown a summary which reflects the sum of all the subbasins processed. A printed version may be obtained with "ALT P." When you are done viewing the output, press Escape.

2.5.6 - MISCELLANEOUS MENU
The "MISCELLANEOUS Menu" is used to perform certain actions which are peripheral to the model. There are three items in the menu: SHELL, ABOUT, and DELAY.

2.5.6.1 - SHELL
Allows the user to shell out to DOS. This is useful if you want to find a particular file or perform some other task which you can not do in QIMENU.

Note: It is advised that you do not edit an input file which QIMENU has already loaded. If the data is written back out to disk, any changes you made while in the DOS shell will be overwritten.

2.5.6.2 - ABOUT
The About screen gives you information on which version of QIMENU you are running as well as credits for the various aspects of the model.

2.5.6.3 - DELAY
Sets the time in seconds that certain messages appear on the screen.

2.5.7 - ON-LINE HELP
Help is available at any time in QIMENU by pressing the Fl key. QIMENU's help is said to be context-sensitive. This means that the help information displayed depends on where you are in the program. If you are editing an input file and press F1, help appropriate to the editing of that file will be shown.

Information for some topics is listed on more than one page. You can use the PgUp and PgDn keys to move among the different pages. If there are multiple pages, the lower right border of the help window will tell you which of the PgUp and PgDn keys are applicable. QIMENU's help was developed using a method called hypertext. Hypertext help, besides providing information for a topic, can also contain links to related topics. For example, if you call up help for the Miscellaneous menu, a description of the menu will appear. In addition, you will see the words "Shell" and "About" and "Delay" which stand out from the rest of the text. These are hypertext links to those topics. You use the arrow keys to move among the links. The current link will be displayed in reverse text (red on white on color monitors), while all other links will be displayed in highlighted text (yellow on color monitors). If you press Enter on a selected link, information for that topic will be displayed. This makes it easy to move from topic to topic.

There is also an "Index" of all help topics if you wish to view information for a topic which is not a link in the current help screen.

When you are through viewing the help information, press the Escape key and you will return to the point in the program where you were when the Fl key was pressed.

2.5.8 - EXIT MENU
The EXIT Menu is used to exit QIMENU. You will be asked to confirm your intention.

2.5.9 - GIS INTERFACE

Introduction
A Geographic Information System (GIS) consists of computer hardware, software, and a database. A computer-oriented GIS performs sophisticated manipulations and analyses which include map overlay, buffer generation, boundary dissolve (regroup and reclassify), tabular data analyses and network analyses. A complete GIS system contains computer mapping and display capabilities for generating high quality cartographic products. The user can specify size and scale to produce the desired map outputs.

Urban runoff quantity and quality are highly dependent upon the land use and hydrologic soil class. To tabulate the land use/soil complex is a time consuming process. To simplify the data collection and management process, an ARC Macro Language (AML) program was developed to retrieve the land use and soil layers in a final format suitable for model input.

The following GIS layers were created to support the simulation of urban runoff quantity/quality.

2.5.9.1- GIS Layers
Soil Layer
The Statewide "General Soil Map of Illinois" was digitized for the Illinois GIS system in 1985 with funding from the Illinois Department of Mines and Minerals (IDMM). This map contains 57 general soil associations in Illinois. The attribute data includes the soil surface color, surface code and the hydrologic class (well drained, moderately well drained, somewhat well drained, and poorly drained). For hydrologic modeling this hydrologic soil class is needed for the AUTO_QI model. The source soil map scale is 1:500,000.

Land Use Layer
The statewide land use maps are available from the USGS LUDA digital data base. The land uses are classified based on LUDA Level II containing 37 land use categories (Appendix D). Updating land use/cover can be implemented by using digital Landsat image data or by scanning aerial photographs (Hsu, 1978; King, Lee, and Singh, 1989; Lee and Ke, 1990; Lee, Kao and Ke, 1990). The Illinois State Water Survey has developed

image analysis capability using the ERDAS image processing package (ERDAS, 1989). The results of the classified land use can easily be transferred to the ARC/INFO system. The source map is 1:100,000.

