Storm Water Modeling at Lawrence Livermore National Laboratory

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Abstract

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This paper is primarily an overview of the methodology used for storm sewer modeling. Storm water modeling is an important component of regulatory compliance for water dischages from the Lawrence Livermore National Laboratory (LLNL). Modeling is also done to study trends in site contaminants and the available capacity of the storm sewer infrastructure. The Storm Water Management Model (SWMM) was used to simulate rainfall events at LLNL. SWMM is a comprehensive computer model simulating of urban runoff quantity and quality in storm and combined sewer systems. Due to time constraints and the extensive need for ongoing research, no comprehensive site wide modeling was completed at LLNL. With detailed information about the storm sewers, a SWMM simulation of a rainfall event on site would aid LLNL staff in the storm sewer infastructure decision making process.

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The Purpose of Storm Water Modeling

Compliance

Environmental regulations govern the release of water from a large industrial facility, such as Lawrence Livermore National Laboratory (LLNL). The environmental regulations that govern such releases at LLNL include:

- Clean Water Act
- Porter Cologne Act
- Storm water National Pollutant Discharge Elimination System (NPDES) permit (#95-174)
- WDRs and NPDES permits for specific activities/releases
- Department of Energy (DOE) Order 5400.1
- DOE Order 5400.5
- DOE requirements regarding construction in floodplains and developing sites that impact storm water drainage systems
- LLNL's Storm Water Pollution Prevention Plan

LLNL water compliance staff use storm water modeling to demonstrate compliance. A model simulates storms or rainfall events on site. This model yields results which are used to evaluate the levels of pollutants. The level of pollutants are compared against the environmental standards to determine if an adverse environmental effect would result from rainfall events.

Trends in Pollutants

Storm water models are also used to study trends in pollutants. The result of a model is run is input to a data base. With a large enough database, trends in pollutants can be compared to the level of pollutants. If there seems to be a trend in pollutant levels above designated action levels, analysts seek to find the identified contaminant's source. Common parameters that are sampled include: pH, volatile organic compounds (VOC's), heavy metals, and radionuclides.

Storm Sewer Infrastructure

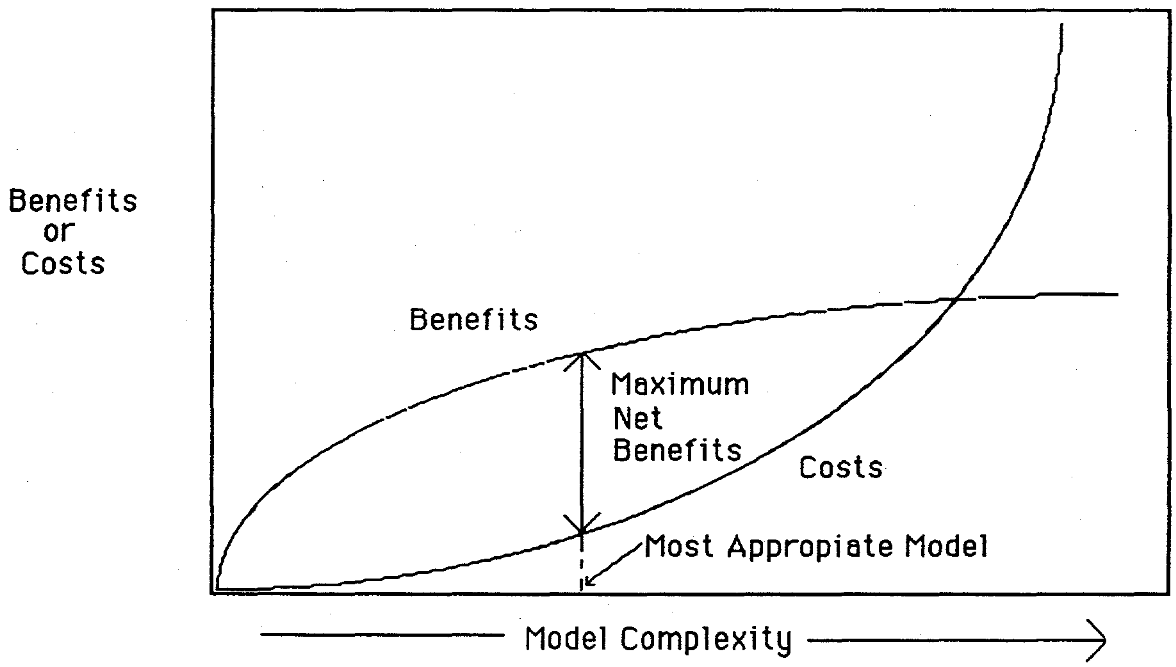
The final use of storm water modeling is to estimate a storm sewer's ability to handle a rainfall event. This is important in determining the effect of a 10 year, or larger, storm event. A 10 year storm event is a theoretical storm that is as large a storm as would occur in 10 years. Using the model, a simulation is run on a 10 year storm. If the model indicates flooding from this storm, it means that the site does not have the storm sewer flow capacity necessary to handle a 10 year storm event. Furthermore, the model can be used to identify specific components of the system that need to be upgraded in order for the system to have adequate capacity.