Street Coverage (DIME file/Tiger line file)

The street coverage was obtained from the 1980 DIME file or the 1990 TIGER/LINE files which were created by the U. S. Census Bureau. The DIME/TIGER files are composed of street segment records. A segment is defined as the length of a street feature between two distinct vertices or nodes. Other features are political boundaries and topologic features (rivers, shorelines, canals, railroads, airports). Additional demographic information is also available in attribute data. This includes state, county and standard metropolitan statistical area codes, aggregate family income, aggregate rental cost for occupied dwelling units, and numerous other demographic statistics. The data can be plotted by census tract. The source map is 1:100,000. This layer is valuable for estimating the pollutant accumulation rate and the imperviousness of the drainage basin.

Sewer Network

For the greater Lake Calumet area, the sewer outfall points were identified from existing city storm sewer maps. These maps were obtained from the City of Chicago Public Works Department. Drainage boundaries were delineated and the outfall points were identified. The maps were then digitized and attribute data were added. The source map is 1:2,400.

This layer provides drainage boundaries and is also used to estimate the parameters of washoff functions.

Aerial Photograph Files

Two sets of aerial photos were obtained for the Lake Calumet area. The positive films of the National Aerial Photographic Program (NAPP) series of the study area with the scale of 1:40,000 were purchased. The second set of photographs was the 1" = 500 ft detailed low altitude color aerial photos taken for the U. S. Army Corps of Engineers, Chicago District, 1987. These two sets of photos were valuable for determining the percent of pervious and impervious areas in the drainage basin.

2.5.9.2 - PRIME Installation

The AML programs provide the link and user interface between the GIS running on a PRIME and the AUTO_QI program running on a PC. These programs process the data for use by AUTO_QI and also enable the user to view the graphic data at the subbasin level via a menu. The programs are to be used with ESRI's ARC/INFO software on a PRIME computer and are grouped into two functions: the preprocessor programs and the menu system programs. PREPROCESSORLANDSOIL.AML, PREPROCESSORBMP.AML, RUNIT.AML and Main.menu are the names of the four main programs.

All programs have been provided on a PC diskette in ARC/INFO's EXPORT format. First load the programs onto the PRIME computer using file transfer software such as Kermit. Wildcards can be used since all files have the extension .E00. Next, use the ARC IMPORT command to IMPORT all the files. For the user's convenience, the file IMPORTALL.AML has been provided for your use. To access it, use the ARC command: IMPORT TEXT IMPORT.E00 IMPORTALL.AML .

Now run IMPORTALL.AML to convert all files. Both INFO and operating system level files are included and will be placed properly by the IMPORT command.

2.5.9.3 - Running the AML Preprocessor Programs
LANDSOIL.AML

SYNTAX: &R PREPROCESSORLANDSOIL <feet | meters> <number subbasins>

INPUT REQUIREMENTS: Three coverages, which are to be provided by the user, must exist: SOIL, LANDUSE and BASINBND. The coverage SOIL must contain the INFO item HYDROLOGIC-CLASS (1,1,I) with values in a range from 1 to 7. The coverage LANDUSE must contain the INFO item LANDUSE (2,2,I) with USGS level 2 landuse coding. The coverage BASINBND must contain only the boundaries of the subbasins and have the basins labeled. The ID numbers of the basins must run from 1 to n, with no numbers being omitted. The number of subbasins cannot exceed 50. Two coverages are optional: STREET and SEWER.

This program needs to be run only one time. It requires a few hours or a lot longer, depending on the number of subbasins. This program will check topology and CLEAN the coverages if necessary: split the SOIL, LANDUSE, and BASINBND coverages along subbasin boundaries: create a new intersected coverage LANDSOIL and split it along subbasin boundaries: and then create the files LS#.OUT (one for each subbasin) from the LANDSOIL coverages for use by Q-ILLUDAS as LU.nnn on the PC. The STREET and SEWER coverages will also be processed if they exist. All programs with the extension .OUT will be moved by the user to the PC for use by the AUTO_QI program.

BMP.AML
SYNTAX: &R PREPROCESSORBMP <feet | meters> < number subbasins > < number BMPs >.

INPUT REQUIREMENTS: This program requires the LANDUSE and BASINBND coverages which were used by the preceding program. In addition, a separate coverage for each BMP is necessary. These coverages must be named BMP1, BMP2, BMPn, up to a maximum of 9. Each BMP coverage must be labeled with the BMP polygons being a 1 and the non-BMP polygons a 0.