Choosing a Storm Water Model

Picking the Correct Storm Water Model

There are numerous storm water models that simulate industrial storm water runoff. Choosing the right model for the job is important for cost effectiveness and the best results. If a project is simple and is not necessarily needed to be highly reliable, use a simple model. When the job is complicated and the model is required to show compliance with regulations, a complex model should be used[4]. Figure 1 is a good reference for choosing a storm water model.

Figure 1. Benefits and costs as a function of model complexity[4]



Introduction to SWMM

The storm water model chosen for this project was the Storm Water Management Model (SWMM). SWMM was developed because a need arose for a computer model which dealt with both quantity and quality problems inherent in storm water modeling. Work began at the University of Florida from 1969-71 under the sponsorship of the EPA. SWMM's effectiveness in simulating rain or storm events can be evaluated by inspection of hydrographs, pollutographs, pollutant loads, and modeled changes in receiving water quality[2].

LLNL chose SWMM because the model has been an accepted standard for a long time among the modeling community. It has proven effective in complex modeling environments such as Livermore's highly populated dynamically changing industrial site. The model addresses all of the components needed by LLNL's staff for storm water modeling.

There are many components to SWMM, however, they can be put in to two categories. The computational blocks and the service blocks[2] (See Figure 2). The computational blocks include:

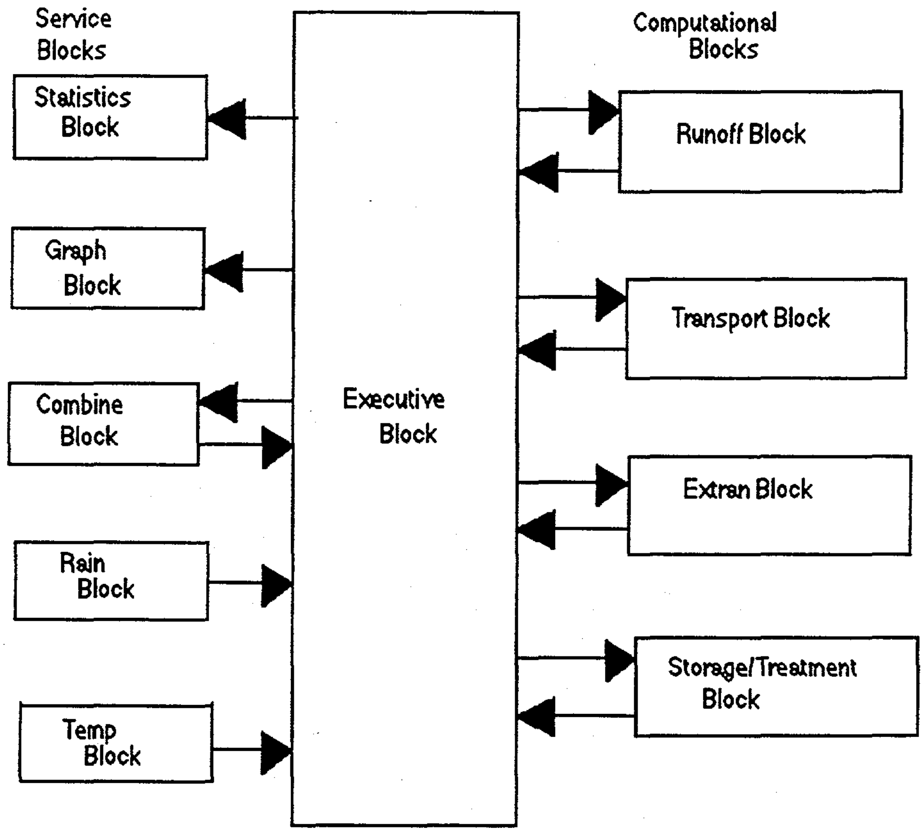
- Runoff block
- Transport block
- Extended transport block
- Storage and treatment block

The service blocks include:

- Statistics block
- Graph block
- Combine block
- Rain block
- Temperature block

All the computational and service blocks can be run together using the executive block. This project focused primarily on the runoff block . The runoff block isolates the storm sewer and has input data specific to the storm sewer.

Figure 2. Components of the Storm Water Management Model[2]



The First Steps of Storm Water Modeling

The Runoff Block

The runoff block was developed to simulate both the quantity and quality runoff phenomena of a drainage basin and the routing of flows and pollutants to the major sewer lines. It represents a site by an aggregate of idealized subcatchments and pipes. The input file accepts rainfall hyteographs and makes a step by step accounting of:

- Infiltration losses in pervious areas
- Surface detention
- Overland flow
- Pipe flow
- Constituents washed into inlets

The runoff block may be run for periods ranging from minutes to years. Simulations less than a few weeks are called single events. All events in this project are single events.

Building an input file

A PC based computer program called PCSWMM is run to begin creating files for the runoff block. PCSWMM allows for easy editing of SWMM input files. Once the files are complete, PCSWMM uses its SWMM engine to compute an output file. There are thirteen different groups of data for the runoff block and they are labeled using letters (A through M). These different categories can be broken down in to six sub-categories listed on the left side of table1.

General Data

The general data input includes all data which will stay consistent throughout the entire SWMM run and identifies the runoff block uniquely so that it can be combined with other blocks. The data which are identified under the A section are the title data. The title is usually descriptive of the type of event being simulated. The B section calls for input data which detail the units and equations used throughout the model. Section C is used to input data parameters which detail snow input data. For this project, no snow data was input. Snow doesn't fall often enough in this part of California to be considered for the model. See figure 5, sections A1 and B1-3.

Precipitation Data

Precipitation data are important in determining the quantity of water that falls on the site. This data group is simplified if snowfall is not modeled. The first step in entering data is deciding whether or not to use the rain block (Group D). The rain block is used if rainfall data are obtained from the National Weather Service (NWS). The rain block collates rainfall data and make it accessible to which ever block calls for it. The next group is identified as the E group and is used when the rain block is not called. This group calls for data from the rain gages to be input. It also contains many general type data inputs that set the units for the rainfall event. Finally this category also includes evaporation data (Group F). These data are usually obtained from climatological summaries.

Table 1. Categorization of SWMM Input Data

Type of Input	Group Name	Description of Data
General Data	A	Two title lines to describe the input file
	B	Selection of units, equations used and time of the storm
	C	Snow input data
Precipitation Data	D	Choose manual rainfall data input or call the rain block
	E	Rainfall data is input if the rain block is not called
	F	Evaporation Data
Pipe Data	G	Parameters that describe the pipes in the storm sewer
Subcatchment Data	H	Parameters that describe the subcatchments
	I	Subcatchment snow input data
Pollutant Data	J	Parameters that describe the pollutants in the storm sewer
	K	Erosion Data
	L	Subcatchment surface quality data
Print Data	M	Set print variables

Pipe Data

Channel/pipe data is a very straight forward section of the input file. The group G input section calls for pipe length, where the pipe is draining to and from, pipe shape (circular, trapezoidal), pipe slope and the Mannings roughness coefficient of the pipe. Group G also accounts for weir and orifices in the pipes. (Figure 3)

Subcatchment Data

The subcatchment data provide a comprehensive description of the ground on which the rain falls. More detail is obtained through the use of more variables. Since there is large attention to detail in this section, a site must be broken down into subcatchments. Subcatchments are smaller areas, divided up from a large area, that outline the path water will take over that small area. Examples of subcatchments are shown in figure 4.

Figure 3. Map of a typical storm sewer[1].