This program needs to be run only one time and unions a variable number of BMP coverages with the LANDUSE coverage. It then sums the acreage by BMP and landuse and produces the following files for each subbasin: LIST#.LU, LIST#.BMP, LIST#.BMPLU, BMP#.OUT and MATRLX#.OUT which becomes BMPAPP.nnn in AUTO_QI. It also creates the file named SIZE.OUT. All files having the extension .OUT will be moved by the user to the PC for use in the AUTO_QI program.

Menu Programs
SYNTAX: &R RUNIT < device >

RUNIT.AML starts Main.menu which is used to access the menu system to view the data after the preprocessor programs are finished. The menu allows the user to choose and view individual subbasins and their data layers. LANDUSE and SOIL coverages can be shaded and the data files LS#.OUT can

be reviewed. The BMP coverages can be viewed over the entire basin.

The AML was designed to have two windows on the screen. The right window shows an index map of the whole drainage basin with the subbasin boundaries. The user can select a subbasin and display the land use, soil, and other layers for the subbasin in the left window.

HELP   CHOOSE SUBBASIN   CHOOSE DATA LAYER   DISPLAY EXIT
                             SOIL
                             LANDUSE
                             SEWERS
                             STREETS
                             BOUNDARY

SUBBASIN 2

HYDROLOGIC CLASS
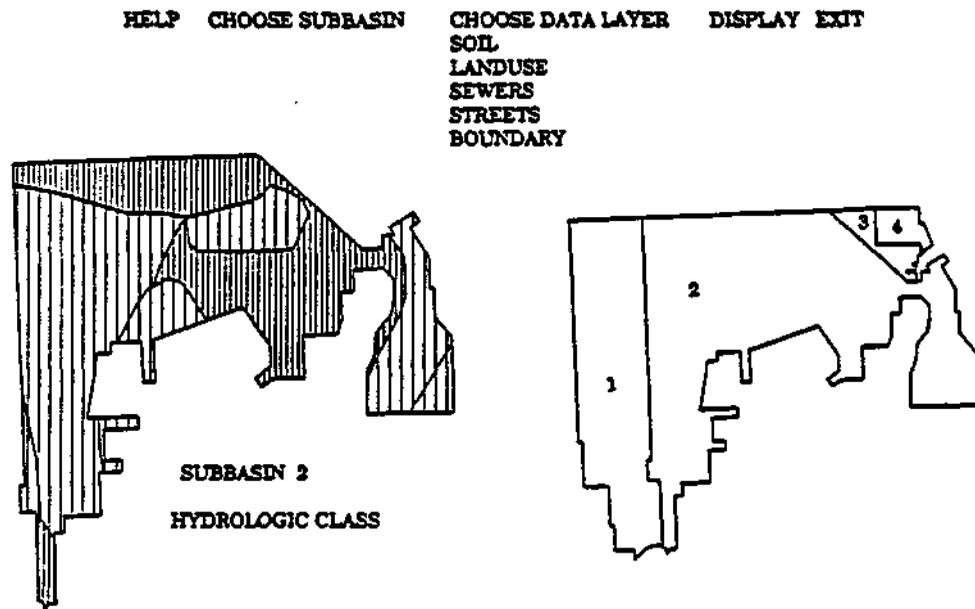
2.5.9.4 - Export Files to the Personal Computer
Since all files to be moved contain the extension .OUT, use file transfer software with a wildcard to move the files easily. The following files should be moved:

LS#.OUT   one for each subbasin
MATRIX#.OUT   one for each subbasin
BMP#.OUT   one for each subbasin
SIZE.OUT

2.5.9.5 - List of Programs on Distribution Diskette
Preprocessor Programs

       PREPROCESSORLANDSOIL.AML
       PREPROCESSORBMP.AML
       SPLITUP.AML created by the preprocessor programs

Menu Programs

       RUNIT.AML - starts the menu
       MAIN.MENU
       ALLBASINS.AML
       COLOR.BMP1   INFO file
       COLOR.BMP2   INFO file
       COLOR.BMP3   INFO file
       COLOR.BMP4   INFO file
       COLOR.BMP5   INFO file
       COLOR.BMP6   INFO file
       COLOR.BMP7   INFO file
       COLOR.BMP8   INFO file
       COLOR.BMP9   INFO file
       BMP.LEGEND
       CHOOSEBMP.AML
       CHOOSEIT.DAT
       CHOOSELAYER.AML
       CURRENTBASIN.AML
       DISPLAYLAYER.AML
       EXIT.AML
       HELP.DAT
       INPUTREQUIRE.DAT
       LAND-SOIL.DAT   INFO file
       COLOR.LANDUSE   INFO file
       LANDUSE.LEGEND
       LISTSUBBASINS.AML
       MISSINGLAYER.DAT
       NOEXTT.AML
       READ.ME
       SHADEIT.AML
       COLOR.SOIL   INFO file
       SOIL.LEGEND