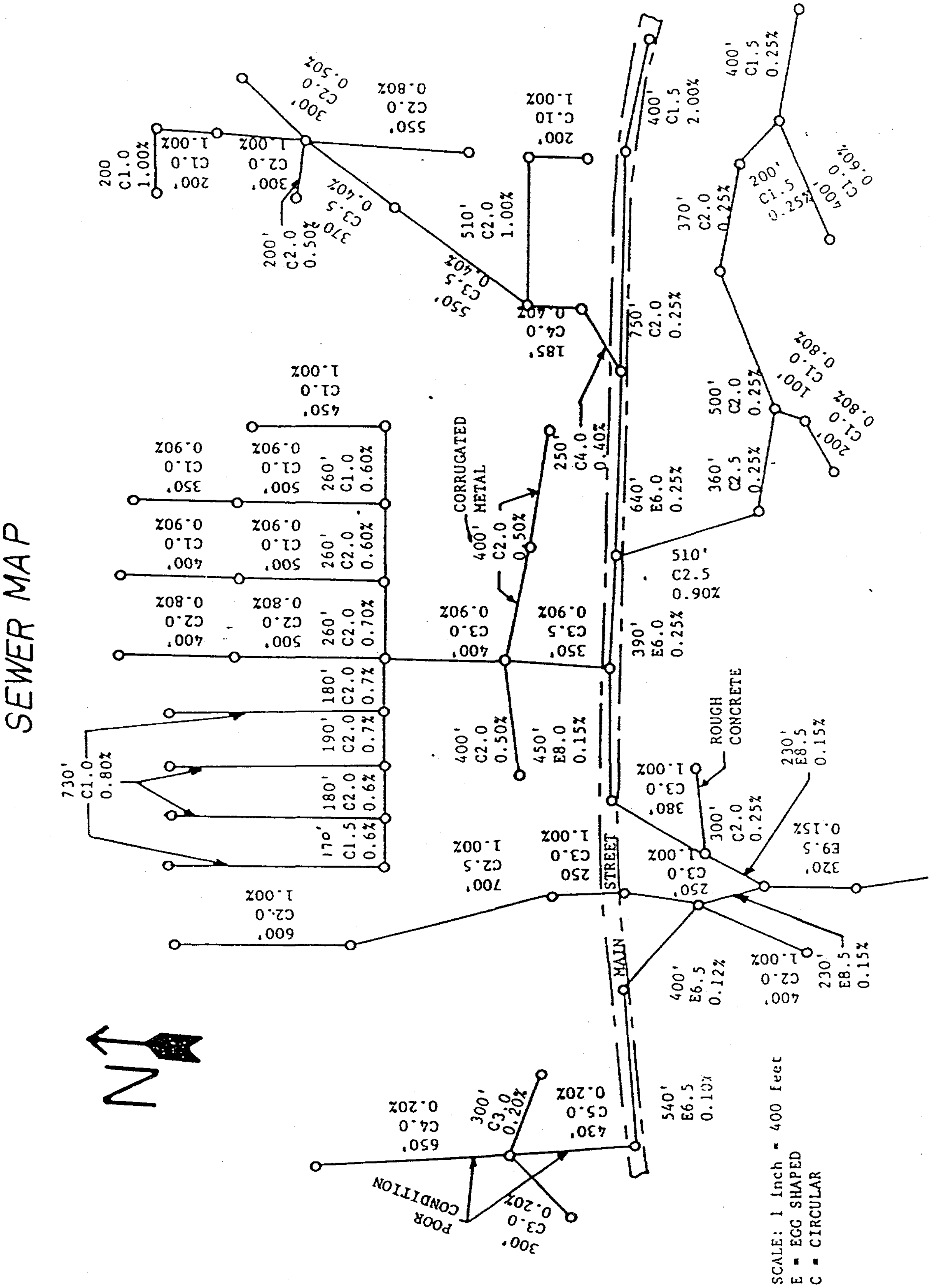
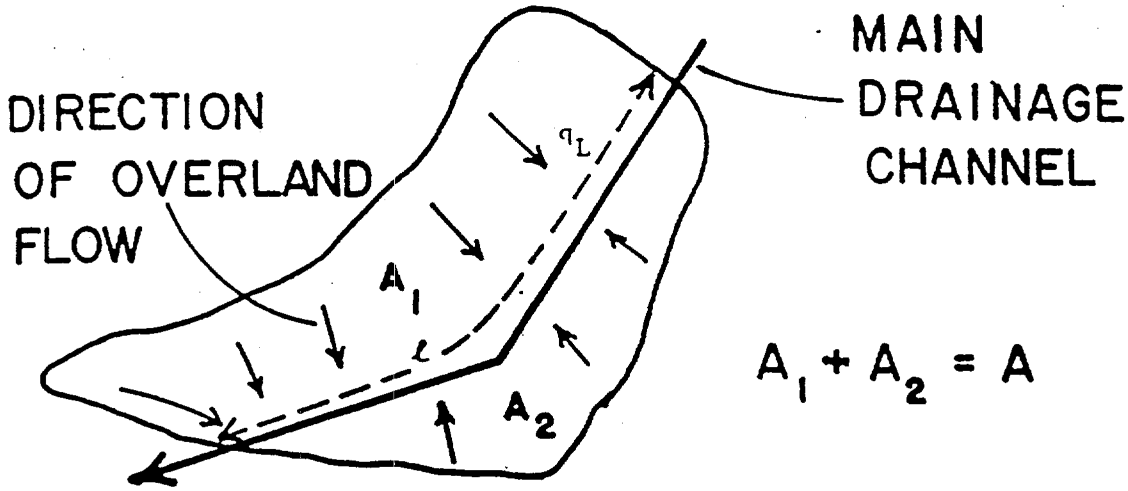


Figure 4. Examples of subcatchments[1]



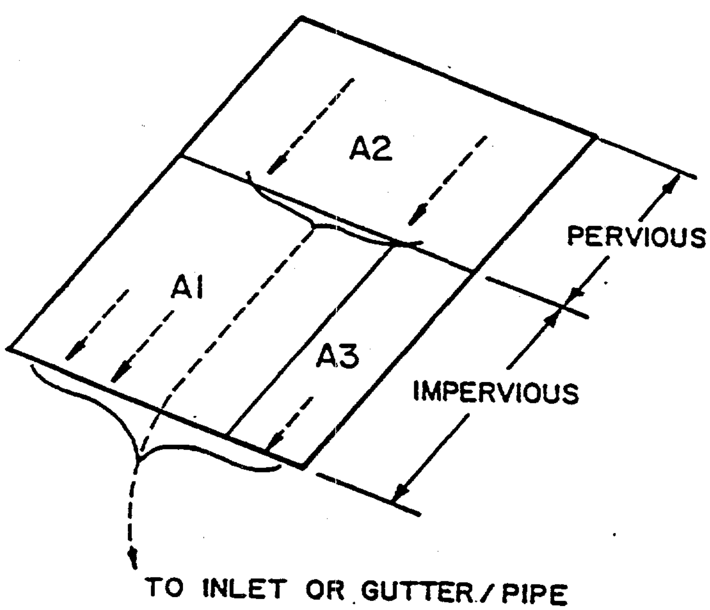
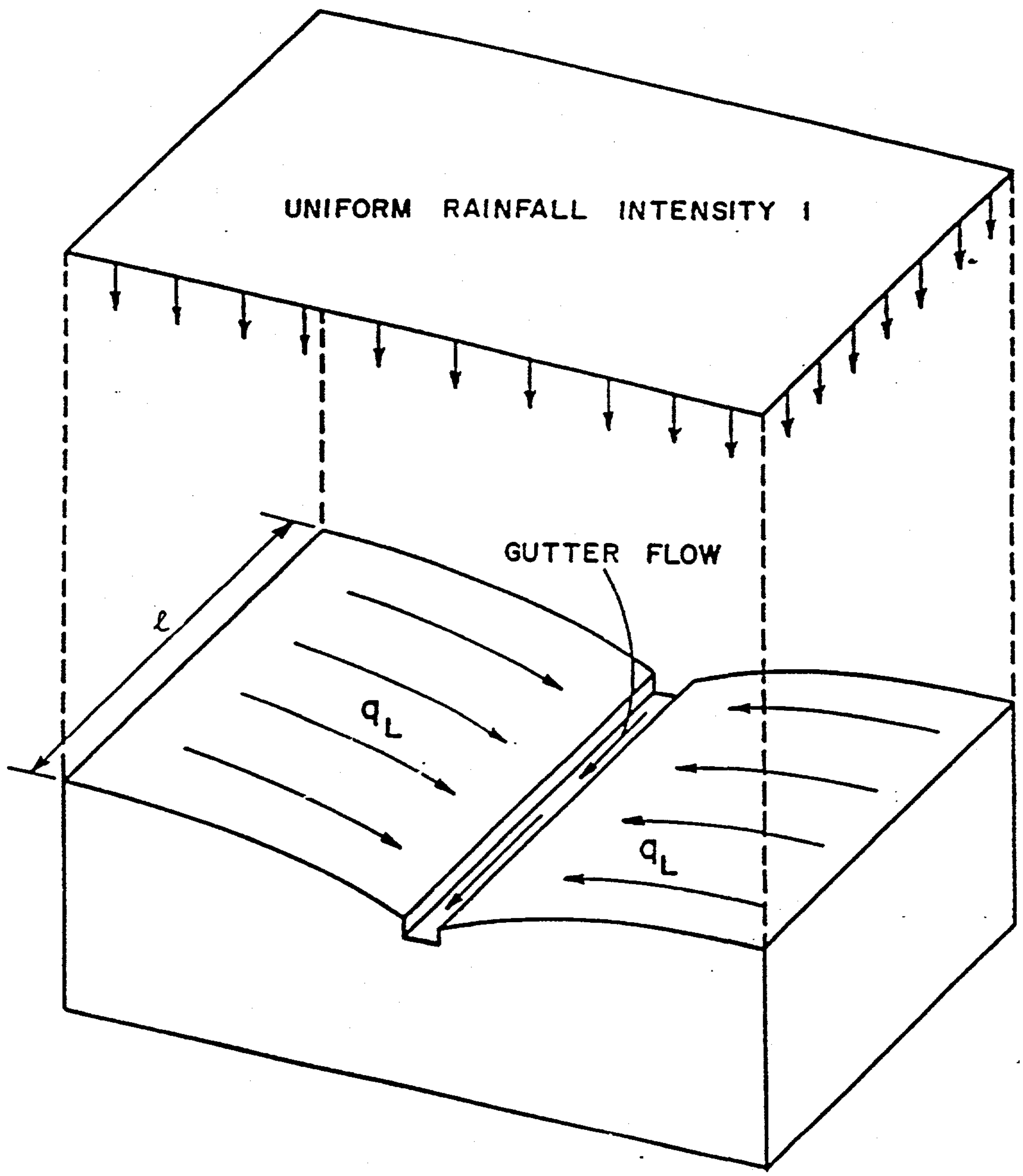