Sample GIS Coverages

       SOIL
       LANDUSE
       BASINBND
       STREET
       SEWER
       BMP1
       BMP2
       BMP3

Transfer Programs

       EXPORTALL.AML
       IMPORTALL.AML

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APPENDIX A: EVAPORATION AND EVAPOTRANSPERATION DATA

Evaporation

Available data for evaporation and evapotranspiration are limited compared with rainfall, temperature and runoff data. The available evaporation data in Illinois were obtained from the Illinois State Water Survey (Personal communication with Wendland, 1990). Table A-1 shows the 1983-89 average monthly evaporation in Illinois. The data for January through March and November and December which were not observed are estimated based on the percent of annual evaporation by month (Neely and Heister, 1987).

Evapotranspiration

The direct measurement of evapotranspiration is difficult and the data are not readily available. The potential evapotranspiration is commonly estimated by using the Penman equation (Russell, 1961). The Soil Conservation Service (1981) has provided estimates of Penman's ET monthly values for the months of March through October for the 12 Midwest states. Using the SCS values and the percent monthly distribution of the evaporation, the missing monthly values were estimated for three Illinois regions. The results are shown in Table A-2.

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Table A-1. Monthly Evaporation Values for Illinois in Inches

Location	Month											
	J	F	M	A	M	J	J	A	S	O	N	D
Hennepin (N)	.90	1.20	2.60	4.60	7.23	7.51	7.36	7.05	5.08	3.88	1.80	.95
Urbana(C)	.94	1.17	2.34	5.06	6.19	7.30	6.78	6.02	4.47	2.74	1.80	.99
Spr'gfld(C)	1.26	1.56	3.12	6.04	8.20	8.91	9.03	7.82	6.19	4.49	2.40	1.32
Belleville (S)	1.20	1.53	2.78	4.65	7.46	8.40	8.82	6.78	5.11	3.40	1.87	1.24
Carlyle(S)	1.40	1.79	3.24	5.77	6.52	8.19	8.76	7.54	5.98	3.84	2.18	1.45
Dixon Spr'g(S)	1.20	1.53	3.21	4.37	5.72	6.69	7.10	6.47	4.84	3.62	2.12	1.24

where N = northern region of Illinois
    C = central region of Illinois
    S = southern region of Illinois
    Spr'gfld = Springfield
    Dixon Spr'g = Dixon Springs

Table A-2. Monthly Potential Evapotranspiration Values for Illinois in Inches

Region	Month											
	J	F	M	A	M	J	J	A	S	O	N	D
North	0.90	1.16	2.79	4.50	6.20	7.50	7.75	6.41	4.80	3.41	1.73	0.91
C'tral	1.10	1.37	3.10	5.10	6.82	7.80	8.06	6.82	5.40	3.72	2.10	1.16
South	1.38	1.76	3.41	5.10	6.82	8.10	8.37	7.13	5.40	4.03	2.15	1.43

APPENDIX B: SOIL PARAMETERS

Four soil parameters for each hydrologic class are needed. They are: initial potential infiltration rate (FO), final infiltration rate (FC), the evapotranspiration storage (EMAX), and the gravitational water storage (GMAX).

Table B-l shows the suggested values for the AUTO_QI model. The initial and final infiltration rates were taken from the values used in the ILLUDAS model (Terstriep and Stall, 1974). The evapotranspiration storage (EMAX) and gravitational storage (GMAX) of the soils were estimated based on the values of the soil's field capacity and wilting point (Eagleson, 1970). The top soil depth was assumed to be 36 inches and a soil porosity of 45 percent was used.