Figure 4 continued



Pollutant Data

The pollutant section of the input file calls for data which describe constituents that may be found in the storm water. Selected constituents are input along with the parameters describing the action of these constituents in storm water. SWMM allows the modeler to choose four different equations that describe the behavior of consituents in storm water. Along with the eqations, constituents are largely affected by:

- Time between storms
- Street sweeping efficiency
- Erosion
- Subcatchment surface
- Site wide material handling practices
- Spill containment plans

Print Data

The print section allows control of many different print options. Printing efficiency is optimized with proper control. Printing out only the information that is essential saves on paper.

Figure 5. Typical input file for SWMM[3]

(Please note, this is not a complete file. It is an example.)

```
$RUNOFF
*
A1  'MODEL OF SIMPLE DRAINAGE NETWORK'
A1  'RUNOFF MODULE DATA SET'
*
*   GENERAL SIMULATION CONTROL
*
*    METRIC   ISNOW  NRGAG  INFILM  KWALTY  IVAP  NHR   NMN  NDAY MONTH
B1     0         0      1       0       0       0     0     0    25     0
*
*  OUTPUT CONTROL
*
*  IPRN(1)  IPRN(2)  IPRN(3)
B2    0        1        1
*
*   TIMESTEP CONTROL
*
*   WET   WETDRY   DRY   LUNIT   LONG
B3   60     120     900     2      10
*
*  ROPT
D1  0
*
*   KTYPE  KINC  KPRINT  KTHIS   KTIME  KPREP  NTHISTO THISTO  TZRAIN
E1     2      1      1       0       0      0        15     15.0      0.0
*
*   STEP-FUNCTION HYETOGRAPH
*
*   TIME=REIN(1)  RAIN=REIN(2)
*
E3      0.0           1.0
E3     15.0           1.0
E3     30.0           1.0
E3     45.0           1.0
E3     60.0           1.0
E3     75.0           1.0
E3     90.0           1.0
```

```
*       CHANNEL/PIPE DATA
*
*   NAMEG  NGTO   NPG  GWIDTH  GLEN  G3   GS1  GS2   G6     DFULL  GDEPTH
G1   100    101    2      3       300  0.1   0     0  0.014    0      0.0
G1   200    101    2      3       300  0.1   0     0  0.014    0      0.0
G1   300    101    2      3       300  0.1   0     0  0.014    0      0.0
G1   101    102    2      3       300  0.1   0     0  0.014    0      0.0
G1   201    202    2      3       300  0.1   0     0  0.014    0      0.0
G1   301    302    2      3       300  0.1   0     0  0.014    0      0.0
*
*       SUBCATCHMENT DATA
*
*   JK NAMEW  NGTO  WIDTH  WAREA %IMP   WSLP IMPN PERN IMPSTOR PSTOR
H1   1    1      100    100     10    100    0.01 0.01 0.01    0        0
H1   1    2     1000    100     10    100    0.01 0.01 0.01    0        0
H1   1    3    10000    100     10    100    0.01 0.01 0.01    0        0

*
*       PRINT CONTROL
*
*    NPRNT          INTERV
M1     3               1
*
*       NDET    STARTP(1)      STOPPR(1)
M2      1        0                  0
*
*       IPRNT(1)...
M3    102  202   302
*
$ENDPROGRAM
```

Gathering Data

Compatibility

Throughout the runoff block there are input variables which indicate the type of units or equation to be used. When a decision is made in one section of the block, that decision must remain consistent throughout the runoff block. An example is the infiltration equations. An equation chosen in the general data section and the input must match in the subcatchment data section. Before a runoff block input file is built, decisions are made on variables.

Climatological

The runoff block calls for climate related data, including:

- Rain gauge readings
- Rain intensity during a storm
- Average evaporation rate

These data are gathered and placed in the input file. Climatological conditions are gathered from a local weather station or the NWS.