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Table B-1. Selected Soil parameters

Hydrologic soil group	Description	F_0 (in./hr.)	F_C (in./hr.)	Emax (inches)	Gmax (inches)
1. A	Low runoff potential, deep sand, deep loess, aggregated silts	10	1.00	2.7	12.6
3. B	Shallow loess, sandy loam	8	0.50	3.9	10.5
5. C	Clay loams, shallow sandy loam, soils low in organic content	5	.25	5.1	4.8
7. D	Soils that swell significantly when wet, heavy plastic clays and certain saline soils	3	.10	4.2	4.5

Note: For the suggested Emax and Gmax values, 36 inches of soil depth is assumed.

APPENDIX C: POLLUTANT ACCUMULATION RATE

The primary pollutants in urban runoff are associated with the small particles in street dust and dirt. The available data for Chicago and eight other cities are listed in Table C-l.

For other chemical constituents, Table C-2, which is provided as a general guide, shows the ratios of the chemicals to the total solids in µg/g. The four major urban land uses (residential, commercial, industrial, and transportation) are tabulated separately. This table is provided for users as a guide for daily pollutant accumulation rates.

For more specific Illinois conditions, the ratios of various constituents to the total solids in eight metropolitan areas were tabulated in Table C-3 as a general guide in selecting the constituent accumulation rates.

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Table C-1. Street Refuse Accumulation

Solids   Accumulation

Land use	Chicago[1] dust and dirt (g/curb m/day)	(lb/ac/day)[3]	Eight American cities[2] total solids (g/curb m/day)	(l6/ac/day)[3]
Single family	10.4	2.1	48	9.5
Multi-family	34.2	6.8	66	13.1
Commercial	49.1	9.7	69	13.7
Industrial	68.4	13.5	127	25.1

Note:
1. American Public Works Association, 1969.
2. Sartor et al., 1972, 1974.
3. The curb length per acre in Chicago was assumed to be 90 meter/ac.

Table C-2. Pollutants Associated with Street Refuse[1] (μg/g of solids)

Land Use

Constituents	Residential	Industrial	Commercial	Transportation
BOD_5	9,166	7,500	8,333	2,300
COD	20,822	35,714	19,444	54,000
Volatile	71,666	53,571	77,000	51,000
KjeldahalN	1,666	1,392	1,111	156
$PO_4 P$	916	1,214	833	610
$NO_3 N$	50	64	500	79
Pb	1,468	1,339	3,924	12,000
Cr	186	208	241	80
Cu	95	55	126	120
Ni	22	59	59	190
Zn	397	283	506	1,500
Total Coliform (no./g)	160,000	82,000	110,000	NR[2]
Fecal Coliform (no./g)	16,000	4,000	5,900	925

Note:
1. Novotny, V. and G. Chesters, 1981.
2. NR = not reported

Table C-3. Ratio of Various Constituents to Total Solids in Eight Illinois Metropolitan Areas[1]

Eight Metropolitan Areas[2] in Illinois

Constituents	KKK	C-U	RKF	SPG	B-N	DCT	Q-C	PIA
Susp. Solids	0.60	0.79	0.60	0.72	0.50	0.79	0.79	0.70
BOD_5	0.03	0.03	0.05	0.05	0.027	0.024	0.031	0.04
Lead	0.0009	0.0010	0.0015	0.0007	0.0007	0.0005	0.0005	0.0010
Copper	0.00015	0.00018	0.0001	0.00012	0.00012	0.00012	0.00012	0.00015
Iron	0.010	0.013	0.012	0.013	0.013	0.010	0.013	0.014
Zinc	0.0006	0.0007	0.0011	0.0006	0.0007	0.0004	0.0004	0.0005
Phosphorus	0.0020	0.0013	0.0013	0.0024	0.0013	0.0006	0.0013	0.0010
COD	0.170	0.215	0.570	0.366	0.098	0.103	0.215	0.200
NO2 + NO3	0.0040	0.0023	0.0032	0.0019	0.0012	0.0015	0.0023	0.0024
Mercury $(x10^{-6})$	0.7	1.5	0.88	0.0	0.26	0.4	0.2	0.7

Note:
1. Illinois Environmental Protection Agency. 1979.
2. KKK = Kankakee, C-U = Champaign-Urbana, RKF = Rockford, SPG = Springfield, B-N = Bloomington-Normal, DCT = Decatur, Q-C = Quad cities, and PIA = Peoria.

APPENDIX D - LUDA DATA

USGS LAND USE AND LAND COVER CLASSIFICATION SYSTEM
FOR USE WITH REMOTE SENSOR DATA

Level 1

Level 2

1 urban or built-up land
- 11 residential
- 12 commercial and services
- 13 industrial
- 14 transportation, communications and services
- 15 industrial and commercial complexes
- 16 mixed urban or built-up land
- 17 other urban or built-up land

2 agricultural land
- 21 cropland and pasture
- 22 orchards, groves, vineyards, nurseries, and ornamental horticultural areas
- 23 confined feeding operations
- 24 other agricultural land

3 rangeland
- 31 herbaceous rangeland
- 32 shrub-brushland rangeland
- 33 mixed rangeland

4 forest land
- 41 deciduous forest land
- 42 evergreen forest land
- 43 mixed forest land

5 water
- 51 streams and canals
- 52 lakes
- 53 reservoirs
- 54 bays and estuaries

6 wetland
- 61 forest wetland
- 62 nonforested wetland

concluded on next page

Level 1	*Level 2*
7 barren land	71 dry salt flats
	72 beaches
	73 sandy areas other than beaches
	74 bare exposed rock
	75 strip mine, quarries, and gravel pits
	76 transitional areas
	77 mixed barren land
8 tundra	81 shrub and brush tundra
	82 herbaceous tundra
	83 bare ground
	84 wet tundra
	85 mixed tundra
9 perennial snow or ice	91 perennial snowfields
	92 glaciers

APPENDIX E: QIMENU ERROR AND WARNING MESSAGES

Error Messages

There are no lines to modify.
>   Location: Edit Removal Efficiency, Edit Subbasin List, Edit
>   Constituent List
>   The list is empty, so there are no lines to modify.
>   Either insert new entries or exit QIMENU and create a new file.

There are no lines to delete.
>   Location: Edit Removal Efficiency, Edit Subbasin List, Edit
>   Constituent List
>   The list is empty so there are no lines to delete.
>   Either insert new entries or exit QIMENU and create a new file.

The *file-type* file is not valid.
>   Location: Any of the files listed in the *Datafiles* menu.
>   The file does not exist in the datafiles path.
>   Exit QIMENU and make sure the file has the proper name and is
>   located in the datafiles path.

The Water Quality List file is empty. The Removal Efficiency file cannot be edited.
>   Location: Edit Removal Efficiency
>   There are no constituents to which to apply removal efficiencies.
>   Create a constituent list by going to the Edit Constituent List menu.

Cannot open *file-type* file for input/reading.
>   Location: Any of the files listed in the *Datafiles* menu.
>   QIMENU was not able to open the file for input.
>   Exit QIMENU and make sure the file exists in the datafiles path.

Cannot open *file-type* file for output/writing.
>   Location: Any of the files listed in the *Datafiles* menu.
>   QIMENU was not able to open the file for output.
>   Exit QIMENU and make sure the file exists in the datafiles path.

Cannot find removal efficiency *x* of BMP *y*.
>   Location: Edit Removal Efficiency
>   For each BMP there must be a removal effiency for every constituent
>   listed in the Constituent List file.
>   Exit QIMENU and make sure the number of constituents is the same
>   in both the Constituent List and Removal Efficiency files.

The printer appears off or offline.
>   Location: Output menu
>   QIMENU is attempting to print the output to a dot-matrix printer
>   connected to LPT1:.
>   Make sure there is such a printer and that it is turned on and online.

No output has been created.
> Location: Output menu
> The Output menu displays the output created by the last run. If no
> run has been completed yet, there is no output to view.
> Create a run by using the Run menu.

Land Use *x* is not in the set of distinct land uses.
> Location: Edit Land Use
> You may only change a land use code in such a way that the set of
> distinct land use codes remains constant.
> Enter a land use which already exists.

The percentage must lie in the range 0-100.
> Location: Edit Land Use
> The value entered for a percentage must be an integer from zero to 100
> inclusive.

Soil type *x* is not defined.
> Location: Edit Land Use
> The soil type must be an integer from one to seven inclusive.

**The Load program requires an input file created by Hydro which
does not exist.**
> Location: Run menu
> The Load program cannot find a file which should have been created
> by the Hydro program.
> The most probable cause is running the Load program without first
> running the Hydro program.
> Run the Hydro program before running the Load program.

**The BMP program requires an input file created by Load which does
not exist.**
> Location: Run menu
> The BMP program cannot find a file which should have been created
> by the Load program.
> The most probable cause is running the BMP program without first
> running the Load program.
> Run the Load program before running the BMP program.