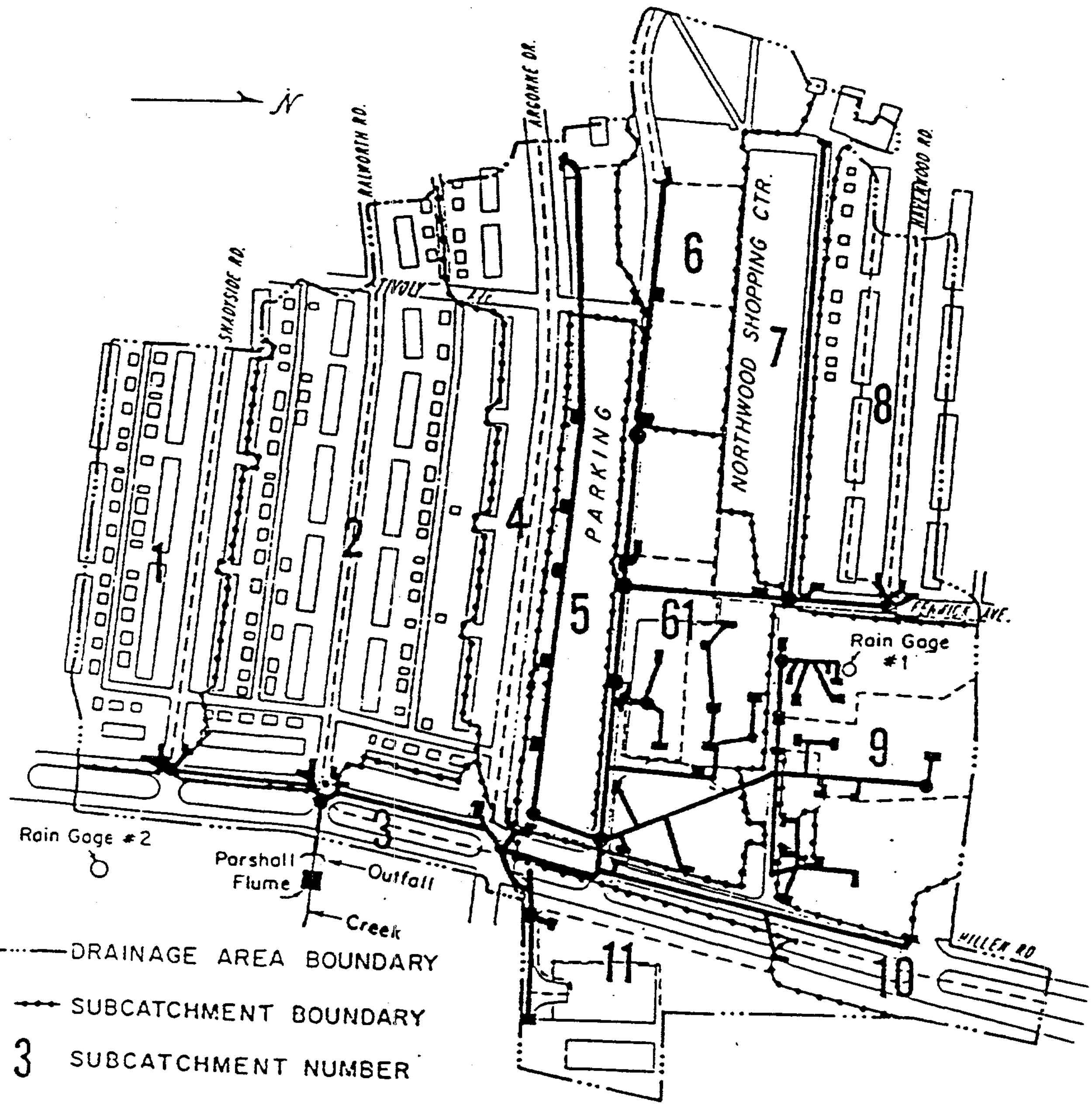
Storm Sewer Parameters

Another important aspect of a runoff block is the features of the storm sewer. These data are collected from a public works office or comparable source. Both maps of the storm sewer and qualities and quantities of the storm sewer are important. Length, diameter, Manning's roughness, slope, and an identifier is needed for each pipe.

Maps

Maps of the site are used for subcatchment breakdowns. A subcatchment is defined by the storm sewer pipes that run somewhat independently through the site. A good breakdown of a site on a map will contain a group of pipes which all drain into a large drainage basin (Figure 6). Subcatchment breakdown is based upon the most likely drainage bed though that subcatchment. For the SWMM model, up to 200 subcatchments can be used in a single block. The LLNL site contained 73 subcatchments that drain into arroyo Seco and arroyo Las Positas

Figure 6. Map of a site's storm sewer broken down into subcatchments[2].



Results

Learning the SWMM model is a dynamic process. The first step in learning the model is reading and understanding the SWMM user's manual especially the section that pertains to the runoff block. The next step of this project was to model a small section of the site. The Northwest corner of the site was modeled in SWMM. Most of the input data were taken off a topographic map of the site. The measurements were taken by ruler and the rest of the data were based on the best guess. There were no hard data, thefore model results are not reliable. It was a very helpful tool in learning the model.

There are several steps involved to take the model to the next step and model a site wide storm water event. The site must also be broken down into subcatchments. Using a couple of different maps, I was able to break the site down into subcatchments. After breaking down the site, I could not complete the model because I was missing many of the needed input parameters. A detailed map of the storm sewer infastructue is required. Along with the map, there should be a database with information pertaining to the storm sewer. The map and the database need to contain information on:

- Numbering system for the storm sewer
- Length of the pipes inthe storm sewer
- Type of pipe (ie trapezoidal, circular, parabolic)
- Length of pipes
- Slope of the pipes
- The type of material that makes up the pipes
- Location of catchbasins
- Location of any weirs or orifices

Summary

All storm water modeling of LLNL has been slowed for a couple of reasons. A study is currently on going at LLNL to complete a map of the storm sewers. There is also an effort to clean the storm drains. Due to these time constraints, no modeling was completed at LLNL. When this study is complete, the information gathered will be used to simulate a rain event at LLNL. This paper is intended to be a short summary of storm water modeling at LLNL and a guide to begin storm water modeling when all the information necessary is available.

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