You must select at least one subbasin for output.
> Location: Run menu
> In order to make a run, at least one subbasin must be selected.
> Select the subbasins of interest and then make the run.

Cannot find the program directory: *path*
> Location: Run menu
> The QILLUDAS programs (HYDRO.EXE, LOAD.EXE, and BMP.EXE)
> could not be found.
> They must be located in the same directory as the datafiles.
> Exit QIMENU and make sure all three programs are in the datafiles
> directory.

Cannot find *the prog-type* program.

    Location: Run menu

    QIMENU could not find one of the QELLUDAS programs.

    They must be located in the same directory as the datafiles.

    Exit QIMENU and make sure all three programs are in the datafiles directory.

Directory *path* does not exist.

    Location: Edit Datafiles Path

    The path does not exist.

    Enter a new path.

The current subbasin must lie in the range 1-*nsub*.

    Location: Edit Current Subbasin

    The current subbasin must be an integer from one to the number of subbasins inclusive.

    Reenter the value.

The list of subbasins is empty.

    Location: Edit Current Subbasin

    There are no subbasins from which to choose.

    Use the Basin menu to create a list.

Couldn't find water quality line *x* of land use *y*.

    Location: Edit Water Quality

    There must be a line for each constituent for each land use.

    Exit QIMENU and check that the Water Quality file has the proper number of lines.

Couldn't find parameter *x* of land use *y*.

    Location: Edit Water Quality

    There must be eight parameters on each line of the Water Quality file.

    Exit QIMENU and check that the Water Quality file has eight parameters on each line.

No sector index on line *x* of the BMP Application file.

    Location: Edit BMP Application

    The first number on each line of the BMP Application file must contain the sector index.

    Exit QIMENU and check the BMP Application file.

Not all percentages on line *x* of the BMP Application file.

    Location: Edit BMP Application

    There must be a removal rate percentage for each constituent listed in the Constituent List file.

    Exit QIMENU and check the BMP Application file against the Constituent List file.

The BMP index must lie in the range 1-*nbmp*.

    Location: Edit BMP Application

    One of the BMPs listed in the BMP Application file was not an integer from one to the number of BMPs inclusive.

    Check the BMP Application file against the Removal Efficiency file.

Cannot find soil ID *x*.
> Location: Edit Soil
> There must be an entry for all seven hydrological classes.
> Exit QIMENU and check that there are seven entries.

Cannot find parameter *x* of soil ID *y*.
> Location: Edit Soil
> There must be four values given for each hydrological class.

That is an unreasonable value.
> Location: Edit Soil, Edit Evap
> The value input is unreasonable for the parameter.
> Change the value to a reasonable number.

Cannot find evapotranspiration for rate *x*.
> Location: Edit Evaporation
> There must be 12 evapotranspiration values, one per month.
> Exit QIMENU and check the Evaporation file.

Cannot find evaporation for rate *x*.
> Location: Edit Evaporation
> There must be 12 evaporation values, one per month.
> Exit QIMENU and check the Evaporation file.

Cannot find the basin description.
> Location: Edit General Basin
> The first line in the General Basin file must contain a basin description
> Exit QIMENU and check the General Basin file.

Cannot find the starting or ending date.
> Location: Edit General Basin
> The second line in the General Basin file must contain the starting and ending dates of the run.
> Exit QIMENU and check the General Basin file.

Cannot find the minimum rainfall value.
> Location: Edit General Basin
> The third line in the General Basin file must contain the minimum rainfall value.
> Exit QIMENU and check the General Basin file.

Cannot find the evaporation filename.
> Location: Edit General Basin
> The fourth line in the General Basin file must contain the name of the evaporation file.
> Exit QIMENU and check the General Basin file.

Cannot find the number of subbasins.
> Location: Edit General Basin
> The fifth line in the General Basin file must contain the number of subbasins in the basin.
> Exit QIMENU and check the General Basin file.

Cannot find the number of constituents.
> Location: Edit Constituent List
> The first line of the Constituent List file must contain the number of constituents.
> Exit QIMENU and check the Constituent List file.

Warning Messages

Cannot open defaults file for writing...
When QIMENU terminates it attempts to update the defaults to QIMENU.INI.
This file could not be opened for output so any changes to the defaults will be lost.